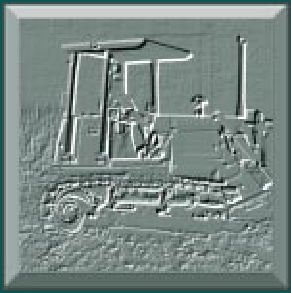
Courtesy R. Hayes/ H. Weiss, BLM



Human Influences

by
Science Editor
Wayne Willford
National Biological Service
1849 C St. NW
Washington, DC 20240

Overview

The following articles are directed at neither a specific species nor an ecosystem, but at human activities that affect living resources nationally and internationally. These broad-scale effects on, and changes in, ecosystem health are frequently the result of local or regional actions and land-use practices that collectively have effects across the nation.

The first article (Stein et al.) examines the significance of federal lands as refugia for the protection and conservation of endangered species. Stein et al. (box) then describe a system used to rank species by their need for conservation measures to prevent their endangerment and future extinction. In the article by Friend, we learn about the history of diseases in waterfowl, the trends in disease outbreak, and how the loss of wetlands and the discharge of water can be associated with these disease outbreaks. Dein et al. describe the use of propagation and translocation (transplanting species to a certain area) to recover or augment threatened or endangered species as well as recreational species. Dein et al. also examine the secondary consequences of such efforts on the transfer and spread of disease to wildlife, domestic animals, and humans. Cumulatively, these articles broaden the focus of status and trends assessments beyond individual species and ecosystems, and begin to reveal the interrelatedness between species, ecosystems, and human activities.

The remainder of the articles focus on the effects of pollution that results from human activities such as agricultural, industrial, and municipal development. The articles pay special attention to monitoring of pollution because the effects of pollution are excellent examples of the links between ecosystem health and the health of organisms, including humans, that depend on those systems.

The first article on pollution (Turgeon and Robertson) describes toxic contaminants in fish and mollusks from U.S. coastal waters. Next, Schmitt and Bunck describe the trends of chemical residues in fish and wildlife from across the nation during the past 25 years. The note by Glaser emphasizes how birds are being affected by the “new family” of pesticides in use across the United States.

Schreiber discusses the adverse impacts of acid deposition (acid rain) on sensitive species and ecosystems and the influence of recent regulatory efforts to control this form of pollution. Everson and Graber describe the results of a long-term study on the effects of acid rain on forest watersheds, the secondary impacts on water chemistry because of leaching of nutrients from soils, and the influence of a forest fire on the process. Allen discusses the agricultural effects on wildlife habitat.

Overall, these varied articles introduce the ways in which large-scale assessments of status and trends in the health and condition of biota also provide an excellent indication of overall ecosystem health, particularly in relation to the less visible effects such as long-term, subtle declines due to diseases and pollution.

Significance of Federal Lands for Endangered Species

by

Bruce A. Stein
The Nature Conservancy

Tom Breden
Association for Biodiversity Information

Richard Warner
The Nature Conservancy

The federal government has overall trust responsibilities for species listed as threatened or endangered under the Endangered Species Act (ESA). The options available for managing and protecting these species, however, are directly related to the ownership of the lands on which the species are found. This article provides information about the presence and numbers of federally listed species on federal lands and the responsibility of federal land managers to care for these species. Our analysis helps evaluate the potential and actual role of federal land-management agencies in the overall protection of threatened and endangered species (Natural Heritage Data Center Network 1993).

Karner blue butterfly (*Lycaeides melissa samuelis*), an endangered species found partially on federal lands.

Natural Heritage Programs—a partnership between state and federal agencies and The Nature Conservancy—gather and manage a variety of information linking both biological and nonbiological factors of relevance to biodiversity conservation. Central to this effort is the inventory of all known occurrences for species of conservation concern, including all federally listed endangered or threatened species. An occurrence is defined as an example of a species at a specific location representing a habitat capable of sustaining the survival of that species. What constitutes an occurrence depends on the biology of the particular species, but most often reflects a mappable and geographically distinct population or subpopulation. Pertinent information is documented for each occurrence, such as the biological health and population trends of the occurrence, habitat quality, protection or management status, and land ownership.

