Disrupting the Balance

Ecological Impacts of Pesticides in California

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One in a series of reports by Californians for Pesticide Reform

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Californians for Pesticide Reform (CPR) is a coalition of public interest organizations, including Pesticide Action Network, committed to protecting public health and the environment from pesticide proliferation. CPR's mission is to 1) educate Californians about environmental and health risks posed by pesticides; 2) eliminate the use of the most dangerous pesticides in California; 3) promote sustainable pest control solutions for our farms, communities, forests, homes and yards; and 4) hold government agencies accountable for protecting public health and Californians' right to know about pesticide use and exposure.

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Executive Summary

Thirty-seven years after Rachel Carson's eloquent warning to the world about the devastating effect pesticides have on birds and beneficial insects, pesticides continue to be a pervasive and insidious threat to California's ecosystems. A massive chemical assault on our environment is launched each year by California's residents, farmers, and official agencies, as we apply hundreds of millions of pounds of pesticide active ingredients in our homes and gardens, on crops and roadsides and in forests. This poisonous barrage aggravates other pressures on ecosystems, such as expanding suburban development and dammed rivers, threatening the survival of many birds, fish, insects, and small aquatic organisms that form the basis of the food web.

Pesticides affect all members of an ecosystem, from the smallest invertebrate to birds and humans. In California, the annual application of more than 100,000,000 pounds of the most toxic pesticides in both urban and agricultural settings is responsible for the deaths of many birds, fish, and the smaller aquatic animals that fish depend on for food. More generally, pesticides reduce species diversity in the animal kingdom and contribute to population declines in animals and plants by destroying habitat, reducing food supplies, and impairing reproduction. This report provides basic information about pesticides and how they are transported through the environment, documents the specific impacts of pesticides on California birds, fish, and their food supply, and presents a brief overview of viable, least-toxic pest control methods.

Pesticides Are Still Killing Birds, Both Directly and Indirectly

More than 25 years after DDT was banned, pesticides are still killing birds and impairing their reproduction. An estimated 672 million birds are exposed to pesticides every year in the United States from agricultural pesticide use alone. An estimated ten percent, or 67 million of these birds die. The loss of even a few individuals from rare, endangered, or threatened species—for example, burrowing owls, Aleutian Canada geese, or raptors like the bald eagle, Swainson's hawk, and the peregrine falcon—pushes the entire species that much closer to extinction. Research and observation have documented that:

- The insecticides diazinon and carbofuran are responsible for most documented bird kills in California. Diazinon is heavily used on almonds and stonefruits, in structural pest control and landscaping, and in unreported home pest control applications. Carbofuran is used primarily on alfalfa, grapes, and rice.
- Organochlorine pesticides (like DDT) continue to impair avian reproduction, years after most organochlorine pesticide use was discontinued. Because synthetic pyrethroids—commonly used in structural pest control and on cotton, alfalfa, and leafy vegetables—have a mode of action similar to the organochlorines, they are likely to have similar effects.
- Birds exposed to sublethal doses of pesticides are afflicted with chronic symptoms that affect their behavior, reproduction, and nervous system. Weight loss, increased susceptibility to predation, decreased disease resistance, lack of interest in mating and defending territory, and abandonment of nestlings have all been observed as side-effects of pesticide exposures.
- Most bird kills caused by pesticides go undocumented, with reported kills representing only a small fraction of actual bird mortality due to pesticides.
- Toxic pesticides are still being sprayed in national wildlife refuges in California, even though the National Wildlife Refuge Improvement Act of 1997 mandates protection of wildlife and the environment as the highest priority use for these areas.

Pesticides Threaten Fish and Their Food Supply

In an ecosystem that is already stressed from too many dams, diversion of water to farms and cities, and invasion of exotic species, the influx of toxic pesticides into California streams, sloughs, rivers, and bays is particularly damaging to many aquatic species. Several well-documented facts emerge from recent studies on pesticides and aquatic organisms in California.

- Multiple pesticides are commonly found in California waters and sediments, frequently at concentrations that exceed lethal levels for many species of zooplankton, small organisms eaten by fish. Because of both high use and significant water solubility, the insecticides diazinon and chlorpyrifos and the herbicides simazine, diuron, and EPTC are found most commonly.
- Toxic pulses of pesticides are a routine occurrence in California rivers, as stormwater and irrigation runoff carry pesticides from urban and agricultural areas into surface waters. These pulses are a violation of the Clean Water Act and the Basin Plans set forth by the Regional Water Quality Control Boards because they create lethal conditions for many consecutive days for the small organisms fish eat. The pesticides most commonly found in toxic concentrations in these pulses are diazinon and chlorpyrifos from sprays to dormant almond and stonefruit orchards, as well as from urban applications to buildings and in landscape maintenance.
- Most fish species and many species of zooplankton in the San Francisco Bay–Delta have experienced dramatic population declines in the last several decades. Multiple factors contribute to these declines, including toxic contaminants in waterways, dams, diversions, exotic species, and reduction in food sources. Pesticides known to kill aquatic animals and plants, impair their reproduction, and reduce food sources for fish are thought to be one of the major stressors affecting the aquatic organisms in the Bay-Delta ecosystem.

Pesticides Disrupt the Natural Balance Between Pest and Predator Insects

Broad-spectrum pesticides such as the organophosphorus, carbamate, and organochlorine insecticides destroy both pest and beneficial organisms indiscriminately, upsetting the balance between pest and predator insects. Many people believe that more insecticides mean fewer pests and higher crop yields. However, even though use of insecticides increased 10-fold from 1945 to 1989, crop losses from insects nearly doubled in the same time period, from 7% to 13%. In addition, the number of insect pests that are resistant to pesticides increased dramatically over the same time period. With fewer and fewer "effective" pesticides left in their arsenals, many growers are increasing the quantities of chemicals they apply to their crops. Others, however, are moving to non-toxic methods of pest control that focus on biological controls to solve their pest problems. Research and experience have shown that:

- Beneficial organisms serve many valuable functions in an agricultural ecosystem, including pollination, soil aeration, nutrient cycling, and pest control.
- Application of insecticides indiscriminately kills pests and beneficial organisms. Pest populations often recover rapidly because of their larger numbers and ability to develop resistance, but beneficial insects do not, resulting in a resurgence of the target pest as well as secondary pests that reproduce rapidly with no predators to check their numbers.
- Resistance and resurgence often lead to escalation of pesticide applications, resulting in pests with even greater resistance to pesticides. The resulting "pesticide treadmill" has created resistance to broad-spectrum insecticides in more than 500 pest species nationwide.

Restoring the Balance: Alternatives to Pesticides Are Available

Pesticides destroy the delicate balance between species that characterizes a functioning ecosystem. Fortunately, there are alternatives to dumping massive quantities of toxic chemicals on our crops, forests, and roadsides, and in our homes and gardens. Every crop in California that is commonly grown with intensive pesticide use is also being grown organically at other farms in the state. Least-toxic methods of pest control are available, and a growing number of California farmers are utilizing them. They include the following strategies:

- "Cultural" pest control methods such as crop rotation, reduction of habitat for pest species, provision of habitat for beneficial insects, and timing of plantings are effective in controlling many pests in agricultural settings. In urban settings, strategies such as pest exclusion by sealing cracks and other openings, as well as reduction of the pests' food supply are effective.
- A number of least-toxic methods for controlling pests are available. In agricultural settings, these include mulching, hand weeding, mating disruption, release of beneficial insects, and judicious application of low-toxicity pesticides such as oils, soaps, biopesticides, and sulfur. In urban settings, insect pests can be controlled with exclusion strategies and low-toxicity baits, and weeds can be controlled by mulching or hand-weeding.

Recommendations

Fish, birds, and wildlife that live in direct contact with environments subject to pesticide exposure are sentinel species that may be predictive of our own fate. With pesticides now found routinely in drinking water, on food, and in the air, we are all taking part in an experiment in pesticide exposure on a global scale, but without the benefit of an unexposed control group for comparison. We will probably not be able to quantify the exact risk of these exposures, or their interaction with other environmental factors affecting human health. Because we can't know for certain the consequences of expanding pesticide use, the rational and most protective course of action is to take a precautionary approach—phasing out use of the most dangerous pesticides, reducing our reliance on toxic chemicals for pest control, and promoting ecologically based pest management.

Recommendations for the California Environmental Protection Agency

- **Ban diazinon and chlorpyrifos immediately to stop the toxic flows in California surface waters.** All available data indicate that diazinon and chlorpyrifos are the worst offenders causing toxicity in California waterways. Neither voluntary efforts nor government regulation is working to protect our waterways from toxic flows. These lethal and illegal toxic pulses must be stopped now so California's aquatic organisms can recover from the onslaught of toxics they face throughout the year.
- **Ban all uses of carbofuran in California to eliminate bird kills caused by this pesticide.** Data show that carbofuran—an insecticide used mostly on rice and grapes—is one of the most hazardous pesticides to birds. Bird deaths result even when only a small quantity of the pesticide is used. Withdrawal of the registration for all uses of carbofuran in California is the only way to ensure that birds will be protected from this pesticide.

- **Phase out the worst pesticides and reduce use of the rest.** California needs a comprehensive program to eliminate use of *all* "bad actor"[1] pesticides. Without such a plan, banning individual pesticides will simply result in shifting to equally toxic substitute pesticides. This "risk shifting" would create new and (at present) unknown adverse effects on birds, fish, and other wildlife. Under current federal "risk assessment" requirements, it could take another ten years of study to establish without a shadow of a doubt that a new pesticide is indeed harmful in the environment. Meanwhile, the ecosystem will have sustained yet another ten years of damage. Rather than regulating pesticides one at a time—which leads to a tremendous regulatory burden and to serial substitution of one toxic material for another—we should adopt a system of ecologically based pest management that reduces the need for toxic pesticides.
- **Require the Department of Pesticide Regulation (DPR) to enforce existing laws and support alternative agriculture.** For years, DPR has consistently stonewalled enforcement of environmental regulations related to pesticides and the environment, and allocated few resources to alternative pest management in agriculture and other sectors. It is time for DPR to take seriously its mission of protecting public health and the environment by:
    - Phasing out all "bad actor" pesticides.
    - Setting and achieving pesticide use reduction goals for all pesticides.
    - Working productively with the State and Regional Water Quality Control Boards to reduce toxic pesticide runoff into surface waters and groundwater.
    - Providing extensive support for non-chemical methods of pest control.
- **Provide tax incentives to reduce pesticide use.** At present, many of the costs associated with pesticide use are borne by the public and the environment. The direct cost of applying a pesticide is only a small fraction of the actual cost. What remains unaccounted for are human illnesses due to pesticide exposures, kills of birds and fish, loss of habitat and food for fish and wildlife, and increased crop damage due to pesticide-resistant pests. Giving growers a tax break for reducing pesticide use and/or requiring pesticide manufacturers to pay more of the external costs associated with pesticide use will provide incentives to reduce use.
- **Provide funding for additional monitoring of fish and wildlife populations, as well as chemical concentrations in water, sediments, and wildlife tissues.** Monitoring of chemical concentrations and fish and wildlife populations, including creation of a centralized system for reporting bird and fish kills, is essential for determining the long-term effects of pesticide use. Understanding pesticide effects on native species in the field, not just in the laboratory, is crucial.
- **Include all high-use pesticides as chemicals to be monitored.** It is impossible to know the true extent of pesticide contamination if high-volume pesticides are not monitored. In particular, the herbicides glyphosate and paraquat dichloride, the insecticide methidathion, and the fungicides ziram, maneb, mancozeb, and fosetyl-Al should be included in State monitoring programs.
- **Promote viable alternatives to toxic pesticides.** Alternatives to toxic pesticides are being used successfully across the state. Growers and other pest managers need support to make the switch from chemical pest management to more sustainable pest-control methods.
- **Adopt the Precautionary Principle.** Because we do not know the full range of adverse effects of pesticides on the environment, we should reduce use of all toxic pesticides.

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1. In this report, we use the term "bad actor" pesticides to refer to those pesticides known to have adverse effects on human health and the environment.

Recommendations for the U.S. Environmental Protection Agency and the Federal Government

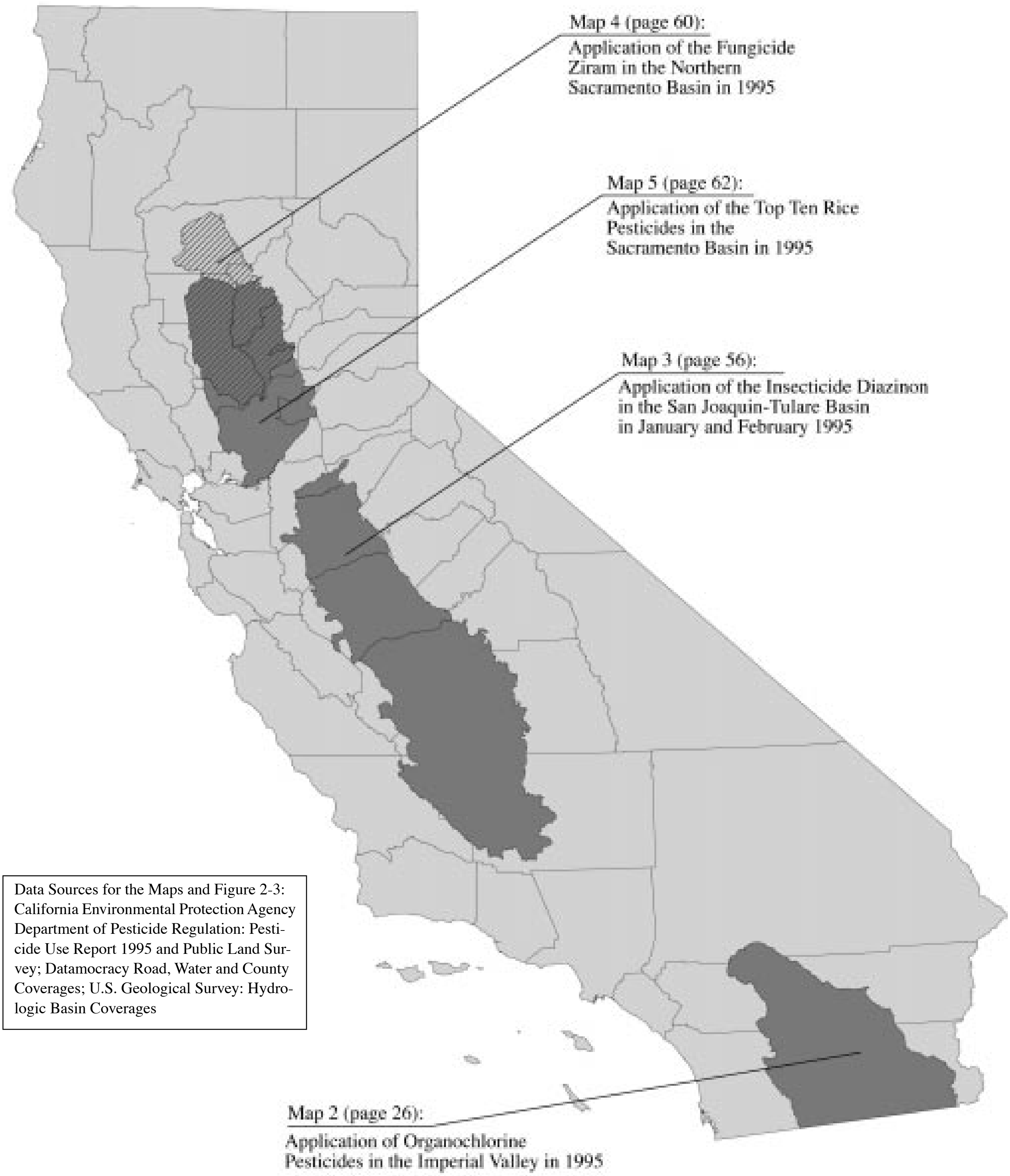
- **Require pesticide manufacturers to conduct long-term studies on ecosystem-wide impacts to demonstrate that a pesticide has no adverse effects before allowing it to be registered.** The fact that present regulations view a pesticide as innocent until proven guilty is detrimental to environmental health. It is critical to know more about the long-term ecological effects of a pesticide *before* it is released into the environment.
- **Prohibit pesticide use on national wildlife refuges.** Enforce the mandate of the National Wildlife Refuge Improvement Act of 1997 to put wildlife first on wildlife refuges. National wildlife refuges are for wildlife, not farms. If farming is to take place in these areas, it should be restricted to organic farming of crops that are compatible with wildlife.
- **Establish controls on agricultural and urban runoff to prevent pesticide contamination of surface waters.** The Clean Water Act does not effectively address non-point source pollution from urban and agricultural runoff. New legislation should be passed to ensure that toxic pesticide discharges from these sources do not contaminate surface waters.

Recommendations for Homeowners, Renters, and Parents

The amount of pesticides used on lawns, gardens and in homes and schools is estimated to be more than 20% of total pesticide use in California. If you are a homeowner, renter, or parent and wish to reduce your impacts on the environment while protecting your and your family's health, here are some steps you can take.

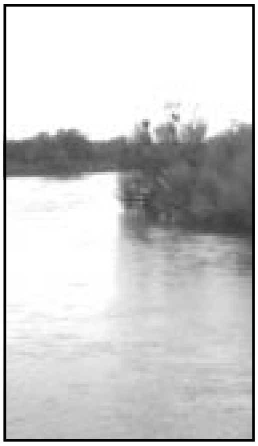
- **Use least-toxic pest control methods around the home and garden.** Exclude pests by caulking cracks, and keep kitchens and other parts of the home free from food sources that attract pests. Use low-toxicity, contained baits instead of spraying potent toxicants into the environment. In the garden, control weeds by mulching or hand weeding and use beneficial insects or least-toxic insecticides such as soaps, oils, and biopesticides to control insect pests. Watch out for "weed and feed" fertilizers containing pesticides. If you hire others to do your gardening work, insist that no pesticides be used. Appendix 3 provides resources for landscaping and pest-control firms specializing in least-toxic methods of pest management.
- **Buy organic foods whenever possible.** Market forces are a powerful incentive to encourage growers to go organic.
- **Insist on least-toxic pest management in your children's schools and support efforts to phase out use of toxic pesticides in schools.** Many schools now have a "no toxic pesticides" policy. If yours doesn't, work with other parents and teachers to implement such a policy at your school. Write your California legislators to give your support to the Healthy Schools Bill, AB 1207, which phases out school use of pesticides known to cause cancer, reproductive and developmental harm, and neurotoxicity.

Map 1: Regional Maps Presented in this Report



Data Sources for the Maps and Figure 2-3: California Environmental Protection Agency Department of Pesticide Regulation: Pesticide Use Report 1995 and Public Land Survey; Datamocracy Road, Water and County Coverages; U.S. Geological Survey: Hydrologic Basin Coverages

Introduction



Lars Neumeister

Driving down the road on a warm summer evening, you used to see house lights in the distance surrounded by a halo of winged insects of all types—mayflies, moths, beetles, gnats, and even those pesky mosquitoes. The riotous singing of frogs was often deafening, as each frog used its limited time on earth to search for a mate and start the cycle of life over again. In the cool morning, the sun would rise on flocks of birds feeding in the fields. Hawks would perch in nearby trees, surveying the scene for unwary field mice. Silvery fish would jump out of the water to catch their early morning meals, then retreat to cool eddies in the river to nibble on stonefly and dragonfly larvae and wait out the heat of the day.

Today, there is no halo around the house lights, and the singing of frogs is only an occasional, muted sound. Many frogs and toads grow extra legs and eyes and do not survive to adulthood. The number of birds, particularly migratory waterfowl, is shrinking dramatically. Chinook salmon that used to number in the millions have only a few thousand surviving progeny in California rivers. Many sportfishing operations that used to take thousands of people on California rivers to fish for striped bass, sturgeon, and salmon have closed down because there are so few fish to catch.[1]

The parallel between this scenario and the introduction in Rachel Carson's *Silent Spring*[2] in 1962 is no coincidence. The threat to our environment she warned of has not gone away. It has, in fact, become more widespread and subtle, aggravating other environmental changes and disrupting nature's balance.

As human populations have grown in California, housing developments and newly cultivated fields have destroyed habitat required by birds, smaller mammals, and beneficial insects. Most of the state's major rivers have been dammed, and much of their water is diverted for both municipal and agricultural use, leaving less water in the rivers to support fish and other aquatic life, particularly during drought years. However, while these factors play a role in the decline of fish and wildlife populations, they are only part of the picture.

One of the most pervasive and insidious threats to California ecosystems today is the massive chemical assault launched each year as we apply hundreds of millions of pounds of pesticide active ingredients in our homes and gardens, on crops and roadsides, and in forests. This legal and widespread release of toxic chemicals into the environment is in stark contrast to the strict treatment and permitting required for hazardous waste discharges from manufacturing, refining, and other industrial processes. In 1995, the most recent year for which official pesticide use data are publicly available, over 250 million pounds[3] of pesticide active ingredients were released into the environment, dwarfing reported industrial emissions in the same year[4] by a factor of four. At least 100 million pounds of this total are pesticides considered hazardous to public health and/or the environment, either because they are carcinogens, reproductive toxicants, endocrine system disruptors, or neurotoxins. Examination of the reproductive and developmental toxicants as an example shows that pesticide use is the single largest source of reported toxic emissions in California, far exceeding reported releases from industrial facilities (see Figure 1-1).

1. Personal communication with Rolf Ono, Ono Custom Rods, Millbrae, CA.
2. R. Carson, *Silent Spring*, Houghton-Mifflin (Boston, 1962).
3. This number includes all reported pesticide use, available from the Pesticide Use Reporting Data collected by the Department of Pesticide Regulation, as well as estimates of unreported use of over-the-counter pesticide sales in hardware and garden stores, as tracked by pesticide sales data, also collected by the Department of Pesticide Regulation.
4. U.S. Environmental Protection Agency Toxic Release Inventory (TRI) database, 1995, made available by Right-to-Know Net, a project of OMB Watch and the Unison Institute.

Comparison of Sources of Reproductive and Developmental Toxicants Released Into the Environment

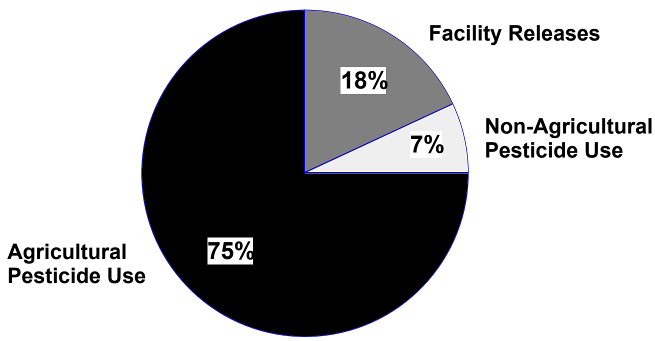


Figure 1-1: Pesticide use is the single largest source of reported toxic emissions in California, dwarfing reported industrial emissions. The chart reports 1995 releases for 78 chemicals that are known reproductive and developmental toxins.[5]

Surface waters are particularly vulnerable to pesticide pollution. Referring to pesticide concentrations in California's waterways, environmental consultant G. Fred Lee said, "If these concentrations of toxic substances were coming out of a wastewater treatment plant or from a waste processing facility or from a commercial laboratory, the operator would be fined and possibly incarcerated."[6]

In this report, we review the impacts of pesticides on birds, beneficial terrestrial insects, fish and other aquatic organisms in California. Beginning with an introduction to pesticides, we analyze the adverse impacts of pesticides on birds, fish, and aquatic insects, highlighting specific regional problems in selected areas of California. The report concludes with a number of recommendations for government regulators and individual pesticide users to improve the health of California's ecosystems, including eliminating use of the worst pesticides, reducing use of the rest, and implementing sustainable pest management practices in agriculture and other sectors.

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5. T. Schettler, G. Solomon, J. Kaplan, and M. Valenti, *Generations at Risk: How Reproductive Toxins May Affect Reproductive Health in California*, Physicians for Social Responsibility (San Francisco and Los Angeles, CA) and California Public Interest Research Group (San Francisco, CA), 1999.
6. G.F. Lee and A. Jones-Lee, "Development of a Regulatory Approach for OP Pesticide Toxicity to Aquatic Life in Receiving Waters for Urban Stormwater Runoff," paper presented at the June 1998 meeting of the Northern California Society of Environmental Toxicology and Chemistry, Reno, NV.

Chapter 1

Pesticide Basics

Hillary Turner

On July 14, 1991, a train tanker car derailed in Dunsmuir, California, spilling 19,000 gallons of metam sodium, a pesticide used as a soil fumigant, into the Sacramento River. The river was sterilized from Dunsmuir down to Lake Shasta, a distance of 20 miles. A million fish in the river died, including most of the native rainbow trout; the aquatic organisms that are the main food source for the fish were decimated.[7] River otters and ducks were found dead on the banks of the river, and nearly 200 people were treated at local hospitals for respiratory problems.[8] In light of the fact that more than 250 million pounds of pesticide active ingredients are used each year in California, probability will ensure that accidents like this continue to happen. But, as horrific as such disasters are, the day-to-day *legal* use of pesticides is a more insidious killer and not so different from a large-scale accident in terms of the absolute counts of dead and injured birds, fish, wildlife, and beneficial insects.

The introduction of pesticides into the environment wreaks havoc with ecosystems, reducing biodiversity and destroying habitat simultaneously. Because pesticide applications kill or limit the reproductive success and alter the developmental fate of the offspring of a wide variety of species, the intricate interdependencies of the ecosystem break down.

In this chapter, we define common terms used to describe pesticides and their environmental effects; provide basic information about different types of environmentally-damaging pesticides currently used in California and how they are transported through the environment; and highlight some of the major adverse effects associated with pesticide use.

Classification of Pesticide Hazards to Animals and Plants

When a large quantity of a potent pesticide is released into the environment, many of the effects are obvious in the number of dead animals that appear. However, the exposure of animals and plants to smaller doses of pesticides occurs much more frequently and causes more subtle effects. The terminology used to describe the range of dose-dependent effects is defined below.

- **Acute toxicity** refers to the immediate effects (0-7 days) of a particular dose of the pesticide on a particular species. There is considerable variation in the sensitivity of different species to different pesticides (see Appendix 1). The LD_{50}, or dose of the pesticide that is lethal to 50% of a set of test organisms, is the most commonly used measure of how acutely toxic a chemical is. A low number indicates that only a small amount of pesticide causes adverse acute effects. For example, the LD_{50} for the insecticide diazinon is 2 mg/kg for Mallard ducks, making them ten times more sensitive to this pesticide than Bobwhite quail, which have an LD_{50} of 20 mg/kg for this pesticide. Appendix 2 provides LD_{50} values for a number of different species and different pesticides commonly used in California.
- **Sublethal poisoning** refers to the effects on plants or animals of a pesticide dose that is not sufficient to kill, but does cause adverse effects to the animal or plant. The damage may include: reduced productivity for plants; inhibited feeding

7. M.T. Brett, C.R. Goldman, F.S. Lubnow, A. Bracher, D. Brandt, O. Brandt, and A. Müller-Solger, "Impact of a major soil fumigant spill on the planktonic ecosystem of Shasta Lake, California," *Canadian Journal of Fisheries and Aquatic Science*, 1995, vol. 52, pp. 1247-1256.
8. D. Garcia, "Spill Threatening Shasta," *San Francisco Chronicle*, July 17, 1991.

behaviors for animals; greater susceptibility to disease; and (in animals) impairment of the nervous system, which results in unusual behaviors that can make the animal more susceptible to predators, uninterested in mating, less vigilant about caring for its young, or unable to navigate correctly during migration.

- **Chronic toxicity** results from long-term and/or repeated exposure to a pesticide. This type of poisoning is of particular concern for pesticides that are applied frequently or break down very slowly in the environment building up (bioaccumulating) in the tissues of birds, fish, and humans. Such chronic exposures are associated with impaired reproduction and development, tumors, increased susceptibility to disease, and damaged livers.
- **Endocrine disruption** refers to the hormone-altering effects of certain chemical substances on animal endocrine systems that impair reproduction or development. Endocrine-disrupting chemicals alter the messages sent through hormones, an effect that can cause permanent functional changes to a developing animal, impair reproduction, and can increase susceptibility to cancer in adult animals. Many commonly used pesticides are suspected endocrine disruptors (see Appendix 1). The rapid decline in bird populations in the 1960s and 1970s caused by organochlorine pesticides such as DDT was due to endocrine-disrupting effects. Certain pesticides have been shown to mimic or block the action of estrogen, the primary female hormone. Exposure of developing animals to these chemicals, *in utero* or in eggs, has been associated with feminization or demasculinization of male offspring or masculinization of female offspring. For example, alligator eggs from Lake Apopka in Florida produced nearly all female offspring due to exposure to high concentrations of the pesticide dicofol.[9] Some pesticides block the action of androgens (male hormones) as well. In humans, increases in reproductive abnormalities of newborn children and lowered sperm counts in men have been linked to exposures to endocrine-disrupting chemicals. High-use endocrine-disrupting pesticides in California are shown in the sidebar.

Top Ten Endocrine-Disrupting Pesticides Used in California in 1995

(in thousands of pounds of active ingredient)

Chlorpyrifos	3,524
Ziram	1,640
Trifluralin	1,434
Maneb	1,309
Carbaryl	856
Simazine	843
Methomyl	830
Malathion	827
Mancozeb	679
Dicofol	598

Types of Pesticides

Several different kinds of pesticides are commonly found in California waters, sediments, and wildlife tissues. The term “pesticide” is used as a general term to represent any chemical substance used to control pests. The major classes of pesticides covered in this report include: herbicides, used to kill plants; insecticides, used to kill insects; and fungicides, used to prevent molds and mildews. In this section, we describe the properties of the major classes of pesticides with high potential to damage the environment and discuss how they control pests. Use patterns of these compounds in California are also examined briefly.

INSECTICIDES

Insecticides constitute nearly 25% of total reported pesticide use in California, accounting for more than 50 million pounds of active ingredients in 1995, the last year for which official pesticide use data is publicly available.[10] From 1991 to 1995, insecticide use in California increased approximately 18%. There are three major categories of insecticides that have detrimental effects on wildlife and the environment: organochlorines (OCs), organophosphates (OPs) and carbamates (grouped together because they function in a similar way), and synthetic pyrethroids. Figure 1-2 shows the top 10 insecticides used in California in 1995.

9. L. H. Keith, *Environmental Endocrine Disruptors: A Handbook of Property Data*, Wiley Interscience (New York, 1997).
10. Pesticide Use Reporting Data, 1995, Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, CA, 1998.

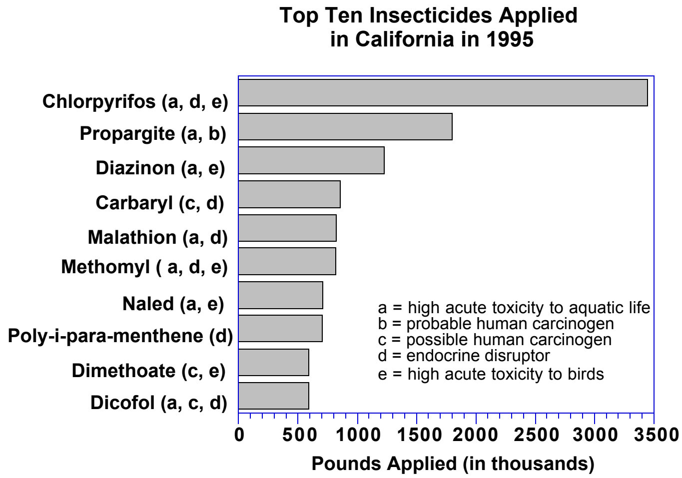
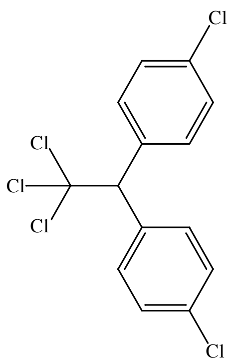


Figure 1-2: Most insecticides have high acute toxicity to aquatic life, and many are highly toxic to birds as well. Chlorpyrifos was the highest use insecticide in California in 1995.



DDT

Organochlorine Insecticides

Organochlorine (OC) pesticides such as DDT, dieldrin, chlordane, and others were widely used in the 1960s and 70s. They are not only acutely toxic, but cause significant chronic adverse effects because they are especially long-lived in the environment. These insecticides work by acting as contact and stomach poisons to insects.

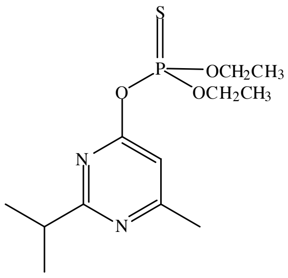
Initially the OCs were hailed as miracle chemicals because, while quite acutely toxic to insects, they were much less poisonous to mammals. However, rapidly declining predatory bird populations in the 1960s pointed to these chemicals as agents that interfered with avian reproduction by mimicking the hormone estrogen. In 1971, a study by the National Institutes of Health found residues of DDT in 100% of human tissue samples tested, showing how extensive the contamination of our environment had become since DDT came into widespread use.[11] Public outcry was extensive; nevertheless, the agrochemical industry fought hard to keep these pesticides on the market. After many regulatory battles, most, but not all of these pesticides were banned from use in the U.S. in the 1970s. Since then, most of these pesticides have been shown to be carcinogens or endocrine disruptors or both.[12]

There are several organochlorine compounds still in use in California, including the common food-use pesticides endosulfan, methoxychlor, and dicofol, as well as lindane, used to treat head-lice. While these compounds are not as long-lived as the banned organochlorines, they can still persist in the environment for more than ten years, depending on soil conditions. While all of the organochlorine pesticides are only slightly water soluble, the newer generation organochlorines are significantly more water soluble than compounds like DDT, a characteristic that allows them to move more freely through the environment, as they are carried with flowing water.

When released into aquatic ecosystems, organochlorines collect in sediments. Away from light and oxygen, these pesticides degrade slowly and are ingested with sediments by small invertebrates at the bottom of the food chain such as the tiny shrimp *Neomysis*, the water flea *Daphnia*, and a variety of other aquatic and terrestrial insects and their larvae. Once inside the organism, organochlorines accumulate in fatty tissues. Fish that eat pesticide-contaminated invertebrates accumulate more of the chemical with each shrimp or caddisfly larva they take in. A large, mature fish, the

11. T. Williams, “Silent Scourge, ” *Audubon*, Jan/Feb 1998, p. 30.
12. J. Liebman, *Rising Toxic Tide: Pesticide Use in California, 1991-1995*, Pesticide Action Network and Californians for Pesticide Reform (San Francisco, CA, 1997).

"big one," is likely to contain much higher pesticide residues because it has eaten more contaminated food over time than a younger fish. The highest concentrations of these persistent, bioaccumulating pesticides are found in those animals at the top of the food chain—humans, predatory birds, seals, and other predatory animals.

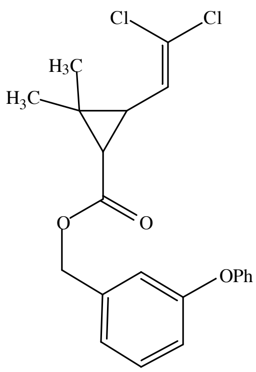


Diazinon

Organophosphate and Carbamate Insecticides

As many of the first-generation organochlorine pesticides were banned, the agrochemical industry turned to the less persistent, but more acutely toxic organophosphate (OP) and carbamate compounds to control insect pests. Use of these pesticides increased rapidly, and by the late 1980s, approximately 65% of insecticides applied nationwide were OPs and carbamate compounds.[13] In California, reported use of OPs and carbamates increased 18% between 1991 and 1995.[14] These chemicals are used on a wide variety of fruit, nut, vegetable, and field crops to control insect pests.

The OPs are very similar to the chemical warfare agents originally produced during World War II. They work by interfering with the nervous system of insects, as well as mammals, birds, and fish. Organophosphates and carbamates block production of an enzyme called cholinesterase (ChE), which ensures that the chemical signal that causes a nerve impulse is halted at the appropriate time. Birds and mammals that have been poisoned by these pesticides respond with uncontrolled nerve impulses. Symptoms of exposure include twitching, trembling, inability to breathe because of paralysis of the diaphragm, convulsions, and at higher doses, death. The OPs and carbamates are among the most acutely toxic pesticides, with most formulations classified by the U.S. Environmental Protection Agency as toxicity class I (highly toxic) or toxicity class II (moderately toxic).



Permethrin

Pyrethroid Insecticides

There are a number of chemical compounds found in nature that act as insecticides. The most commonly used are pyrethrins, compounds derived from certain species of chrysanthemum flowers. Synthetic pyrethrins, called pyrethroids, are compounds that are similar in structure and activity to pyrethrins, but are produced by a chemical manufacturing process. This class of insecticides includes the widely used compounds permethrin, cypermethrin, fenvalerate, bifenthrin, esfenvalerate, and flucythrinate. Other pyrethroids exist, but are used in smaller amounts.

Pyrethroids are very similar in many ways to the organochlorine insecticides. Their mode of action against pests is identical to that of the organochlorines. These compounds also contain chlorine, which contributes to their persistence in the environment, as measured by their half-life, the time required for degradation of half of the pesticide (see Appendix 1). Similar to the organochlorines, most pyrethroids are suspected endocrine system disruptors as well,[15] and while they have only moderate acute toxicity to mammals and birds, they have very high acute toxicity to beneficial insects, fish, and other aquatic organisms.

In California, pyrethroids are used predominantly for structural pest control and on cotton, alfalfa, leafy vegetables such as lettuce and spinach, and nuts.[16] Because pyrethroids and organochlorines have similar mechanisms of action against insect pests, cross-resistance is a concern, with insects that have developed resistance to organochlorines also resistant to pyrethroids.[17]

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13. S. J. Larson, P.D. Capel, and M.S. Majewski, *Pesticides in Surface Waters: Distribution, Trends, and Governing Factors*, Ann Arbor Press, Inc. (Chelsea, MI, 1997), p. 190.
14. Ibid.., reference 12.
15. Ibid., reference 9.
16. Ibid., reference 10.
17. For more information on insect resistance to pesticides, see Chapter 4, page 70.

