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Wildlife Mortality Attributed to Organophosphorus and Carbamate Pesticides

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Organophosphorus (OP) and carbamate pesticides are used widely in agricultural and residential applications as insecticides, herbicides, fungicides, and rodenticides. This family of chemicals replaced the organochlorine pesticides banned for use in the United States in the 1970's. Unlike organochlorine pesticides, which are long-lived in the environment and cause biological damage when they accumulate in an organism's system over time, OP and carbamate pesticides are short-lived in the environment and fast-acting on their "target pest." Direct mortality of wildlife from organochlorine pesticides was uncommon (Hayes and Wayland 1975); however, mortality is the primary documented effect on wildlife from OP and carbamate pesticides (Grue et al. 1983). Organophosphorus and carbamate pesticide toxicity is not specific to a target "pest," and lethal effects are seen in nontarget organisms; birds appear to be the most sensitive class of animals affected by these pesticides.

Organophosphorus and carbamate pesticides primarily affect the nervous system by inhibiting acetylcholinesterase (AChE) enzyme activity. This enzyme's main function in the nervous system is to break down the neurotransmitter acetylcholine. When AChE is altered by OP and carbamate pesticides, it cannot perform this breakdown function and acetylcholine accumulates. Acetylcholine accumulation increases nerve impulse transmission and leads to nerve exhaustion and, ultimately, failure of the nervous system. When the nervous system fails, muscles do not receive the electrical input they require to move. The respiratory muscles are the most critical muscle group affected, and respiratory paralysis is often the immediate cause of death.

Documentation of Poisoning

Virtually no reported findings of dead or affected birds are based on planned surveys or

follow-ups to specific pesticide applications. In fact, there is often no suspicion of OP or carbamate pesticide poisoning because it is only after necropsy and laboratory testing that the poisoning is revealed. A cholinesterase (ChE) screening test compares brain ChE activity (primarily acetylcholinesterase activity) in a bird suspected of being poisoned with the ChE activity of normal birds of the same species. Enzyme activity reduced 20% or more is considered evidence of exposure to a cholinesterase-inhibiting compound; a reduction greater than 50% is evidence of lethal exposure (Ludke et al. 1975). In these incidents the cholinesterase-inhibiting compounds are OP and carbamate pesticides, and specific OP and carbamate compounds may be identified by chemical analysis of esophagus or stomach contents.

Effects on Wildlife

Wildlife mortality attributed to OP and carbamate pesticides has been documented for at least two decades, and the number of incidents recorded since 1980 is increasing (Fig. 1). In this article, 207 separate mortality incidents related to an OP or carbamate pesticide are described. These incidents occurred in nonendangered wildlife from 1980 to 1993. Of the 207 mortalities, a specific chemical compound was identified as the cause of death in 124 incidents and 19 different compounds were detected. Of the specific compounds identified, 4 were carbamates and 15 were OP compounds (Table). Carbamates were responsible in 31 mortalities while OP compounds were responsible in 93. On the basis of inhibited ChE activity in the brain, carbamate and OP pesticides were suspected as the cause of 64 additional incidents. In 19 unconfirmed reports, 5 had 20%-40% brain ChE inhibition, exposure levels not considered high enough to be lethal. The remaining 14 had a history suggesting pesticide exposure, but a diagnostic evaluation was not made.

Thousands of birds representing more than 50 species including waterfowl, passerines, colonial waterbirds, shorebirds, gulls, raptors, and others have been killed in these incidents. A die-off incident can involve a few birds of one species or hundreds of birds of a variety of species. Gross necropsy findings in birds dying from OP and carbamate toxicity were minimal. Lung edema and hyperemia (*see* glossary) were the predominant findings when lesions were observed. Mammals such as Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), and coyote (*Canis latrans*) were occasionally involved.

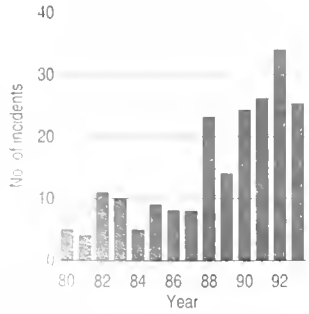

Fig. 1. Number of organophosphorus and carbamate pesticide-related wildlife mortality incidents, 1980-93.

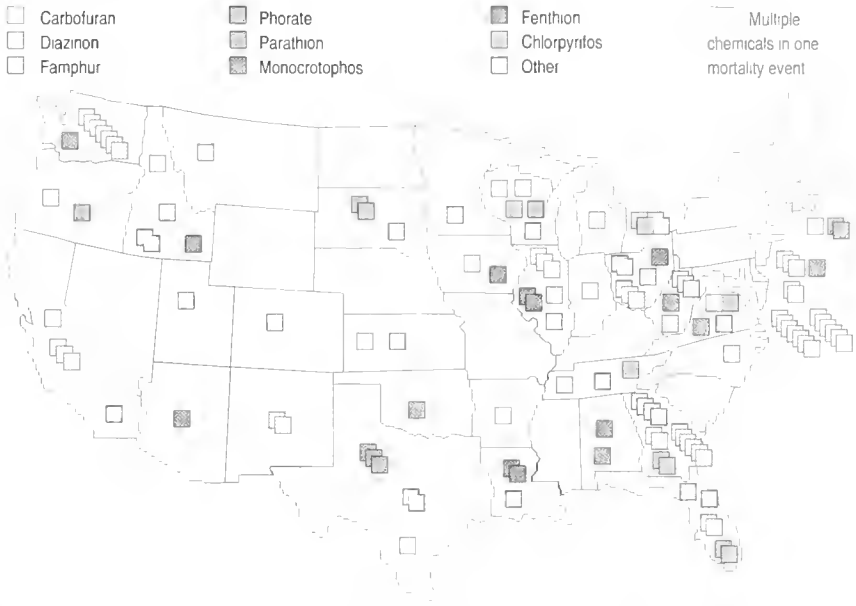

Fig. 2. Location by state of organophosphorus and carbamate compounds in pesticide-related wildlife mortality incidents, 1980-93.