Heritage Programs in all 50 states queried their data bases for all documented occurrences of federally listed species in their jurisdiction and reported the class of landowner or type of managing agency. (Note: "Species" under the ESA includes subspecies as well as full species; in the strictest taxonomic sense these collectively would be referred to as "taxa.") Only occurrences observed since 1973 were included in the analysis.

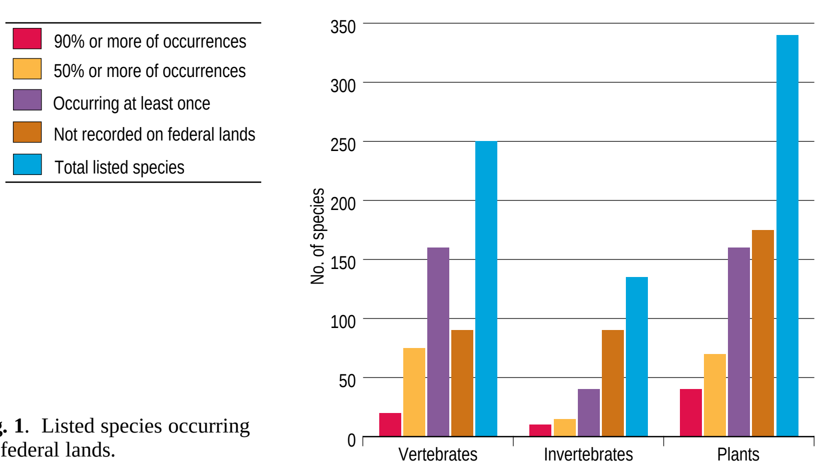


Fig. 1. Listed species occurring on federal lands.

While the Heritage Programs are the most comprehensive source for such locality information on rare species and reviewed about 350,000 occurrence records for this analysis, this information is incomplete for four reasons: (1) Heritage Programs may not be aware of all occurrences, and indeed, many populations for species of concern may yet be discovered; (2) most programs have a data-entry backlog; (3) not all data centers have completely recorded the land ownerships for all their occurrence records; and (4) species occurrences in lakes and rivers are generally not recorded as under the jurisdiction of a federal agency except where they are entirely included in such areas as national parks or wildlife refuges. On the other hand, in many states more is known about the status of listed species on federal lands than on state or private lands. This imbalance in the available data, largely the result of federally funded inventories on federal lands, will tend to overstate the proportion of a species' range or population on federal lands.

Species on Federal Lands

This analysis includes 344 plant, 254 vertebrate, and 130 invertebrate species found in the 50 United States that as of March 1993 were

Status of U.S. Species: Setting Conservation Priorities

by
Bruce A. Stein
Lawrence L. Master
Larry E. Morse
Lynn S. Kutner
Melissa Morrison
The Nature Conservancy

Resources available for conservation of species and ecosystems invariably are in short supply relative to the needs for those resources. Targeting conservation and management actions toward those species and ecosystems in greatest need, and where opportunities for success are greatest, requires clearly established priorities. Accordingly, setting priorities is a necessary prerequisite for effective biodiversity conservation and ecosystem management.

Many systems and methods for setting priorities and determining endangerment status have been developed, including those used by the U.S. Fish and Wildlife Service, the IUCN (World Conservation Union; formerly International Union for the Conservation of Nature and Natural Resources), and many individual states. Among the most widely applied systems is the biodiversity status-ranking system developed and used by the Natural Heritage Network and The Nature Conservancy (Master 1991; Morse 1993; Stein 1993). This ranking system has been designed to evaluate the biological and conservation status of plant and animal species and within-species taxa as well as ecological communities. For status-ranking purposes, collectively these are all referred to as "elements" of natural diversity (Jenkins 1988).

Status ranks are based primarily on objective factors relating to a species' rarity, population trends, and threats. Four aspects of rarity are considered: number of individuals, number of populations or occurrences, rarity of habitat, and size of geographic range. Ranks are assigned according to a rigorous and standardized process, with all supporting information documented in Heritage Program data bases. Ranking is based on an approximately logarithmic scale, ranging from (1) critically imperiled to (5) demonstrably secure (Table). Typically species with ranks from one to three would be considered of conservation concern and broadly overlap with species that might be considered for review under the Endangered Species Act or similar state or international statutes.