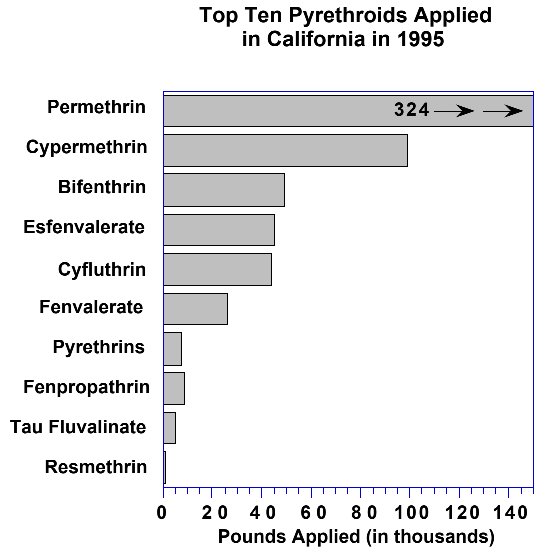
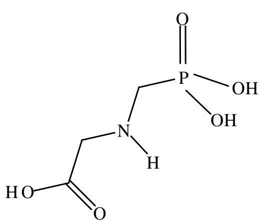


Figure 1-3: Permethrin is the highest-use pyrethroid in California, with major uses in structural pest control and on lettuce, almonds, and alfalfa.

Use of pyrethroids on crops is increasing steadily, as insect pests develop resistance to the organophosphates and carbamates. For example, use of permethrin on crops increased from 120,700 pounds in 1991 to 155,400 pounds in 1995.[18] Structural pest control in homes and other buildings accounts for the remainder of permethrin use, accounting for slightly more than the amount used on crops. Bifenthrin and cypermethrin use on cotton in California increased substantially between 1991 and 1995, from a total of 10,600 pounds in 1991 to 48,800 pounds in 1995.[19]

HERBICIDES

With continuing economic pressure to reduce human labor in agricultural production and the advent of no-till farming, use of herbicides to control weeds is rapidly increasing. In 1995, more than 25 million pounds of herbicide active ingredients were applied in California.[20] The top ten herbicides are shown in Figure 1-4. The primary uses of these herbicides are for applications to rights-of-way and agricultural applications to orchards, rice, corn, cotton, and grapes.



Glyphosate

There are several major types of herbicides used in California. Glyphosate, the active ingredient in Monsanto's Roundup®, is in a class by itself because its structure and mode of action are very different from any of the other herbicides. Applied to the leaves of unwanted plants (a post-emergent herbicide), glyphosate inhibits an enzyme essential for plant survival, causing death of the plant. Glyphosate has the highest reported use of any herbicide in California, with well over 4.1 million pounds applied statewide in 1995—more than twice as much as any other single herbicide. Reported use of this chemical increased 44% between 1991 and 1995 and is anticipated to increase even more, as Monsanto expands its markets for genetically engineered "Roundup Ready®" cotton, corn, and soybeans—crops that are not affected by the herbicide.[21]

18. Ibid., reference 10.
19. Ibid., reference 10.
20. Ibid., reference 10.
21. A. M. Thayer, "Transforming Agriculture," *Chemical and Engineering News*, April 19, 1999, pp. 21-35.

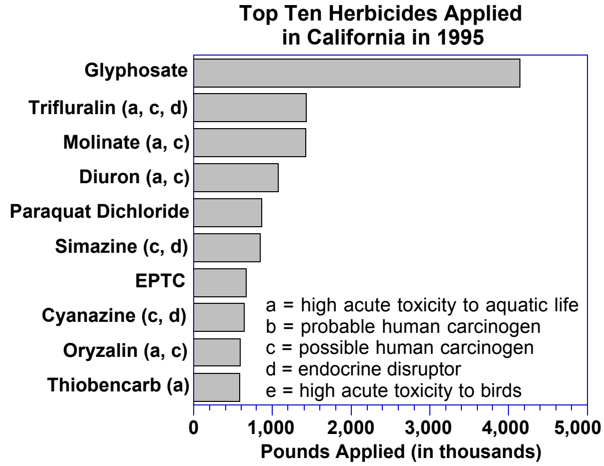
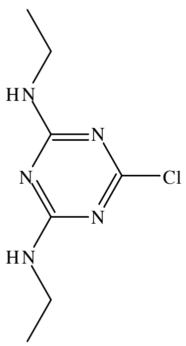


Figure 1-4: Glyphosate is the highest use herbicide in California, with major uses in roadside applications, almonds, cotton, and landscape maintenance.

While glyphosate has low to moderate acute toxicity relative to many pesticides (see Appendix 1), its widespread use is cause for concern. Few U.S. monitoring programs analyze for this herbicide or its breakdown products in surface waters and groundwater; however, in Denmark, where monitoring is conducted, a breakdown product of glyphosate has been found in drinking-water wells.[22]



Simazine

The triazines and acetanilides are two classes of herbicides used as pre- and post-emergent herbicides, primarily on corn, soybeans, sorghum, and for clearing roadside vegetation. Some of these herbicides work by inhibiting photosynthesis in the plant; others by inhibiting protein synthesis and therefore affect plant growth. While not as acutely toxic to animals as the insecticides, many of these compounds are classified as probable (alachlor) or possible (simazine, atrazine, cyanazine, metolachlor, and propazine) human carcinogens by the U.S. Environmental Protection Agency.[23] Several of these compounds are also of special concern because research demonstrates that they are endocrine disruptors.[24] Concern in Germany over the potential impacts of the triazine herbicides led to a ban of atrazine in that country in 1991.[25] Several other European countries followed suit, and many localities in both the U.S. and Europe have reduced the allowable application rates of atrazine. Cyanazine is presently being voluntarily phased out in the U.S. because of evidence presented by the U.S. Environmental Protection Agency implicating it as a carcinogen and a reproductive toxin.[26]

The primary known environmental impact of widespread herbicide use is destruction of habitat for beneficial insects, birds, and aquatic life.[27] In turn, this reduces the food supply of birds and other animals. Additional impacts include: 1) inhibition of the growth of phytoplankton, the organisms that form the basis of the food web and act as a "support system" for higher organisms,[28] 2) disruption of the

22. *Danske undersøgelser for glyphosat og AMPA*, MILJØstyrelsen, Vandforsyningskontoret, May 5, 1997 (Copenhagen).
23. Ibid., reference 13, p. 194.
24. Ibid., reference 9.
25. H. Schmitt, *The Triazine Pesticides: Reasons for Concern*, World Wildlife Fund (Bremen, Germany, 1996).
26. U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, *Status of Chemicals in Special Review*, EPA-738-R98-001, February 1998.
27. K. Freemark and C. Boutin, "Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: A review with special reference to North America," *Agriculture, Ecosystems and Environment*, 1995, vol. 52, pp. 67-91.
28. Ibid., reference 25.

endocrine systems in amphibians, fish, and birds,[29] and 3) other sublethal effects such as immune system depression in fish.[30]

Because so little is known about any of these effects, the extent of potential damage to the entire ecosystem cannot be assessed at this time. It is not safe to assume that these compounds are therefore harmless. We have many examples, including all of the now-banned organochlorine pesticides, which remind us that it is too simplistic to assume no harm is occurring because we cannot immediately recognize the damage.

FUNGICIDES

Fungicides are used to control molds and mildews on crops and in the soil, as well as on golf courses, turf farms, and ornamentals. The fungicides of particular concern for the environment include copper salts and synthetic compounds with high toxicity to some species. Figure 1-5 shows the top ten environmentally damaging fungicides used in 1995.

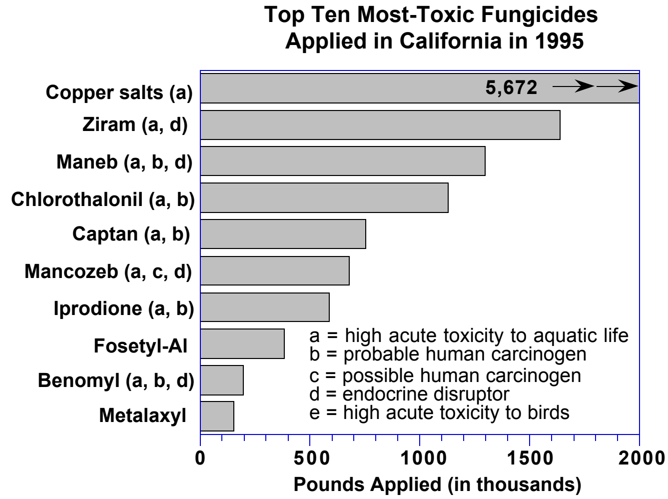
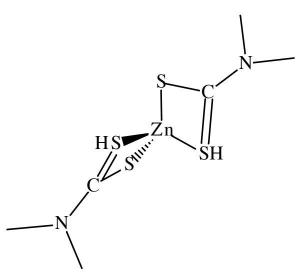


Figure 1-5: The top ten most-toxic fungicides used in California are dominated by copper salts.[31] The chart excludes sulfur, lime, and lime-sulfur mixtures because of their lower toxicity.[32]

Many fungicides are highly toxic to aquatic life, including copper salts, ziram, maneb, chlorothalonil, captan, and mancozeb (see Appendix 1). Some of these compounds cause chronic toxicity as well. Ziram, maneb, mancozeb, and benomyl are endocrine disruptors. Captan, chlorothalonil, iprodione, maneb, and mancozeb are classified as probable or possible human carcinogens by the U.S. Environmental Protection Agency. Copper salts cause reproductive harm and liver damage in mammals and fish.

Very few studies to date have tested for fungicides in water, sediments, and tissues of aquatic organisms. Because the data on the presence of fungicides in California air, waters, sediments and wildlife are so limited, we have much less information



Ziram

29. Ibid., reference 9.
30. R.D. Ewing, *Diminishing Returns: Salmon Decline and Pesticides*, Oregon Pesticide Education Network (Eugene, OR, 1999), http://www.pond.net/~fishlifr/salpest.pdf.
31. Excludes copper sulfate used as an herbicide/insecticide on rice.
32. Although sulfur has lower toxicity than other fungicides, it is the number one cause of reported farmworker injuries.

about the extent of their occurrence compared to other pesticides. More work is needed in monitoring fungicide concentrations in air, water, and tissues to determine where these pesticides have the most serious adverse effects.

Pesticides in the Environment

Release: How Pesticides Are Introduced Into the Environment

Pesticides make their way into waterways, lakes, oceans, nature preserves, wildlife refuges, forests, and urban areas by many routes.

- **Agricultural applications:** In agricultural areas, massive amounts of pesticides are introduced into the environment through aerial and ground spraying of crops. Livestock operations also introduce pesticides into the environment through spraying and dipping animals to control flies and other pests. Soil and storage fumigations, as well as chemigation (application of pesticides with irrigation water), use large quantities of pesticides also. Environmental contamination occurs when pesticides drift away from the application site through the air, infiltrate groundwater by leaching through the soil, run off treated land with storm water or irrigation water, or otherwise migrate away from the application site.

U.S. Fish and Wildlife Service

A crop duster drops the highly toxic insecticide chlorpyrifos on an alfalfa field. The free-fall from the crop duster is only the beginning of this chemical's long journey through the environment.

- **Urban applications:** Lawn, garden, and structural pesticides such as diazinon and chlorpyrifos wash into waterways with irrigation water or during rain storms. Reported commercial applications of these two chemicals in California alone account for 12.5 million pounds of active ingredients in 1995. Although home use of pesticides is not required to be reported, estimates from sales data suggest that such applications constitute approximately 20% of pesticide use statewide.[33]

- **Right-of-way applications:** Along roadsides and railways all over the state, herbicides are used to control plant growth, and fungicides and insecticides are applied to structures. A reported total of 3.5 million pounds of pesticides were applied to California right-of-ways in 1995. High use pesticides are shown in the sidebar.[34] These pesticides wash into streams and rivers with storm runoff. Because most herbicides are quite persistent in the environment, they are frequently found in both surface waters and groundwater.

Top Five Right-of-Way Pesticides Used in California in 1995

(in thousands of pounds of active ingredient)

Glyphosate	1,066
Diuron	505
Copper sulfate	492
Acrolein	243
Simazine	13

33. S. R. Templeton, D. Zilberman, and S. J. Yoo, "An Economic Perspective on Outdoor Residential Pesticide Use," *Environmental Science and Technology*, 1998, vol. 32, pp. 416A-423A.

Top Five Forestry Pesticides Used in California in 1995 (in thousands of pounds of active ingredient)	
Triclopyr derivatives	81
Hexazinone	47
Glyphosate	32
2,4-D	18
Atrazine	4

- **Forestry applications:** Herbicides are applied liberally to newly planted forests to reduce surrounding vegetation that might compete with young trees. Insecticides are frequently applied to more mature forests to control insect pests. Approximately 238,000 pounds of pesticides were applied to California forests in 1995 (see sidebar).[35] Because forested land is in the wetter parts of the state and often on steep slopes, pesticide drift and storm runoff into waterways are the predominant means by which these pesticides contaminate the environment.
- **Accidental releases:** Accidental spills can occur during transport of pesticides from the manufacturer to the end user, as well as at airports, farms, homes, or storage areas. The spill of metam sodium into the Sacramento River near Dunsmuir, California is an example of an accidental release that caused major environmental damage.

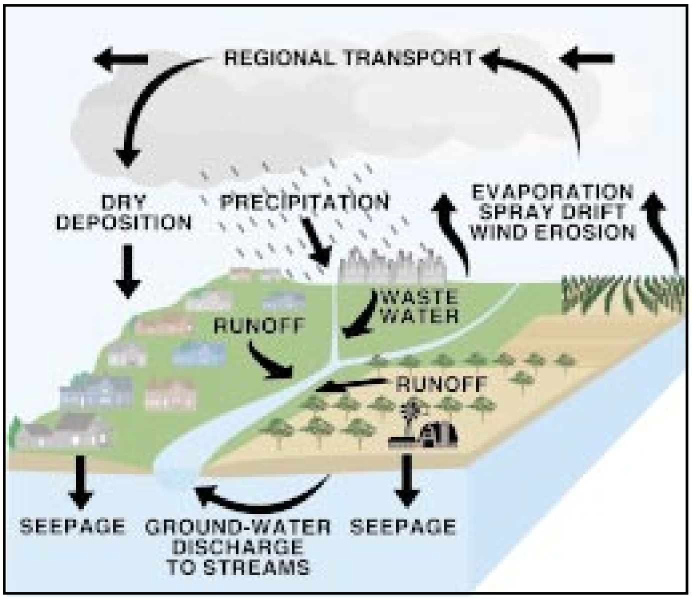


Figure 1-6: Pesticides don't always remain where they are applied and are transported through air and water. As they volatilize, they are transported by winds and precipitate out with rainfall. Runoff from agricultural and urban areas into surface waters contributes significant pollution to groundwater and surface waters (reproduced with permission of the U.S. Geological Survey).[36]

Transport: Pesticides Do Not Always Stay Where They Are Applied

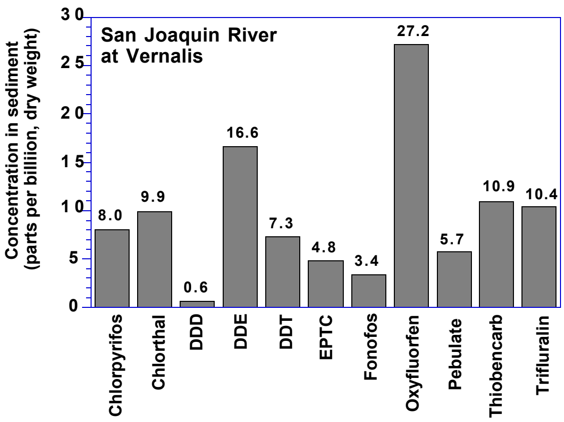
Once a pesticide is released into the environment, it can be transported to different locations in a number of different ways. Figure 1-6 details the many ways pesticides move through the environment, including:

- **Aerial drift and evaporation from application sites:** Tiny droplets of pesticide sprays and small particles from pesticide dusts rarely stay within the confines of the field on which they are applied, but travel with prevailing winds, sometimes for many miles. A recent review of studies on spray drift from aerial and ground applications indicates that an average of 50% of the applied pesticide typically does not hit the target application site, and as much as 80% drifts away from the site.[37] Additionally, many pesticides evaporate readily, particularly at warmer

34. Ibid., reference 10.
35. Ibid., reference 10.
36. "Pesticides in Surface Waters," U.S Geological Survey, Fact Sheet FS-039-97, U.S. Geological Survey, 1997, http://water.wr.usgs.gov/pnsp/fs-039-97/.

temperatures. These volatilized pesticides move with wind currents into nearby areas. Airborne pesticides can drift for miles before settling and sometimes re-volatilize to travel even further. The long-lived organochlorine compounds, found as far away as the Arctic and Antarctic, travel in this way.

- **Deposition of airborne pesticides:** Airborne pesticides can be deposited back on land as rain washes them out of the air and into surface waters and groundwater. This means of transport can contribute significantly to the overall pesticide concentration in a body of water. For example, during high-use periods for the insecticide diazinon, this pesticide has been found in rainwater at concentrations high enough to exceed the toxic dose for sensitive aquatic insects.[38]
- **Transportation through the food web:** Pesticides that are ingested by animals but not readily excreted can be transported to other locations when the host animal travels. Migrating fish, marine mammals, and birds carry pesticides long distances where they can be eaten by humans or other animals.
- **Irrigation or rainwater runoff:** Irrigation water runoff, through overland flow or underground drains to groundwater, is the primary source of pesticide contamination of surface waters in the dry season in California. In rainy months, storms wash pesticides off fields and orchards and into nearby surface waters. The amount of pesticide that washes into the receiving water depends on a number of factors, including the amount and identity of pesticide applied, water solubility of the pesticide, and type of soil and vegetation present in the application area. While some pesticides bind tightly to soils and are transported only via sediments (see Figure 1-7), others dissolve readily in water and travel with the overland flow into streams, agricultural drains, and rivers.



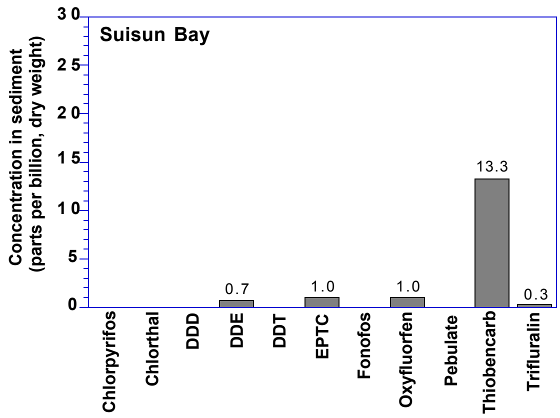


Figure 1-7: Pesticides are transported on sediments with storm water and irrigation water. This figure shows pesticide concentrations in suspended sediments in the San Joaquin River near Vernalis and in the Suisun Bay.[39] Because the San Joaquin sediments are geographically close to massive applications of pesticides, both historic and present, the concentrations are higher than in the Suisun Bay, which is farther from applications.

37. J. Bennett, "Pesticide Drift and Runoff: Considerations for the U.S. Fish and Wildlife Service Draft Biological Opinion on Effects of 31 Pesticides on Threatened and Endangered Species," Washington Cooperative Fish and Wildlife Research Unit, University of Washington, March 1, 1992.
38. V. Connor, Central Valley Regional Water Quality Control Board, as cited in J. P. Fox and E. Archibald, *Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley,* California Urban Water Agencies, 1998, p. 112.
39. B.A. Bergamaschi, K.L. Crepeau, and K.M. Kuivila, *Pesticides Associated with Suspended Sediments in the San Francisco Bay Estuary*, U.S. Geological Survey Open-File Report 97-24 (http://water.wr.usgs.gov/ofr97-24/spatial.html).

FATE: PESTICIDES ARE TRANSFORMED IN THE ENVIRONMENT

In the environment, pesticides degrade into a variety of other substances as a result of interactions with soil, water, sunlight, and oxygen. The presence and potential environmental effects of pesticide breakdown products are only now being included in environmental fate studies by the agencies responsible for monitoring concentrations of these compounds in the environment. When these breakdown products are monitored, they are commonly found in measurable quantities in water, sediments, and tissues.[40]

Pesticides are also degraded by living organisms. Soil microbes are responsible for catalyzing the breakdown of many pesticides, and in higher animals, most pesticides are broken down in the liver to more soluble compounds which are then excreted.

Generally, pesticide breakdown products are less toxic than the pesticide itself, but this is not always true. For example, atrazine breaks down into de-ethyl atrazine, a compound that is more toxic than atrazine itself. Similarly, ethyl parathion is not particularly toxic until it is transformed into paraoxon, a chemical more acutely toxic to mammals than the original pesticide.

The rate of breakdown of a particular pesticide in the environment is a function of the pesticide, its location (whether it is buried in soil or sediment, on an exposed leaf surface, in water, etc.), temperature, soil or water pH, and the moisture content of the surrounding medium. Certain pesticides, such as the organochlorines, are particularly resistant to degradation and can survive unchanged in sediments and soils for decades.

REGULATION: A LEGACY OF INEFFECTIVE ENVIRONMENTAL PROTECTION

Because pesticides are known to have adverse effects on public health and the environment, a variety of federal and state laws have been passed in an effort to minimize these impacts. However, in spite of extensive regulation, the mitigation of impacts of pesticides on the environment has been, and continues to be, too little, too late. Specific problem areas include:

- Existing state and federal laws do not protect the environment from adverse effects caused by pesticides. Even though pesticides are the largest single source of toxic releases to the environment in California, they are exempt from regulations that require permitting of toxic releases. Only two states in the U.S., California and New York, require full pesticide use reporting.
- The instructions printed in fine print on the labels of pesticide containers are the primary control over the use of most pesticides. The lack of enforcement of label instructions and the absence of punishment for violators make this strategy an ineffective tool for regulating toxic substances in the environment.
- New pesticides must be tested for acute environmental effects before they can be used; however, pesticides registered before 1984 are "grandfathered" in until they are re-evaluated, a practice that permits continued use of pesticides that are hazardous to humans and damaging to ecosystems. Even for new pesticides, the U.S. Environmental Protection Agency does not require pesticide manufacturers to conduct studies on their long-term environmental effects. As a result, adverse effects may not be noticed until years of damage has already occurred.
- While the federal Clean Water Act mandates regulation and permitting to control industrial "end-of-pipe" pollution, there is no parallel mechanism for controlling toxic runoff from urban and agricultural areas.

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40. J.E. Barbash and E.A. Resek, *Pesticides in Ground Water: Distribution, Trends, and Governing Factors*, Volume 2 in the series *Pesticides in the Hydrologic System,* U.S. Geological Survey, Ann Arbor Press (Chelsea, MI, 1996).

- The Endangered Species Act is supposed to protect populations of endangered plants and animals from further decline by protecting habitat and reducing stress caused by human activities. However, insufficient funding and the glacially slow process required to document the locations, habits, and pesticide impacts for endangered species mean protection often comes too late.
- The California Department of Pesticide Regulation (DPR), whose stated mission is to protect public health and the environment, has invested little time and few resources to support non-chemical pest control measures that would protect fish, birds, wildlife, and humans.
- Finally, both federal and state regulatory processes that affect pesticide registration and use are subject to intense political pressure from the pesticide manufacturing industry. Indications that a pesticide might be banned often result in an uproar from industry representatives in an effort to save the targeted pesticide.

Chapter 2

Effects of Pesticides on Birds

More than 25 years after DDT was banned, pesticides are still killing birds and impairing their reproduction. An estimated 672 million birds are exposed to pesticides every year in the United States from agricultural pesticide use alone. An estimated ten percent, or 67 million of these birds die.[1] The loss of even a few individuals from rare, endangered, or threatened species—for example, the burrowing owl, Aleutian Canada geese, or raptors like the bald eagle, Swainson's hawk, and the peregrine falcon—pushes the entire species that much closer to extinction. Research and observation have documented that:

- The insecticides diazinon and carbofuran are responsible for most documented bird kills in California. Diazinon is heavily used on almonds and stonefruits, in structural pest control and landscaping, and in unreported home pest control applications. Carbofuran is used primarily on alfalfa, grapes, and rice.
- Organochlorine pesticides (like DDT) continue to impair avian reproduction, years after most organochlorine pesticide use was discontinued. Because synthetic pyrethroids—commonly used in structural pest control and on cotton, alfalfa, and leafy vegetables—have a mode of action similar to the organochlorines, they may have similar effects.
- Birds exposed to sublethal doses of pesticides are afflicted with chronic symptoms that affect their behavior, reproduction, and nervous system. Weight loss, increased susceptibility to predation, decreased disease resistance, lack of interest in mating and defending territory, and abandonment of nestlings have all been observed as side-effects of pesticide exposures.
- Most bird kills caused by pesticides go undocumented, with reported kills representing only a small fraction of actual bird mortality due to pesticides.
- Toxic pesticides are still being sprayed in national wildlife refuges, even though the National Wildlife Refuge Improvement Act of 1997 mandates protection of wildlife and the environment as the highest priority use for these areas.

Routes of Exposure

Birds can be exposed to pesticides in many ways as they lead their daily lives, foraging for food in fields, forests, backyards and wetlands. Some of the primary exposure pathways are:

- **Eating the pesticide directly:** Pesticides are sometimes sold in granular form which is typically applied together with the seeds a farmer plants. Birds ingest these granules as they forage for seed, probe the soil, and prey on granule coated earthworms.[2] Pesticide-treated seeds can also be ingested.

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1. D. Pimentel, H. Acquay, M. Biltonen, P. Rice, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Horowitz, and M. D'Amore, "Environmental and Economic Costs of Pesticide Use," *BioScience*, 1992, vol. 42, pp. 750-760.
2. D.M. Fry, "Reproductive Effects in Birds Exposed to Pesticides and Industrial Chemicals," *Environmental Health Perspectives*, 1995, vol. 103, pp. 165-171.

- **Eating contaminated food:** Many birds are exposed to pesticides by eating recently sprayed insects or plants. Predatory and scavenging birds are often affected when they eat other birds or small mammals that have recently ingested a pesticide-contaminated meal.
- **Exposure through the skin and respiration:** Inhalation and skin exposures occur when birds are present during or shortly after pesticide applications. Birds often follow tractors to take advantage of the insects and worms turned up by plowing. But birds don't know the difference between a tractor that is merely plowing and one that is applying pesticides. Contaminated objects—tree branches, wires, fence posts—that birds come in contact with can also cause poisoning by absorption of the pesticide through their feet and skin or through ingestion when they groom their feathers.

Problem Pesticides for Birds

Approximately 40 pesticides used in the U.S. are known to be highly toxic to birds. The primary culprits are the organophosphate, carbamate, and organochlorine insecticides. Different bird species have different exposures and tolerances to different pesticides (see Appendix 2, Table 1).[3] Bird kills are only the most obvious indicator of poisoning, and although the reported numbers of kills are substantial (see Figure 2-1), they represent only a small fraction of the total damage. Pesticides have a wide range of sublethal adverse effects on birds, including paralysis, seizures, behavior changes, and reproductive failures.

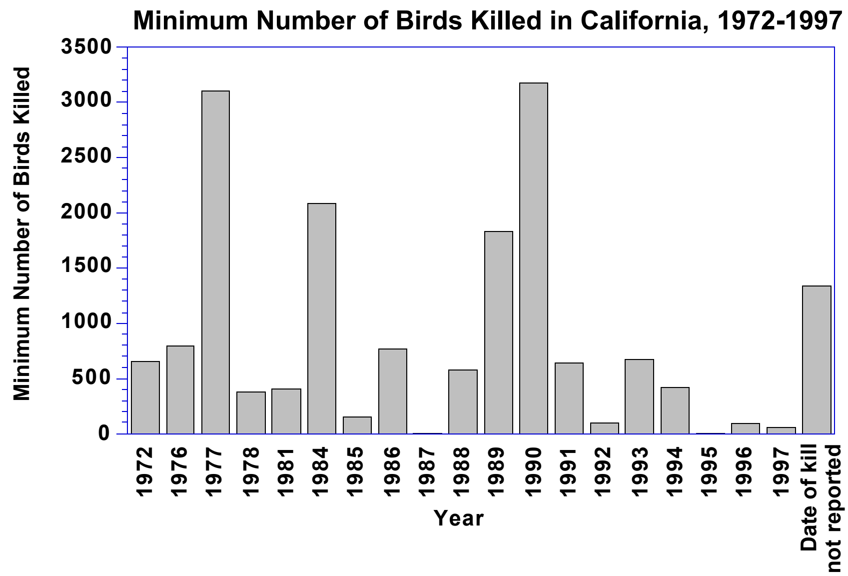

Figure 2-1: Pesticide poisonings kill many birds every year. The plot represents the documented number of birds killed in California due directly to pesticide poisonings, as reported to the U.S. Environmental Protection Agency.[4] Because most dead birds are neither found nor counted, the reports represent only the *minimum* number of birds killed and vastly underestimate mortality.

Organophosphates and Carbamates Cause Many Bird Kills

The U.S. Department of the Interior's National Wildlife Health Center reports that 50% of the documented cases of lethal poisonings of birds are caused by organophos-

3. For example, the dose of carbofuran that kills at least 50% of Mallard ducks (LD_{50}) is 3 mg/kg of body weight, while the LD_{50} for Bobwhite quail is 720 mg/kg of body weight.
4. U.S. Environmental Protection Agency Ecological Incident Information System (EIIS) Summary Report, April 1998.

phates (OPs) and carbamates.[5] Carbofuran alone is responsible for most bird kills in California, followed by diazinon (see Figure 2-2).[6] The frequency and number of reported bird kills closely parallels agricultural activities in California. In the last 10 years, Colusa, Glenn, San Joaquin, Monterey, Sacramento, Imperial, and Napa counties had the highest reported number of birds killed by pesticides, with carbofuran applications to grapes or rice responsible for the majority of poisonings. Diazinon poisonings have occurred near golf courses, orchards, and other intensively treated landscapes. Many bird species are affected, from songbirds to waterfowl to raptors.

Mechanism of Toxicity

The OPs and carbamates kill birds by disrupting the nervous system, and in general do not build up in tissues. Many of these pesticides are acutely toxic to birds even at low concentrations (see Appendix 2, Table 1). Birds are more susceptible to poisoning than mammals because they cannot detoxify these pesticides as rapidly. For example, birds are 100 times more sensitive than mammals to the common OP insecticide diazinon.[7]

The primary symptom exhibited by animals suffering from acute OP and carbamate toxicity is a reduction of cholinesterase (ChE) activity, resulting in tremors, loss of muscular control, and paralysis (see page 12). Most animals that die from exposure to OPs and carbamates suffocate because of respiratory paralysis.

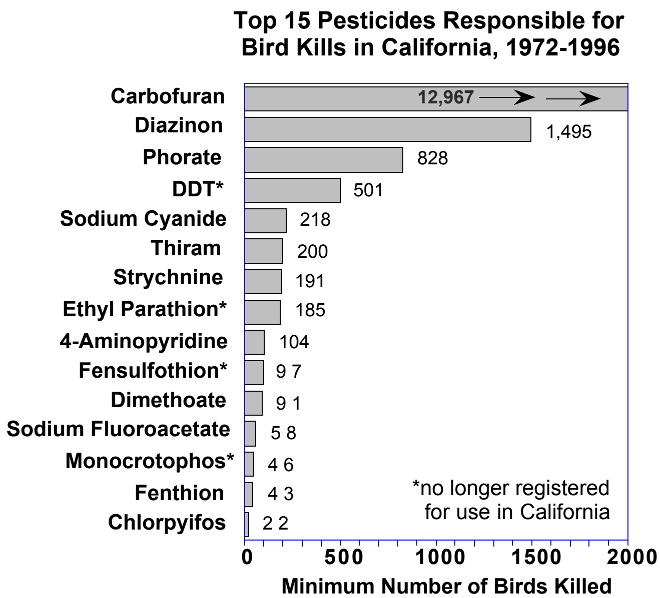

Figure 2-2: Carbofuran and diazinon account for the majority of kills in California and throughout the U.S.[8]

Carbofuran and Diazinon Are Responsible for Most Bird Kills

Bird kills caused by OPs and carbamates are common, and can be massive. Two pesticides are particularly problematic for birds, diazinon and carbofuran.

Diazinon applications to lawns, golf courses and turf farms have killed thousands of birds in the U.S.[9] Diazinon predominantly affects herbivorous waterfowl such as

5. *A Decade (1980-1990) of Organophosphorus (OP) and Carbamate-Related Mortality in Migratory Birds*, U.S. Fish and Wildlife Service, National Wildlife Health Research Center (Madison, WI, 1993).
6. Ibid., reference 4.
7. *Pesticides and Wild Birds*, Canadian Wildlife Service, http://www.ec.gc.ca/cws-scf/hww-fap/pesticides/pest.html.
8. Ibid., reference 4.

ducks and geese. Because these birds travel in large flocks, large and very noticeable bird kills occur when they land on treated areas and eat grass and other plants. Other, less noticeable birds are affected as well, but are rarely counted. Because of such problems, diazinon use on golf courses and turf farms was canceled in the U.S. in 1990. However, golf course and turf uses accounted for only 5% of total U.S. diazinon applications. The threat to birds continues since diazinon is still available for sale at local hardware and garden supply stores for use in homes and yards, and is also used for structural pest control, in landscaping, and on many crops. In California, reported use of diazinon totaled more than 1.2 million pounds in 1995, with 22% of this total used in structural pest control, 2.6% in landscape maintenance, 19% on almonds, and smaller amounts on a wide variety of crops, including stone fruits, lettuce, walnuts, corn, alfalfa, and others.[10]

U.S. Fish and Wildlife Service

The carbamate pesticide carbofuran was responsible for 76% of reported bird kills in California between 1972 and 1997. This pesticide is particularly problematic because it is marketed as granules resembling seeds, which birds mistake for food or grit. Controlled studies show that applications of granular carbofuran typically result in bird kills ranging from one to 17 birds for every five acres of land treated, with even greater losses observed from applications in areas with high bird populations.[11] These numbers are likely to be gross underestimates, since dead birds are difficult to find (see page 28).

Bird deaths do not occur only at the time of pesticide application. In locations where soil pH is low and soils remain wet, carbofuran granules may cause poisonings up to a year after application.[12] While use of granular carbofuran has now been restricted in the U.S., the remaining exemption for its use is on rice, a major crop in California. Other formulations (liquids, powders) are still used on alfalfa, grapes, and cotton grown in California and continue to cause bird kills.

Other OPs have also killed birds. For example, in late 1995 and early 1996, an estimated 20 thousand Swainson's hawks were killed in Argentina after farmers sprayed their fields with highly toxic monocrotophos to control grasshopper pests. The hawks died after eating the contaminated grasshoppers.[13] Leg bands indicated that the birds were from both the U.S. and Canada.

Another incident involved red-tailed hawks in the western U.S. that were poisoned with the OP pesticide famphur by eating contaminated magpies. The magpies were exposed by eating contaminated insects from the backs of the cattle treated with famphur, applied to kill warbles, pests that burrow under the skin of cattle.[14]

Sublethal Exposures

Sublethal OP and carbamate poisonings appear to be common and have been studied by capturing birds and other wildlife near areas where pesticides have recently been applied. A study on the effects of ethyl and methyl parathion on wildlife near California rice fields following application of parathion found that 7%, 40%, 54%, and 57% of the blackbirds, pheasants, mice, and coots respectively had reduced brain activity of cholinesterase (ChE), indicating significant exposure to OPs and/or carbamates.[15]

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9. A. Tattersall, "How Many Dead Birds Are Enough? Cancellation of Diazinon's Uses on Golf Courses," *Journal of Pesticide Reform*, Northwest Coalition for Alternatives to Pesticides, Fall 1991.
10. California Pesticide Use Reporting Data, 1995, California Department of Pesticide Regulation, Sacramento, CA, 1998.
11. P. Mineau, *The Hazard of Carbofuran to Birds and Other Vertebrate Wildlife*, Technical Report Series No. 177, Canadian Wildlife Service (Ottawa, Canada, 1993).
12. Ibid., reference 11.
13. Ibid., reference 7.
14. C.J. Henny, E. Kolbe, E. Hill, and L. Blus, "Case Histories of Bald Eagles and Other Raptors Killed by Organophosphorus Insecticides Topically Applied to Livestock," *Journal of Wildlife Diseases*, 1987, vol. 23, p. 292.
15. T. Custer, E. Hill, and H. Ohlendorf, "Effects on Wildlife of Ethyl and Methyl Parathion Applied to California Rice Fields," *California Fish and Game,* 1985, vol. 71, pp. 220-224.

Another study of 150 hawks from Stanislaus, Merced, and Kern counties in California showed that hawks trapped near orchards recently treated with the OPs diazinon and chlorpyrifos had statistically lower levels of ChE than hawks in a control group. The decrease in ChE levels was larger in hawks found nearest the treated orchards, with 43% of hawks found less than a quarter mile away from the treated orchards exhibiting depressed levels of ChE while only 27% of the hawks found further away showing abnormally low ChE levels. Analysis of wash samples taken from the hawks' feet showed that hawks were being contaminated through their feet as they perched in the OP-treated trees.[16]

Sublethal poisonings likely contribute to many additional bird deaths from other causes. Impairment of coordination and judgement is an effect of sublethal OP and carbamate poisoning that can result in an increased incidence of entanglement, electrocution in power lines, collisions, and predation. As Mineau, *et al*. suggest:[17]

> "A good analogy from a human perspective would be traffic accidents and impaired driving: the exact circumstances surrounding accidents are varied, yet the root cause is impairment."