The geographic distribution of mortality associated with specific compounds varied, although multiple incidents where the same compound was identified occurred within states (Fig. 2). Of the 124 deaths where a specific pesticide was identified, 64 had a known pesticide application (Fig. 3). The application varied from use on agricultural crops or livestock (agricultural) to lawn care or other uses in residential areas (residential) and on golf courses. Other known applications did not fall into these three categories and are primarily incidents of intentional baiting with grain.

Documentation of wildlife mortality in this manner has supported restrictions on the use of some OP and carbamate pesticides, such as the removal of diazinon from use for turf applications and limiting the use of granular carbofuran. Studies are under way to determine the sublethal effects of these chemicals (Grue et al.

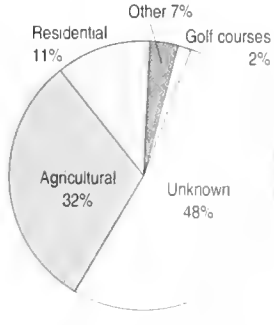

Fig. 3. General type of application associated with organophosphorus and carbamate pesticide-related wildlife mortality incidents, 1980-93.

Table. Specific compounds identified in organophosphorus and carbamate pesticide-related wildlife mortality incidents, 1980-93.

Carbamates	Organophosphorus compounds
Carbofuran	Chlorpyrifos
Methiocarb	Diazinon
Oxamyl	Dicrotophos
Aldicarb	Dimethoate
	Disulfoton
	Famphur
	Fenamiphos
	Fensulfothion
	Fenthion
	Fonofos
	Methamidiphos
	Monocrotophos
	Parathion
	Phorate
	Phosphamidon

1991; Hart 1993); preliminary findings indicate that OP and carbamate pesticides cause alterations in behavior and physiology and could affect survival in the wild. The total effect of carbamate and organophosphorus pesticides to wildlife is still unknown.

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Acidic Deposition ("Acid Rain")

by
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Acidic deposition, or "acid rain," describes any form of precipitation, including rain, snow, and fog, with a pH of 5.5 or below (Note: pH values below 7 are acidic; vinegar has a pH of 3). It often results when the acidity of normal precipitation is increased by sulfates and nitrates that are emitted into the atmosphere from burning fossil fuels. This form of airborne contamination is considered harmful, both directly and indirectly, to a host of plant and animal species.

Although acid rain can fall virtually anywhere, ecological damages in environmentally sensitive areas downwind of industrial and urban emissions are a major concern. This includes areas that have a reduced capacity to neutralize acid inputs because of low alkalinity soils and areas that contain species with a low tolerance to acid conditions. To determine the distribution of acidic deposition and evaluate its biological effects, research and monitoring are being conducted by the federal government with support from states, universities, and private industry.

The national extent of the acid rain problem has been estimated by sampling water from 3,000 lakes and 500 streams (Irving 1991), representing more than 28,000 lakes and 56,000 stream reaches with a total of 200,000 km (125,000 mi). Some particularly sensitive areas, such as the Adirondack Mountain region, have been more intensively sampled and the biota examined in detail for effects from acidity.

To identify trends in aquatic ecosystems, present and historical survey data on water chemistry and associated biota are compared. In lakes, the chemical and biological history and pH trends may be inferred or reconstructed in some cases by examining assemblages of fossil diatoms and aquatic invertebrates in the sediment layers. In terrestrial ecosystems, vegetation damage is surveyed and effects of acidic deposition to plants and animals are determined from laboratory and field exposure experiments. Natural variation in populations and the complex interactions between acidity and other ecosystem components make it difficult to extend many of the research findings to populations or communities. Acidity can also modify ecosystem processes such as decomposition and the flow of nutrients. Therefore, models are often used to predict such effects by combining information on individual species' effects, population distributions, and the patterns and amounts of acidic deposition.

Status and Trends

Aquatic Species

Research in the United States, Scandinavia, and Canada has demonstrated that acidity affects the physiology, reproduction, food resources, and habitat of aquatic species. Laboratory experiments and field surveys have shown that sensitive aquatic species, ranging from plankton and aquatic invertebrates at the bottom of the food chain to fish at the top (Figure), decrease in numbers with increased acidity (i.e., decreased pH). Some reductions in sensitive species may be partially offset by increases in more acid-tolerant species, resulting in little change in the total number of organisms in the community even though the diversity of species may change.

Melting snow, which accumulates the winter's deposition of acidic materials, and episodes of spring rainfall can be especially damaging to sensitive streams and lakes. The acidity that flushes from the surrounding landscape often enters the aquatic ecosystem at a time of important reproductive activity in fish and invertebrates. Acid conditions leach aluminum from the watershed soils, creating toxic levels for aquatic organisms in the lakes and streams that receive the runoff. Acidity also increases the availability and toxicity of other metals, such as mercury, that may be present in the aquatic environment (Longcore et al. 1993).

The Adirondack region of New York, one of the most extensively studied areas in the United States, has exhibited some of the most evident