For conservation priorities to be set at local as well as rangewide scales, ranking is carried out at three hierarchical levels: subnational (e.g., state), national, and global. Thus, a species may be relatively common and secure globally (G4), but within a given state may be critically imperiled (S1). The combined rank within that state (G4/S1) allows local priorities to be set within a global context.

Table. Definition of biodiversity status ranks.

Rank	Definition
GX	Presumed extinct; not located despite searches
GH	Of historical occurrence; possibly extinct but some expectation of rediscovery
G1	Critically imperiled; typically 5 or fewer occurences or 1,000 or fewer individuals
G2	Imperiled; typically 6 to 20 occurrences or 1,000 to 3,000 individuals
G3	Rare or uncommon but not imperiled; typically 21 to 100 occurrences or 3,000 to 10,000 individuals
G4	Uncommon but not rare; apparently secure, but with cause for some long-term concern; usually more than 100 occurrences or 10,000 individuals
G5	Common; demonstrably widespread, abundant, and secure

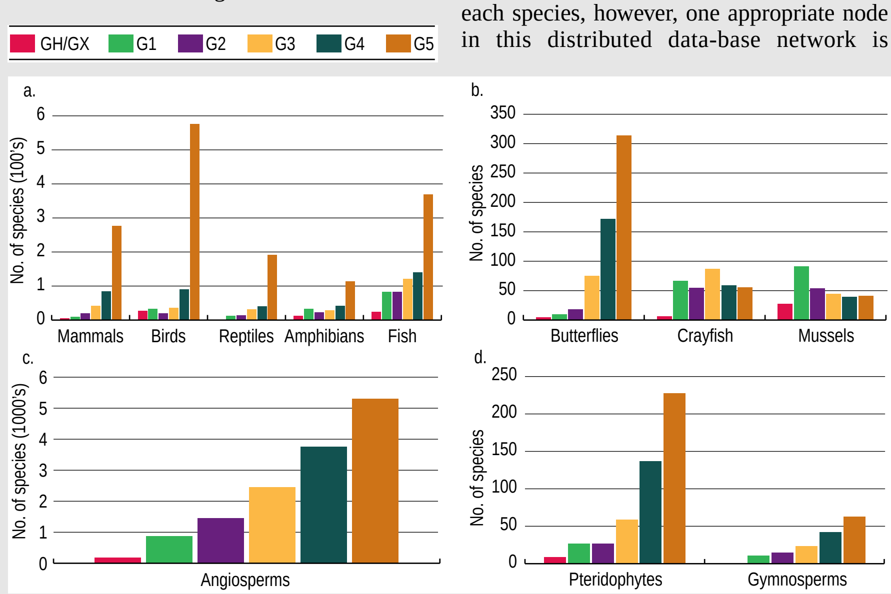


Figure. GH/GX - potentially extinct; G1 to G5 rank species from rarest (G1) to most common (G5). a - status ranks of U.S. vertebrate species (fish include freshwater only); b - status ranks of selected invertebrate groups: native U.S. species of butterflies, crayfish, and freshwater mussels; c - status ranks of native U.S. flowering plant species; and d - status ranks of native U.S. fern and conifer species.

The natural world is extremely dynamic, due to both intrinsic ecological factors and increasing human influences. At the same time, our knowledge of the distribution, abundance, and basic biology of species and ecological communities is imperfect, but continually improving. For these reasons, biodiversity status ranks must be viewed as working hypotheses based on the best available information. Ranks are continually reevaluated and refined as new populations are discovered, known populations are extirpated, or new or better information is available on overall status, trends, or threats. Indeed, ranks initially assigned to some poorly known species may reflect the inadequate state of knowledge about the organism more than its actual biological status. The very process of assigning these ranks and documenting the gaps in our understanding, however, works as a powerful tool in setting priorities for additional inventory and research. The increased inventory attention accorded highly ranked (i.e., rare) species tends to improve understanding of the species' distribution and status, often showing the species to be more common or secure than previously known and, therefore, of lesser concern from a conservation perspective.

The Natural Heritage Network is a distributed data-base network operating on the principle of shared information-management concepts and shared responsibilities. Each state is responsible for assessing the status of each species and natural community within its jurisdiction and for assigning and documenting a state rank for those elements. For each species, however, one appropriate node in this distributed data-base network is responsible for maintaining the current global rank based on a combination of the state and national-level status ranks together with other available information.