Organochlorines Cause Acute Poisoning and Impair Reproduction

Persistent organochlorine (OC) pesticides have been banned in the U.S.; other, less persistent OCs are still used however, and continue to pose problems for birds. For example, current legal use of the OC pesticides dicofol and endosulfan is extensive in California, with 594,800 pounds of dicofol and 238,400 pounds of endosulfan applied to crops in 1995. These pesticides are used extensively on farmlands adjacent to the Salton Sea National Wildlife Refuge (see Map 2 on following page), with water from agricultural areas draining into the Salton Sea. Migratory birds are also exposed to organochlorines in their travels to other countries where DDT and other organochlorines are still used.[18]

Evidence of Organochlorine Contamination

Although bird kills due to OCs have declined since the mid-1970s, evidence of continuing organochlorine contamination in birds is widespread. Bald eagles around the Klamath River basin in northern California and southern Oregon were discovered to have substantial levels of the DDT breakdown product DDE in their bodies, a result of eating DDE-contaminated voles.[19] The eagles feasted when farmers flooded their fields, causing the voles to leave their burrows. The voles became contaminated with DDE by eating soil insects in crop areas. Even non-migratory predatory birds such as the great horned owl have been contaminated with DDT by preying on migratory waterfowl exposed to organochlorines in the Southern Hemisphere. A variety of recent

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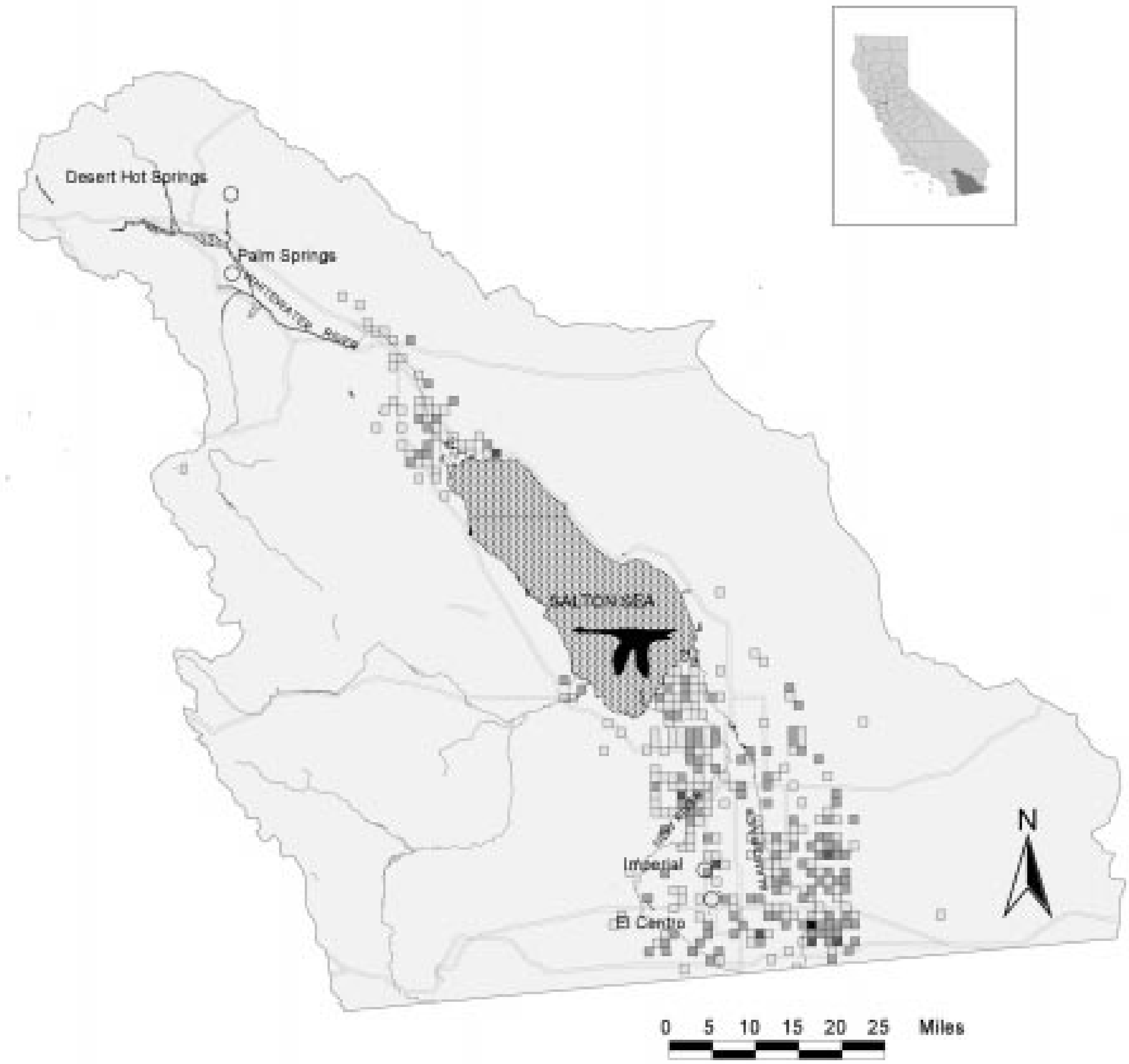
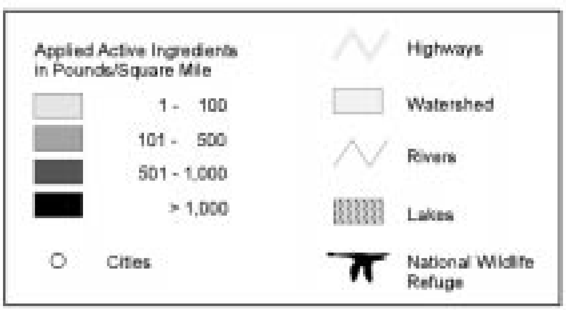
16. B. Wilson, M. Hooper, E. Littrell, P. Detrich, M. Hansen, C. Weisskopf, and J. Seiber, "Orchard Dormant Sprays and Exposure of Red-Tailed Hawks to Organophosphates," *Bulletin of Environmental Contamination and Toxicology*, 1991, vol. 47, pp. 717-724.
17. P. Mineau, M.R. Fletcher, L.C. Glaser, N.J. Thomas, C. Brassard, L.K. Wilson, J.E. Elliot, L.A. Lyon, C.J. Henny, T. Bollinger, and S.L. Porter, "Poisoning of Raptors with Organophosphorous and Carbamate Pesticides with Emphasis on Canada, U.S., and U.K.," *Journal of Raptor Research*, 1999, vol. 33, pp. 1-37.
18. United Nations Environment Programme, *UNEP Survey on Sources of POPs,* report prepared for IFCS Expert Meeting on Persistent Organic Pollutants, Manila, the Philippines, June 1996.
19. R. Frenzel and R. Anthony, "Relationship of Diets and Environmental Contaminants in Wintering Bald Eagles," *Journal of Wildlife Management,* 1989, vol. 53, pp. 792-802.

Map 2: Application of Organochlorine Insecticides in the Imperial Valley in 1995





Applied Organochlorine Insecticides in California

Insecticide	Applied Pounds
Dicofol	594,789
Endosulfan	238,455
Lindane	4,653
Methoxychlor	1,049
Chlordane	184

studies document organochlorine contamination of California ducks, prairie falcons, and coastal birds.[20]

Exposures to Organochlorines Cause Reproductive Failures

Chronic, low-level exposure to organochlorines affects the reproductive success of birds, interfering with fertility as well as mating and maternal behavior. Changes in mating behavior induced by organochlorine contamination have been well documented, with exposed birds showing less interest in mating and exhibiting abnormal behaviors. Birds poisoned by organochlorines ignore territorial barriers, devote less attention to their young, and decrease the extent of their home range. Such changes result in devastating interruptions to the incubation and care of hatchlings and reduce their survival rates.[21]

U.S. Fish and Wildlife Service photo by E.J. O'Neill

The survival rate of nestlings like these gulls drops precipitously when high levels of organochlorine compounds are present in the eggs.

Exposure to organochlorines also leads to eggshell thinning and low hatch rates. Because organochlorines interfere with eggshell formation by disrupting hormone production, the female doesn't assimilate enough calcium into the shell during development of the egg. These eggs are often crushed by the weight of the mother as she tries to incubate her brood. Studies of osprey around Eagle Lake in California showed egg shell thinning due to DDE, a breakdown product of DDT, 20 years after DDT was banned.[22]

A 1996 study of prairie falcons in Pinnacles, Mount Diablo, and Goat Rock in central California showed hatching failures similar to those observed 20 years earlier for DDT-contaminated eggs. Concentrations of DDE in eggs from Pinnacles National Monument were two to six times higher than the levels known to cause hatching failures.[23] No chicks hatched from the 17 eggs in the three nests with the highest concentrations of DDE or lindane over the three-year sampling period. The contamination of falcons living in Pinnacles National Monument was attributed to ingestion of contaminated prey (birds, reptiles, and small mammals) from nearby agricultural areas in the Salinas Valley.[24]

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20. a) W.M. Jarman, S.A. Burns, C.E. Bacon, J. Rechtin, S. DeBenedetti, J.L. Linthicum, and B.J. Walton, "High Levels of HCB and DDE Associated with Reproductive Failure in Prairie Falcons (*Falco mexicanus*) from California," *Bulletin of Environmental Contamination and Toxicology*, 1996, v. 57, pp. 8-15.
b) S. Hothern and S.G. Zador, "Environmental Contaminants in Eggs of California Least Terns (*Sterna antillarum browni)," Bulletin of Environmental Contamination and Toxicology*, 1995, vol. 55, pp. 658-665.
c) H. Ohlendorf and M. Miller, "Organochlorine Contaminants in California Waterfowl," *Journal of Wildlife Management*, 1984, vol. 48, pp. 867-877.
21. Ibid., reference 2.
22. E.E. Littrell, "Shell Thickness and Organochlorine Pesticides in Osprey Eggs from Eagle Lake, California," *California Fish and Game,* 1986, vol. 72, pp. 182-185.
23. Concentrations of DDE in eggs higher than 2,000 μg/kg are associated with significant hatching failures.

Even when OC-contaminated eggs hatch, the hatchlings often do not survive to adulthood. In 1995, only five chicks survived out of 273 eggs laid (2%) in a nesting colony of caspian terns in Elkhorn Slough, a catastrophic failure compared to the previous (1994) season when 150 chicks survived out of 313 eggs laid (48%). Unhatched eggs and dead chicks examined in 1995 were found to contain extremely high concentrations of DDE and toxaphene, two organochlorines that were heavily used in the agricultural areas of the Pajaro and Salinas valleys in the 1960s and 1970s. The difference between the 1994 and 1995 breeding seasons is thought to be a large storm that occurred in March that flooded agricultural lands next to the Pajaro River. Contaminated sediments from the river were deposited in the upper part of Elkhorn Slough, a favorite feeding location for the terns, which ingested organochlorine-contaminated crayfish and shellfish.[25]

Low-level organochlorine exposure in developing chicks also causes malformed beaks and skeletons, fluid retention in the heart, and problems in sexual determination.[26] Because sexual development is hormonally controlled, exposure to chemicals that block or alter the messages of the hormones can lead to effects like feminization of male birds. In some cases, males retain vestigial ovaries, a result of arrested fetal development. The effect on female offspring is much less marked.[27]

Documenting Bird Kills

Hard data on the total number of birds killed by pesticides are impossible to come by. While the National Wildlife Health Center of the Department of the Interior,[28] the U.S. Environmental Protection Agency, and the California Department of Fish and Game all track reported bird kills, these reports show only the tip of the iceberg, and vastly underreport total bird mortality due to pesticides. Reported bird kills are strongly biased towards large flocks of waterfowl because a kill is much more obvious when many large birds die. Kills of widely dispersed species such as songbirds are very difficult to measure, even though controlled studies have shown that when pesticides with high avian toxicity are applied, one to 17 birds die for every five acres of treated ground.[29]

There are several reasons why available bird kill counts are incomplete:[30]

- **Poisoned birds leave the area of pesticide application and die off-site, where they go unnoticed.** Sick birds often retreat to protected areas, where they may die unseen.
- **Carcasses are difficult to find if surrounding vegetation is heavy.** When bird carcasses are placed in fields and people are sent to search for them on the same day, recovery rates are typically around 50%.[31]
- **Bird carcasses are scavenged by mammals and other birds.** One study showed that 62-92% of fresh songbird carcasses placed in freshly planted cornfields disappeared overnight. The recovery rate dropped below 20% after several days.[32]

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24. Ibid., reference 20a.
25. State of California Department of Fish and Game Pesticide Laboratory Report on Caspian Tern Eggs and Nest Cup Sediments from Elkhorn Slough, Lab No. P-1743, E.P. No. L-284-95, November 1995.
26. M. Gilbertson and G.A. Fox, "Pollutant-associated embryonic mortality of Great Lakes Herring gulls," *Environmental Pollution*, 1977, vol. 12, pp. 211-216.
27. Ibid., reference 2.
28. U.S. Geological Survey, National Wildlife Health Center Wildlife Mortality Reports, http://www.emtc.usgs.gov/http_data/nwhc/quarterl/.
29. Ibid., reference 13.
30. P. Mineau, "Avian Mortality in Agro-Ecosystems: 1. The Case Against Granular Insecticides in Canada," *Environmental Effects of Pesticides*, BCPC Monograph No. 40, 1988, pp. 3-12.
31. P. Mineau and B.T. Collins, "Avian mortality in agro-ecosystems. 2. Methods of detection," *Environmental Effects of Pesticides*, BCPC Monograph No. 40, 1988, p. 12.
32. R. Balcomb, "Songbird carcasses disappear rapidly from agricultural fields," *Auk*, 1986, vol. 103, pp. 817-820.

Pesticide Manufacturers Contest Efforts to Ban Granular Carbofuran

In the late 1980s, the U.S. Environmental Protection Agency moved to ban granular carbofuran from the U.S. market due to the pesticide's extensive negative impacts on birds. In response, the FMC Corporation, the sole manufacturer of granular carbofuran (Furadan®), used the lack of hard data on numbers of birds actually killed to keep their product on the shelves and in the environment. Tactics included sending a letter to pesticide dealers who handled the product stating:[1]

> "On January 5, 1989, the United States Environmental Protection Agency (EPA) issued a statement recommending cancellation of registration of granular formulations of Furadan® insecticide-nematicides. This action represents a direct threat to your business."

Citing no sources and ignoring extensive scientific data indicating otherwise,[2] they proclaimed:

> "Although Furadan® and other granular insecticides can kill birds when accidentally eaten, these products do not interfere with the life cycle of the bird species and have not had an effect on bird populations."

The claim that populations are not affected is an argument commonly used by pesticide manufacturers. However, when Ciba-Geigy tried to use this argument in an attempt to protect diazinon from an imminent ban for certain uses, the U.S. Environmental Protection Agency reminded them that the Federal Insecticide Fungicide and Rodenticide Act (the major federal legislation controlling registration and use of pesticides) mandates protection of individual birds as well as populations, so proof of population-wide impacts is not required to ban a pesticide.

Despite the fact that at least 18 supervised field trials and 36 additional investigations of reported kills had documented the acute hazard of carbofuran to birds,[3] the company accused the U.S. Environmental Protection Agency of misinterpreting the data:

> "From their [the U.S. EPA's] Washington perspective, they have misinterpreted scientific data and have taken positions that are inconsistent with field experience."

In 1991, a settlement agreement was reached between FMC and the U.S. Environmental Protection Agency to phase out most uses of granular carbofuran. However, a Special Local Needs Registration exemption was requested and has been approved in all subsequent years for rice, a major crop in California. The maximum amount of granular carbofuran that can be applied to rice in California is 250,000 pounds of active ingredient per year. In spite of these restrictions on use, carbofuran was responsible for the documented deaths of at least 1,000 birds between 1992 and 1997.

While data continues to mount against carbofuran and other highly toxic pesticides, the chemical companies fight to maintain their product lines and profits at the expense of birds, fish, and other wildlife.

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1. P. Mineau, *The Hazard of Carbofuran to Birds and Other Vertebrate Wildlife*, Technical Report Series No. 177, Canadian Wildlife Service (Ottawa, Canada, 1993), Appendix 3.
2. B. Jobin, J.-L. Des Granges, and C. Boutin, "Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley," *Agriculture, Ecosystems, and Environment*, 1996, vol. 57, pp. 103-116.
3. *Pesticides and Wild Birds*, Canadian Wildlife Service, http://www.ec.gc.ca/cws-scf/hww-fap/pesticides/pest.html.

- **Treated areas are often in isolated places where few people pass.** Pesticide applicators may spray areas that then remain undisturbed for several days. Time restrictions on reentry into pesticide-treated fields lower the probability that any bird carcasses will be found.
- **No monitoring or reporting of bird kills is required after pesticide applications.** Because reporting is voluntary, those who apply the pesticides generally do not report bird kills. This leaves only the interested and motivated bystanders who happen to be in the area to notice and report the kill.

Pesticides and the Pacific Flyway: Klamath Basin Case Study

Millions of birds travel along the Pacific Flyway as they migrate between Canada and South America every year. In the winter months, California becomes home to 60-90% of these migrating birds. Marshes, lakes, and fields serve as resting and feeding areas where birds can recharge and recover from their long journeys, mate, and raise their young.

Many migrant birds winter in California's Great Central Valley. Historically, this region was once a large wetland but now is home to some of the most intensively farmed lands in the world. The agricultural centers in the Imperial and Coachella valleys of southern California are also wintering grounds for migrating birds. The Klamath Basin National Wildlife Refuges on the California-Oregon border are additional important stopover points for birds. The map on page 33 shows total pesticide use in California by county, with the locations of national wildlife refuges highlighted. The overlap of high pesticide use with wildlife refuge areas is extensive.

U.S. Fish and Wildlife Service

Of the original 350,000 acres of wetlands in the Klamath Basin National Wildlife Refuges, only 20% remain.

The Klamath Basin is a prime example of the problems that arise when areas set aside for wildlife use overlap with a region of high pesticide use, reflecting many areas in the state that serve as both migratory bird habitat and prime agricultural land. The Klamath Basin is home to six different national wildlife refuges that are critical stopover areas on the Pacific Flyway, with one to two million birds counted per day during the peak seasons of fall and spring (see Figure 2-3). These refuges support the largest aggregation of wintering bald eagles (about 1,000) in the lower 48 states. Two of these refuges, Tule Lake and Lower Klamath National Wildlife Refuges (both in California), are extensively farmed, with approximately 28,000 acres of the former wetland area now leased (or sharecropped), primarily for growing potatoes, sugar beets, onions, and small grains. The original 350,000 acres of wetland has been reduced by 80%.

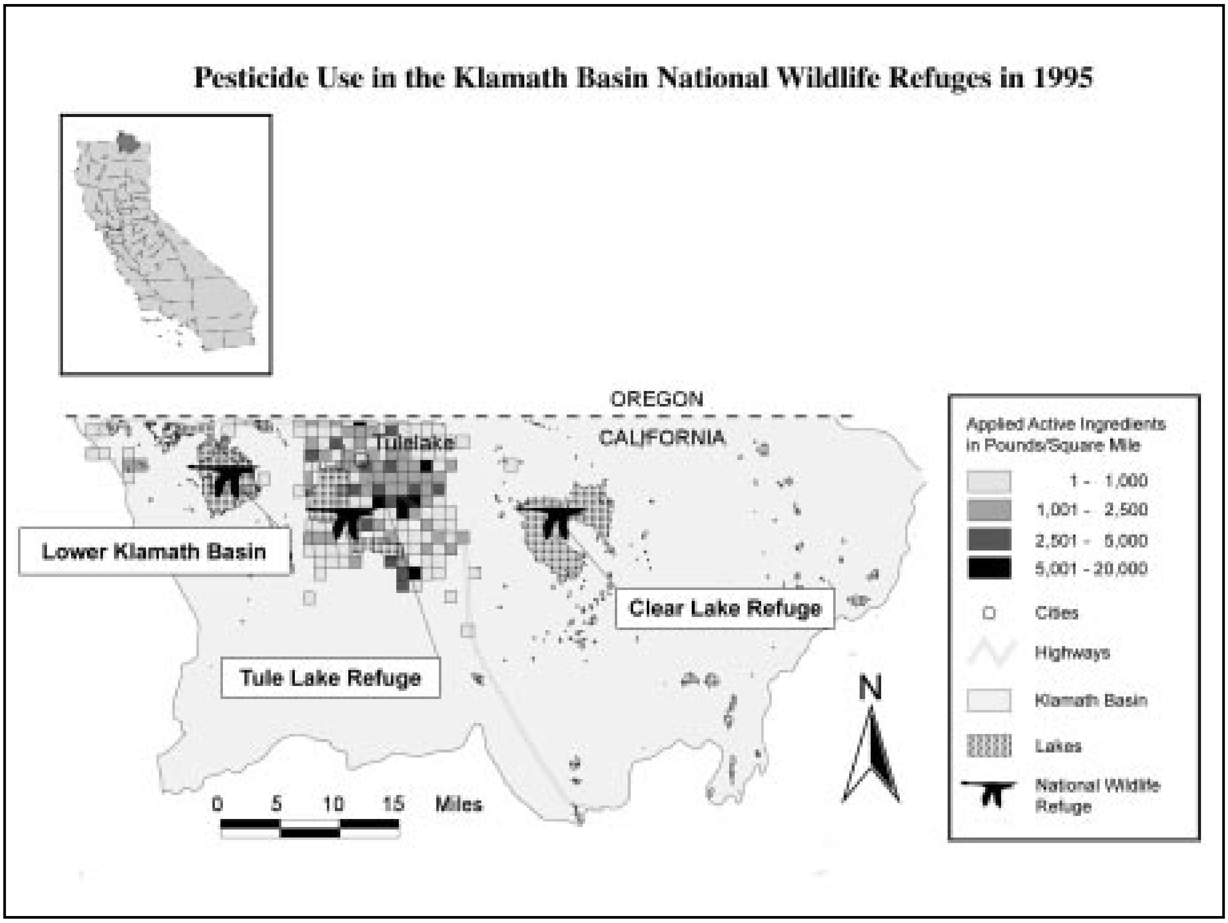

Figure 2-3: The Klamath Basin National Wildlife Refuges lie on the border of California and Oregon, providing essential habitat for birds. Pesticide use is particularly heavy in the Tule Lake Refuge.

PESTICIDE USE RESULTS IN BIRD KILLS

The use of pesticides within the Klamath Basin refuges is widespread, including a number of pesticides that are toxic to birds, fish, and other wildlife. While U.S. Fish and Wildlife Service pesticide use policies require that wildlife receive priority treatment in wildlife refuges, the implemented farming practices approved by refuge biologists do not always reflect these priorities.

Many birds, fish, and other wildlife on the Klamath Basin Refuges have been killed by pesticides in the last several decades. In the 1950s, 1960s, and 1970s, organochlorines, including DDT, dieldrin, endrin, and toxaphene, were responsible for hundreds of thousands of bird deaths.[33] Although acute poisoning incidents declined after these pesticides were banned in the 1970s and early 1980s, high residues of organochlorines in fish and birds caused continued reproductive failures in waterfowl and predatory birds throughout the 1980s and were a major contributing factor to the decline of bald eagles and peregrine falcons. The listing of these two species as federally endangered is due in large part to organochlorine pesticides.

More recently, the organophosphate and carbamate insecticides, along with rodenticides (e.g., strychnine and zinc phosphide) have been the primary causes of

33. Personal communication with Elaine Snyder-Conn, Environmental Contaminants Specialist, U.S. Fish and Wildlife Service, Portland, OR.

bird kills in the Klamath Basin National Wildlife Refuge. Between 1984 and 1993, the deaths of bald eagles, Ross's geese, snow geese, greater white-fronted geese, ring-billed gulls, and California gulls from exposure to these pesticides were documented by the U.S. Fish and Wildlife Service.[34] In 1992, five adult bald eagles died from secondary exposure to the OP pesticide terbufos applied to sugar beets.[35] This poisoning incident was thought to be the result of a secondary poisoning because the remains of water birds were found in the eagles' gullets. Phorate, another OP pesticide used on potatoes, was responsible for the death of 50-60 waterfowl in 1988.[36] Several pheasants were killed near potato fields sprayed with the OP methamidophos in 1991-1992. Further study of cholinesterase (ChE) levels (see page 12) in pheasants and sparrows in the same area—near methamidophos and disulfoton applications—showed depression of ChE levels ranging from 22% to 92%.[37]

U.S. Fish and Wildlife Service

In winter and spring, one to two million birds use the Klamath Basin National Wildlife Refuges as a place to rest, breed, and raise their young.

While few pesticide-related bird kills have been reported in the recent past, minimal routine monitoring by the U.S. Fish and Wildlife Service, a critical tool for understanding pesticide-bird interactions, was only initiated in 1998. Although much of the pesticide application occurs in the summer when most birds have migrated to other locations, these summer applications are harmful to resident breeding birds, fish, and amphibians. Woody plants such as willows, important as nesting and cover vegetation, have been all but eliminated by years of intensive agricultural activities, including herbicide spraying, further stressing both resident and migrating wildlife.

Regulation of Pesticide Use in the Klamath Basin National Wildlife Refuges

Pesticide use in national wildlife refuges has long been controversial. The Kuchel Act, a 1964 federal law specifically dealing with the Klamath Basin National Wildlife Refuges, mandates that the Refuges be administered for the major purpose of waterfowl management, and that all crops planted be compatible with wildlife. However, the Kuchel Act also reserved land within the refuges specifically for farming, setting

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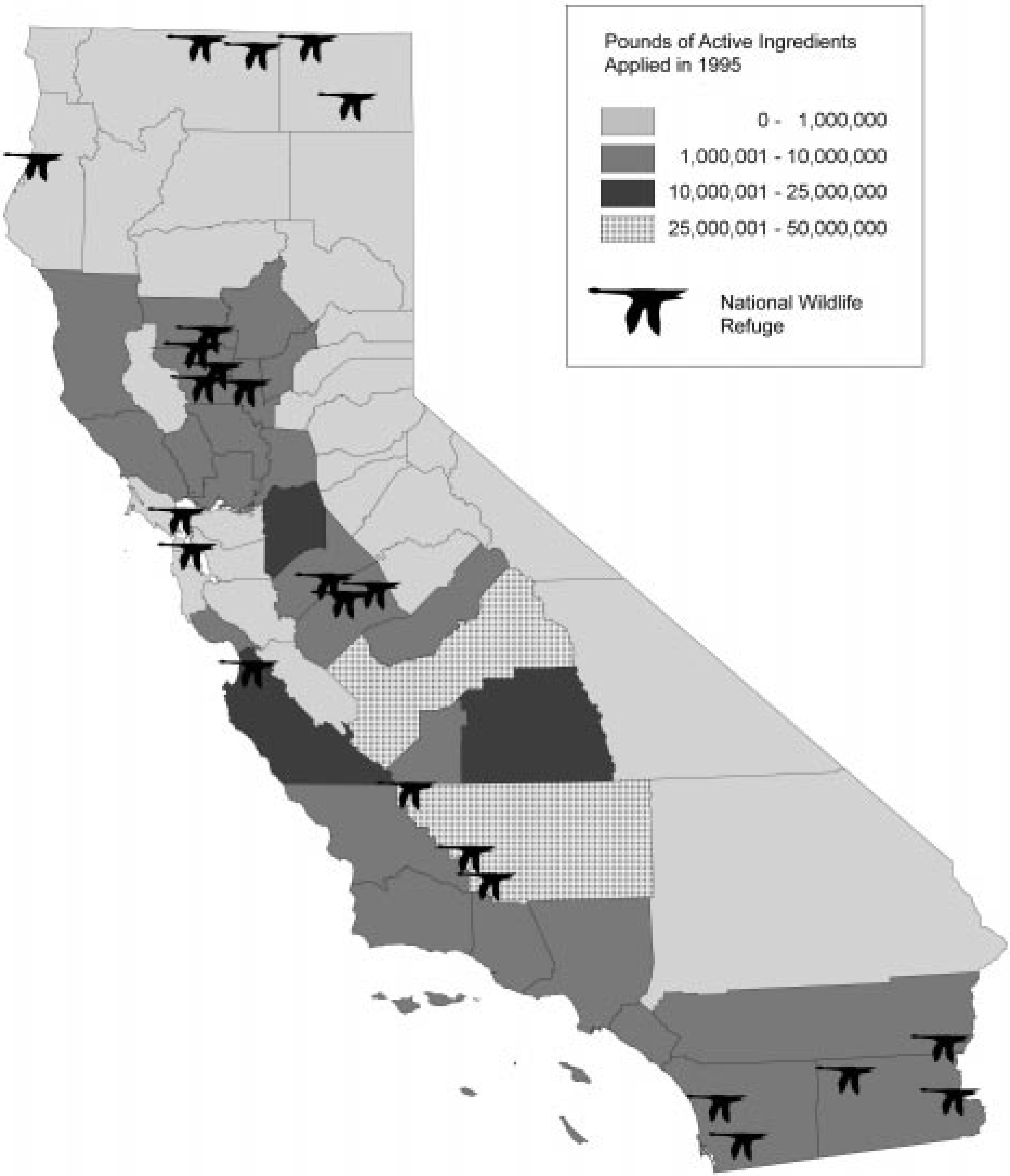
34. *Diagnostic Cases Submitted from Region 1, Jan. 1, 1984 – May 1, 1993*, U.S. Fish and Wildlife Service, National Wildlife Health Center.
35. Draft Environmental Assessment on the Implementation of the Integrated Pest Management Plan for the Klamath Basin National Wildlife Refuges, U.S. Department of the Interior, July 9, 1998.
36. Memo from Dick Stroud, U.S. Fish and Wildlife Service environmental contaminant coordinator, to Jim Hainline, Klamath Basin Refuges wildlife biologist, May 2, 1988.
37. R.A. Grove, "Evaluation of current agriculture practices and organophosphorus insecticide use in relation to ring-necked pheasant numbers at Klamath Basin Refuges, California," M.S. thesis, Oregon State University, Corvallis, 1995.

Location of National Wildlife Refuges in California and Total Pounds of Pesticides Applied in 1995 by County



the stage for conflicts between farms and wildlife. The National Wildlife Refuge Improvement Act of 1997 mandates that wildlife have first priority on wildlife refuges; other uses must be compatible with the primary purpose of providing wildlife habitat. The U.S. Fish and Wildlife Service also has policy guidelines regarding pesticide applications in national wildlife refuges which state:[38]

> "The Service will eliminate unnecessary use of pesticides by implementing integrated pest management techniques and by selecting crops that are beneficial to fish and wildlife but do not require pesticides."

and

> "Land management practices, including farming programs, will be examined to ensure that 1) they have a high value for fish and wildlife resources, 2) they do not encourage the exposure to pathogens or development of disease vectors that affect fish or wildlife resources, and that 3) they require minimal or no application of hazardous chemicals."

In spite of these guidelines, crops grown within the Klamath Basin Refuges still include conventionally grown potatoes, sugar beets, and onions, which are of no (or minuscule) value as food for wildlife and are routinely treated with many pesticides that are toxic to wildlife.

In an attempt to reduce impacts of pesticides, the U.S. Fish and Wildlife Service has recently eliminated the use of some very highly toxic pesticides such as methyl parathion, methamidophos, and aldicarb on refuge lands.[39] However, a number of other neurotoxic organophosphates and carbamates, as well as endocrine-disrupting pesticides are still in use (see sidebar table).[40] The Service has also placed restrictions on the timing and method of pesticide applications, and on the number and total area of applications. Buffer zones are used reduce the effects of pesticide application on sensitive aquatic sites for pesticides known to be toxic to aquatic life.

Pesticides Toxic to Wildlife Used in the Klamath Basin Wildlife Refuges

1,3-dichloro-propene	CA
2,4-D	ED
Carbaryl	ED, CARB
Chlorothalonil	CA
Chlorpyrifos	OP, ED
Disulfoton	OP
Iprodione	CA
Malathion	OP, ED
Mancozeb	ED, CA
Metam sodium	CA
Metribuzin	ED
Permethrin	ED, CA

ED = endocrine disruptor; OP = neurotoxic organophosphorus pesticide; CA= carcinogen; CARB = neurotoxic carbamate pesticide

Policies Fail to Prevent Use of Toxic Pesticides in National Wildlife Refuges

The U.S. Department of the Interior policy requires prior approval of pesticides applied to National Wildlife Refuges. Growers typically submit Pesticide Use Proposals (PUPs) in the fall for the next growing season for review by a panel of refuge personnel and environmental contaminants specialists. For proposals to use restricted pesticides,[41] pesticides that could impact endangered species, or for any pesticide application to more than 2,500 acres, the review is required to be conducted by a panel of experts from the Washington, DC office of the U.S. Fish and Wildlife Service to avoid local politicization of the process. Despite this requirement, no external reviews of the PUPs were conducted until 1994. As a result, many restricted use pesticides were routinely approved by local officials for use in the Klamath Basin National Wildlife Refuges.

In 1993, the Oregon Natural Resources Council (ONRC) requested the Inspector General of the Department of the Interior to investigate these violations of U.S. Fish and Wildlife Service policy.[42] After the investigation, the policy of external review of Pesticide Use Proposals was enforced for a brief time. The result was that, in 1994,

38. U.S. Fish and Wildlife Service Administrative Manual Pest Management Policy and Responsibilities, Part 30 AM 12, August 22, 1990.
39. Ibid., reference 33.
40. "Approved Lease Land Pesticide Uses for 1999," U.S. Fish and Wildlife Service, April 12, 1999.
41. Restricted use pesticides are those determined by the U.S. Environmental Protection Agency to be sufficiently hazardous to humans, crops, or the environment that they may only be legally applied by a certified applicator or someone under the direct supervision of a certified applicator.

90% of the Klamath Basin National Wildlife Refuges PUPs sent to Washington for external review were rejected because the proposed pesticides were considered too toxic for application near fish and wildlife.

Within a year, most of the control of PUPs returned to the local and regional Fish and Wildlife Service, with only occasional oversight from Washington staff. The approval process for pesticide use reverted to its previous state, resulting in near blanket approval of pesticides previously classified as too hazardous for application in a National Wildlife Refuge.[43]

In March 1998, the ONRC and the Northwest Coalition for Alternatives to Pesticides (NCAP) spearheaded a new request from 18 conservation organizations to the Inspector General to reopen the investigation of policy violations. One year after the request was filed, no action has been taken. The only response from the Inspector General's office so far has been to request copies of documents they had misplaced.[44]

Integrated Pest Management on the Klamath Basin Refuges

In a related development, the U.S. Fish and Wildlife Service recently evaluated several options for an Integrated Pest Management (IPM) plan for the Klamath Basin Refuges in 1997 after the ONRC and NCAP applied pressure to eliminate pesticide use in the refuges. The draft environmental assessment states:[45]

> "Habitat loss or degradation is at a critical point within the refuges, particularly Tule Lake National Wildlife Refuge. Any activity that contributes to the degradation of aquatic habitat or decrease in habitat diversity should be avoided if the refuges are to function as such."

The IPM option finally recommended in February 1999 by the U.S. Fish and Wildlife Service permits the use of even more pesticides than were previously approved, but does require "crop scouting" or monitoring for pests by refuge-certified individuals. In theory, before a pesticide can be applied, it must be determined that an "established" pest threshold specific to the Klamath Basin has been reached. This approach is still problematic however, because few pest thresholds have been established specifically for the Klamath Basin area. In the absence of known pest thresholds, it is likely that pesticide use will be little changed under the IPM plan.

The majority of the public comments on the IPM plan opposed the recommended alternative, requesting instead that a policy allowing only organic farming be adopted. Conservation groups that reviewed the proposed IPM plan pointed out repeatedly that the plan does not comply with established policy requirements of the Department of the Interior, "… to reduce the use of pesticides through IPM …" and to select "…crops that are beneficial to fish and wildlife but do not require pesticides." Nor does the IPM plan comply with U.S. Fish and Wildlife Service pest management policies and responsibilities established to ensure that farming programs "… have a high value for fish and wildlife resources" and that "… they require minimal or no application of hazardous chemicals."[46]

Instead, crops of no known value (onions and sugar beets) or only minuscule value (potatoes) as a food source for wildlife are grown with heavy pesticide use because farmers can make much higher profits from these crops than from grains or hay, which are beneficial to wildlife. Elimination of these non-beneficial row crops

42. Oregon Natural Resources Council letter to Joyce N. Fleischman, Acting Inspector General, U.S. Department of the Interior, Office of Inspector General, November 22, 1993.
43. Oregon Natural Resources Council letter to Suzanne A. Gorey, Director, Division of Operations and Special Investigations, U.S. Department of the Interior, Office of Inspector General, March 4, 1998.
44. Personal communication with Wendell Wood, Oregon Natural Resources Council.
45. Ibid., reference 35.
46. Ibid., reference 38.

could result in elimination of some 12 insecticides, 15 herbicides, 17 fungicides, and 3 nematicides not used on other crops grown on the refuges.[47]

The chosen IPM alternative for the refuges has been criticized as "falling between being an Intelligent Pesticide Management plan and an Intensive Pesticide Management plan."[48] A total of 427 public comments were received on the draft plan, with 91% stating that the IPM plan needed to eliminate or greatly reduce pesticide use on refuge lands. Yet, in spite of all of the negative comments received from the public on its IPM plan, the U.S. Fish and Wildlife Service determined that "no significant impacts" would be expected from continuing pesticide use. This is a surprising contradiction to their previous statement in the draft environmental assessment that "taking" of endangered species such as the Lost River sucker, a native fish, was acknowledged to be likely with the chosen IPM plan.[49]

> "...[T]he occasional and irretrievable loss of threatened and endangered suckers due to pesticides combined with their already degraded habitat, would continue."

Growers and the irrigation district apply heavy pressure on local U.S. Fish and Wildlife Service staff to allow pesticide use because the cost of leasing public lands is less than for other cropland in the area. Commercial growers use cheaper public land to grow higher profit, high-pesticide-input crops that have few benefits to wildlife and contribute to the degradation of wildlife populations. In the Klamath Basin National Wildlife Refuges, it appears that benefits to commercial growers' bank accounts take precedence over protection of wildlife.

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47. J. R. Anderson, "Pesticide Saga Likely to Continue at Klamath Basin National Wildlife Refuges," *Oregon Conifer*, Oregon Chapter of the Sierra Club, 1999.
48. Ibid., reference 47.
49. Ibid., reference 35.

Chapter 3

Effects of Pesticides on Aquatic Animals and Plants

Rivers, streams, estuaries, lakes, and other water bodies are unique and critical ecosystems, providing enormous biodiversity and offering recreation, beauty and a change of pace to people seeking respite from their fast-paced daily lives. There have been significant declines in California's aquatic ecosystems over time, as human activities encroach on land and water once primarily the realm of fish and wildlife. While habitat destruction, introduction of exotic species, damming and diversion of water resources all play a role, it is becoming clear that in recent history, the application of massive quantities of pesticides, both in urban and agricultural settings, is a significant contributor to the decline of aquatic ecosystems.

Several well-documented facts emerge from recent studies on pesticides and aquatic organisms in California.

- Multiple pesticides are commonly found in California waters and sediments, frequently at concentrations that exceed lethal levels for many species of zooplankton, small organisms eaten by fish. Because of both high use and significant water solubility, the insecticides diazinon and chlorpyrifos and the herbicides simazine, diuron, and EPTC are found most commonly.
- Toxic pulses of pesticides are a routine occurrence in California rivers, as stormwater and irrigation runoff carry pesticides from urban and agricultural areas into surface waters. These pulses are a violation of the Clean Water Act and the Basin Plans set forward by the Regional Water Quality Control Boards because they create lethal conditions for many consecutive days for the small organisms fish eat. The pesticides most commonly found in toxic concentrations in these pulses are diazinon and chlorpyrifos from sprays to dormant almond and stonefruit orchards, as well as from urban applications to buildings and in landscape maintenance.
- Most fish species and many species of zooplankton in the San Francisco Bay-Delta have experienced dramatic population declines in the last several decades. Multiple factors contribute to these declines, including toxic contaminants in waterways, dams, diversions, exotic species, and reduction in food sources. Pesticides known to kill aquatic animals and plants, impair their reproduction, and reduce food sources for fish are thought to be one of the major stressors affecting the aquatic organisms in the Bay-Delta ecosystem.

Routes of Exposure

Aquatic animals and plants are significantly more exposed to pesticides than birds and humans because they are surrounded by water and spend all of their lives in it. Being literally "in the soup" makes aquatic plants and animals very susceptible to toxic effects through two exposure routes: absorbing dissolved pesticides from the water and sediments they live in, and; for the aquatic animals, ingesting pesticides with the food they eat.

To understand the different ways plants and animals are exposed to pesticides through their food supply, it is important to know more about the interdependence of different organisms in the ecosystem. The critical connections in the food web, or the "who eats whom" of the natural world, begin with two major categories of small aquatic organisms. These tiny organisms serve as the basis for the food web for larger aquatic animals such as fish, amphibians, mollusks, and terrestrial insects:

- **Phytoplankton** are tiny aquatic plants that live in open water in streams, rivers, lakes, and the oceans. These plants use sunlight, carbon dioxide, nutrients, and water, and provide oxygen, habitat, and food for aquatic animals. Common phytoplankton species found in California include *Thalassiosira*, *Melosira, Skeletonema*, and *Chlamydomonas.*
- **Zooplankton** are small invertebrate animals that live their entire lives in the water, consuming detritus (decaying organic matter), phytoplankton, and/or other zooplankton for food. These animals are critical elements of the food web, serving as the primary food source for larval fishes. In the Sacramento–San Joaquin estuary, there are four major groups of zooplankton: the opossum shrimp (*Neomysis mercedis*), the copepods, the cladocerans (waterfleas), and the rotifers.

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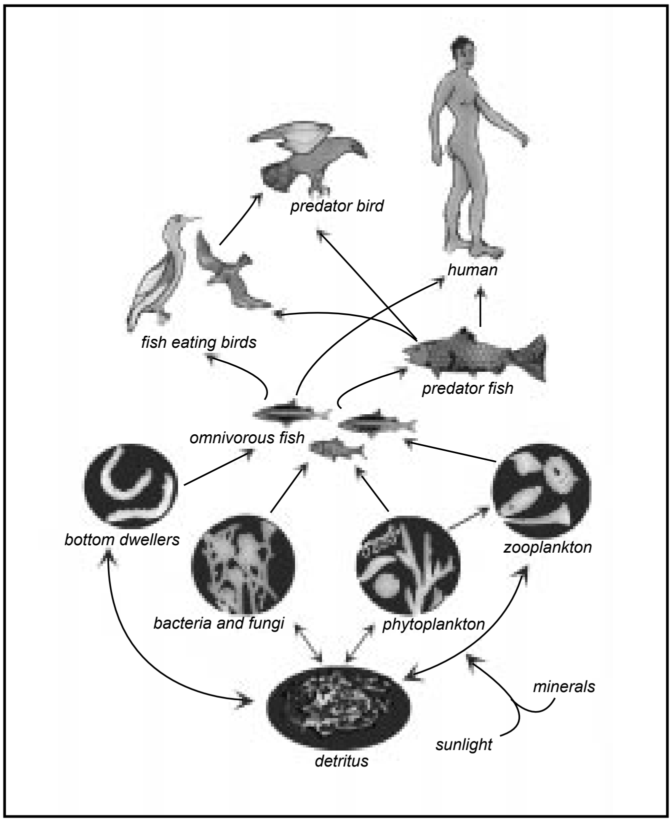

Figure 3-1: The food web for aquatic organisms also includes birds and humans, which eat the fish that eat the lower organisms. This interconnected web is disrupted by pesticides, which reduce the populations of the organisms forming the basis for the food web—the phytoplankton and zooplankton.

The food web is a closed loop—when animals and plants die, they break down into detritus, carbon dioxide, water, and nutrients, providing the starting materials for the cycle to begin again (see Figure 3-1). These small animals and plants may seem unimportant to humans because they don't provide food for us directly, but they are critical for sustaining populations of fish, which both humans and birds eat. A stable ecosystem depends on healthy populations of each organism in the web. Such healthy populations have new individuals available to replace those dying or being eaten. The health of each species ensures the success of those other species that rely on them. If one species is weakened, that effect is disseminated throughout the food web, affecting species in the entire community and altering the biodiversity of the ecosystem. While there are always natural swings in populations, pesticides enhance the magnitude and duration of these variations and can lead to permanent changes or gaps in the food web that can bring an ecosystem to the brink of disaster.

Multiple Pesticides Are Commonly Found in California Surface Waters

Over 100,000,000 pounds of the most toxic "bad actor" pesticide active ingredients (excluding sulfur, soaps, and oils) are released into the environment each year in California alone.[1] Because many routes exist for transport of pesticides to water, it is no surprise that numerous pesticides are commonly found in the state's waters, sediments, and animal tissues. Recent studies show that:

- A wide variety of pesticides are found in California surface waters.
- Multiple pesticides are often found in the same sample, typically more than seven different pesticides and as many as 22.
- Concentrations of pesticides periodically exceed levels known to be toxic to aquatic life.
- The frequency of detection of pesticides in water is related to the amount of pesticide use in the nearby area, the water solubility of the pesticide, the soil and vegetation characteristics, and the proximity of the application site to water.
- Both urban and agricultural areas are sources of pesticide runoff.

In order to more accurately assess exposures of aquatic organisms to pesticides, it is necessary to monitor water, sediments, and tissue samples for the presence of pesticides. There are inherent limitations to monitoring studies: they are expensive and time-consuming, and few government agencies are equipped and/or funded to carry out comprehensive monitoring. Nevertheless, there is a significant amount of information available on concentrations of pesticides in surface waters and groundwater, sediments, and animal tissues due to the activity of the U.S. Geological Survey, the California Regional Water Quality Control Boards, the San Francisco Estuary Institute, the California Department of Pesticide Regulation, and the California Department of Fish and Game.

Central Valley Surface Waters Contain Multiple Pesticides

Between 1991 and 1995, the U.S. Geological Survey sampled Central Valley rivers, sloughs, and streams to determine the concentrations of pesticides in the water and sediments of the region.[2] The study looked for a total of 83 pesticides, including most, but not all of the major use pesticides. Most samples tested contained more than one pesticide, and typically more than seven. Some samples contained as many as 22 different pesticides.

During 1993 alone, 143 samples were taken by the U.S. Geological Survey at regular intervals at four sites representative of the variety of water bodies in the southern Central Valley: Orestimba Creek, Salt Slough near the San Joaquin River, the Merced River, and the San Joaquin River near Vernalis. A total of 49 different pesticides were detected, out of 83 in the monitoring plan. Only one sample out of the 143 tested contained no detectable levels of the 83 pesticides. The most frequently detected pesticides include the herbicides simazine, dacthal (chlorthal-dimethyl), metolachlor, and EPTC, and the insecticides diazinon, chlorpyrifos, and carbaryl.

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1. Pesticide Use Reporting Data, 1995, Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, CA, 1998.
2. N. M. Dubrovsky, C. R. Kratzer, L. R. Brown, J.M. Gronberg, and K.R. Burow, *Water Quality in the San Joaquin-Tulare Basins, California, 1992-95,* USGS Circular 1159, U.S. Geological Survey, 1998.

Criteria for Protection of Aquatic Life

One tool for protecting aquatic organisms from the adverse effects of pesticides is setting limits for maximum concentrations of pesticides in water. In California, these limits are called Water Quality Objectives, expressed in both narrative and numerical forms. The narrative objectives are "general descriptions of water quality that must be attained through pollutant control measures and watershed management."[1] Numeric objectives "represent the maximum amount of pollutants that can remain in the water column without causing any adverse effect on organisms using the aquatic system as habitat, on people consuming those organisms or water, and on other current or potential beneficial uses." The numeric objectives are based on the toxicity of the pesticide to a selection of aquatic organisms, with a margin of safety built in to take into account unknown adverse effects or especially sensitive species. These objectives are incorporated into the Basin Plans written by the Regional Water Quality Control Boards, as required by the Clean Water Act.

With regard to toxicity due to pesticides or any other contaminant, the narrative part of the Basin Plans expressly states that "All waters shall be maintained free of toxic substances in concentrations that are lethal to or that produce other detrimental responses in aquatic organisms. Detrimental responses include, but are not limited to, decreased growth rate and decreased reproductive success of resident or indicator species. There shall be no acute toxicity in ambient waters....There shall be no chronic toxicity in ambient waters."

Numeric objectives are often called "criteria for protection of aquatic life." Both acute and chronic criteria exist, where acute criteria provide limits for a high-level, one-time exposure. Chronic criteria provide the maximum allowable concentration assuming repeated, long-term exposure. Several organizations have developed aquatic life criteria for pesticides, including the U.S. Environmental Protection Agency, the National Academy of Sciences (NAS), the California State Water Quality Control Boards, and the California Department of Fish and Game, to name a few (see Table 3-1). Criteria have been set regionally in some cases, resulting in a patchwork of different criteria for different pesticides in different parts of the U.S. and internationally. The U.S. Environmental Protection Agency has been particularly slow about setting criteria, having set them for only six pesticides, most of which are the now-banned organochlorines. The NAS criteria are the most widely cited but are quite outdated now, having been set in 1973. The German equivalent of the U.S. Environmental Protection Agency has created one of the most extensive lists of aquatic life criteria for 35 pesticides, a subset of which is shown in Table 3-1.

The setting of Water Quality Objectives by the Regional Water Quality Control Boards is the first step in controlling pesticide runoff into surface waters. However, it is not sufficient for truly protecting aquatic life, as evidenced by the recurring incidents of pesticide pulses in California rivers that are acutely toxic to aquatic organisms for many days at a time (see page 54). All of these toxicity incidents are a violation of the Central Valley Regional Water Quality Control Board Basin Plan narrative water quality objectives, and therefore a violation of the Clean Water Act.[2]

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1. *Water Quality Control Plan*, California Regional Water Quality Control Board, San Francisco Bay Region (Region 2), Oakland, CA, June 21, 1995.
2. Personal communication with Chris Foe, Central Valley Regional Water Quality Control Board.

Table 3-1: Chronic Water Quality Criteria for Selected Pesticides[a]

Pesticide	California Department of Fish and Game (µg/L)[b]	U.S. EPA[c] (µg/L)	International Joint Commission[d] (µg/L)	National Academy of Sciences[e] (µg/L)	German Umwelt-bundesamt[f] (µg/L)	Canadian Council of Ministers of the Environment[g] (µg/L)
2, 4-D	—	—	—	3.0	2	—
Azinphos-methyl	—	—	—	0.001	0.1	—
Carbaryl	2.53/2.53	—	—	0.020	h	—
Chlorpyrifos	0.02	0.041/0.083	—	0.001	—	—
Diazinon	0.04/0.08	—	0.080	0.009	—	—
Diuron	—	—	—	1.6	0.006	—
Endosulfan	—	—	—	—	0.005	—
Hexazinone	—	—	—	—	0.07	—
Lindane	—	1.0	—	—	0.03	—
Malathion	— /0.43	—	—	0.008	0.02	—
MCPA	—	—	—		0.9	2.6
Metolachlor	—	—	—	—	0.2	8.0
Simazine	—	—	—	10	0.1	—
Trifluralin	—	—	—	—	0.03	0.1

a. If two values are given, the second value is the acute criteria. In general, if the criteria is a lower number, the pesticide is more toxic to aquatic life. Dashes mean the criteria has not been set. All criteria are given in micrograms per liter (µg/L). One microgram is 0.000001 gram.
b. M. Menconi and C. Cox, *Hazard Assessment Report of the Insecticide Diazinon to Aquatic Organisms in the Sacramento-San Joaquin River System*, California Department of Fish and Game, Environmental Services Division Administrative Report 94-2, 1994.
c. U.S. Environmental Protection Agency, 1986, *Quality Criteria for Water 1986,* ("Gold Book"), U.S. Environmental Protection Agency Office of Water Regulations and Standards, EPA 440/5-86-001.
d. International Joint Commission, 1977, *New and Revised Great Lakes Water Quality Objectives, Vol. II.* an IJC report to the governments of the United States and Canada: IJC, Windsor, Ontario, Canada.
e. National Academy of Sciences and National Academy of Engineering, 1973, *Water Quality Criteria, 1973*, U.S. Environmental Protection Agency, Ecological Research Series, EPA R3-73-033.
f. Rolf Altenburger, "Gewässerzielvorgaben für Pestizide," Pestizid -Brief, 7/98, Pestizid Aktions-Netzwerk (PAN) e.V. (Hamburg, 1998).
g. Canadian Council of Ministers of the Environment, 1993, *Canadian Water Quality Guidelines*, Ottawa, Ontario, Environmental Quality Guidelines Division, Inland Waters Directorate.
h. Not registered for use in Germany.

Detections of these pesticides were strongly correlated to agricultural applications of the same pesticides in the area.[3]

Concentrations of pesticides in the smaller streams exceeded the California Department of Fish and Game criteria for protection of freshwater aquatic life (see page 41) for 37% of the samples, with the herbicides diuron and trifluralin and the insecticides azinphos-methyl, carbaryl, chlorpyrifos, diazinon, and malathion presenting particular problems. Diazinon alone was responsible for 40% of the incidents exceeding the criteria. The region's smaller streams are of particular concern, since they serve as important nurseries for young fish and other aquatic organisms that constitute their food supply.[4]

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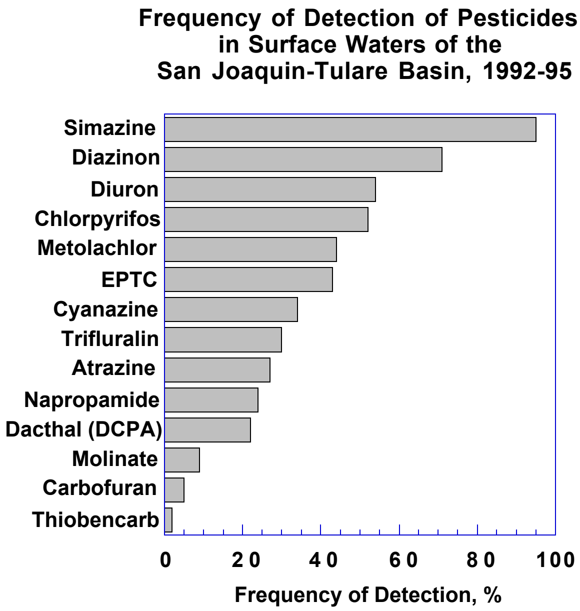
3. S.Y. Panshin, J.L. Domagalski, and N.M. Dubrovsky, "Pesticide concentrations in surface water as a function of agricultural land use in five small watersheds, western San Joaquin Valley, California," *Transactions of the American Geophysical Union*, 1994, vol. 75, no. 44, Supplement, p. 246.
4. P. Moyle, *Inland Fishes of California,* UC Press (Berkeley, CA, 1976).

The frequency of detection of pesticides in water does not always parallel the amount of pesticide use in the area (see Figure 3-2). Several factors affect the likelihood that a pesticide will be found in water, among them the amount of pesticide used, the water solubility of the compound, how long it persists in the environment, how far the application site is from nearby surface waters, the soil type and vegetative cover, and the volatility of the pesticide. For example, although metolachlor is not one of the top ten herbicides used in the San Joaquin-Tulare Basin, it is detected in 44% of the samples analyzed because it is extremely water soluble and is easily washed off of the application site by rainwater and/or irrigation water.



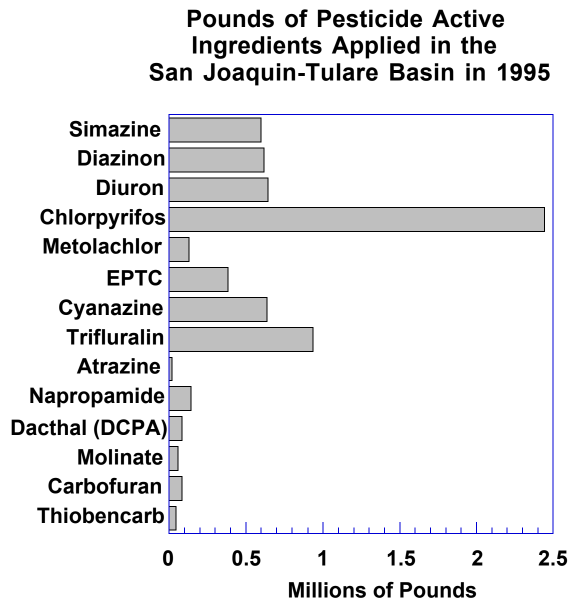


Figure 3-2: The frequency of detection of a pesticide in surface waters is not always correlated to the amount of pesticide applied. These figures show the frequency of detection of pesticides in the San Joaquin-Tulare basin during 1992-95 (left) and the amount of each of the same pesticides applied in 1995 as a representative year (right).

Urban Runoff Contributes Significant Amounts of Pesticides to Surface Waters

Agricultural applications are not the only source of pesticides in surface waters. Pesticides applied around homes, in gardens, and on roadsides also find their way into creeks and rivers. Diazinon and chlorpyrifos are two of the major problem pesticides, typically used in lawn treatments as well as in and around homes. These chemicals are applied around the perimeter of a house to kill ants, fleas, and termites. Irrigation or rain water runoff then carries these pesticides down street drains and directly into urban creeks. Many urban streams have the potential to support a rich and varied population of fish and smaller aquatic organisms. However, frequent inflows of toxic runoff from homes and gardens cause concentrations of diazinon and chlorpyrifos to rise above toxic levels for sensitive aquatic organisms that form the basis for the food web in these streams.

Although agricultural and commercial pesticide applications are reported to the California Department of Pesticide Regulation, over-the-counter pesticide use (estimated to be 20% of total pesticide use)[5] goes unreported. This unreported percentage is even higher for diazinon (see sidebar[6]). Approximately 2.2 million pounds of diazinon active ingredient are sold in California every year, with unreported use accounting for 45% of the total.[7] A breakdown of diazinon use is shown in the sidebar. Nearly

Breakdown of Diazinon Use in 1995

(in thousands of pounds of active ingredient)

Unreported use	1,009
Agricultural use	925
Structural pest control	272
Landscape maintenance	31
Total diazinon sold	2,237

200 different products containing diazinon are registered for use in California, many available at hardware and garden stores (see Table 3-2).

Table 3-2: Representative Household Pesticides Available Over-the-Counter[a]

Products Containing Diazinon	Products Containing Chlorpyrifos
Ace 5% Diazinon Lawn Insect Control	Ace Dursban Insecticide Lawn Insect Control
Black Leaf 25% Diazinon	Black Leaf Dursban
Cooke Diazinon Spray	d-Con d-Stroy Roach Killing station
Enforcer Ant Kill Granules	Cooke Dursban Granules
Green Light Many Purpose Dust	Lilly/Miller Dursban Insect Spray
Ortho Diazinon Soil and Turf Insect Control	Ortho Dursban Ready-Spray Outdoor Flea &Tick Killer
Spectracide Soil & Turf Insect Control 6000	Raid Liquid Roach & Ant Killer Formula 1
Whitmire Knox-Out PT 1500 R	Raid Ant Baits
	Zodiac Yard and Kennel Spray

a. Jane Kay, "New Threat to the Bay: Poisons from Home," *San Francisco Examiner*, March 29, 1998.

Household pesticides have been detected in many urban streams and rivers. In Alameda County, a study by the California Regional Water Quality Control Board, San Francisco Region showed the presence of diazinon and chlorpyrifos in most urban creeks.[8] Some samples contained both pesticides, a concern since the effects of these two compounds are additive, due to their similar mechanism of toxicity. Concentrations of diazinon ranged from less than 0.03 micrograms per liter (μg/L) to greater than 1.3 μg/L, with many samples exceeding the 0.04 μg/L set as a water quality objective for protection of aquatic life by the California Department of Fish and Game. Chlorpyrifos was detected at concentrations ranging from less than 0.08 μg/L to 0.38 μg/L, with several samples exceeding the U.S. Environmental Protection Agency criteria for chronic toxicity of 0.041 μg/L (see page 41 for more information about criteria). Concentrations at all sampling sites were variable, depending on water flows, weather, and recent pesticide applications. In 1999, the San Francisco Regional Water Quality Control Board added Bay Area streams to the 303(d) list[9] of impaired water bodies because of diazinon and chlorpyrifos toxicity.[10]

The San Francisco Estuary Institute sampled for pesticides in and around the San Francisco Bay and found a variety of organochlorines, diazinon, chlorpyrifos, and the herbicide dacthal.[11] High pesticide concentrations were found in samples from Grizzly Bay, Guadalupe Slough, and Coyote Creek, particularly during winter rainstorms.

In 1995, the U.S. Geological Survey sampled and analyzed urban storm runoff from the Modesto area for 46 pesticides.[12] Fifteen different pesticides were detected,

5. *Pesticides Sold in California by Pounds of Active Ingredients*, 1995 Annual Report, California Department of Pesticide Regulation, August, 1997 (Sacramento, CA).
6. Ibid., reference1.
7. Ibid., reference 6.
8. R. Katznelson and T. Mumley, *Diazinon in Surface Waters in the San Francisco Bay Area: Occurrence and Potential Impact*, California Regional Water Quality Control Board, San Francisco Bay Region, June 30, 1997.
9. The Clean Water Act, Section 303(d), requires states to list impaired water bodies and the contaminants that cause the impairment.
10. Personal communication with Will Bruhns, San Francisco Regional Water Quality Control Board.
11. a) *Regional Monitoring Program for Trace Substances, 1996 Annual Report*, San Francisco Estuary Institute, San Francisco, CA, 1996.
b) *Regional Monitoring Program for Trace Substances, 1995 Annual Report*, San Francisco Estuary Institute, San Francisco, CA, 1995.

with seven pesticides detected in 100% of the samples: carbaryl, chlorpyrifos, DCPA, diazinon, malathion, simazine, and trifluralin (see Figure 3-3). While the absolute amount of most pesticides contained in agricultural runoff was greater than that from urban sources, concentrations (amount per liter of water) of most pesticides found in urban runoff exceeded concentrations downstream of agricultural areas. The concentrations of carbaryl, chlorpyrifos, diazinon, and malathion in all samples exceeded the National Academy of Sciences criteria for protection of aquatic life (see page 41). The median concentration of diazinon exceeded levels known to be acutely toxic to the aquatic invertebrate *Ceriodaphnia*, the aquatic equivalent of a canary in a coal mine.

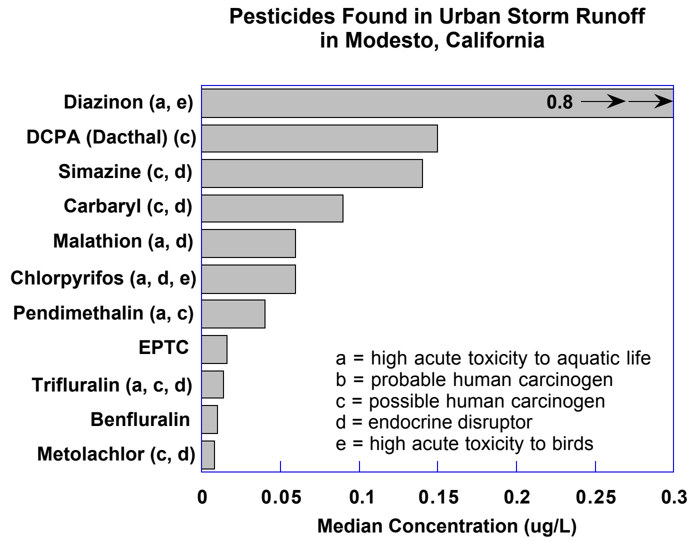


Figure 3-3: Urban areas are a significant source of pesticides in surface waters. The plot above shows the median concentrations of pesticides found in urban stormwater runoff in Modesto, California.

In urban areas all over the state, from Los Angeles[13] to Sacramento,[14] the story is the same, with levels of diazinon and chlorpyrifos often above concentrations lethal to important invertebrate species.

12. C.R. Kratzer, *Pesticides in storm runoff from agricultural and urban areas in the Tuolumne River Basin in the vicinity of Modesto, California*, U.S. Geological Survey, Water-Resources Investigations Reports 98-4017.
13. G.F. Lee and A. Jones-Lee, “Development of a Regulatory Approach for OP Pesticide Toxicity to Aquatic Life in Receiving Waters for Urban Stormwater Runoff,” paper presented at the June 1998 meeting of the Northern California Society of Environmental Toxicology and Chemistry, Reno, NV.
14. V. Connor, Central Valley Regional Water Quality Control Board, as cited in J. P. Fox and E. Archibald, *Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley, California Urban Water Agencies*, 1998, p. 162.

Reported Detections of Pesticides Do Not Tell the Whole Story

While a great deal of data have been collected on pesticides in water, sediments and tissues, the process of implementing a pesticide monitoring program is prone to errors that result in consistent underreporting of the true concentrations of pesticide residues and pesticide inert ingredients in the environment. A number of factors contribute to these errors.

- **Recovery of pesticide residues from soil, water, or tissues is rarely close to 100% effective.** Pesticides are usually analyzed by extracting them from a water, soil, or tissue sample. Common analytical methods typically extract only 30-90% of the residues present.
- **Some pesticide active ingredients are difficult or impossible to measure accurately.** For example, ziram, a fungicide used in large quantities on almonds, has not yet been included in the standard set of pesticides to be monitored because a practical method for measuring it has only recently been developed.[1] Glyphosate was not included in the U.S. Geological Survey study of pesticides in watersheds because the method for analysis is difficult and time-consuming.[2]
- **Inert ingredients are typically not reported or measured.** Pesticide active ingredients are usually combined with "inert" ingredients, chemicals that make application and mixing with other pesticides easier or make the active ingredients more effective. These "inert" ingredients are sometimes more toxic than the active ingredients and frequently constitute a major portion of the formulated product, yet are rarely included in pesticide use reports or monitored in environmental samples.[3]
- **Pesticide breakdown products are typically not reported or measured.** Most monitoring programs only look for the pesticide itself, and not its breakdown products, some of which are more toxic than the pesticide itself. Similarly, toxicity studies are only beginning to examine the effects of these breakdown products on birds, fish, and plants.
- **It is easy to skew the results of a study by choosing sample sites or sample times inappropriately.** The concentration of a pesticide in water or sediment can vary dramatically depending on the location and the timing of sampling. The best studies are those that sample frequently (to detect variations due to weather and irrigation flows) and in locations that are likely to be representative of both the highest and lowest concentrations.
- **Improved technologies for detecting pesticides in environmental samples make comparison with older data difficult.** With the introduction of new technologies, it is possible to detect lower and lower concentrations of pesticides every year. Pesticides listed as "nondetects" in 1981 might easily be detected in 1999. This makes it difficult to compare concentrations of pesticides in samples from different time periods and establish trends in pesticide occurrence in environmental samples.
- **Monitoring programs can only detect and quantify the pesticides analysts choose to look for.** For example, while glyphosate is the number one herbicide used in California and paraquat dichloride is number five, none of the major monitoring programs include these two chemicals in the suite of chemicals to be analyzed. As a result, we have no idea how much of these chemicals is present in the water and sediments in our rivers and streams. According to Central Valley Water Quality Control Board Environmental Scientist Chris Foe, "Absence of data is usually taken to mean that there isn't a problem when it actually means we don't know."[4]

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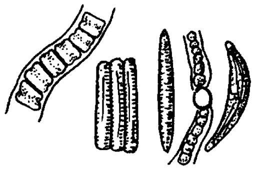
1. K.W. Weissmahr, C.L. Houghton and D.L. Sedlak "Analysis of the dithiocarbamate fungicides Ziram, Maneb, and Zineb and the flotation agent ethylxanthogenate by ion-pair reversed-phase HPLC," *Analytical Chemistry*, 1998, vol. 31, pp. 4800-4804.
2. Personal communication with Joseph Domagalski at U.S. Geological Survey, Western Regional Office, Sacramento, CA.
3. S. Marquardt, C. Cox, and H. Knight, *Toxic Secrets: "Inert" Ingredients in Pesticides 1987-1997*, Northwest Coalition for Alternatives to Pesticides (Eugene, OR) and Californians for Pesticide Reform (San Francisco, CA, 1998).
4. J. Mayer, "Scientists say pesticides may endanger river life," *The Sacramento Bee*, June 28, 1993.

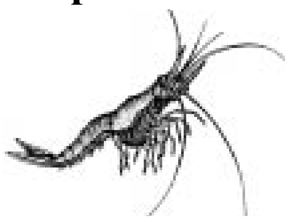
Effects of Pesticides on Phytoplankton



The precise impact of pesticides on phytoplankton populations is unknown, but because they are designed to kill plants, herbicides have the largest impacts. In addition, some insecticides are toxic to aquatic plants.[15] A number of pesticides are routinely found in California waters, and many samples contain more than one chemical. Even though concentrations of pesticides found in California waters do not often exceed lethal concentrations for most species of phytoplankton, the existence of multiple pesticides in the same sample is cause for concern because many pesticides have a similar mechanism of action and may act additively or synergistically. Appendix 2, Table 2 gives the concentrations at which pesticides significantly inhibit phytoplankton growth.

Levels of herbicides below lethal concentrations are not necessarily innocuous. Inhibition of photosynthesis and reduction in the growth of algae cultures have been observed at concentrations as low as 1 μg/liter for triazine herbicides.[16] Because phytoplankton are the basis of the food web, reduction in their numbers has the potential to compromise the productivity of the entire ecosystem, reducing the availability of food and habitat for zooplankton.

Effects of Pesticides on Zooplankton



Small aquatic animals known as zooplankton are most affected by organophosphorus, carbamate, and organochlorine insecticides. These chemicals target the nervous systems of these animals and are often lethal at low concentrations. Concentrations of diazinon and chlorpyrifos exceeding water quality criteria (see page 41) are frequently found in California waters, and toxic pulses of some pesticides are so concentrated that stream and river water are lethal to zooplankton for many days in a row.

A survey of zooplankton population trends in the Sacramento-San Joaquin Estuary from 1972 to 1988 shows a decline in the populations of 12 out of 20 major groups of zooplankton, most of them species that serve as primary food sources for young fish.[17] This may be a conservative estimate, since long-term trends were calculated during a study period beginning when surface waters were already impacted by agricultural and industrial runoff.

Too little is presently known about the ecosystem to determine how much of the overall population decline is attributable to pesticides. However, in smaller streams and sloughs where larval fish feed[18] we know pesticides have significant impacts on localized zooplankton populations.

The effects of individual pesticides on zooplankton have been studied to determine concentrations at which they are toxic (see Appendix 2, Table 3). Different species can have widely different sensitivities to a particular pesticide. Similarly, a particular organism can have a very different sensitivity to different pesticides, and to the same pesticide at different stages of development. For example, zooplankton nymphs and larvae are more susceptible to pesticides than adults. Because zooplankton have not been studied under controlled conditions in the presence of multiple pesticides, the long-term effects of exposure to the chemical cocktail found in California waters are not well known.

The full explanation for the decline in Delta zooplankton populations is most likely one that incorporates a combination of factors, including dams and diversions and introduction of non-native species. However, the fact that concentrations of diazinon and chlorpyrifos in the main stem of the San Joaquin and Sacramento Rivers commonly exceed levels known to kill essential organisms in the food chain strongly suggests that pesticides may have population-wide effects.

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15. *Environmental Health Criteria 198: Diazinon*, World Health Organization, Geneva, Switzerland, 1998.
16. World Wildlife Fund Germany, *The Triazine Pesticides – Reason for Concern*, and references contained therein, WWF Germany, Bremen, Germany, 1996.
17. S. Obrebski, J. Orsi, and W. Kimmerer, *Long-Term Trends in Zooplankton Distribution and Abundance in the Sacramento- San Joaquin Estuary*, California Department of Fish and Game and California Department of Water Resources Technical Report 32, May 1992.
18. Ibid., reference 4.

How Do Scientists Determine Pesticide Damage to Aquatic Ecosystems?

To understand how pesticides play a role in population declines, scientists must determine the identities and concentrations of pesticides present and ascertain the levels that cause harm to plants and animals, both in the laboratory and in tests with real riverwater and streamwater. They must then evaluate the data in the context of all factors that might affect the health of the ecosystem to determine whether population level impacts are caused by pesticides.

1. **Water Chemistry Analysis: What concentrations of pesticides are present?** A necessary first step for determining whether pesticides are causing problems in the environment is to measure how much of a particular pesticide is present in the ecosystem and how it is distributed between water, sediments, and animal and/or plant tissues. Whether or not measurable concentrations of a specific pesticide will be found in water or sediment depends on the water solubility of the pesticide, how fast it breaks down, the type of sediment present in the area, and how strongly the pesticide adheres to sediments.
2. **Bioassay LC_{50} Measurements: What concentration of the pesticide is lethal to organisms in laboratory studies?** Before a pesticide can be implicated as the cause of toxicity in water or sediment, it is important to know the concentration at which it causes noticeable effects on aquatic organisms. This is done by culturing certain test species such as water fleas, oysters, shrimp, fathead minnows, and phytoplankton in the presence of known concentrations of the pesticide under controlled laboratory conditions to determine the LC_{50}, the lethal concentration of the pesticide that kills 50% of the test animals in a specified period of time. These LC_{50} values can be quite different for different organisms and may vary by factors of as much as 10,000 between related species. Appendix 2 lists specific LC_{50} values for fish, birds, zooplankton, phytoplankton, and bees for a variety of pesticides.
3. **Bioassay Toxicity Tests: Does the water or sediment taken from a sample site cause death to aquatic organisms?** Once the presence of a particular pesticide (or several pesticides) has been confirmed in a sample, researchers will often use the sample water (or sediment) from the river or stream to culture aquatic organisms and measure their survival rates. The percent mortality in sample water is compared to a control group cultured in clean laboratory water with the same mineral content and pH as the sample water. The difference in survival between the sample and control groups provides a measure of the overall toxicity of a water or sediment sample taken from a particular location. Researchers typically use the U.S. Environmental Protection Agency Three-Species Bioassay which uses fathead minnows (*Pimephales sp.*), water fleas (*Ceriodaphnia*), and the algae *Selenastrum* to evaluate the toxicity of the water sample.
4. **Toxicity Identification Evaluation (TIE): What class of pesticide or other toxicant is responsible for the death of organisms in sample water?** The U.S. Environmental Protection Agency developed the TIE protocol to identify the source of toxicity in water samples.[1] Test organisms are cultured in the sample water and compared to controls. Toxic samples are identified and divided into several parts, and each part is then treated with a substance that removes or renders harmless a specific class of toxicants. The treated water samples are then used to culture test organisms to determine which treatment(s) successfully removed the toxicity from the water sample. The TIE test can identify toxicity due to organophosphorus and carbamate insecticides, ammonia, metals, and non-polar organic compounds such as the synthetic pyrethroids.
5. **Population-Level Effects: Are pesticides causing declines in the populations of organisms in the ecosystem?** In a large and diverse ecosystem like San Francisco's Bay-Delta, this is the most difficult question to answer. There are many factors that affect the health of the ecosystem, including the amount of rainfall, dams, quantity of water diverted away from the rivers, introduction of exotic species, overfishing, and toxicants of all types, especially pesticides. While a definitive answer will require much more research, an evaluation of the relative importance of these factors by the Bay-Delta scientific community estimates that in the upstream areas of the Delta, pesticides have a large effect on fish and their food supply, with evidence suggesting that population level effects are likely.[2]

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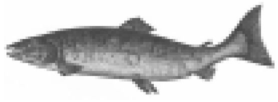
1. *Marine Toxicity Identification Evaluation (TIE): Phase I, Guidance Document*, EPA/600/R-96/054, U.S. Environmental Protection Agency, September 1996 (Washington, DC).
2. *Working Conceptual Model for the Food Web of the San Francisco Bay-Delta Estuary*, Interagency Ecological Program for the San Francisco Bay-Delta Estuary, Technical Report 42, California Department of Water Resources, August 1995.

Effects of Pesticides on Fish



Endangered or Threatened Fish Species in the San Francisco Bay-Delta Estuary[20]

Winter-run chinook salmon
Spring-run chinook salmon
Fall-run chinook salmon
Steelhead trout
Sacramento splittail
Delta smelt

Even with hatchery support for some species, nearly all of California's major fish species are in decline. Populations of green sturgeon, striped bass, steelhead, salmon (see Figure 3-1), and smelt have dropped precipitously since the 1960s.[19] Several are listed as endangered or threatened species (see sidebar). Many factors have contributed to this decline, including the influx of toxic substances into streams and rivers, overfishing of oceangoing fishes, habitat destruction by timber harvest practices, development and damming of rivers and streams, introduction of exotic species, reduction of the fishes' food supply, and entrapment of larval and juvenile fish in pumps and diversion dams.

There is clear evidence that California fish are stressed by exposure to pesticides. with both acute and chronic toxicity observed. In addition, concentrations of pesticides in surface waters are often high enough to be lethal to the zooplankton that serve as a food source for larval and adult fish. Adult fish are able to move to less-impacted areas to find food, but young fish cannot, a fact which is likely to reduce their survival. Because fish populations are already so low and because other stressors (low water flows, dams, diversions, and exotic species) are also present, there is little margin for recovery when even a small number of fish fail to survive to adulthood.

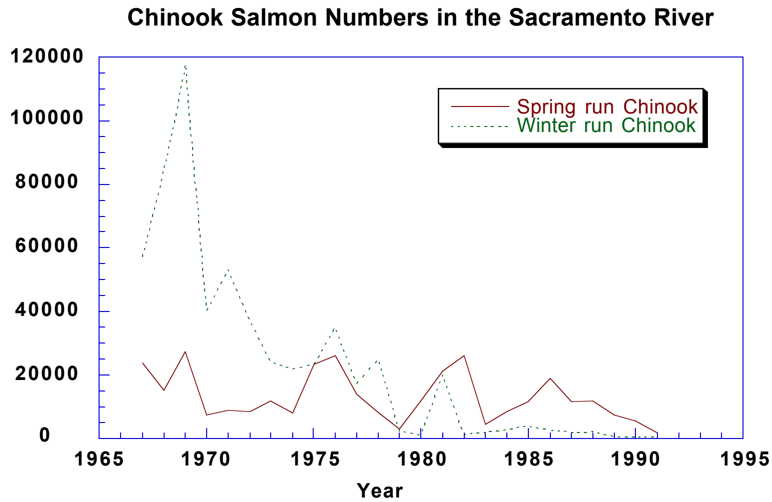


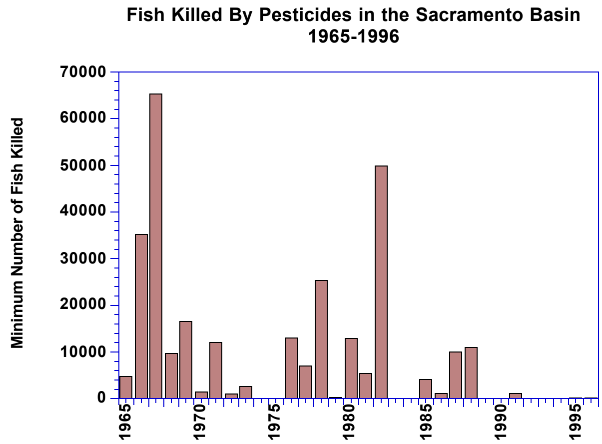
Figure 3-1: The populations of spring run and winter run chinook salmon have declined dramatically over the last 30 years.[21]

Evidence of Acute Toxicity to Fish

Most fish can tolerate higher concentrations of pesticides than aquatic invertebrates before suffering acute poisoning. However, in spite of their relative robustness, many fish have been killed by pesticides in California (see Figure 3-2). The sensitivity of different fish species to different pesticides varies considerably (see Appendix 2, Table 4). For example, fathead minnows are somewhat tolerant to diazinon, but are almost 1,000 times more sensitive to ziram. Sensitivity to a specific pesticide varies between species as well. For example, rainbow trout are particularly sensitive to malathion. In contrast, coho salmon are 40 times more tolerant of malathion than rainbow trout, and goldfish are 2,500 times more tolerant (See Appendix 2, Table 4).

19. "Central Valley Anadromous Sport Fish Annual Run-Size, Harvest, and Population Estimates, 1967 through 1991," California Department of Fish and Game, 1994.
20. *State and Federally Listed Endangered and Threatened Animals of California*, California Department of Fish and Game, Natural Heritage Division, Sacramento, CA, July 1998.
21. California Department of Fish and Game abundance statistics available at the web site http://darkstar.delta.dfg.ca.gov/baydelta/monitoring/monitor.html.

Between 1965, when the California Department of Fish and Game began keeping records, and the 1980s, massive fish kills caused by pesticides were common, with over 100,000 fish killed in 1982 alone in the Sacramento-San Joaquin Estuary. The 1982 fish kills were mostly due to molinate, thiodan and acrolein. These reports are underestimates, since dead fish are often scavenged or carried downstream before they can be counted and larval and juvenile fish are too small to be noticed. For example, the fish kill due to the metam sodium spill in the Sacramento River near Dunsmuir in 1991, was estimated at approximately 1,000,000 fish killed; however, it was included in the fish kill data only as "1000+" dead fish.[22]



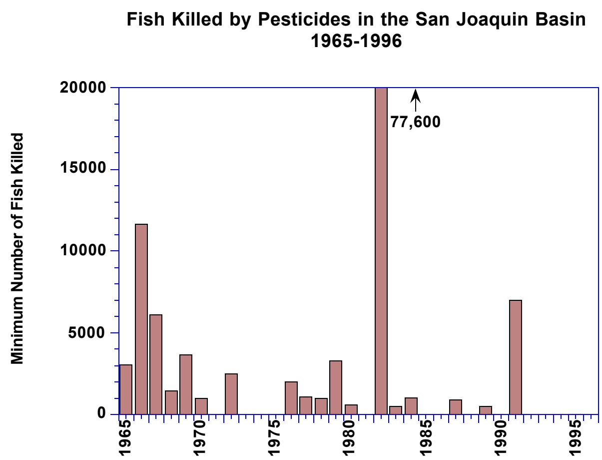


Figure 3-2: Reported fish mortality due to pesticides for the Sacramento and San Joaquin basins.[23] These numbers reflect only the minimum number of fish killed, since many kills are not noticed or reported.

In the 1960s and 1970s, the organochlorine pesticides DDT, endosulfan, acrolein, toxaphene, and copper compounds were primarily responsible for fish kills. In the 1980s, drainage of pesticide-contaminated water containing molinate, methyl parathion, malathion, thiobencarb, and carbofuran from rice fields in the Sacramento Valley caused predictable fish kills every spring and summer until longer holding

22. J. P. Fox and E. Archibald, *Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley,* California Urban Water Agencies, 1999, p. 42.
23. Ibid., reference 22, pp. 38-42 and 203-205.

Striped Bass – Introduced, Beloved, Threatened

The striped bass is not a California native, but was introduced to California from East Coast fisheries in 1879. Between 1900 and 1935, the population of striped bass in the Sacramento–San Joaquin Estuary sustained a sizeable commercial fishery. While commercial striped bass fishing was banned in 1935 by the state legislature, recreational fishing for striped bass is a favorite pastime for many Californians. In recent years however, the striped bass population has plummeted to historically low numbers (see Figure A below).

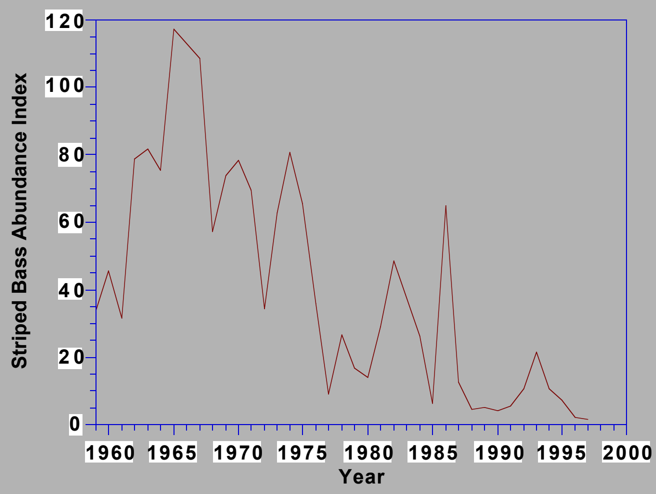


Figure A: The abundance of young striped bass in the Bay-Delta Estuary has declined over time. The abundance index is a measure of young fish at least 38 mm in length.[1]

Striped bass are estuarine fish that live in waters of widely varying salinity and temperature. Traveling long distances to find food and good spawning habitat, they move throughout the Bay-Delta estuary and into the ocean during their 30-year lifetime. Striped bass spawn upriver in the freshwater reaches of the estuary between April and May when the water temperature reaches 15–20°C. A large, healthy female bass can produce up to two million eggs per season.

After the eggs are fertilized, they drift downstream for several days. On hatching, larval fishes drift further downstream into the mixing zone where freshwater and saltwater meet. There they begin to feed on zooplankton, preying on cladocerans, rotifers and copepods (see Figure B on facing page). As young fish grow, their diet changes to the larger opossum shrimp (*Neomysis mercedis)*. This species is the food staple of the “young-of-the-year,” although they will shift to other food sources if opossum shrimp populations are low. In their second year, the bass are about four inches long and start to prey on smaller fish, even their own species. During the second year, striped bass may leave the estuary for the ocean or remain in the estuary.[2] There are many possible reasons for the decline in the striped bass population to its present low point, including acute and chronic exposure to toxic substances, overfishing, dams, loss of larval fish into water diversion projects, limitations in the food chain of the striped bass, and reduction in egg production. Pesticides may contribute to the population decline because they have been shown to poison the main food sources of young striped bass (see page 54) and impair reproduction by acting as hormone mimics.[3] Because the population is already so low, additional stresses such as those imposed by pesticides can prevent recovery of the population.

1. The abundance index is determined as follows: For each survey, the catch for each sample site is summed and multiplied by the water volume in acre feet at the site to derive the weighted catch. The weighted catches are then summed and divided by 1,000 to calculate the index for that survey. The index is the estimated abundance when the mean size equals 38.1 mm. From California Department of Fish and Game, 1997 Summer Townet Survey web site, http://www.delta.dfg.ca.gov/data/mwt96/mwt1196.html.
2. P. Moyle, *Fish: An Enthusiast’s Guide*, University of California Press, (Berkeley and Los Angeles, 1993).
3. R.D. Ewing, *Diminishing Returns: Salmon Decline and Pesticides*, Northwest Coalition for Alternatives to Pesticides, (Eugene, OR, 1999), web site, http://www.pond.net/~fishlifr/salpest.pdf.

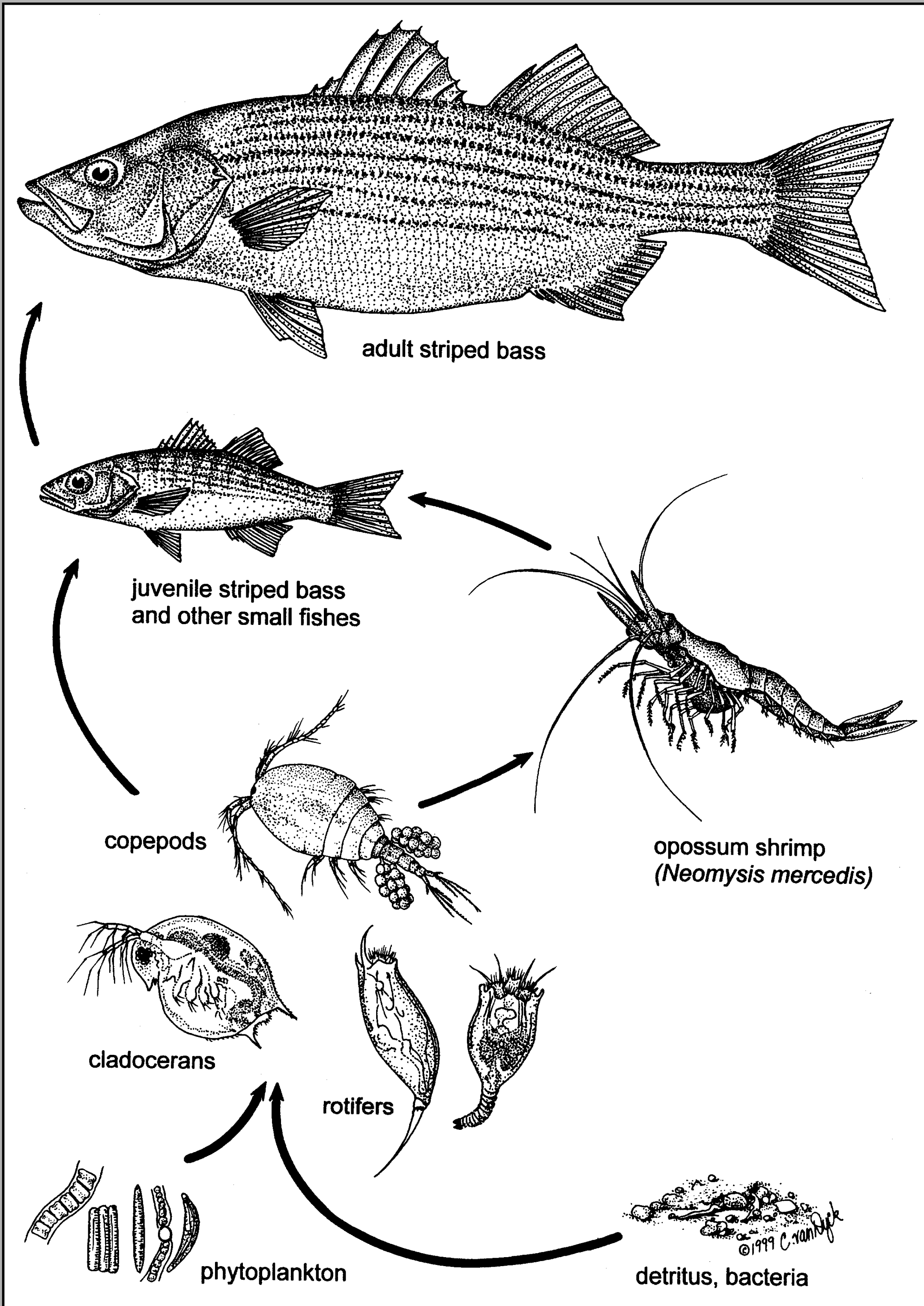


Figure B: Striped bass depend on a number of different organisms for food. The young striped bass eats zooplankton, including copepods, cladocerans, and rotifers. While some zooplankton feed predominantly on phytoplankton, rotifers and other copepods feed on detritus (decaying organic matter) or on a combination of phytoplankton and detritus. Opossum shrimp feed on smaller zooplankton as well as on phytoplankton.

times for water in rice fields were mandated to reduce the concentrations of toxic chemicals to sub-acute levels.[24]

River and agricultural drainwater in California is still periodically toxic to fathead minnows, salmon smolts, and larval striped bass,[25] although the absolute number of reported fish kills due to pesticides has declined in recent years. This decline is partially due to improved farm management practices and a shift toward less acutely toxic pesticides. This hopeful shift is offset to some degree by an increase in the total amount of pesticides used in the state, up 31% between 1991 and 1995.[26] The decrease in reported fish kills is probably also due to the fact that there are fewer fish remaining to be killed, making it less likely that large numbers of fish would die and be noticed.

SUBLETHAL EFFECTS OF PESTICIDES ON FISH

Sublethal exposure to low levels of pesticides may have a more significant effect on fish populations than acute poisonings. Doses of pesticides that are not high enough to kill fish are associated with subtle changes in behavior and physiology that impair both survival and reproduction. Sublethal doses of pesticides have been found to reduce swimming ability and change schooling behavior, rendering fish more susceptible to predation. Survival is threatened further by pesticides that suppress the immune systems of fish, resulting in an increase in the number of fish that die from disease. Pesticides have also been shown to impair the ability of young anadromous fishes such as salmon and striped bass to adapt to higher salinities as they migrate towards the ocean.[27]

Evidence of Chronic Toxicity to Fish

There is a significant amount of evidence available showing that fish are being chronically exposed to a variety of pesticides that accumulate in tissues. Several federal and state monitoring programs regularly test fish tissue for pesticide residues. Results show that most fish sampled in urban and agricultural areas of the state contain detectable levels of pesticides, with particularly high levels detected in fish from the Los Angeles and San Diego harbors, parts of the San Francisco Bay, and the Sacramento and San Joaquin Rivers.[28] Concentrations of DDT and DDE in fish tissue have decreased from the time of peak use in 1970, but remain high, in some cases significantly above the National Academy of Sciences guidelines for human consumption.[29] Other pesticides detected in fish tissues include chlordane, toxaphene, endosulfan, aldrin, chlorpyrifos, dacthal, dicofol, lindane (HCH), hexachlorobenzene, thiobencarb, trifluralin, and methyl parathion. According to the U.S. Geological Survey, concentrations of organochlorine pesticides found in fish and clam tissue in the San Joaquin-Tulare Basin are among the highest in the nation.[30]

Evidence of chronic toxicity caused by pesticides was also suggested by the U.S. Geological Survey study, with a very high occurrence of diseased and deformed fishes with tumors, skeletal deformations, and external parasites found in the study area. In areas where pesticide concentrations in surface waters are monitored, there

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24. Ibid., reference 22.
25. Ibid., reference 22.
26. J. Liebman, *Rising Toxic Tide: Pesticide Use in California, 1991-1995*, Pesticide Action Network and Californians for Pesticide Reform (San Francisco, CA, 1997).
27. R.D. Ewing, *Diminishing Returns: Salmon Decline and Pesticides*, Northwest Coalition for Alternatives to Pesticides, (Eugene, OR, 1999), web site http://www.pond.net/~fishlifr/salpest.pdf.
28. *National Study of Chemical Residues in Fish*, Volume I and II, U.S. Environmental Protection Agency (Washington, DC, 1992).
29. National Academy of Sciences and National Academy of Engineering, 1973, *Water Quality Criteria, 1973*, U.S. Environmental Protection Agency, Ecological Research Series, EPA R3-73-033.
30. Ibid., reference 2.

are many examples of pesticide concentrations that exceed chronic criteria for aquatic life (see page 41).

Evidence of Endocrine Disruption in Fish

The endocrine-disrupting capabilities of certain pesticides are suspected to be one of the contributing factors to the decline of fish, amphibian, and bird populations.[31] Such hormone-disrupting effects have been observed for at least 50 pesticides, including high-use chemicals such as chlorpyrifos, carbaryl, ziram, maneb, malathion, vinclozolin, simazine and other triazines, and trifluralin.[32] The mechanisms of endocrine disruption are not thoroughly understood; however, there is ample evidence that pesticides do impair the reproductive capabilities of fish.

Interference with endocrine hormones affects reproduction, immune function, development, and neurological functions in many species of animals (see page 10). In fish, endocrine disruptors interrupt normal development and cause male fish to have female characteristics. These outward symptoms of developmental disruption are accompanied by reduced fertility and even sterility in adults, as well as lower hatch rates and viability of offspring. Several studies show a direct relationship between concentrations of endocrine-disrupting compounds in fish tissues and depressed hormone concentrations.[33] Disruption of the balance of endocrine hormones during development of young fish can also cause defects of the skeletal system, resulting in deformities and stunted growth.[34]

Evidence shows that "inert" ingredients in pesticides can also disrupt the endocrine system. Applications of the insecticide Matacil, containing the "inert" ingredient 4-nonylphenol, to northeastern forests in the U.S. and Canada to control the spruce budworm resulted in concentrations of 4-nonylphenol that were high enough to cause endocrine disruption in Atlantic salmon. Significant salmon smolt mortality and low salmon returns were observed in rivers draining watersheds where the pesticide was applied.[35]

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31. T. Colborn, F.S. Vom Saal, and A.M. Soto, "Developmental effects of endocrine disrupting chemicals in wildlife and humans," *Environmental Health Perspectives*, 1993, vol. 101, pp. 378-384.
32. L. H. Keith, *Environmental Endocrine Disruptors: A Handbook of Property Data*, Wiley Interscience (New York, 1997).
33. S.L. Goodbred, R.J. Gilliom, T.S. Gross, N.P. Denslow, W.L. Bryant, and T.R. Schoeb, *Reconnaissance of 17ß-Estradiol, 11-Ketotestosterone, Vitellogenin, and Gonad Histopathology in Common Carp of United States Streams: Potential for Contaminant-Induced Endocrine Disruption*, U.S. Geological Survey, 1996, Open-File Report 96-627, web site http://water.wr.usgs.gov/pnsp/rep/carp2/.
34. Ibid., reference 27.
35. W.L. Fairchild, E.O. Swansburg, J.T. Arsenault, and S.B. Brown, "Does an Association between Pesticide Use and Subsequent Declines in Catch of Atlantic Salmon (*Salmo salar*) Represent a Case of Endocrine Disruption?" *Environmental Health Perspectives,* vol. 107, May 1999.

Toxic Pesticide Pulses Occur Regularly in California Waterways

Lars Neumeister

Multiple water quality monitoring studies conducted in California by Regional Water Quality Control Boards, the U.S. Geological Survey, and the Department of Pesticide Regulation show that pulses of toxic pesticides in the rivers of the Central Valley of California are routine occurrences. Aquatic species are almost continually exposed to a variety of pesticides, frequently in concentrations high enough to kill. The high concentrations have been shown to be closely correlated to pesticide applications.[36]

Zooplankton are killed in these toxic pulses. Estimates of kill rates can be made based on toxicity testing, where water fleas (*Ceriodaphnia*) are cultured in water collected from agricultural drains, urban runoff, rivers, or streams. In such tests, the death of the test organisms correlates strongly with measured concentrations of pesticides.[37]

Many of these toxic pulses coincide with the spawning, incubation, and hatching of many Delta fishes, including salmon, sturgeon, steelhead, Longfin smelt, American shad, Sacramento splittail, and Delta smelt.[38] A loss of zooplankton due to pesticide pulses results in a reduction in the food supply for larval and juvenile fishes during sensitive life stages of the fish. Figure 3-3 overlays pesticide pulses on spawning periods for several fish species.

Studies by the Central Valley Regional Water Quality Control Board and the U.S. Geological Survey (see below) show that toxic flows of some pesticides are most severe at times of high water flows, when agricultural and urban runoff carry large quantities of pesticides into streams and rivers. Thus, in a wet year when fish might have a chance to recover because of increased water for spawning and rearing of fish fry, they are instead faced with high concentrations of pesticides and a reduction in their food supply.

It is not known how long it takes for zooplankton populations in California waters to recover from a kill caused by pesticides, but evaluation of data from other parts of the country provides some insight. In the northeastern U.S. and Canada, forests were treated with the insecticides fenitrothion and permethrin to control the spruce budworm.[39] Drift nets were set up to collect zooplankton (mostly stonefly, mayfly, and black fly larvae) in the affected streams, and dead zooplankton were counted and correlated to application rates of the two pesticides. For most application rates, large numbers of dead zooplankton were trapped as they drifted downstream from the sprayed area. To assess the recovery time of zooplankton populations in the affected streams, the stomach contents of trout living in the stream were analyzed over time to determine their diets. In streams where zooplankton populations were significantly reduced by the pesticide application, trout switched mostly to terrestrial insects as a food source. Recovery of zooplankton to previous levels was slow, requiring several months in areas where parts of the watershed had not been sprayed and up to two years in streams in which the entire watershed was sprayed, because repopulation of the area from zooplankton drifting from upstream was not possible.

In California rivers, zooplankton recovery from a pesticide-induced kill might be hampered by several factors, including: repeated pesticide pulses; exposure to the mixtures of chemicals found in rivers and streams, and the fact that upstream areas that might help repopulate zooplankton in rivers downstream are either dammed or even more seriously impacted by pesticide runoff than downstream areas.

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36. Ibid., reference 3.
37. C. Foe, L. Deanovic, and D. Hinton, *Toxicity Identification Evaluations of Orchard Dormant Spray Storm Runoff 1996-97*, California Regional Water Quality Control Board, Central Valley Region, 1998 and references cited therein.
38. F. Reynolds, T. Mills, R. Benthin, and A. Low, *Restoring Central Valley Streams: A Plan for Action*, California Department of Fish and Game, Inland Fisheries Division (Sacramento, CA, 1993).
39. R.C. Muirhead-Thomson, *Pesticide Impact on Stream Fauna*, Cambridge University Press (New York, 1987), pp. 128-160.

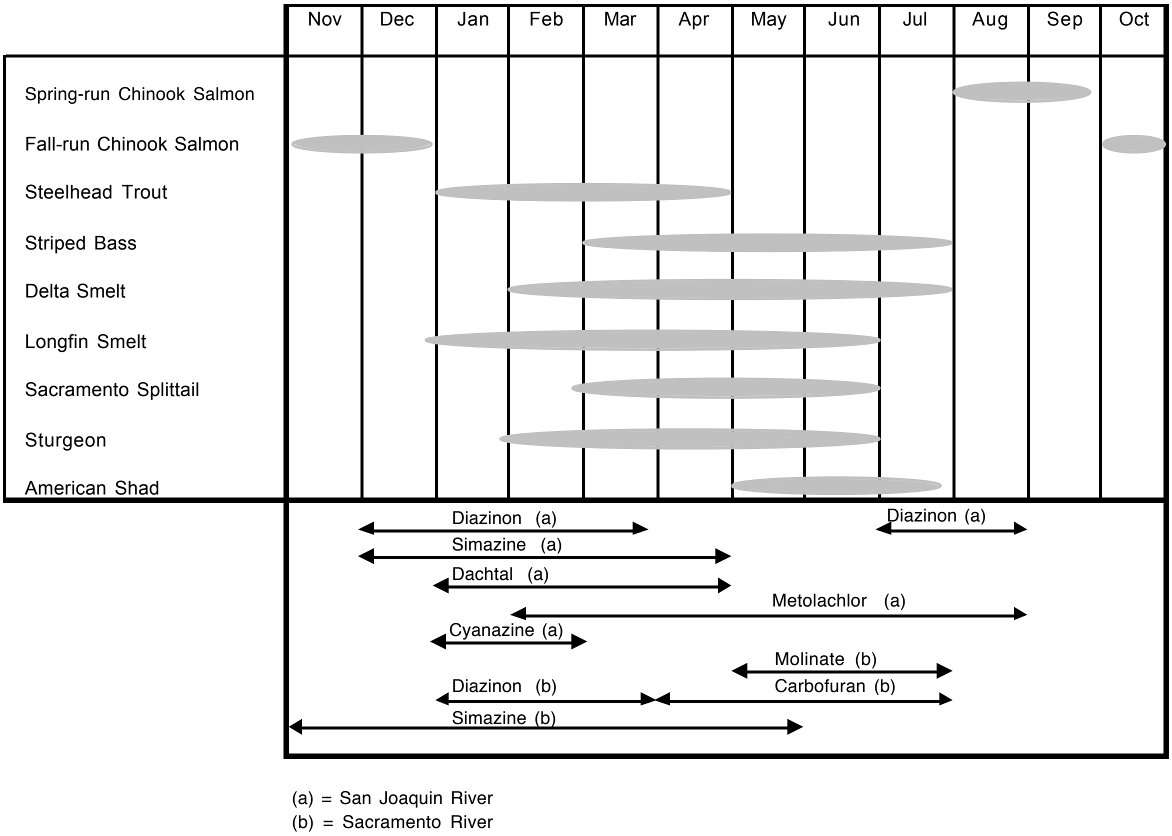
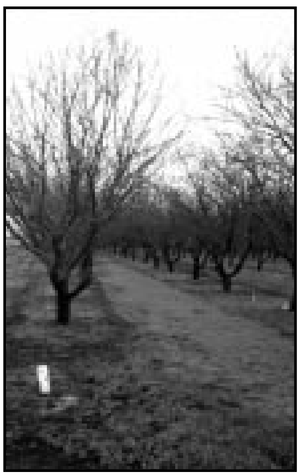


Figure 3-3: Pesticide pulses in the Sacramento and San Joaquin Rivers (shown on the bottom of the chart) often coincide with spawning periods for several important fish species—times when populations are most sensitive to toxic exposures.[40,41]

RUNOFF FROM ORCHARDS CAUSES WATER TOXICITY



Lars Neumeister

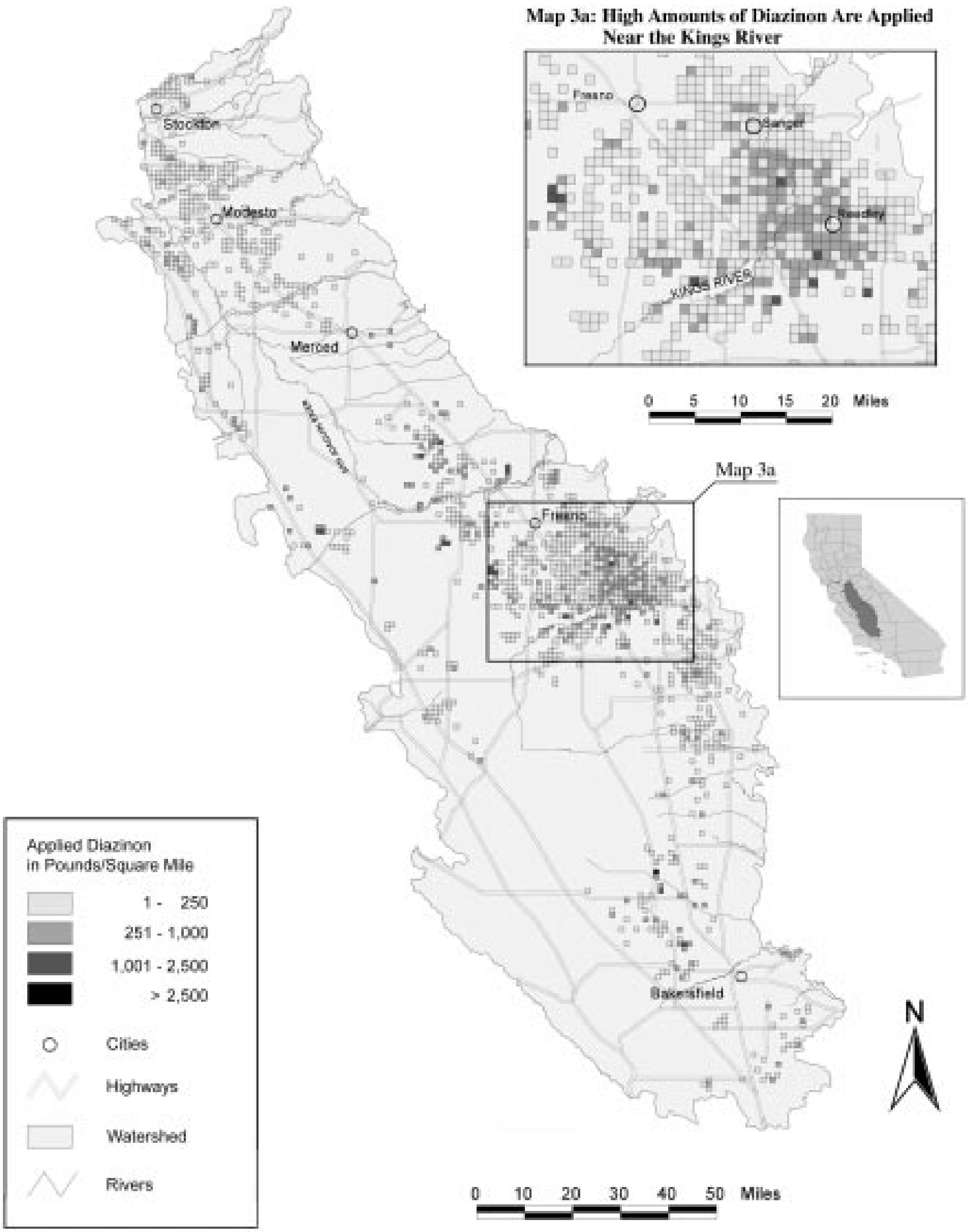
Diazinon

Almonds, walnuts, plums, peaches, and nectarines are among the major crops grown in the San Joaquin-Tulare Basin. During January and February, these dormant orchards are sprayed with insecticides, primarily the organophosphorus pesticides diazinon and chlorpyrifos and the pyrethroid permethrin to control insects such as the peach twig borer, San Jose scale, and aphids (see Map 3 on page 56). Unfortunately, the timing of these heavy pesticide applications coincides with the rainy season. It is not uncommon to see aerial applications of pesticides an hour before a torrential rainstorm which washes the freshly applied pesticide directly into surface waters.

Studies over the last ten years by the U.S. Geological Survey, the Central Valley Regional Water Quality Control Board, the Department of Pesticide Regulation, and Novartis, the manufacturer of diazinon, have documented levels of diazinon in surface waters that are toxic to zooplankton and fish. In many cases, the toxicity lasts for several weeks and greatly exceeds the California Department of Fish and Game acute

40. Novartis Crop Protection, Inc., *An Ecological Risk Assessment of Diazinon in the Sacramento-San Joaquin River Basin*, (Greensboro, NC, 1997).
41. D. MacCoy, K.L. Crepeau and K.M. Kuivila, *Dissolved Pesticide Data of the San Joaquin River at Vernalis and the Sacramento River at Sacramento, California, 1991-1994*, USGS Open File Report 95-110, U.S. Geological Survey, 1995.

Map 3: Application of the Insecticide Diazinon in the San-Joaquin Tulare Basin in January and February 1995



criteria for protection of freshwater life of 0.08 μg/L (see page 41). For protection of aquatic life, this concentration should not be exceeded for more than one hour once every three years.[42]

- In studies conducted between 1990 and 1994, the U.S. Geological Survey and the Central Valley Regional Water Quality Control Board found that 68% of samples collected from the San Joaquin River and three agricultural drains exceeded aquatic life criteria because of high concentrations of diazinon and chlorpyrifos. In February 1993, a pulse of diazinon in the Sacramento River was tracked from its source all the way out into the San Francisco Bay, with toxicity in the river extending as far west as Chipps Island in the Delta, 60 miles downriver from Sacramento.[43] In the same study, a diazinon pulse lasting for 12 consecutive days was traced down the San Joaquin River to the city of Stockton, 45 miles downstream from Vernalis. This 12-day pulse contained concentrations of organophosphorus insecticides high enough to cause 100% mortality to water fleas (*Ceriodaphnia*). The California Department of Fish and Game's acute and chronic water quality criteria for the protection of aquatic life from diazinon toxicity were exceeded for 21 consecutive days.
- Between 1988 and 1990, the Central Valley Regional Water Quality Control Board found that water from a 43-mile stretch of the San Joaquin River was toxic to water fleas approximately half the time.[44] The cause of this toxicity was unknown initially, but follow-up studies in 1991-92[45] confirmed that toxicity in most samples (65%) was due to pesticides, particularly diazinon, chlorpyrifos, fonofos, and carbaryl. In 1997, the Central Valley Regional Water Quality Control Board found toxic levels of diazinon in the San Joaquin River for eight consecutive days.[46]
- Even Novartis, the manufacturer of diazinon, concluded that sensitive invertebrates in the main stem of the San Joaquin River would experience acute toxicity over 20% of the time, and even more frequently in smaller watercourses closer to agricultural drains.[47] Using Novartis data, Central Valley Regional Water Quality Control Board staff estimated that the peak concentrations of diazinon in the San Joaquin River at Vernalis exceeded the LC_{50} for approximately 50% of all arthropod species for which toxicity data are available. Similar estimates for Sacramento Slough near the confluence of the Sacramento and Feather Rivers suggest that the peak concentrations would exceed the LC_{50} for approximately 30% of all arthropod species.[48]

While concentrations of diazinon were not high enough to cause fish kills, the net effect may be the same if the food supply for young fish is destroyed by pesticide pulses.

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42. M. Menconi and C. Cox, *Hazard Assessment Report of the Insecticide Diazinon to Aquatic Organisms in the Sacramento-San Joaquin River System*, California Department of Fish and Game, Environmental Services Division Administrative Report 94-2, 1994.
43. a) J.L. Domagalski, N.M. Dubrovsky, and C.R. Kratzer, "Pesticides in the San Joaquin River, California: Inputs from Dormant Sprayed Orchards," *Journal of Environmental Quality*, vol. 26, 1997, pp. 454-465.
    b) K. Kuivila and C. Foe, "Concentrations, Transport and Biological Effects of Dormant Spray Pesticides in the San Francisco Estuary, California, " *Environmental Toxicology and Chemistry,* 1995, vol. 14, pp. 1141-1150.
44. C. Foe and V. Connor, *San Joaquin Watershed Bioassay Results*, *1988-90*, Central Valley Regional Water Quality Control Board Staff Report, July 1991.
45. C. Foe, *Insecticide Concentration and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin,* Central Valley Regional Water Quality Control Board Staff Report, December 1995.
46. Ibid., reference 37.
47. Ibid., reference 40.
48. Ibid., reference 37.

Interagency Agreement Fails to Control Diazinon Runoff

Diazinon and chlorpyrifos runoff from urban runoff and dormant orchard sprays are some of the most problematic sources of toxicity to California waters. According to the narrative water quality objectives of the Basin Plan of the Central Valley Regional Water Quality Control Board,

> "...all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses...in aquatic life."

The toxic pulses of diazinon that occur every winter with storm runoff from orchards are in clear violation of these water quality objectives and therefore in violation of the Federal Clean Water Act.

Who Regulates Pesticides in Water in California?

The California Porter-Cologne Water Quality Control Act places the authority to enforce the Clean Water Act and regulate toxic discharges to water in the hands of the State and Regional Water Boards. While the Water Boards have been quite effective in reducing toxic inflows from industry discharges through pipes, ditches, and drains, they have had little success regulating pesticides in agricultural and urban runoff. Complicating the issue is that control of pesticide runoff is best handled by imposing restrictions on pesticide use, which only the California Department of Pesticide Regulation (DPR) has the authority to regulate.

The plan that was implemented in 1996 to deal with the problem of dormant sprays of organophosphorus insecticides created a Management Agency Agreement (MAA) between the State Water Resources Control Board and DPR. The MAA defined an approach that initially required DPR to work with growers and conservation districts to obtain voluntary cooperation to change application practices and reduce pesticide runoff. If volunteers were not forthcoming, mandatory controls were to be implemented by DPR within one year.

After three years, no volunteers have yet stepped forward, and DPR has not even taken the first step in the process, which is to set "Quantitative Response Limits"—the concentration of diazinon that would trigger action to control runoff. In the meantime, monitoring data collected by the Central Valley Regional Water Quality Control Board[1] continue to show that toxic pulses of diazinon remain common in Central Valley waters from orchards after rainfall. Ten years after the problem was first discovered, the fact that nothing substantive has been done to control diazinon runoff from orchards represents a failure of the California Environmental Protection Agency to work with the Water Boards and DPR to protect California's waters for all beneficial uses.

Using the Clean Water Act and the Total Maximum Daily Load (TMDL) Process

The approach that is now being taken to control organophosphate runoff into surface waters is to use the Clean Water Act, Section 303(d), which requires the State Water Board to list impaired water bodies every two years and the contaminant(s) that cause them to be listed. The Central Valley Water Quality Control Board now lists many small creeks and sloughs in the Central Valley, as well as the San Joaquin and Sacramento Rivers and the San Francisco Bay-Delta as impaired due to diazinon. The San Joaquin and the San Francisco Bay-Delta are impaired due to chlorpyrifos as well.[2] The next step is to establish total maximum daily loads (TMDLs) for each contaminant that is judged to be problematic, a process that is supposed to be complete by 2005.

The final step in the TMDL process is for the Water Boards to create a management plan to achieve the TMDL goals that will ensure no toxicity in the rivers. This approach is in progress and will likely result in mandatory controls on diazinon and chlorpyrifos applications. However, even using the TMDL process, regulations that will actually eliminate river toxicity are still years away.

The TMDL process comes up short in one other area: When one pesticide is regulated more strictly, pesticide applicators typically switch to another pesticide that may be equally toxic to aquatic life. With such extensive proof required to demonstrate environmental problems, it is likely that another ten years of data collection will be required to document problems caused by the new pesticide and implement control measures. This piecemeal approach to regulating pesticide runoff will not succeed in controlling toxic flows to surface waters. What is needed is a system that regulates all pesticides simultaneously.

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1. C. Foe, L. Deanovic, and D. Hinton, *Toxicity Identification Evaluations of Orchard Dormant Spray Storm Runoff 1996-97*, California Regional Water Quality Control Board, Central Valley Region, 1998 and references cited therein.
2. *Draft Functional Equivalent Document Consolidated Toxic Hotspot Cleanup Plan*, California State Water Quality Control Board (Sacramento, CA, 1999).

Ziram

Recent work on aquatic toxicity in the Sacramento Basin suggests that some of the toxicity observed in Sacramento River water might be due to the fungicide ziram.[49] In 1995, over 1.6 million pounds of ziram active ingredient were used in California, with approximately 600,000 pounds used on almonds, nectarines, peaches and other stone-fruits in the Sacramento Basin (see Map 4 on page 60). The primary application season is February through April. Like diazinon, ziram is water soluble enough to be washed off the trees and into the river by winter and spring rains.

In a 1990-92 study conducted by the Sacramento Regional County Sanitation District, 44% of Sacramento River samples taken at the Freeport Marina were found to be toxic to fathead minnows.[50] Fathead minnow mortality ranged from 20%-86%, with the highest mortalities associated with months of heavy ziram use on almonds and coinciding with the rainy season. Subsequent studies from 1993 through 1997 show continuing mortality to fathead minnows (see Figure 3-4). Overall, since 1990, 51% of samples taken from the Sacramento River were toxic to fathead minnows. Toxicity Identification Evaluation (TIE) tests suggest, but do not confirm, that ziram or a degradation product of ziram may the toxic agent in the spring. Studies are presently underway to determine the source of this toxicity.

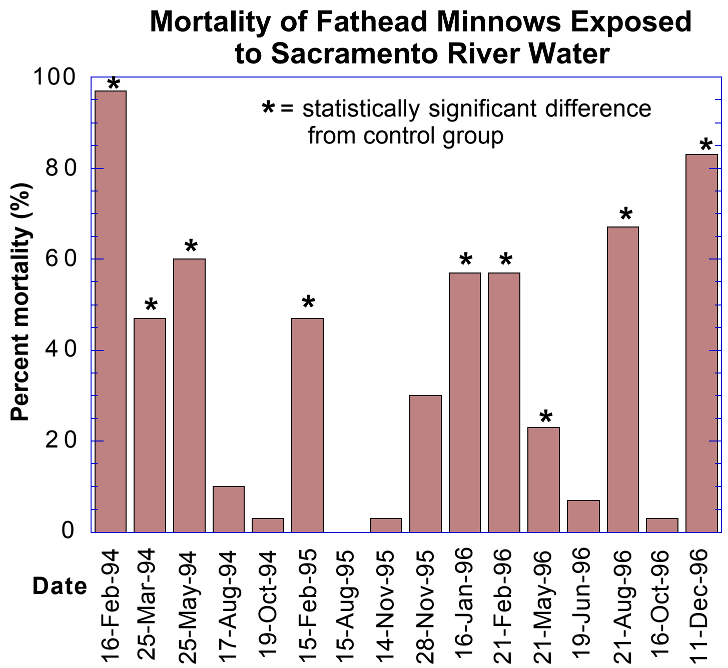
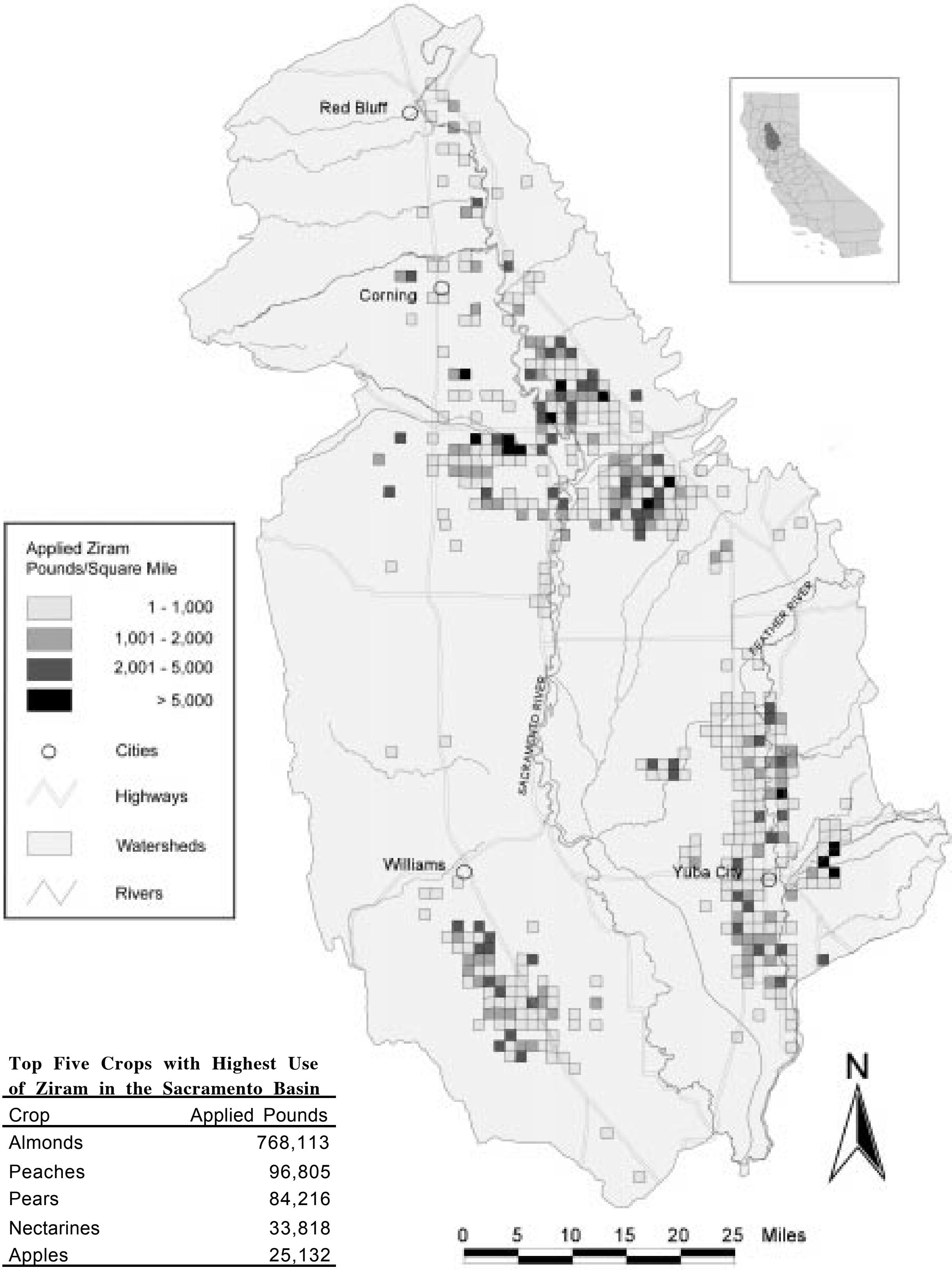


Figure 3-4: Sacramento River water is toxic to fathead minnows during winter and spring. The spring toxicity is thought to be due to the fungicide ziram.

49. Personal communication with Jeff Miller, AQUA-Science.
50. AQUA-Science, *Phase II Effluent Variability Study, Summary Report*, April 12, 1993.

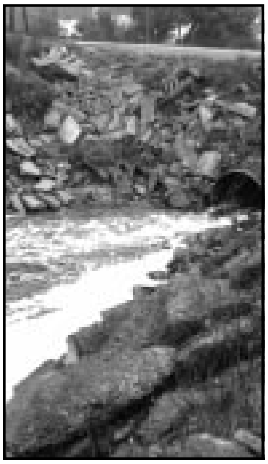
Map 4: Application of the Fungicide Ziram in the Northern Sacramento Basin



Top Five Crops with Highest Use of Ziram in the Sacramento Basin

Crop	Applied Pounds
Almonds	768,113
Peaches	96,805
Pears	84,216
Nectarines	33,818
Apples	25,132

RICE PESTICIDES IMPACT FISHERIES[51]



Lars Neumeister

Rice accounts for approximately 40% of planted acreage in the Sacramento Basin, which includes Butte, Colusa, Glenn, Placer, Sacramento, Sutter, Yolo, and Yuba counties. A variety of pesticides are used on rice to control weeds and algae as well as insect and invertebrate pests (see Map 5 on page 62). Rice farming poses a particular problem for aquatic ecosystems because pesticide-treated fields are irrigated continuously, resulting in a constant influx of pesticide-contaminated water into nearby agricultural drains that lead to the Sacramento River and its tributaries. Major sources of rice pesticide runoff are the Colusa Basin drain for fields on the west side of the Sacramento River, and Sacramento Slough (near the confluence of the Feather and Sacramento Rivers) for fields on the east side.

Fish Kills From Rice Pesticides Were Common in the 1980s

Historically, large fish kills were caused by release of pesticide-contaminated water from rice fields, with molinate, thiobencarb, or carbofuran responsible for kills of 30,000 fish in 1980, 10,000 fish in 1981, 13,000 fish in 1982, and 7,000 fish in 1983. Even though these pesticides are not known for their ability to bioaccumulate, fish near the Colusa Basin drain still contained high levels of molinate and thiobencarb from continuous exposure to high levels of the pesticides. The concentration of thiobencarb in Sacramento River water was high enough that residents of Sacramento who received their drinking water from the river complained about the noxious taste and odor of the water. Protests in Sacramento resulted in prompt attention to the matter.

To deal with pesticide runoff, the Department of Pesticide Regulation (DPR) set up the Rice Herbicide Program in 1984, which specified farm management practices to reduce pesticide movement into the Sacramento River. Rice growers are now required to keep pesticide-contaminated irrigation water on the fields for 28 days after application of the pesticides carbofuran, malathion, methyl parathion, molinate, and thiobencarb. The implementation of this practice resulted in an immediate drop in the number of fish killed; since 1984, no major fish kills have been reported as a direct result of rice pesticide runoff. However, the concentrations of rice pesticides in agricultural drains still periodically exceed levels that are toxic to zooplankton that are part of the food supply for fish (see Table 3-3).

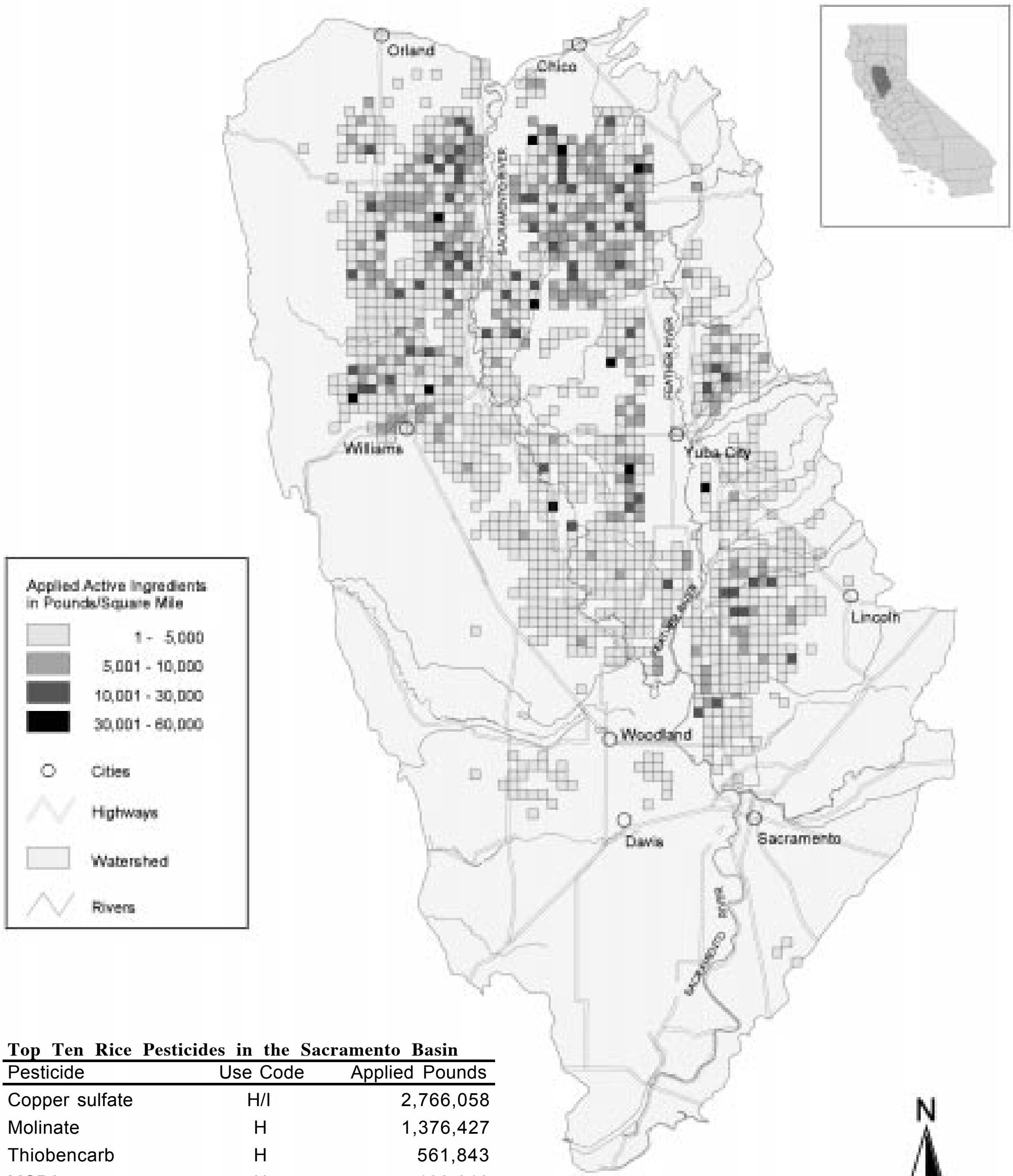
Table 3-3: Frequency of Detection of Rice Pesticides in Colusa Basin Drain, Butte Slough and the Sacramento River at the Village Marina in 1996[a]

Pesticide	Frequency of Detection	Percent of Samples with Detections Exceeding Performance Goal
Molinate	74%	48%
Thiobencarb	55%	31%
Carbofuran	40%	100%
Malathion	21%	100%
Methyl Parathion	10%	0%

a. J.P. Fox and E. Archibald, *Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley*, California Urban Water Agencies, 1998, p. 75.

51. Ibid., reference 22, pp. 64-100.

Map 5: Application of the Top Ten Rice Pesticides in the Sacramento Basin in 1995



Top Ten Rice Pesticides in the Sacramento Basin

Pesticide	Use Code	Applied Pounds
Copper sulfate	H/I	2,766,058
Molinate	H	1,376,427
Thiobencarb	H	561,843
MCPA	H	109,918
2,4-D	H	67,269
Carbofuran	I	61,114
Bensulfuron methyl	H	43,775
Methyl parathion	I	31,030
Propanil	H	22,454
Malathion	I	13,109

H= Herbicide, F= Fungicide, I= Insecticide

Levels of rice pesticides found in agricultural drainwater in the spring still exceed the performance goals set by the Central Valley Regional Water Quality Control Board (CVRWQCB) for protecting aquatic life (see Table 3-3). For example, in 1996, molinate was detected in 74% of samples taken from agricultural drains in May and June. The CVRWQCB's performance goal of 10 μg/L for molinate was exceeded in 48% of samples having detections.[52]

Levels and Toxicity of Pesticide Degradation Products Are Largely Unknown

Pesticide concentrations in irrigation water discharges from rice fields are now lower than before the Department of Pesticide Regulation began to regulate rice pesticides, largely because most of the pesticides degrade and/or volatilize during the 28-day holding period. Little is known about the concentrations and toxicity of the breakdown products. In a study done by the U.S. Geological Survey, several degradation products (p-nitrophenol from methyl parathion, carbofuran phenol from carbofuran, and two breakdown products from molinate) were detected.[53] This is only a fraction of the total number of degradation products—there are at least 25 possible breakdown products from molinate, carbofuran, methyl parathion, malathion, and thiobencarb alone,[54] some of them more toxic than the parent pesticide or able to act synergistically with other pesticides or degradation products to cause toxic effects.[55]

Copper-Containing Pesticides Do Not Degrade Over Time

One rice pesticide that does not break down over time is copper sulfate, used to control tadpole shrimp and algae in rice fields. Nearly 2.8 million pounds of copper sulfate were applied to rice fields in the Sacramento Basin in 1995. Release of irrigation water carries copper into surface waters, either in dissolved form or bound to sediment. Similar to the organophosphorus and carbamate insecticides, copper is acutely toxic to phytoplankton, zooplankton, and fish (see Appendices 1 and 2). Additionally, it has recently been shown that copper acts synergistically with organophosphorus and carbamate pesticides to enhance their toxicity.[56]

In the southern San Francisco Bay, copper from industrial sources has been an issue of great concern because of high levels found in shellfish and sediments in the area. Point-source controls have reduced industrial discharges of copper to the San Francisco Bay substantially. In contrast, the amount of copper salts applied in Central Valley agricultural use is increasing, from approximately six million pounds in 1991 to just under nine million pounds in 1995. Because copper is also present in some industrial discharges and wastewater from mines, we do not know the extent of copper contamination in the state's rivers that is due to pesticides. However, elevated levels of copper were found in 100% of the sediment and fish and clam tissue samples taken by the U.S. Geological Survey in 1992-95.[57] Copper is certainly among the major contaminants released into the Sacramento River when irrigation water is drained from the rice fields in late spring and summer. While concentrations of copper in water rarely exceed the chronic water quality criteria of 9.0 μg/L set by the U.S. Environmental Protection Agency,[58] its presence in sediments and the tissues of liv-

52. Ibid., reference 22, p. 75.
53. J.L. Domagalski and K.M. Kuivila, *Transport and Transformation of Dissolved Rice Pesticides in the Sacramento River Delta, California*, USGS Open-File Report 91-227, U.S. Geological Survey, 1991.
54. Ibid., reference 22, p. 96.
55. M.E. Bender, "The Toxicity of the Hydrolysis and Breakdown Products of Malathion to the Fathead Minnow (*Pimephales promelas*, Rafinesque)," *Water Research*, vol. 3, 1969, pp. 571-582.
56. J. Forget, J.-F. Pavillon, B. Beliaeff, and G. Bocquené, "Joint Action of Pollutant Combinations (Pesticides and Metals) on Survival (LC_{50} Values) and Acetylcholinesterase activity of *Tigriopus brevicornis* (Copepoda, Harpacticoida)," *Environmental Toxicology and Chemistry*, 1999, vol. 18, pp. 912-917.
57. Ibid., reference 2.
58. *Water Quality Standards: Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California: Proposed Rule,* Federal Register, vol. 62, No. 150, August 5, 1997.

ing animals indicates that it is likely transported into the ecosystem bound to sediments.

Organochlorine Pesticides Continue to Cause Problems

Most organochlorine pesticides (see page 11) are classified as probable human carcinogens by the U.S. Environmental Protection Agency.[59] Additionally, new research has shown that many of them are known endocrine system disrupting chemicals, which in humans are linked to lowered sperm counts, an increased incidence of undescended testicles, and a variety of other birth defects of the reproductive system. In animals, especially fish, reptiles, and amphibians, these compounds cause feminization of male animals and result in lower rates of reproduction arising from developmental defects of the reproductive system.[60]

Even in the U.S., where organochlorine pesticides have not been used for 25 years, they can still be found in measurable amounts in water, sediments, fish, birds, and humans. A recent U.S. Geological Survey assessment of surface waters in the San Joaquin-Tulare Basin found that 4% to 14% of the water samples analyzed had measurable concentrations of DDE (a breakdown product of DDT), dieldrin, or HCH.[61]

Table 3-4: Top Organochlorine Pesticides Found in Fish Tissues Across the U.S.[a]

Chemical	Percent of Sites Showing Detections	Maximum concentration (ng/g or ppb by wet weight)	Median concentration (ng/g or ppb by wet weight)	Maximum Fish Tissue Residue Allowed by EPA CA Toxics Rule[b]
DDE	99	14,000	58.3	31.6
cis-Chlordane	64	378	3.66	8.3
trans-Chlordane	61	310	2.68	8.3
Dieldrin	60	450	4.16	0.67

a. From reference 28. Measurements are given in nanograms of pesticide per gram of fish tissue (wet weight), which is the same as parts per billion. A nanogram is 0.000000001 gram.
b. From reference 58.

In a 1992 U.S. Environmental Protection Agency study of chemical residues in fish across the U.S., 53% to 99% of the samples contained measurable amounts of organochlorine pesticides, depending on the pesticide (see Table 3-4). High concentrations of DDT and its breakdown products are still found in sediments near the Palos Verdes Shelf, where they were dumped by the Montrose Chemical Company from 1947 through 1980.[62] In the San Francisco Bay, high levels of DDT and its breakdown product DDE are still found in sediments and fish tissue.[63] These high concentrations of DDT continue to accumulate in fish, shellfish, birds, and even people. Ingesting toxic levels of organochlorine pesticides disproportionately affects low-income and immigrant populations, since they commonly fish these areas.

59. S.J. Larson, P.D. Capel, and M.S. Majewski, *Pesticides in Surface Waters: Distribution, Trends, and Governing Factors*, Ann Arbor Press, Inc. (Chelsea, MI, 1997), p. 184.
60. Ibid., reference 32.
61. Ibid., reference 2.
62. R. Gossett, G. Wikholm, J. Ljubenkov, and D. Steinman, "Human Serum DDT Levels Related to Consumption of Fish from the Coastal Waters of Los Angeles," *Environmental Toxicology and Chemistry*, vol. 8, pp. 951-955, 1989.
63. a) J.A. Davis, A.J. Gunther, B.J. Richardson, J.M. O'Connor, R.B. Spies, E.Wyatt, E.Larson, and E.C. Meiorin, *Status and Trends Report on Pollutants in the San Francisco Estuary*, San Francisco Estuary Institute, San Francisco, CA, 1991.
b) A.J. Gunther, J.A. Davis, and D.J.H. Phillips, *An Assessment of the Loading of Toxic Contaminants to the San Francisco Bay-Delta*, San Francisco Estuary Institute, 1987.
c) D.J.H. Phillips, *Toxic Contaminants in the San Francisco Bay-Delta and Their Possible Biological Effects*, San Francisco Estuary Institute, San Francisco, CA, 1987.

A U.S. Geological Survey study conducted in 1994–95 evaluated the transport of organochlorine pesticide-contaminated sediments into the San Joaquin River.[64] Widespread use of organochlorines in the 1950s and 1960s resulted in the contamination of agricultural soils in the region. Twenty-five years later, these chemicals are still detected as they are transported downstream on suspended sediments with winter storm runoff and irrigation water return flows. In the study, the most commonly detected pesticides on sediments were DDT and its breakdown products, toxaphene, dieldrin, and chlordane. Most of the samples exceeded the U.S. Environmental Protection Agency freshwater chronic criteria (see page 41) for supporting aquatic life (see Figure 3-5).

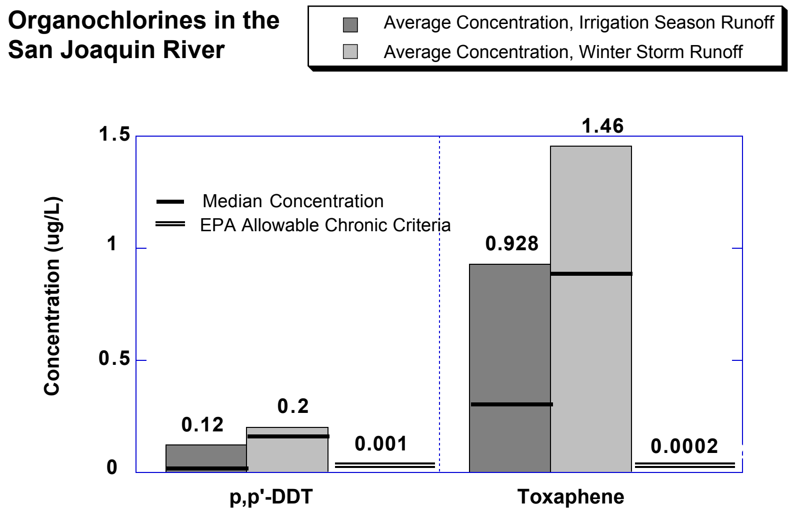


Figure 3-5: The median concentrations of DDT and toxaphene[65] in the San Joaquin River during irrigation flows and during storm flows exceeded the U.S. Environmental Protection Agency allowable chronic freshwater criteria for aquatic life.

Gaps in Our Knowledge

We already know a great deal about the impacts of pesticides on the aquatic environment; however, in order to fully assess the adverse affects, it is important to know more about:

- **The effects of pesticides on native species of fish and zooplankton.** At present, methods for reliably culturing these species and protocols for testing them in the laboratory have not been developed. Scientists have focused most of their work on a small set of indicator species instead. While experiments with indicator species are necessary for comparison to data from other parts of the country, tests with native species will provide much-needed information about how their populations might be affected by pesticides.
- **Zooplankton population trends in areas of critical habitat where young fish live.** Most of the available data are for the estuarine waters of the Delta. Much less is known about freshwater areas.
- **How fast phytoplankton and zooplankton repopulate an area after a kill caused by pesticides.** While studies have been done on zooplankton recov-

64. C.R. Kratzer, “Transport of Sediment-Bound Organochlorine Pesticides to the San Joaquin River, California,” U.S. Geological Survey, Open File Report 97-655, 1998.
65. Concentrations reflect the sum of amounts present in the water column and adsorbed to sediment. See reference 77.

ery following pesticide-induced kills in the northeastern U.S. and Canada (see page 54), little information is available for California ecosystems.

- **The distribution and concentrations of *all* high-use pesticides.** In particular, the high-use herbicides glyphosate and paraquat dichloride should be included in monitoring studies to track their distribution and detection frequencies over time.
- **The endocrine-disrupting effects of pesticides on fish and amphibians.** Sublethal concentrations of pesticides comparable to those we now find in California surface waters have been shown to have endocrine-disrupting effects in fish and wildlife. More work needs to be done to assess the ecosystem-wide impacts of these chemicals.
- **The effects of simultaneous, repeated exposures to multiple pesticides and other contaminants on aquatic organisms.** Because multiple pesticides are commonly detected in California surface waters, it is important to learn more about the additive and/or synergistic effects of these chemicals. Field work is important to validate the results of these studies.

Because there are still areas in which we lack knowledge, a precautionary approach that would eliminate the use of the most toxic pesticides and reduce overall pesticide use is the best way to prevent further ecological damage from pesticides.

Lars Neumeister

Chapter 4

Effects of Pesticides on Beneficial Organisms

Lars Neumeister

Beneficial organisms encompass a broad spectrum of beetles, bees, wasps, spiders, birds, bats, earthworms, and soil microorganisms. Insects, birds, and bats act as pollinators or prey on pest species or their larvae. Soil microorganisms and earthworms increase soil fertility by breaking down organic matter to create nutrients for plants. These "beneficials" are integral to a functional ecosystem, bolstering crop production by providing checks and balances on pest insects.

Broad-spectrum pesticides such as the organophosphorus, carbamate, and organochlorine insecticides destroy both pest and beneficial organisms indiscriminately, upsetting the delicate balance between pest and predator insects. Many people believe that more insecticides mean fewer pests and higher crop yields. However, even though the use of insecticides increased 10-fold from 1945 to 1989 in the U.S., crop losses from insects nearly doubled in the same time period, from 7% to 13%.[1] In addition, the number of insect pests resistant to pesticides increased dramatically over the same time period. With fewer and fewer "effective" pesticides left in their arsenals, many growers are increasing the quantities of chemicals they apply to their crops. Others, however, are moving to non-toxic methods of pest control that focus on biological controls to solve their pest problems. Research and experience have shown that:

- Beneficial organisms serve many valuable functions in an agricultural ecosystem, including pollination, soil aeration, nutrient cycling, and pest control.
- Application of insecticides indiscriminately kills pests and beneficial organisms. Pest populations often recover rapidly because of their larger numbers and ability to develop resistance, but beneficial insects do not, resulting in a resurgence of the target pest as well as secondary pests that reproduce rapidly with no predators to check their numbers.
- Resistance and resurgence often lead to escalation of pesticide applications, leading to pests with even greater resistance to pesticides. The resulting pesticide treadmill has created resistance to broad-spectrum insecticides in more than 500 pest species nationwide.[2]

Beneficial Insects

Beneficial insects include pollinators and predators, as well as insects that serve a variety of other beneficial roles in pest reduction, such as competing for habitat or causing a chemical response in a plant that repels pests. This section will focus on pollinators and predators.

Pollinating insects are essential to plant procreation. Most crop plants require assisted pollination, which involves another organism in the fertilization process. Without these pollinating insects, many plants would not produce seeds and fruits at all. Others would have greatly reduced yields.

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1. W. Quarles, "Beneficials and Pesticides" proceedings from the conference Wildlife Pesticides and People, September 25-26, 1998, and references therein.
2. C.M. Benbrook, E. Groth, J.M. Halloran, M.K. Hansen, and S. Marquardt, *Pest Management at the Crossroads*, Consumers Union (Yonkers, NY, 1996).

Table 4-1: Classes of Pollinators for the Wild Flowering Plants of the World[a]

Pollinator	Percent of Total Flowering Plants Pollinated by These Pollinators[b]
Beetles	88.3
Hymenoptera (wasps, bomber bees, hornets)	18.0
Bees	16.6
Wind	8.3
Butterflies	8.0
Flies	5.9
Other (water, thrips, birds, and mammals)	1.4

a. Adapted from reference 3, p. 274.
b. The total percentage sums to greater than 100% because some plants are pollinated by several different mechanisms.

Pollinating insects prefer certain species of plants and often have evolved in concert with their preferred species. For crop plants, the most important pollinators are bees, with approximately 80% of major crop species pollinated by some species of bee.[3] Many pesticides are acutely toxic to bees (see Appendix 2, Table 5). For example, exposure of honeybees to as little as 0.00000002 grams of pyrethrin per bee causes death.

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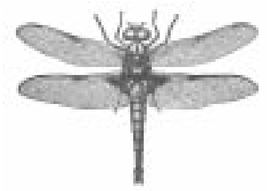
Predatory insects serve as checks and balances in the insect world, helping to keep pest insect populations (prey insects) under control. Beneficial predatory insects include lady beetles, lacewings, spiders, some beetle species, and predatory mites. Parasitic insects such as wasps and flies control pests indirectly by laying their eggs in

3. L.S. Buchmann, and G.P. Nabhan, *The Forgotten Pollinators*, Island Press/Shearwater Books (Washington DC/Covelo, CA, 1996), p. 260.

or on pest insects in their larval stages. Without predators, prey insect populations would rapidly grow out of control.



When an insecticide is applied, it affects beneficial predatory insects either by killing them directly or by disrupting the food web and reducing their food supply. When beneficial insect populations are reduced, the only remaining controls on pest populations are to reduce the availability of their food supply (usually a crop) or to apply ever greater amounts of pesticides. In areas where hundreds of acres of a single crop species is planted, it is difficult to limit the availability of food to the pest. Because of the complexity of the interactions between members of a healthy food web, and the simplification of the ecosystem that occurs when a pesticide is applied, it can take a long time for the food web to recover to the extent that predatory insects can survive.

Pesticides also deplete populations of earthworms and soil microorganisms. With no earthworms to break down organic matter in the soil, more fertilizers must be applied. A reduction in the biodiversity of soil microorganisms reduces the chances that soil-borne pests such as nematodes will succumb to their own natural predators.[4]

Relationships Between Pest and Predator Insects

The relationships between beneficial predatory insects and prey insects are similar to those between lions and wildebeest on the African savanna. Like the population of lions, populations of predatory insects are much smaller than those of their prey because large prey populations are essential for survival of a predator. It takes many growing seasons for predator-prey relationships to be built in the insect world, but the balance in these relationships can be destroyed in a single season through the use of pesticides. Broad spectrum insecticides such as organophosphates and carbamates wipe out both beneficial and pest insects. While pest insect populations normally recover, beneficials often do not.

There are several reasons why predatory insect populations are more sensitive to the effects of pesticides. Because their numbers are much lower than those of pest insects, there are fewer opportunities for natural selection, making it less likely that an insecticide-resistant strain of insect will evolve. In contrast, large populations of pest insects make the development of resistance an effective coping strategy for target pests.

Beneficial predatory insects also have a lower tolerance to pesticides. In contrast to pest insects, which have evolved mechanisms to cope with plant toxins, predator species have not had to deal with overcoming toxic chemical hurdles and do not have the appropriate enzymes to detoxify chemicals. Instead, selective pressures have led to evolution of predators with greater speed, visual acuity, and other characteristics that provide physical advantages over their prey. Because predator species are more active, they also have higher respiratory rates and are more mobile than their prey. This gives them a statistically greater chance of coming in contact with pesticides.[5]

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4. Ibid., reference 1.
5. a) H. Gordon, "Nutritional Factors in Insect Resistance to Chemicals," *Annual Reviews in Entomology*, 1961, vol. 6, pp. 27-54.
   b) B. Croft and A. Brown, "Response of Arthropod Natural Enemies to Pesticides," *Annual Reviews in Entomology*, 1975, vol. 20, pp. 285-335.
   c) B. Croft, *Arthropod Biological Control Agents and Pesticides,* John Wiley and Sons (New York, 1990), p. 723.

Why More Pesticides Can't Solve the Problem

Pesticides interfere with the natural balance of insect populations by causing an imbalance in the natural order of predators and prey. Pollinator loss is an unfortunate and costly side effect, and growers often must resort to artificial means of pollinating their crops. The predominant effects of pesticides on an agricultural ecosystem include:

- Target pest resurgence
- Secondary outbreaks of different pests
- Increased resistance to pesticides
- Loss of insect diversity and resulting ecosystem simplification.

Resistance, Resurgence, and Escalation[6]

While beneficial predator insect populations rarely recover to full strength after a pesticide onslaught, the population of pest insects typically explodes unchecked. This resurgence of the target pest is caused by the fact that insects that survive the first spraying are selected to carry on the population, giving new offspring the acquired resistance to that particular pesticide.[7] This often triggers a reapplication of pesticides, more loss of diversity, and more resistance.[8] Because fewer predators are present, secondary outbreaks of new pests can now attack the crop undisturbed, until the farmer applies even more pesticides. The resistance/resurgence/escalation phenomenon can be seen in the increase in application rates of insecticides with no resulting gains in crop protection.

Many examples of the resistance/resurgence/escalation cycle show that repeated applications of broad-spectrum insecticides such as DDT, organophosphates (OPs), carbamates, and pyrethroids lead to total destruction of beneficial predatory insects and up to 1000-fold increases of the target pest. In California, this effect was noted in resurgence of the whitefly on cotton after repeated sprayings with OP and pyrethroid insecticides. The result was a 43% increase in the cost of cotton insecticides in one year.[9] Resistance in black aphids on cotton in the Central Valley resulted in a 2000% increase in applied chlorpyrifos between 1991 and 1995.[10] On grapes, application of carbaryl led to increased populations of the Pacific mite.[11] In citrus, organochlorine and OP pesticides were responsible for the rise of the citrus red mite from minor or non-pest status to the most important citrus pest in California.[12]

Like an addiction, once pesticides are used, they must often be used more regularly and more heavily to achieve the desired results. Will there come a time when current pesticides won't work and new pesticides will be too toxic to be practical? Possibly, but through use of biocontrol agents, cessation of broad spectrum sprays, and preservation of natural predatory species, pest insects can be kept in check without use of highly toxic pesticides.[13]

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6. More specific information can be found in: K. Walker, J. Liebman, and W. Pease, *Pesticide-Induced Disruptions of Agricultural Ecosystems*, California Policy Seminar, Berkeley, CA, 1996).
7. W. Ripper, J. Greenlaw, D. Heath, and K. Barker, "New Formulation of DDT with Selective Properties" *Nature*, 1948, vol. 161, p. 484.
8. R. van der Bosch, P. Messenger, A. Gutierrez, *An Introduction to Biological Control*, Plenum (New York, 1982), p. 247.
9. a) R.G. Breene, D. Dean, and W. Quarles, "Predators of the sweet potato whitefly," *IPM Practitioner*, 1994, vol. 16, pp. 1-9.
   b) Ibid., reference 2, p. 272.
10. L. Wilhoit, D. Supkoff, J. Steggall, A. Braun, C. Goodman, B. Hobza, B. Todd, and M. Lee, *An Analysis of Pesticide Use in California, 1991-1995*, Department of Pesticide Regulation, December 1998.
11. P. DeBach and D. Rosen, *Biological Control by Natural Enemies,* 2nd ed., Cambridge University Press (New York, 1991), p. 440.
12. Ibid., reference 11.
13. Ibid., reference 5.

Chapter 5

Restoring the Balance: Alternatives to Pesticides


Lars Neumeister

Pesticides destroy the delicate balance between species that characterizes a functioning ecosystem. Fortunately, there are alternatives to dumping massive quantities of toxic chemicals on our crops, forests, roadsides, and in our homes and gardens. Every crop in California that is commonly grown with intensive pesticide use is also being grown organically at other farms in the state. Least-toxic methods of pest control are available, and a growing number of California farmers are utilizing them. They include the following strategies:

- "Cultural" pest control methods such as crop rotation, reduction of habitat for pest species, provision of habitat for beneficial insects, and timing of plantings are effective in controlling many pests in agricultural settings. In urban settings, strategies such as pest exclusion by sealing cracks and other openings, as well as reduction of pests' food supply are effective.
- A number of least-toxic methods for controlling pests are available. In agricultural settings, these include mulching, hand weeding, mating disruption, release of beneficial insects, and judicious application of low-toxicity pesticides such as oils, soaps, biopesticides, and sulfur. In urban settings, insect pests can be controlled with exclusion strategies and low-toxicity baits, and weeds can be controlled by mulching or hand-weeding.

This chapter is not meant to be comprehensive;[1] instead, it provides an overview of least-toxic pest management methods in both agricultural and urban settings, and highlights progress in non-chemical methods of pest control in the almond industry.

Least-Toxic Methods for Controlling Pests in Agricultural Settings

There are many ecologically based pest management practices now being used to control insects, weeds, and fungi in agricultural settings. These methods rely on the natural interactions of plants, animals, and microorganisms, in contrast to chemical methods that attempt to simplify the farm ecosystem by eliminating nearly all organisms except the crop plant. What follows are some examples of ecologically based farm management practices.

Crop Rotation and Soil Health

The cornerstones of non-chemical pest control methods are crop rotation and maintaining healthy soil. These practices help control soil-borne pests such as nematodes, as well as aphids, beetles, fungi, and weeds. Because pests are often specific to a par-

1. For more detailed information about sustainable agricultural practices, see:
a) *Ecologically Based Pest Management: New Solutions for a New Century*, Committee on Pest and Pathogen Control Through Management of Biological Control Agents and Enhanced Cycles and Natural Processes, National Research Council, National Academy Press (Washington, DC, 1996).
b) *Alternative Agriculture*, Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, National Research Council, National Academy Press (Washington, DC, 1989).
c) University of Minnesota IPM web site, http://ipmworld.umn.edu/.
d) University of California, Davis IPM web site, http://www.ipm.ucdavis.edu/.
e) Pest Management at the Crossroads, Benbrook Consulting web site, http://www.pmac.net/.

ticular crop, they require both the food and habitat provided by that crop to survive. The life cycle of the pest can be interrupted by planting a different crop in that field for the next several seasons. Cover crops enrich the soil, support natural beneficial species, and effectively compete with weeds, promoting both pest control and soil fertility.

PLANTING STRATEGIES

One of the reasons it is difficult to control pests such as insects and fungi in industrial scale monocultures like most of our farms is that pests are provided with a nearly unlimited food supply. One effective planting strategy for disrupting the explosive spread of pests is mixed plantings, with two or more crops that have different pests interspersed in a field. If a pest succeeds in getting a foothold in one part of the field, its migration to the rest of the crop is slowed or stopped by areas of inhospitable surrounding crops. Farmers can enhance pest control efficiency by providing good habitat for beneficial predatory insects in some of these interspersed plots, and by ensuring that pest habitat is unavailable.

Timing plantings appropriately can also result in lower pest pressures. For example, potatoes planted late in the season in New England on unrotated fields are less susceptible to destruction by beetles. This strategy works because the beetles typically emerge from overwintering in the soil several weeks earlier. Finding no food when they emerge, many leave the area.[2]

The use of compost instead of synthetic fertilizers is effective in controlling some pests and in providing and maintaining necessary nutrients for crop plants. Instead of trying to sterilize the soil, organic farmers take advantage of the fact that soil organisms—from earthworms to microorganisms—play an important role in limiting soil pests.

CONTROL OF WEEDS

There are several effective cultural approaches for controlling weeds without using synthetic chemical pesticides. Tilling or hand weeding are used for removing weeds, particularly if they are removed before they go to seed or develop extensive root networks. Mulching plants with clean straw, wood chips, or plastic sheeting also prevents weed growth and is less labor intensive than hand weeding. Cover crops that compete effectively with weeds help reduce weed problems and provide organic matter for the soil. Plant pathogens that attack certain weeds are also used.[3]

PEST MONITORING AND CONTROL OF OUTBREAKS

In any agricultural endeavor, a critical element of pest-control activities is monitoring pest populations and limiting them before they get out of control. If the problem pest is discovered early, the farmer only needs to control the pest in a small area instead of launching large-scale warfare against the pest.

Growers can control certain insect pests by disrupting their mating behavior using chemical attractants called pheromones. Pheromones are specific to a certain pest and, in most cases, act as a sex attractant for males searching for a mate. They work by confusing the males, with the result that the male is unable to follow the pheromone trail to a mate. Breeding occurs at a much lower frequency, resulting in lower pest populations. The release of sterile insects is also used to similar effect, resulting in fewer successful hatches of future generations of pest insects.

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2. D.N. Ferro, "Cultural Control," *Radcliffe's IPM World Textbook*, E.B. Radcliffe and W.D. Hutchison, eds., University of Minnesota IPM web site, http://ipmworld.umn.edu/.
3. Ibid., reference 1a.

Controlling Almond Orchard Pests Without Toxic Pesticides

Almond orchards occupy nearly 500,000 acres in California,[1] with most growers using a variety of toxic pesticides. In conventional almond orchards, pest control efforts focus on application of organophosphate (OP) or pyrethroid insecticides to dormant orchards during the winter months to control peach twig borer, San Jose scale, and aphids. These applications cause significant water quality problems when pesticides are washed into surface waters during winter rains. Levels of the OPs diazinon and chlorpyrifos in Central Valley rivers routinely exceed water quality criteria for protection of aquatic life (see page 55).

Because of environmental contamination, threat of regulation, and insect resistance, efforts are now being made to control orchard pests without application of toxic pesticides. The Biologically Integrated Orchard Systems (BIOS) program, coordinated by the Community Alliance with Family Farmers (CAFF) and supported by the University of California Sustainable Agriculture Research and Education Program (UC SAREP) and the University of California Statewide Integrated Pest Management Project, has worked with almond growers since 1993 to develop and implement least-toxic pest management methods for almonds.

There are four main principles promoted by the BIOS program:[2]

- **Feed the soil first.** BIOS farmers make their trees strong and the soil rich by applying compost and planting nitrogen-fixing cover crops such as clover and vetch. This in turn helps develop a healthy population of soil organisms, and creates a soil that will retain moisture and nutrients.
- **Make a home for predators.** An orchard with a clean floor provides little habitat for beneficial insects that prey on pest insects. To attract beneficial insects such as mites and spiders, BIOS farmers plant cover crops between rows of trees. A diverse ecosystem flourishes in the cover crop and tree canopy, allowing beneficial insects to keep pest insects in check.
- **Keep your eyes peeled.** Monitoring for pests is a critical part of the BIOS system. Because small populations of pest insects are allowed in the orchard to maintain populations of predator insects, the balance between pests and predators must be monitored closely.
- **Work with nature.** Instead of routinely applying broad-spectrum sprays that kill indiscriminately, BIOS farmers use beneficial insects, mating disruption, and judicious application of least-toxic pesticides to control pests (see Chapter 4). While few BIOS farmers are growing almonds completely organically, most have eliminated dormant sprays of OP and pyrethroid insecticides and only use conventional pesticides during the growing season as a last resort.

The Results: Yields Remain Competitive with Conventional Orchards

Although the BIOS program is in its infancy, results are encouraging. In Merced County BIOS orchards, yields of almonds in pounds per acre were comparable to yields from conventional orchards, with some BIOS orchards even outperforming conventional ones.[3] The percent of insect-damaged almonds from the BIOS orchards was either lower than that for conventional orchards or identical, with only one farm out of the ten participating reporting a slightly higher damage rate for the BIOS almonds.

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1. California Department of Food and Agriculture Resource Directory, 1997.
2. *BIOS for Almonds: A Practical Guide to Biologically Integrated Orchard Systems Management*, Community Alliance with Family Farmers Foundation and Almond Board of California, 1995.
3. Ibid., reference 2.

Predatory insects also reduce pest insect populations. If natural populations of beneficial insects are not sufficient to keep pest insects in check, it is now possible to buy beneficial predatory insects that are mass produced in insectaries. When large numbers of a pest's natural enemy are released into a pest-infested area, rapid destruction of the pest insects occurs. The parasitic wasp *Encarsia formosa Gahan* is used in this way to effectively suppress the greenhouse whitefly, *Trialeurodes vaporariorum*, a pest that infests vegetables and flowers.[4]

When pest outbreaks occur, organic farmers also have a selection of low-toxicity alternatives to synthetic chemical pesticides available. These include:

- **Oils and soaps:** Oils and soaps are used to kill insects. Oils work by smothering the pests, and soaps change the permeability of the insects' outer shell, causing dehydration and death.
- **Biopesticides:** Biopesticides are naturally-occurring compounds produced by a plant or animal. Examples are the pyrethrins, naturally occurring in plants from the chrysanthemum family, and *Bacillus thuringensis* (Bt), a bacterium that produces a substance toxic to insects in the Lepidoptera family (moths and butterflies and their larvae). Bt is used in conventional agricultural settings, as well as on organic farms. A new biofungicide called AQ10 is now being used to control powdery mildew by parasitizing it.[5]
- **Sulfur:** Sulfur is used to control the growth of molds and mildews on crops.

With broad spectrum pesticides being so damaging to the environment and costly due to the resistance/resurgence cycle of pest insects, the conversion to more natural methods of pest control only seems logical. Ecosystems and natural predator/prey relationships have been evolving for as long as there have been predators and prey. By harnessing these relationships rather then destroying them, it is possible to take advantage of the systems already in place, providing both economic and ecological benefits.

Least-Toxic Methods for Controlling Pests in Urban Settings[6]

Least-toxic control of pests in urban settings relies on a number of strategies that center on preventing pests from entering buildings, using low-toxicity baits when necessary, and for weeds, using mulch or hand weeding to prevent undesired plant growth.

Schools

Across the U.S.—in environments as diverse as California, New York, Oregon, Michigan, Florida, Washington, and Washington, DC—concerned parents, teachers, and school administrators are finding ways to eliminate many pesticides and reduce total use in schools.

Los Angeles Unified School District, San Francisco Unified School District, Placer Hills Unified School District, Mendocino Unified School District, and Arcata School District are among the school systems in California with policies that either ban pesticides or strongly favor non-toxic pest control.[7]

School IPM programs use a diverse set of pest control techniques, but like other IPM programs, they rely on monitoring pest populations, educating those affected

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4. D.A. Landis and D.B. Orr, "Biological Control: Approaches and Applications," *Radcliffe's IPM World Textbook*, Edward B. Radcliffe and William D. Hutchison, eds., University of Minnesota IPM web site, http://ipmworld.umn.edu/.
5. C. Benbrook, "Biopesticides: Promising Products," Pest Management at the Crossroads web site, http://www.pmac.net/bios.htm. A complete list of available biopesticides can be found at http://www.ecologic-ipm.com/newai.html.
6. This section was adapted from a fact sheet in *Pesticides: California's Toxic Time Bomb*, Californians for Pesticide Reform (San Francisco, CA, 1998).
7. J. Kaplan, *Failing Health: Pesticide Use in California Schools*, California Public Interest Research Group Charitable Trust and Californians for Pesticide Reform (San Francisco, CA, 1998).

(e.g., teachers, children and parents), and evaluating the effectiveness of control tactics to fine-tune future actions. Those responsible for pest management learn to identify pests accurately, determine levels of pest problems that trigger treatments, and select least disruptive tactics. Often this is done because parents, teachers and community members want to protect themselves and their children from exposure to toxic pesticides. Other times, administrators calculate that cost savings of cutting pesticides can be significant. For example, Maryland's Montgomery County Public Schools reported that their IPM program cut pest control costs by $6,000 in the first 3 years.[8]

The most effective tactics for controlling insect pests in schools are largely preventative and center on keeping cafeteria areas clean, removing other sources of food, and sealing entry points that might be used by ants, roaches, and other insects. Schools can eliminate their use of herbicides by mulching or hand weeding, or even altering their landscaping so that weed control is not necessary.

CITY PARKS

In October 1996, the San Francisco Board of Supervisors voted unanimously to ban most pesticides in city parks and buildings and implement a sweeping IPM program. Like other municipalities, the City and County of San Francisco had regularly used a variety of hazardous pesticides in parks. A year after starting the IPM program, however, the city cut its pesticide use by approximately two-thirds. Use of pesticides linked to cancer and reproductive harm was almost completely eliminated.

These impressive reductions occurred thanks to collaboration between local activists, city officials and IPM professionals, who helped implement an effective pest management program. According to Bob Fiorello, Acting IPM Coordinator for the San Francisco Recreation and Parks Department, the city is making strides toward developing non-toxic pest control, but still has much to learn. For example, the city has used beneficial insects to manage insect pests in city nurseries, but is still exploring ways to use beneficials effectively in the field. Fiorello has also experimented with using hot water for killing insects, and he wants to explore whether this technique could be used on a large scale. He found that, when sprayed on leaves, water heated to 70˚F kills young aphids without damaging the plants.

For the San Francisco Recreation and Park Department, weed control is the major pest management issue. One of the most significant steps toward reducing herbicide use has been to change attitudes—among staff and the public—regarding which weeds should be removed and when. Some weeds, such as *Ehrharta erecta* (a grass weed), are truly invasive and damaging to other plants. Maintenance workers are trained to identify young seedlings of this species—when they can be removed mechanically or by hand. Getting rid of this weed is given priority over controlling certain other weeds, like oxalis or *Poa annua*, which do not survive the dry summer months anyway. Some weeds—like *Ranunculus*—are simply tolerated because they do not present serious problems. *Ranunculus* even works well as a turf plant for picnics, soccer games, and other field uses.[9]

GOLF COURSES

Golf courses use large quantities of pesticides and synthetic fertilizers. Many U.S. golf courses use more pesticides per acre than do agricultural lands. But some golf courses are successfully reducing or eliminating pesticides through IPM. Golf course IPM programs generally begin with scouting and monitoring for pests. Grass varieties are selected based on whether they are optimal for local soil and climate conditions;

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8. S. Daar, T. Drlik, H. Olkowski, and W. Olkowski, *IPM for Schools: A How-To Manual*, Bio-Integral Resource Center (BIRC), (Berkeley, CA, 1996).
9. B. Fiorello, Acting IPM Coordinator, San Francisco Recreation and Park Dept., personal communication, May 15, 1998.

rich, natural soil life is encouraged; slow-release organic fertilizers are used; and, irrigation is carefully tuned to be adequate for grass while discouraging weeds.

In California, the Resort at Squaw Creek, near Lake Tahoe, has not used pesticides since it opened in 1991. Superintendent Mike Carlson says, "We can do as good a job, if not better, without the chemicals."[10] San Francisco's Arnold Palmer Golf Course has been cutting pesticide use since 1996. According to superintendent Kevin Hutchins, the need for pesticides has been reduced through a range of mechanical and cultural tactics, such as building up soil microbial life in the fairways to keep diseases in check. In addition, every morning golf course maintenance workers drag a 200 foot-long hose through the course to reduce the amount of dew that remains on grass leaves, thus limiting fungal growth.[11]

HOME

Household IPM incorporates many of the same tactics used in schools, parks and other non-agricultural settings, including monitoring and identifying pests. For example, Argentine ants (*Iridomyrmex humilis*) may be effectively controlled by mopping them up with soapy water, using caulking to seal cracks in walls and other entry points, and properly storing food and waste. However, only by positively identifying this pest is it possible to choose appropriate control tactics. The Argentine ant does not threaten a building's structural integrity, but carpenter ants do—they destroy wood as they build their nests. Once identified, carpenter ants can be controlled by replacing damaged wood, because they prefer damaged wood for their homes; eliminating moisture sources such as leaky gutters, which create favorable conditions for the ants; and finding and physically removing the nest. If the nest can't be removed, it can be destroyed with least toxic measures, including electricity and diatomaceous earth, a dust that kills the ants by dehydrating them.

Similar to Argentine ants, cockroaches can often be prevented through proper food and waste storage and by sealing entry points with caulking. Cockroaches can be eliminated through direct physical controls, including carbon dioxide fumigation, steam cleaning and vacuuming, or by using least-toxic baits and biological controls such as natural enemies. For example, the tiny parasitic miniwasp, *Comperia merceti*, gets rid of brownbanded roaches by killing roach embryos.

CONCLUSION

Non-toxic and least-toxic pest control methods are effective, affordable, and proven. Then why are pesticides so common? Part of the reason is that, although information about alternatives exists, it isn't widely available and the pesticide industry works hard to make their products seem like the only choice. There are also a number of institutionalized incentives that encourage pesticide use. For example, pest control advisors—professionals who help farmers manage pests—frequently work for businesses that profit by pesticide sales, and consequently tend to highlight chemical methods over natural control. In addition, government-financed research into alternatives is notoriously inadequate. The U.S. Department of Agriculture devotes less than one-tenth of one percent of its research budget to studying organic farming systems.[12]

While more research is greatly needed, the examples above show that Californians have the capacity to greatly reduce pesticide use right now. The greatest obstacles are attitudes, political will and lack of support for on-the-ground implementation. Despite these obstacles, people who use organic and bio-intensive IPM systems have moved forward dramatically in a few short years, with little or no help from the public sector. The next step is to put non-toxic alternatives into practice on a large scale—and make dangerous pesticides a memory.

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10. S. Marquardt, "Golf's Green Handicap," *The Green Guide*, March 21, 1997.
11. K. Hutchins, Superintendent, Arnold Palmer Golf Course, personal communication, May 19, 1998.
12. A. Aspelin, *Pesticides Industry Sales and Usage: 1994 and 1995*, Market Estimates, U.S. Environmental Protection Agency, 1997.

Chapter 6

Recommendations

> "The world of air and water and soil supports not only the hundreds of thousands of species of animals and plants, it supports man himself. In the past we have often chosen to ignore this fact. Now we are receiving sharp reminders that our heedless and destructive acts enter into the vast cycles of the earth and in time return to bring hazard to ourselves."
>
> (Rachel Carson, June 4, 1963, testimony to U.S. Congress)

Fish, birds, and wildlife that live in direct contact with environments subject to pesticide exposure are sentinel species that may be predictive of our own fate. With pesticides now found routinely in drinking water, on food, and in the air, we are all taking part in an experiment in pesticide exposure on a global scale, but without the benefit of an unexposed control group for comparison. We will probably not be able to quantify the exact risk of these exposures, or their interaction with other environmental factors affecting human health. Because we can't know for certain the consequences of expanding pesticide use, the rational and most protective course of action is to take a precautionary approach—phasing out the use of the most dangerous pesticides, reducing our reliance on toxic chemicals for pest control, and promoting ecologically based pest management.

Recommendations for the California Environmental Protection Agency

- **Ban diazinon and chlorpyrifos immediately to stop the toxic flows in California surface waters.** All available data indicate that diazinon and chlorpyrifos are the worst offenders causing toxicity in California waterways. Neither voluntary efforts nor government regulation is working to protect our waterways from toxic flows. These lethal and illegal toxic pulses must be stopped now so California's aquatic organisms can recover from the onslaught of toxics they face throughout the year.
- **Ban all uses of carbofuran in California to eliminate bird kills caused by this pesticide.** Data show that carbofuran—an insecticide used mostly on rice and grapes—is one of the most hazardous pesticides to birds. Bird deaths result even when only a small quantity of the pesticide is used. Withdrawal of the registration for all uses of carbofuran in California is the only way to ensure that birds will be protected from this pesticide.
- **Phase out the worst pesticides and reduce use of the rest.** California needs a comprehensive program to eliminate use of *all* "bad actor" pesticides. Without such a plan, banning individual pesticides will simply result in shifting to equally toxic substitute pesticides. This "risk shifting" would create new and (at present) unknown adverse effects on birds, fish, and other wildlife. Under current federal "risk assessment" requirements, it could take another ten years of study to establish without a shadow of a doubt that a new pesticide is indeed harmful in the environment. Meanwhile, the ecosystem will have sustained yet another ten years of damage. Rather than regulating pesticides one at a time—which leads to a tremendous regulatory burden and to serial substitution of one toxic material for another—we should adopt a system of ecologically based pest management that reduces the need for toxic pesticides.[1]

- **Require the Department of Pesticide Regulation (DPR) to enforce existing laws and support alternative agriculture.** For years, DPR has consistently stonewalled enforcement of environmental regulations related to pesticides and the environment, and allocated few resources to alternative pest management in agriculture and other sectors. It is time for DPR to take seriously its mission of protecting public health and the environment by:
  - Phasing out all "bad actor" pesticides
  - Setting and achieving pesticide use reduction goals for all pesticides
  - Working productively with the State and Regional Water Quality Control Boards to reduce toxic pesticide runoff into surface waters and groundwater
  - Providing extensive support for non-chemical methods of pest control
- **Provide tax incentives to reduce pesticide use.** At present, many of the costs associated with pesticide use are borne by the public and the environment. The direct cost of applying a pesticide is only a small fraction of the actual cost. What remains unaccounted for are human illnesses due to pesticide exposures, kills of birds and fish, loss of habitat and food for fish and wildlife, and increased crop damage due to pesticide-resistant pests. Giving growers a tax break for reducing pesticide use and/or requiring pesticide manufacturers to pay more of the external costs associated with pesticide use will provide incentives to reduce use.
- **Provide funding for additional monitoring of fish and wildlife populations, as well as chemical concentrations in water, sediments, and wildlife tissues.** Monitoring of chemical concentrations and fish and wildlife populations, including creation of a centralized system for reporting bird and fish kills, is essential for determining the long-term effects of pesticide use. Understanding pesticide effects on native species in the field, not just in the laboratory, is crucial.
- **Include all high-use pesticides as chemicals to be monitored.** It is impossible to know the true extent of pesticide contamination if high-volume pesticides are not monitored. In particular, the herbicides glyphosate and paraquat dichloride, the insecticide methidathion, and the fungicides ziram, maneb, mancozeb, and fosetyl-Al should be included in state monitoring programs.
- **Promote viable alternatives to toxic pesticides.** Alternatives to toxic pesticides are being used successfully across the state. Growers and other pest managers need support to make the switch from chemical pest management to more sustainable pest-control methods.
- **Adopt the Precautionary Principle.** Because we do not know the full range of adverse effects of pesticides on the environment, we should reduce use of all toxic pesticides.

Recommendations for the U.S. EPA and the Federal Government

- **Require pesticide manufacturers to conduct long-term studies on ecosystem-wide impacts to demonstrate that a pesticide has no adverse effects before allowing it to be registered.** The fact that present regulations view a pesticide as innocent until proven guilty is detrimental to environmental health. It is critical to know more about the long-term ecological effects of a pesticide *before* it is released into the environment.
- **Prohibit pesticide use on national wildlife refuges.** Enforce the mandate of the National Wildlife Refuge Improvement Act of 1997 to put wildlife first on wildlife refuges. National wildlife refuges are for wildlife, not farms. If farming is to

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1. *Ecologically Based Pest Management: New Solutions for a New Century*, Committee on Pest and Pathogen Control Through Management of Biological Control Agents and Enhanced Cycles and Natural Processes, National Research Council, National Academy Press (Washington, DC, 1996).

take place in these areas, it should be restricted to organic farming of crops that are compatible with wildlife.

- **Establish controls on agricultural and urban runoff to prevent pesticide contamination of surface waters.** The Clean Water Act does not effectively address non-point source pollution from urban and agricultural runoff. New legislation should be passed to ensure that toxic pesticide discharges from these sources do not contaminate surface waters.

Recommendations for Homeowners, Renters, and Parents

The amount of pesticides used on lawns, gardens and in homes and schools is estimated to be more than 20% of total pesticide use in California. If you are a homeowner, renter and/or parent and wish to reduce your impacts on the environment while protecting your and your family's health, here are some steps you can take:

- **Use least toxic pest control methods around the home.** Exclude pests by caulking cracks, and keep kitchens and other parts of the home free from food sources that attract pests. Use low toxicity, contained baits instead of broadcasting potent toxins into the environment. Appendix 3 provides resources for commercial pest control companies specializing in least-toxic methods of pest management.
- **Don't buy or use toxic flea and tick control products such as flea collars and bombs.** Alternative methods for controlling fleas and other pet pests are now available through your veterinarian (see Appendix 3).
- **Use least-toxic methods to care for your lawn and garden.** Control weeds by mulching or hand weeding. Use only least-toxic methods to control insect pests such as beneficial insects, insecticidal soaps, and biopesticides. Even when using a least-toxic pesticide, be sure to apply it only to the specific problem site and don't apply any pesticide within 25 feet of streams, rivers, or lakes.
- **Read fertilizer labels closely and don't buy fertilizers containing pesticides.** Insecticides and herbicides are often mixed into fertilizers. Such "weed and feed" fertilizers often do not list the pesticide by trade name, but by the technical chemical name. Common pesticides included in fertilizers are shown with their chemical name in Table 6-1.

Table 6-1: Chemical Names of Pesticides Commonly Mixed with Fertilizers

Common Name	Chemical Name
Diazinon	O,O-Diethyl-O-[2-isopropyl-6-methyl-4-pyrimidinyl]-phosphorothioate
2,4-D	2,4-Dichlorophenoxyacetic acid
Chlorpyrifos	O,O-Diethyl-O-[3,5,6-trichloro-2-pyridyl]-phosphorothioate
Disulfoton	O,O-Diethyl-S-[2-(ethylthio)ethyl]-phosphorodithioate
Prometon	2-Methoxy-4,6-bis(isopropylamino)-s-triazine
Pendimethalin	N-[1-Ethylpropyl]-3,4-dimethyl-2,6-dinitrobenzeneamine
Trifluralin	N,N-Dipropyl-N-[2,6-dinitro-4-trifluoromethyl]amine
Dicamba	2-Methoxy-3,6-dichlorobenzoic acid

- **If you hire others to do your gardening work, hire certified organic landscapers or others knowledgeable in low environmental impact methods.** If you use conventional gardening services, insist that no pesticides be used.

Appendix 3 provides resources for commercial landscaping firms specializing in least-toxic methods of pest management.

- **Buy organic foods whenever possible.** Market forces are a powerful incentive to encourage growers to go organic.
- **Insist on least-toxic pest management in your children's schools and support efforts to phase out use of toxic pesticides in schools.** Many schools now have a "no toxic pesticides" policy. If yours doesn't, work with other parents and teachers to implement such a policy at your school. Write your California legislators to give your support to the Healthy Schools Bill, AB 1207, which phases out school use of pesticides known to cause cancer, reproductive and developmental harm, and neurotoxicity.

APPENDIX 1: WATER SOLUBILITY, HALF-LIFE, AND GENERAL TOXICITY INFORMATION FOR SELECTED PESTICIDES

The data in this table were taken from a variety of sources, listed at the end of the appendix. Inclusion of pesticides in this appendix was based on:

- High frequency of use in California.
- High acute or chronic toxicity to wildlife.
- High frequency of detection in the environment.

The table is subdivided into sections on insecticides, herbicides, and fungicides, with further subdivisions between classes of these types of pesticides. The information provided for each pesticide includes the following:

Water solubility is the amount of the pesticide in milligrams (mg) that will dissolve in one liter (L) of water. The larger this number is, the more water soluble the pesticide, and the more readily the pesticide will be transported away from the application site by stormwater or irrigation water runoff.

Half-life is defined as the time required for half of the pesticide to break down into degradation products. The numbers given represent field half-lives. This time is usually expressed as a range because the rate of pesticide breakdown depends on a variety of factors, including temperature, soil pH, and whether or not the pesticide is exposed to light, water, and oxygen. It is worth noting that many of the breakdown products themselves are toxic and may have significant half-lives as well.

Pounds of active ingredient applied in California in 1995 is the amount of pesticide active ingredients used in 1995, as reported in the California Pesticide Use Reporting Data, 1995, California Department of Pesticide Regulation, Sacramento, CA, 1998.

Acute toxicity to wildlife refers to the immediate (hours to a few days) effects of a pesticide when the subject is exposed to a particular dose, given orally. The shading associated with each category of organisms is correlated to the acute toxicity of the chemical to the particular class of organisms (mammals, birds, fish, etc.), with **bold** text used for very highly toxic or highly toxic pesticides, <u>underlined</u> text used for moderately or slightly toxic pesticides, and plain text used for practically non-toxic pesticides. The acute toxicity is defined by the LD_{50} or LC_{50} values as given in M.A. Kamrin, *Pesticide Profiles: Toxicity, Environmental Impact, and Fate*, Lewis Publishers (Boca Raton, FL, 1997). The LD_{50} is the dose of the chemical (in mg/kg) that kills 50% of the test organisms and the LC_{50} is the concentration of the chemical in micrograms per liter (μg/L) that kills 50% of the test organisms within a specified study time (see Appendix 2 for more information). These numbers vary widely by species (see Appendix 2 for specific values). In this table, the most sensitive species in the test group was used to rank the toxicity. For example, if a pesticide is highly toxic to Bobwhite quail, but only moderately toxic to Mallard ducks, the pesticide is ranked as highly toxic to birds overall.

Toxicity Category	Mammal Acute Oral LD_{50} (mg/kg)	Bird Acute Oral LD_{50} (mg/kg)	Fish and Aquatic Invertebrates Acute LC_{50} (μg/L)
Very highly or highly toxic	< 50	< 50	< 1,000
<u>Moderately or slightly toxic</u>	> 50-5,000	> 50-2,000	> 1,000-100,000
Practically nontoxic	> 5,000	> 2,000	> 100,000

Chronic toxicity refers to the toxicity due to long-term or repeated exposure to a compound. Because wildlife is wild, it is impossible to quantify lifetime exposures to pesticides and the resulting toxic effects on wildlife species. We have substituted instead available toxicity data from rat and mouse studies to provide an estimate of the additional hazards that may be posed by the pesticide. The absence of chronic effects in mammals in this table does not necessarily indicate that the pesticide is harmless; rather, it indicates a lack of comprehensive testing to date. Chronic toxicity category definitions are as follows:

CA-B Probable human carcinogen, as listed in the U.S. Environmental Protection Agency Office of Pesticide Programs List of Chemicals Evaluated for Carcinogenic Potential, June 10, 1998.

CA-C Possible human carcinogen, as listed in the U.S. Environmental Protection Agency Office of Pesticide Programs List of Chemicals Evaluated for Carcinogenic Potential, June 10, 1998.

CA-L Likely human carcinogen, the U.S. Environmental Protection Agency's new proposed method of listing carcinogens (for evaluations recently conducted) categorizes compounds as Known/Likely, Cannot Be Determined, or Not Likely, as listed in the U.S. Environmental Protection Agency Office of Pesticide Programs List of Chemicals Evaluated for Carcinogenic Potential, June 10, 1998.

CA-P65 Carcinogen, as listed in California's Proposition 65 Pesticides that Cause Cancer, Office of Environmental Health Hazard Assessment, January 1998.

ED Suspected endocrine disruptor, as listed in L.H. Keith, *Environmental Endocrine Disruptors*, Wiley Interscience (New York, 1997); T. Colborn, D. Dumanoski, and J.P. Myers, *Our Stolen Future*, Penguin Books (New York, 1996), p. 253; or Illinois Environmental Protection Agency, *Report on Endocrine Disrupting Chemicals,* Illinois Environmental Protection Agency, 1997.

DEV Developmental toxicant, as listed in California's Proposition 65 Pesticides that Cause Developmental Toxicity, Office of Environmental Health Hazard Assessment, January 1998.

REP Reproductive toxicant, as listed in California's Proposition 65 Pesticides that Cause Reproductive Toxicity, Office of Environmental Health Hazard Assessment, January 1998.

Pesticide	Water Solubility at 20-25°C (mg/L)	Half-life	Pounds of Active Ingredient Applied in California in 1995	Acute Toxicity to Wildlife	Chronic Toxicity to Mammals
INSECTICIDES					
Organochlorines					
Aldrin	0.02	20-100 days	0*	**Mammals, birds, fish, aquatic invertebrates, bees**	CA-B, CA-P65, ED
Chlordane	0.1	3.3 yr	184*	**Mammals**, birds, **fish, aquatic invertebrates, bees**	CA-B, CA-P65, ED
DDT	<1	2-15 yr	0*	**Mammals**, birds, **fish, aquatic invertebrates, bees**	CA-B, CA-P65, ED, DEV, REP
Dicofol (Kelthane)	0.8	2 wk–2 mo	594,789	Mammals, birds, **fish, aquatic invertebrates**, bees	CA-C, CA-P65, ED
Dieldrin	0.17	4 mo-7 yr	0*	**Mammals, birds, fish, aquatic invertebrates, bees**	CA-B, ED
Endosulfan	0.32	1-6 mo	238,455	**Mammals, birds, fish, aquatic invertebrates**	ED
Endrin	1	14+ yr	0*	**Mammals, birds, fish, aquatic invertebrates, bees**	ED, REP, DEV
Heptachlor	0.056	0.4-0.8 yr	0*	**Mammals, birds, fish, aquatic invertebrates, bees**	CA-B, ED, CA-P65
Lindane (γ-HCH)	0.005	2.7-7.5 yr	4,653	Mammals, birds, **fish, aquatic invertebrates, bees**	CA-B, CA-P65, ED
Methoxychlor	0.1	2 mo	1,049	Mammals, birds, **fish, aquatic invertebrates,** bees	ED
Pentachlorophe-nol (PCP)	80	45 days	0*	Mammals, birds, **fish**	CA-B, CA-P65, ED
Toxaphene	0.55	1-14 yr	1,353*	**Mammals, birds, fish, aquatic invertebrates,** bees	CA-B, CA-P65, ED
Organophosphorus compounds					
Acephate	650,000	3-6 days	477,493	**Mammals,** birds, fish, bees	
Azinphos-methyl	30	1-50 wk	432,248	**Mammals**, birds, **fish, aquatic invertebrates, bees**	
Chlorpyrifos	2	2-50 wk	3,443,138	Mammals, **birds, fish, aquatic invertebrates, bees**	ED
DEF (Tribufos)	23	2-3 yr	885,595	**Mammals, birds, fish, aquatic invertebrates,** bees	CA-L
Diazinon	40	2-4 wk	1,228,066	Mammals, **birds, fish, aquatic insects, bees**	
Dichlorvos (DDVP)	10,000	4-7 days	6,621*	**Mammals**, **birds, fish, aquatic invertebrates**, bees	CA-C, CA-P65

Pesticide	Water Solubility at 20-25°C (mg/L)	Half-life	Pounds of Active Ingredient Applied in California in 1995	Acute Toxicity to Wildlife	Chronic Toxicity to Mammals
Dimethoate	25	4-122 days	596,014	Mammals, **birds**, fish, aquatic invertebrates, **bees**	CA-C
Disulfoton	25	1-5 wk	97,688	**Mammals**, birds, **fish, aquatic invertebrates,** bees	
Ethyl parathion	12	1-4 wk	13,642*	**Mammals, birds, fish, aquatic invertebrates, bees**	CA-C, ED
Fenamiphos	700	7 wk	190,026	**Mammals, birds, fish,** bees	
Fonofos	13	6-12 wk	74,936	**Mammals, birds, fish, aquatic invertebrates,** bees	
Malathion	130	4 days- 21 wk	825,077	Mammals, birds, **fish, aquatic invertebrates, bees**	ED
Methamidophos	90	2-12 days	515,127	**Mammals, birds, fish, aquatic invertebrates,** bees	
Methidathion	240	5-23 days	321,750	**Mammals, birds, fish, aquatic invertebrates,** bees	CA-C
Methyl parathion	60	1-30 days	153,346	**Mammals, birds**, fish, bees	ED
Mevinphos	>10	2-3 days	55,270*	**Mammals, birds, fish, aquatic invertebrates, bees**	
Naled	< 1	2 days	708,927	**Mammals, birds, fish, aquatic invertebrates,** bees	
Phorate	50	2 days-6 mo	135,887	**Mammals, birds, fish, aquatic invertebrates,** bees	
Phosmet	25	4-20 days	267,886	Mammals**, birds, fish, aquatic invertebrates, bees**	CA-C
Terbufos	5	2 wk	0*	**Mammals, birds, fish, aquatic invertebrates,** bees	
Carbamates					
Aldicarb	6,000	2 wk-3 yr	358,659	**Mammals, birds,** fish, bees	ED
Carbaryl	40	1-4 wk	856,687	**Mammals**, birds, fish, **bees**	CA-C, ED
Carbofuran	320	2 days-8 wk	247,861	**Mammals, birds, fish, aquatic invertebrates,** bees	
Methomyl	58,000	2 -54 wk	823,399	**Mammals, birds, fish, aquatic invertebrates,** bees	ED
Pyrethroids					
Bifenthrin	0.1	7-8 mo	48,914	Mammals, birds, **fish, aquatic invertebrates, bees**	CA-C, ED
Cypermethrin	0.004	4-8 wk	98,827	Mammals, birds, **fish, aquatic invertebrates, bees**	CA-C, ED
Esfenvalerate	< 0.3	2-12 wk	44,698	Mammals, birds, **fish, aquatic invertebrates, bees**	ED

Pesticide	Water Solubility at 20-25°C (mg/L)	Half-life	Pounds of Active Ingredient Applied in California in 1995	Acute Toxicity to Wildlife	Chronic Toxicity to Mammals
Fenvalerate	< 0.3	2-12 wk	25,770	Mammals, birds, **fish, aquatic invertebrates, bees**	ED
Flucythrinate	0.5	3-9 wk	225	**Mammals**, birds, **fish, bees**	ED
Permethrin	0.2	4-5 wk	323,663	Mammals, birds, **fish, aquatic invertebrates, bees**	CA-C, ED
Pyrethrin	< 0.1	3-4 mo	7,741	Birds, **fish**	
Other Insecticides					
Propargite	0.6	7-14 wk	1,799,584	Mammals, birds, **fish**, **aquatic invertebrates,** bees	CA-B, CA-P65
Tributyltin salts	4	1-34 wk	338	Mammals, birds, **fish, aquatic invertebrates**	ED
HERBICIDES					
Triazines and Acetanilides					
Acrolein	21,500	1-4 wk	363,127	**Mammals, birds, fish**	CA-C
Alachlor	242	2-3 wk	41,119	Mammals, birds, **fish**, bees	CA-L, CA-P65, ED
Atrazine	28	2-4 mo	36,192	Mammals, birds, fish, aquatic invertebrates, bees	CA-C, ED
Cyanazine	171	2-14 wk	646,409	Mammals, birds, fish, aquatic invertebrates, bees	CA-C, ED, REP, DEV
Metolachlor	530	2-10 wk	183,489	Mammals, birds, fish, aquatic invertebrates, bees	CA-C, ED
Metribuzin	1050	1-4 mo	30,669	Mammals, birds, fish, bees	ED
Prometryn	48	1-3 mo	211,978	Mammals, birds, fish, aquatic invertebrates, bees	
Simazine	185	3-9 mo	841,310	Mammals, birds, fish, aquatic invertebrates, bees	CA-C, ED
Other Herbicides					
2,4-D	540	<1 day-3 wk	462,204	**Mammals**, birds, **fish**, **aquatic invertebrates,** bees	ED
Dacthal (DCPA or Chlorthal-di-methyl)	0.5	2-14 wk	571,014	Mammals, birds, fish, aquatic invertebrates, bees	CA-C
Diuron	42	1 mo-1 yr	1,071,028	Mammals, birds, **fish, aquatic invertebrates,** bees	CA-L
EPTC	375	1-4 wk	663,701	Mammals, birds, fish, aquatic invertebrates, bees	
Glyphosate	12,000	1-174 days	4,135,662	Mammals, birds, fish, aquatic invertebrates, bees	

Pesticide	Water Solubility at 20-25°C (mg/L)	Half-life	Pounds of Active Ingredient Applied in California in 1995	Acute Toxicity to Wildlife	Chronic Toxicity to Mammals
Hexazinone	33,000	1-6 mo	102,101	Mammals, birds, fish, aquatic invertebrates, bees	
Molinate	880	5-21 days	1,411,346	Mammals, birds, **fish, aquatic invertebrates**	CA-C
Oryzalin	2.5	3-18 wk	595,111	Mammals, birds, **fish**, aquatic invertebrates, bees	CA-C
Paraquat dichloride	700,000	16 mo-3 yr	862,832	**Mammals**, birds, fish, aquatic invertebrates, bees	
Pendimethalin	0.3	40 days	431,201	Mammals, birds, **fish, aquatic invertebrates**, bees	CA-C
Thiobencarb	30	2-3 wk	571,075	Mammals, fish, **aquatic invertebrates**	
Triclopyr, amine salt and ester	440 (amine salt)	1-3 mo	159,701	Mammals, birds, fish, bees	
Trifluralin	0.1	720 days	1,428,913	Mammals, birds, **fish, aquatic invertebrates,** bees	CA-C, ED
FUNGICIDES					
Benomyl	2	6-12 mo	196,154	Mammals, birds, **fish**, bees	CA-C, DEV, ED, REP
Captan	3.3	1-10 days	752,677	Mammals, birds, **fish**, aquatic invertebrates, bees	CA-B, CA-P65
Chlorothalonil	0.6	1-3 mo	1,130,282	Mammals, birds, **fish, aquatic invertebrates**, bees	CA-L, CA-P65
Copper salts (sulfate, oxide, hydroxide)	from 4 to 230,500 mg/L, depending on the salt	Does not degrade	8,592,358	**Mammals**, birds, **fish, aquatic invertebrates**, bees	
Iprodione	13	1-9 wk	587,301	Mammals, birds, fish, **aquatic invertebrates,** bees	CA-L, CA-P65
Mancozeb	6	1-7 days	678,316	Mammals, birds, **fish**, aquatic invertebrates, bees	CA-B, CA-P65, ED
Maneb	6	2-5 wk	1,295,589	Mammals, birds, **fish, aquatic invertebrates**, bees	CA-B, CA-P65, ED
Metalaxyl	7,100	1-25 wk	153,109	Mammals, birds, fish, aquatic invertebrates	
Myclobutanil	142	9-11 wk	100,856	Mammals, birds, fish, **aquatic invertebrates**	
Vinclozolin	3.4	3 days-3 wk	49,869	Mammals, birds, fish, bees	CA-C, DEV, ED
Ziram	65	30 days	1,638,552	Mammals, birds, **fish**	ED

*Not registered for use in California as of January 1999.

Sources:

EXTOXNET, Extension Toxicology Network, a cooperative effort of University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. Primary files are maintained and archived at Oregon State University web site: http://ace.ace.orst.edu/info/extoxnet/ghindex.html.

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Farm Chemicals Handbook, 1997, vol. 83, Meister Publishing Co. (Willoughby, OH, 1997).

APPENDIX 2: TOXICITY DATA FOR BIRDS, PHYTOPLANKTON, ZOOPLANKTON, FISH, AND BEES

The tables in this appendix are a compilation of data on the acute toxicity of selected pesticides to birds, phytoplankton, zooplankton, fish, and bees. Acute toxicities are determined by exposing an organism to a measured dose of pesticide for a specified length of time (the study time), and noting the dose that causes a measurable effect (death or reduction in growth) in 50% of the organisms within the specified study time. This dose is expressed in one of several ways.

- The LD_{50} is the dose of the pesticide in milligram (mg) or microgram (µg) of pesticide per kilogram (kg) of body weight that is lethal to 50% of the test organisms within the stated study time. Equivalent units are: ppm (mg/kg) and ppb (µg/kg). For bees, the dose is given in microgram per bee.
- The LC_{50} is defined as the amount of pesticide present per liter of aqueous solution that is lethal to 50% of the test organisms within the stated study time. Units used are mg or µg of pesticide per liter of solution. Equivalent units are ppm (mg/L) and ppb (µg/L).
- The EC_{50} is the effective concentration of the pesticide in mg/L or µg/L that produces a specific measurable effect in 50% of the test organisms within the stated study time. The measurable effect is lethality for zooplankton and a reduction in photosynthetic activity by 50% for phytoplankton.
- For pesticides and species for which data from more than one study were available, we calculated the geometric means of the results, consistent with U.S. Environmental Protection Agency guidelines.[1] These values are in bold font in the tables.

For aquatic organisms (fish, zooplankton, and phytoplankton), tests are carried out using either static or flow-through methods. In the static method, the pesticide and test organisms are added to the test solution and kept there for the remainder of the study time. In the flow-through method, a freshly prepared, pesticide-spiked test solution flows through the test chamber continuously for the duration of the test. The flow-through method provides a higher continuous dose of the pesticide; however, the static method does not remove waste products and may accumulate toxic pesticide breakdown products. Neither method exactly mimics a natural system.

The data in the tables were taken from the U.S. Environmental Protection Agency Pesticide Ecotoxicity Database (AQUIRE), December 1998 update, now available at http://www.epa.gov/ecotox. Inclusion of pesticides in this appendix was based on:

- High frequency of use in California.
- High acute or chronic toxicity to wildlife.
- High frequency of detection in the environment.
- Availability of toxicity data. The AQUIRE database does not contain data for all pesticides.
- Study time. We chose to include only pesticides for which study times could be compared across different pesticides and species.

Because there is variability in susceptibility to pesticides among individuals due to age and genetic makeup, as well as variability between laboratory test methods used to measure acute toxicity, the toxicities in the table should not be viewed as precise numbers; rather, as an approximate concentration (or dose) that causes the observable adverse effect.

1. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses, PB85-227049, U.S. Environmental Protection Agency, 1985.

Table 1: Toxicity of Selected Pesticides to Birds

Pesticide	Species	LD_{50}* (mg/kg)	Study Time
2,4-D (Dimethylamine salt)	Bobwhite quail	500	14 D
Carbaryl	Canada goose	1,800	14 D
Carbofuran	Mallard duck	**0.4**	14 D
	Ring-necked pheasant	4	14 D
	Bobwhite quail	5	14 D
Chlorpyrifos	Ring-necked pheasant	8	14 D
	Red-winged blackbird	10	14 D
	Chukar	60	14 D
	California quail	70	14 D
	Mallard duck	80	14 D
	Bobwhite quail	**190**	14 D
	Canada goose	4,100	14 D
Copper sulfate, pentahydrate	Bobwhite quail	**380**	14 D
DDT	California quail	600	14 D
	Ring-necked pheasant	1,300	14 D
	Bobwhite quail	5	8 D
Diazinon	Mallard duck	**2**	14 D
	Ring-necked pheasant	4	14 D
	Canada goose	6	14 D
Dicofol	Ring-necked pheasant	270	14 D
Dieldrin	California quail	10	14 D
	Chukar	25	14 D
	Ring-necked pheasant	80	14 D
	Mallard duck	380	14 D
	Canada goose	< 140	14 D
Dimethoate	Ring-necked pheasant	20	14 D
	Mallard duck	**50**	14 D

Pesticide	Species	LD_{50}* (mg/kg)	Study Time
Diuron	Bobwhite quail	940	21 D
Endrin	California quail	1	14 D
	Ring-necked pheasant	2	14 D
	Mallard duck	6	14 D
Iprodione	Bobwhite quail	930	14 D
Malathion	Ring-necked pheasant	170	14 D
	Mallard duck	1,500	14 D
Maneb	Ring-necked pheasant	<1,500	14 D
Metalaxyl	Mallard duck	1,500	14 D
Metam sodium	Bobwhite quail	500	14 D
Methidathion	Canada goose	10	14 D
	Mallard duck	**10**	14 D
	Ring-necked pheasant	30	14 D
	Chukar	225	14 D
Methomyl	Ring-necked pheasant	15	14 D
	Mallard duck	**20**	14 D
	Bobwhite quail	20	14 D
Methyl Parathion	Ring-necked pheasant	8	14 D
	Mallard duck	**16**	14 D
	Red-winged blackbird	24	14 D
	Bobwhite quail	**29**	14 D
Metolachlor	Mallard duck	4,600	8 D
Myclobutanil	Bobwhite quail	510	21 D
Naled	Canada goose	40	14 D
	Mallard duck	< 50	14 D
Oryzalin	Bobwhite quail	500	14 D
Paraquat dichloride	Bobwhite quail	180	8 D
	Mallard duck	**280**	8 D

* Bold values are geometric means of results from all available studies for that particular study time.

Table 2: Toxicity of Selected Pesticides to Phytoplankton

Test Method: Static

Pesticide	Species	EC50* (µg/L)	Study Time
2,4-D (Dimethylamine salt)	*Selenastrum capricornutum*	51,200	5 D
	Skeletonema costatum	148,500	5 D
	Anabaena flos-aquae	188,500	5 D
	Navicula pelliculosa	4,670	5 D
Atrazine	*Chlamydomonas sp.*	60	3 D
	Thallassiosira fluviatilis	110	3 D
	Nitzschia closterium	290	3 D
	Isochrysis galbana	20	5 D
	Skeletonema costatum	20	5 D
	Navicula pelliculosa	60	5 D
	Selenastrum capricornutum	**70**	5 D
	Anabaena flos-aquae	230	5 D
	Dunaliella tertiolecta	**280**	5 D
	Chlorella pyrenoidosa	280	5 D
Benomyl	*Selenastrum capricornutum*	3,000	5 D
Carbaryl	*Selenastrum capricornutum*	**1,100**	5 D
Chlorothalonil	*Selenastrum capricornutum*	190	5 D
Chlorpyrifos	*Isochrysis galbana*	140	4 D
	Thalassiosira sp.	150	4 D
	Skeletonema costatum	300	4 D
Copper sulfate, pentahydrate	*Selenastrum capricornutum*	3	5 D
	Navicula pelliculosa	125	5 D
	Anabaena flos-aquae	29	5 D
	Skeletonema costatum	250	5 D
Cyanazine	*Navicula pelliculosa*	5	5 D
	Selenastrum capricornutum	6	5 D
	Skeletonema costatum	20	5 D
	Anabaena flos-aquae	30	5 D
Diuron	*Chlamydomonas sp.*	40	3 D
	Nitzschia closterium	50	3 D
	Thalassiosira fluviatilus	100	3 D
	Selenastrum capricornutum	2	4 D
EPTC	*Selenastrum capricornutum*	**1,400**	4 D
	Skeletonema costatum	6,100	4 D
	Anabaena flos-aquae	41,000	5 D
Glyphosate	*Anabaena flos-aquae*	11,750	4 D
Ipridione	*Navicula pelliculosa*	21	5 D
	Selenastrum capricornutum	226	5 D
Metolachlor	*Selenastrum capricornutum*	10	5 D
	Skeletonema costatum	60	5 D
	Navicula pelliculosa	380	5 D
	Anabaena flos-aquae	1,200	5 D
Molinate	*Selenastrum capricornutum*	220	4 D
	Skeletonema costatum	**4,300**	4 D
	Navicula pelliculosa	10,000	4 D
Myclobutanil	*Selenastrum capricornutum*	830	5 D
Naled	*Navicula pelliculosa*	10	5 D
	Skeletonema costatum	15	5 D
	Selenastrum capricornutum	20	5 D
	Anabaena flos-aquae	640	5 D
Napropamide	*Selenastrum capricornutum*	3,400	4 D
Oryzalin	*Anabaena flos-aquae*	20	5 D
	Skeletonema costatum	40	5 D
	Selenastrum capricornutum	40	5 D
	Navicula pelliculosa	70	5 D
Paraquat dichloride	*Navicula pelliculosa*	1	4 D
	Selenastrum capricornutum	320	4 D
	Skeletonema costatum	2,800	4 D
	Anabaena flos-aquae	15	5 D
Permethrin	*Skeletonema costatum*	92	4 D
Simazine	*Anabaena flos-aquae*	40	5 D
Thiobencarb	*Selenastrum capricornutum*	20	5 D
	Skeletonema costatum	70	5 D
	Navicula pelliculosa	380	5 D
Thiophanate–methyl	*Navicula pelliculosa*	930	5 D
Trifluralin	*Navicula pelliculosa*	15	5 D
	Skeletonema costatum	30	5 D
Ziram	*Selenastrum capricornutum*	70	5 D

* Bold values are geometric means of results from all available studies for that particular study time.

TABLE 3: TOXICITY OF SELECTED PESTICIDES TO ZOOPLANKTON: Test Methods: Static (S), Flow-through (F)

Pesticide	Species	Common Name	LC50/EC50* (µg/L)	Method	Study Time	EC/LC
2,4-D (Dimethylamine salt)	*Daphnia magna*	water flea	4,000	S	48 hr	EC
Atrazine	*Penaeus aztecus*	shrimp	1,000	F	48 hr	LC
	Gammarus fasciatus	scud	5,700	S	48 hr	LC
	Daphnia magna	water flea	**28,000**	S	48 hr	EC
Benomyl	*Daphnia magna*	water flea	**290**	S	48 hr	EC
Captan	*Daphnia magna*	water flea	8,400	S	48 hr	EC
Carbaryl	*Penaeus aztecus*	shrimp	2	F	48 hr	LC
	Daphnia pulex	water flea	6	S	48 hr	EC
	Daphnia magna	water flea	**5**	F	48 hr	EC
	Daphnia magna	water flea	**140**	S	48 hr	EC
	Gammarus lacustris	scud	20	S	96 hr	LC
	Gammarus fasciatus	scud	30	S	96 hr	LC
	Penaeus duorarum	shrimp	30	F	48 hr	LC
Carbofuran	*Daphnia magna*	water flea	**40**	S	48 hr	EC
	Penaeus duorarum	shrimp	**10**	F	96 hr	LC
Chlorothalonil	*Daphnia magna*	water flea	70	S	48 hr	EC
	Penaeus duorarum	shrimp	165	S	96 hr	LC
Chlorpyrifos	*Gammarus lacustris*	scud	0.1	S	96 hr	LC
	Daphnia magna	water flea	0.1	F	48 hr	EC
	Daphnia magna	water flea	1.7	S	48 hr	EC
	Penaeus duorarum	shrimp	2	F	48 hr	LC
	Penaeus aztecus	shrimp	0.2	F	48 hr	LC
Copper sulfate, pentahydrate	*Gammarus lacustris*	scud	1,500	S	48 hr	LC
	Daphnia magna	water flea	180	S	96 hr	EC
	Penaeus duorarum	shrimp	16,000	S	96 hr	LC
Cyanazine	*Daphnia magna*	water flea	**45,000**	S	48 hr	EC
	Gammarus fasciatus	scud	2,000	S	96 hr	LC
Cypermethrin	*Daphnia magna*	water flea	**20**	S	48 hr	EC
	Penaeus duorarum	shrimp	0.04	F	96 hr	LC
DCPA (Dacthal or Chlorthal-dimethyl)	*Daphnia magna*	water flea	**61,000**	S	48 hr	EC
DDT	*Daphnia pulex*	water flea	0.4	S	48 hr	EC
	Penaeus duorarum	shrimp	0.6	F	48 hr	LC
	Daphnia magna	water flea	5	S	48 hr	EC
	Gammarus lacustris	scud	1	S	96 hr	LC
	Gammarus fasciatus	scud	0.8	F	96 hr	LC
	Gammarus fasciatus	scud	1.8	S	96 hr	LC
Diazinon	*Daphnia magna*	water flea	**1**	S	48 hr	EC
	Daphnia pulex	water flea	0.8	S	48 hr	EC
	Penaeus aztecus	shrimp	28	F	48 hr	LC
	Gammarus fasciatus	scud	0.2	S	96 hr	LC
Dicofol	*Penaeus duorarum*	shrimp	50	F	48 hr	LC

* Bold values are geometric means of results from all available studies for that particular study time.

TABLE 3: CONTINUED

Pesticide	Species	Common Name	LC50/EC50* (µg/L)	Method	Study Time	EC/LC
Dieldrin	*Daphnia pulex*	water flea	250	S	48 hr	EC
	Penaeus duorarum	shrimp	**1**	F	96 hr	LC
	Gammarus fasciatus	scud	600	S	96 hr	EC
Dimethoate	*Gammarus lacustris*	scud	200	S	96 hr	LC
Diuron	*Daphnia pulex*	water flea	1,400	S	48 hr	EC
	Daphnia magna	water flea	8,400	S	48 hr	EC
	Gammarus fasciatus	❊	160	S	96 hr	LC
Endrin	*Penaeus aztecus*	shrimp	0.2	F	48 hr	LC
	Daphnia magna	water flea	**10**	S	48 hr	EC
	Daphnia pulex	water flea	20	S	48 hr	LC
	Penaeus duorarum	shrimp	0.04	S	96 hr	LC
	Gammarus fasciatus	scud	1.3	S	96 hr	LC
	Gammarus lacustris	scud	3	S	96 hr	LC
EPTC	*Daphnia magna*	water flea	**8,800**	S	48 hr	EC
	Gammarus fasciatus	scud	**39,000**	S	96 hr	LC
Fosetyl-Al	*Daphnia magna*	water flea	300,000	S	48 hr	EC
	Daphnia pulex	water flea	190,000	S	96 hr	EC
Glyphosate	*Daphnia pulex*	water flea	**4,400**	S	48 hr	EC
	Daphnia magna	water flea	**79,000**	S	48 hr	EC
Iprodione	*Daphnia magna*	water flea	**900**	S	48 hr	EC
Malathion	*Daphnia magna*	water flea	1	S	48 hr	EC
	Daphnia magna	water flea	2.2	F	48 hr	EC
	Daphnia pulex	water flea	2	S	48 hr	EC
	Gammarus lacustris	scud	2	S	48 hr	LC
	Penaeus duorarum	shrimp	280	F	48 hr	LC
	Gammarus fasciatus	scud	0.5	F	96 hr	LC
Mancozeb	*Daphnia magna*	water flea	760	S	48 hr	EC
Maneb	*Penaeus duorarum*	shrimp	3,800	S	48 hr	LC
Metalaxyl	*Daphnia magna*	water flea	**33,000**	S	48 hr	EC
Metam sodium	*Daphnia magna*	water flea	2,400	S	48 hr	EC
Methidathion	*Daphnia magna*	water flea	7	S	48 hr	EC
	Penaeus duorarum	shrimp	15	F	48 hr	LC
Methomyl	*Daphnia magna*	water flea	**20**	S	48 hr	EC
	Penaeus duorarum	shrimp	20	S	96 hr	LC
Metolachlor	*Daphnia magna*	water flea	25,000	S	48 hr	EC
Molinate	*Daphnia magna*	water flea	**13,000**	S	48 hr	EC
Myclobutanil	*Daphnia magna*	water flea	11,000	S	48 hr	EC
Naled	*Gammarus lacustris*	scud	0.1	S	48 hr	LC
	Daphnia magna	water flea	**0.4**	S	48 hr	EC
	Daphnia magna	water flea	**2**	F	48 hr	EC
	Gammarus fasciatus	scud	20	S	96 hr	LC

* Bold values are geometric means of results from all available studies for that particular study time.

TABLE 3: CONTINUED

Pesticide	Species	Common Name	LC50/EC50* (µg/L)	Method	Study Time	EC/LC
Napropamide	*Daphnia magna*	water flea	**19,000**	S	48 hr	EC
	Penaeus duorarum	scud	20,000	S	96 hr	LC
Oryzalin	*Daphnia magna*	water flea	1,500	S	48 hr	EC
Paraquat dichloride	*Daphnia pulex*	water flea	4,000	S	48 hr	EC
	Gammarus fasciatus	scud	11,000	S	96 hr	LC
Permethrin	*Daphnia magna*	water flea	**1**	S	48 hr	EC
	Penaeus duorarum	shrimp	0.22	F	96 hr	LC
	Penaeus duorarum	shrimp	0.51	S	96 hr	LC
	Penaeus aztecus	shrimp	0.3	S	96 hr	LC
Propargite	*Daphnia magna*	water flea	74	S	48 hr	EC
	Daphnia magna	water flea	91	F	48 hr	EC
Simazine	*Daphnia magna*	water flea	1,100	S	48 hr	EC
	Gammarus lacustris	scud	13,000	S	96 hr	LC
	Penaeus duorarum	shrimp	110,000	S	96 hr	LC
Thiobencarb	*Daphnia magna*	water flea	**210**	S	48 hr	EC
	Penaeus aztecus	shrimp	470	S	96 hr	LC
	Penaeus duorarum	shrimp	570	S	96 hr	LC
Thiophante-methyl	*Daphnia magna*	water flea	5,400	F	48 hr	EC
	Daphnia magna	water flea	63,000	S	48 hr	EC
Trifluralin	*Daphnia pulex*	water flea	630	S	48 hr	EC
	Gammarus fasciatus	scud	2,200	S	96 hr	LC
Ziram	*Daphnia magna*	water flea	50	S	48 hr	EC

* Bold values are geometric means of results from all available studies for that particular study time.

TABLE 4: TOXICITY OF SELECTED PESTICIDES TO FISH

Study Time: 96 hours, Test Methods: Static (S), Flow-through (F)

Pesticide	Species	LC50* (µg/L)	Method
2,4-D (Dimethylamine salt)	Bluegill sunfish	**210,000**	S
	Rainbow trout	250,000	S
	Fathead minnow	**290,000**	S
Atrazine	Brook trout	4,900	S
	Rainbow trout	**12,000**	S
	Fathead minnow	15,000	S
	Bluegill sunfish	**30,000**	S
Benomyl	Rainbow trout	**340**	S
	Bluegill sunfish	**820**	S
	Fathead minnow	**2,000**	S
Captan	Brook trout	30	F
	Lake trout	50	S
	Cutthroat trout	60	S
	Coho salmon	60	F
	Chinook salmon	60	S
	Rainbow trout	70	S
	Fathead minnow	**90**	F
	Bluegill sunfish	72	F
	Bluegill sunfish	**210**	S
Carbaryl	Lake trout	690	S
	Cutthroat trout	1,000	S
	Coho salmon	2,400	S
	Rainbow trout	**2,050**	S
	Rainbow trout	3,300	F
	Chinook salmon	2,400	F
	Brook trout	3,000	S
	Fathead minnow	7,700	S
	Bluegill sunfish	5047	F
	Bluegill sunfish	**18,600**	S
Carbofuran	Lake trout	160	F
	Bluegill sunfish	**410**	S
	Rainbow trout	**430**	S
	Coho salmon	530	S
	Fathead minnow	**1,300**	S
Chlorothalonil	Bluegill sunfish	26.3	F
	Bluegill sunfish	**100**	S
	Rainbow trout	61	F
	Rainbow trout	**120**	S
Chlorpyrifos	Cutthroat trout	5	S
	Bluegill sunfish	5.8	F
	Bluegill sunfish	**8**	S
	Rainbow trout	7.1	S
	Rainbow trout	**15**	F
	Lake trout	70	S
	Fathead minnow	**150**	F
	Striped bass	<1,000	S
Copper sulfate, pentahydrate	Rainbow trout	420	S
	Bluegill sunfish	2,400	S
Cyanazine	Rainbow trout	9,000	S
	Fathead minnow	**18,000**	S
	Bluegill sunfish	23,000	S
Cypermethrin	Bluegill sunfish	**3**	F
	Rainbow trout	**2**	F
	Rainbow trout	13	S
DCPA (Dacthal or Chlorthal-dimethyl)	Rainbow trout	**14,000**	S
DDT	Bluegill sunfish	2	S
	Coho salmon	4	S
	Rainbow trout	4	S
	Cutthroat trout	6	S
	Fathead minnow	9.9	F
	Fathead minnow	12.4	S
Diazinon	Bluegill sunfish	**150**	S
	Bluegill sunfish	460	F
	Rainbow trout	**580**	S
	Lake trout	600	S
	Brook trout	770	F
	Cutthroat trout	1,700	S
	Fathead minnow	7,800	F
Dicofol	Cutthroat trout	**50**	S
	Lake trout	**90**	S
	Fathead minnow	510	F
	Bluegill sunfish	**920**	S
Dieldrin	Rainbow trout	**1**	S
	Fathead minnow	4	S
	Bluegill sunfish	**5**	S
	Cutthroat trout	6	S
Dimethoate	Bluegill sunfish	6,000	S
	Rainbow trout	**6,800**	S
Diuron	Cutthroat trout	**1,000**	S
	Lake trout	**1,800**	S
	Coho salmon	<2,400	S
	Bluegill sunfish	**9,100**	S
	Rainbow trout	11,000	S
	Fathead minnow	14,000	S
Endrin	Coho salmon	0.1	S
	Fathead minnow	0.2	F
	Bluegill sunfish	0.3	S
	Rainbow trout	0.7	S
	Fathead minnow	1.8	S

* Bold values are geometric means of results from all available studies for that particular study time.

TABLE 4: CONTINUED

Pesticide	Species	LC50* (µg/L)	Method
EPTC	Lake trout	11,500	S
	Cutthroat trout	12,500	S
	Rainbow trout	21,000	S
	Bluegill sunfish	**25,000**	S
Fosetyl-Al	Bluegill sunfish	141,000	S
	Rainbow trout	**180,000**	S
Glyphosate	Fathead minnow	**13,000**	S
	Rainbow trout	**33,000**	S
	Bluegill sunfish	**41,000**	S
Iprodione	Rainbow trout	4,200	S
	Bluegill sunfish	**5,400**	F
	Bluegill sunfish	6,300	S
Malathion	Rainbow trout	4	S
	Bluegill sunfish	20	S
	Striped bass	60	S
	Lake trout	76	S
	Brown trout	101	S
	Coho salmon	170	S
	Cutthroat trout	1,700	S
	Fathead minnow	8,700	S
Mancozeb	Rainbow trout	**700**	S
	Bluegill sunfish	**1,700**	S
Maneb	Bluegill sunfish	270	F
	Bluegill sunfish	**4,100**	S
	Rainbow trout	0.04	S
Metalaxyl	Rainbow trout	**68,000**	S
	Bluegill sunfish	**83,000**	S
Metam sodium	Bluegill sunfish	510	S
	Rainbow trout	34,000	S
Methidathion	Bluegill sunfish	**7**	S
	Rainbow trout	**11**	S
Methomyl	Brook trout	**1,300**	S
	Bluegill sunfish	**1,400**	S
	Rainbow trout	**1,800**	S
	Fathead minnow	**2,000**	S
	Cutthroat trout	**5,200**	S
Metolachlor	Rainbow trout	3,900	S
	Fathead minnow	8,200	S
	Bluegill sunfish	10,000	S
Molinate	Rainbow trout	**6,000**	S
	Striped bass	**10,000**	F
	Chinook salmon	13,000	F
	Bluegill sunfish	**21,000**	S
	Fathead minnow	27,000	S

Pesticide	Species	LC50* (µg/L)	Method
Naled	Lake trout	90	S
	Cutthroat trout	130	S
	Rainbow trout	**220**	S
	Bluegill sunfish	**1,600**	F
	Fathead minnow	3,300	S
Oryzalin	Bluegill sunfish	2,900	S
	Rainbow trout	**3,400**	S
Paraquat dichloride	Bluegill sunfish	**8,100**	S
	Rainbow trout	**33,500**	S
Permethrin	Fathead minnow	**4**	S
	Brook trout	**4**	S
	Rainbow trout	**7**	S
	Bluegill sunfish	**8.5**	F
	Bluegill sunfish	**8.7**	S
	Rainbow trout	**12**	F
	Coho salmon	20	S
Propargite	Bluegill sunfish	**70**	S
	Rainbow trout	143	F
	Rainbow trout	**230**	S
Simazine	Fathead minnow	**25,000**	S
	Bluegill sunfish	**38,000**	S
	Rainbow trout	**53,000**	S
Thiobencarb	Rainbow trout	**1,200**	S
	Bluegill sunfish	**1,300**	S
Thiophanate-methyl	Rainbow trout	**14,500**	S
	Bluegill sunfish	**30,300**	S
Trifluralin	Bluegill sunfish	8	S
	Rainbow trout	15	S
	Fathead minnow	100	S
Ziram	Fathead minnow	8	S
	Bluegill sunfish	10	S
	Rainbow trout	680	S

* Bold values are geometric means of results from all available studies for that particular study time.

Table 5: Toxicity of Selected Pesticides to Honeybees (*Apis mellifera*)

Pesticide	LD50* (µg/bee)	Study time
Acephate	1.2	24 hr
Acetochlor	1715	48 hr
Aldicarb	0.3	48 hr
Allethrin	3.4	48 hr
Ametryn	100	48 hr
Arsenic acid	7.7	48 hr
Avermectin	0.4	48 hr
Azinphos-methyl	**0.25**	48 hr
Benfluralin	14.5	48 hr
Bensulfuron methyl	12.5	48 hr
Bensulide	24.0	48 hr
Bifenthrin	0.015	48 hr
Bromacil	193	48 hr
Carbaryl	<1.3	24 hr
	1.14	48 hr
Carbofuran	0.2	48 hr
Chlorothalonil	181.3	48 hr
Chlorpyrifos	0.1	24 hr
	0.17	96 hr
Cyanazine	193.4	48 hr
Cypermethrin	**0.08**	48 hr
DDT	**5.25**	48 hr
Diazinon	0.2	24 hr
	0.27	48 hr
Dicamba	3.6	48 hr
Dichlorvos	0.5	48 hr
Dieldrin	**0.19**	48 hr
Dimethoate	**0.12**	48 hr
Diuron	145	48 hr

Pesticide	LD50* (µg/bee)	Study time
Endrin	**0.55**	24 hr
Fenthion	0.3	48hr
Fenvalerate	0.4	48 hr
Fluvalinate	**0.78**	48 hr
Lindane	**0.33**	48 hr
Malathion	**0.28**	48 hr
	0.7	96 hr
Mancozeb	178	48 hr
Maneb	12	48 hr
Metam sodium	36	96 hr
Methamidophos	1.4	48 hr
Methidathion	0.2	96 hr
Methiocarb	0.4	48 hr
Methoxychlor	24	48 hr
Paraquat dichloride	6	48 hr
Pendimethalin	50	48 hr
Permethrin	0.2	24 hr
	0.06	48 hr
	0.1	96 hr
Phorate	**0.38**	24 hr
	10	48 hr
Phosmet	1.1	48 hr
Prometon	36	48 hr
Pyrethrin	0.02	48 hr
Resmethrin	0.1	48 hr
Tetramethrin	0.2	48 hr
Trifluralin	24	48 hr
Ziram	47	48 hr

* Bold values are geometric means of results from all available studies for that particular study time.

Appendix 3: Resources for Least-Toxic Pest Management

Gardening Without Pesticides

Plant'It Earth 2215 Market St. San Francisco, CA 415-626-5082	Common Ground Organic Garden Supply 2225 El Camino Real Palo Alto, CA 650-328-6752
O'Donnel's Fairfax Nursery 1700 Sir Francis Drake Boulevard Fairfax, CA 415-453-0808	Sloat Garden Supply 1 Blackfield Drive Tiburon, CA 415-388-4721
Green Jeans Garden Supplies 690 Redwood Highway Mill Valley, CA 415-389-8333	Dirt Cheap Organics 3070 Kerner Boulevard, Unit T San Rafael, CA 415-454-8278

Pest Control With Least Toxic Products

Bio-Pest P.O. Box 5295 Petaluma, CA 707-765-6565	Pestec P.O.Box 2393 Antioch, CA 415-587-6817
North Bay Structural Service P.O. Box 9446 San Rafael, CA 415-927-4122	Peaceful Valley Farm Supply P.O. Box 2209 Grass Valley, CA 916-272-4769
Northwest Termites 4145 Sebastopol Road Santa Rosa, CA 800-281-2710	Tallon Termite Pest Control 30073 Ahern Avenue Union City, CA 800-300-2653

Other Resources

1998 Directory of Least-Toxic Pest Control Products Bio-Integral Resource Center (BIRC) P.O. 7414 Berkeley, CA, 94707 Phone: 510-524-2567 Fax: 510-524-1758	*The Other Road to Flea Control* by Diana Post, V.M.D. Rachel Carson Council, Inc. 8940 Jones Mill Road Chevy Chase, MD 20815 Phone: 301-652-1877 Fax: 301-951-7179
From Your Backyard to the Bay: A Bay Area Resource Guide for Alternatives to Toxic Pesticides Pesticide Watch Education Fund 450 Geary Street, Suite 500 San Francisco, CA 94102 Phone: 415-292-1486 Fax: 415-292-1497	*How to Control Garden Pests Without Killing Almost Everything Else* by Helga and William Olkowski Rachel Carson Council, Inc. 8940 Jones Mill Road Chevy Chase, MD 20815 Phone: 301-652-1877 Fax: 301-951-7179
Resource List for Pesticide Alternatives http://members.aol.com/homeview2/info/	

Appendix 4: Web Sites Related to Pesticides and Wildlife

Water Quality and Regulation

U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. Information about water quality of surface and groundwater.

http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html

San Francisco Estuary Institute. Information about pesticides and metals in tissues, water, and sediments in the San Francisco Bay-Delta.

http://www.sfei.org/

CalFed Bay-Delta Program. A joint state-federal program that is working to resolve water issues in California.

http://calfed.ca.gov/

U.S. Environmental Protection Agency Total Maximum Daily Load (TMDL) Program. Information about the TMDL program and status reports on progress of all states in listing water bodies.

http://www.epa.gov/owowwtr1/tmdl/index.html

Pesticide Toxicity Information

Extension Toxicology Network (ExToxNet). Toxicology and environmental chemistry with a variety of information about specific pesticides. Developed and maintained by University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho.

http://ace.orst.edu/info/extoxnet/

U.S. Environmental Protection Agency Eco-Tox Database System. A source for locating single chemical toxicity data for aquatic life, terrestrial plants and wildlife. ECOTOX integrates three U.S. EPA, Office of Research and Development (ORD), National Health and Environmental Effects Research Laboratory (NHEERL), Mid-Continent Ecology Division, toxicology effects databases; AQUIRE (aquatic life), PHYTOTOX (terrestrial plants), and TERRETOX (terrestrial wildlife).

http://www.epa.gov/ecotox/

Columbia Environmental Research Center (CERC). Web links to a database with results from aquatic acute toxicity tests conducted by the U.S. Geological Survey, Biological Resources Division.

http://www.cerc.usgs.gov/data/acute/acute.htm

Integrated Pest Management in New York State. A method to quantify the environmental impact of pesticides has been developed. Contains a list of pesticides and the sum of their environmental impacts.

http://www.nysaes.cornell.edu/ipmnet/ny/program_news/EIQ.html

California Department of Pesticide Regulation. Toxicology data review summaries for many pesticides.

http://www.cdpr.ca.gov/docs/toxsums/toxsumlist.htm

San Francisco Bay-Delta Ecosystem

Central Valley Bay-Delta Branch of the California Department of Fish and Game. Information about the distribution, abundance and population of fish in the San Francisco Bay-Delta.

http://darkstar.delta.dfg.ca.gov/baydelta/monitoring/monitor.html

Interagency Ecological Program. A joint program of a number of state and federal agencies that do work related to the Bay-Delta estuary.

http://iep.water.ca.gov/

California Department of Water Resources. Information about water resources in California.

http://wwwdwr.water.ca.gov/

Birds and General Wildlife Sites

American Bird Conservancy. Information about bird kills related to pesticides.

http://www.abcbirds.org/pesticides.htm

Canadian Wildlife Service. Information about pesticide-wildlife related issues.

http://www.cws-scf.ec.gc.ca/nwrc/pesticid.htm

U.S. Fish and Wildlife Service Klamath Basin National Wildlife Refuges.

http://www.klamathnwr.org/

U.S. Fish and Wildlife Service Endangered Species Page. Information about endangered species in the U.S.

http://www.fws.gov/r9endspp/endspp.html

California Department of Pesticide Regulation Endangered Species Page. Information about endangered species and pesticide use in California.

http://www.cdpr.ca.gov/docs/es/reports.htm

U.S. Geological Survey's National Wildlife Health Center. Information about bird kills and amphibian declines. Quarterly mortality reports.

http://www.emtc.usgs.gov/http_data/nwhc/

California Environmental Resources Evaluation System (CERES). A general site for environmental resources on the web.

http://ceres.ca.gov/