Global-level ranks have been assigned to all U.S. vertebrate species, selected groups of invertebrates (including all federally listed, proposed, and candidate species), all vascular plant species, and selected nonvascular plant species (e.g., many lichens and bryophytes). Preliminary global ranks also have been assigned to all rare terrestrial natural communities for the United States.

A summary of status ranks is presented in the Figure for the approximately 2,500 species of native U.S. vertebrates, for more than 1,200 invertebrate species from several groups for which complete data sets are available (butterflies, crayfish, and freshwater mussels), for the approximately 16,300 species of native U.S. flowering plants, and for the approximately 675 species of ferns and conifers native to the United States. These ranks are the result of collaborative work with Heritage Programs, conservation data centers, The Nature Conservancy's scientific staff, and many other state, federal, and private cooperators.

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For further information:

Bruce A. Stein
The Nature Conservancy
1815 N Lynn St.
Arlington, VA 22209

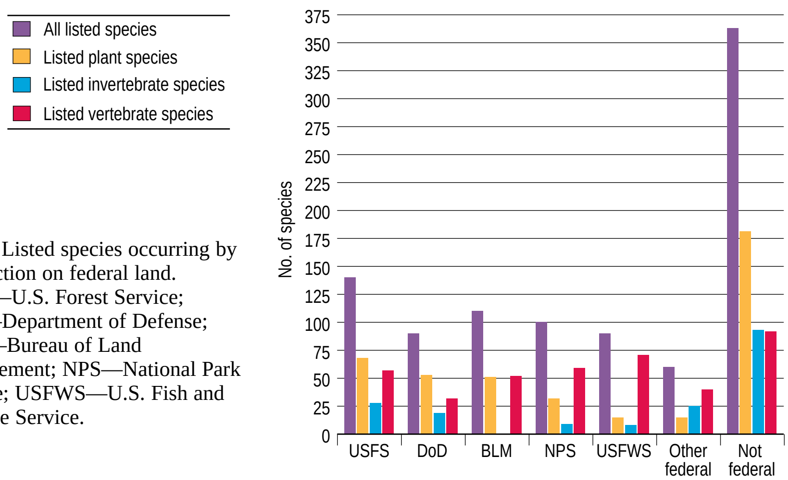

Fig. 2. Listed species occurring by jurisdiction on federal land. USFS—U.S. Forest Service; DoD—Department of Defense; BLM—Bureau of Land Management; NPS—National Park Service; USFWS—U.S. Fish and Wildlife Service.

listed as endangered or threatened under the ESA. About 50% of all federally listed threatened and endangered species occur at least once on federal lands (Fig. 1). The other half of the listed species are found on either state and local public lands, tribal lands, or private lands. About 25% of listed species have more than half of their known occurrences on federal lands and can benefit substantially from federal land-management protection and recovery actions. About 12% of listed species are found almost exclusively on federal lands, with 90%-100% of their known occurrences restricted to lands under federal management.

Number of Listed Species

About 100 species occur on land managed by most major federal agencies (Fig. 2). With nearly 150 species, the U.S. Forest Service (USFS) harbors the largest number of federally listed species of any federal agency. This larger number reflects not only the size and geographic extent of the landholdings, but also the intensive biological surveys that have been conducted on many national forests.

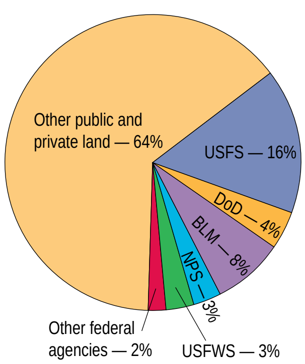

Fig. 3. Occurrences of all listed species by land ownership category. See Fig. 2 for definitions of abbreviations.

Occurrences of Listed Species

Of the 24,573 occurrences of federally listed species recorded by the Natural Heritage Network nationwide, 36% are found on federal lands (Fig. 3). The USFS, with 16% of the total, has the largest number of occurrences followed by the Bureau of Land Management (8%) and the Department of Defense (4%). Both the U.S. Fish and Wildlife Service and the National Park Service have 3% of known occurrences on their lands.

The average number of occurrences per listed species varies markedly among plants, vertebrates, and invertebrates. There are an average of 34 occurrences per listed species for all species combined, 17 occurrences per plant species, 13 occurrences per invertebrate species, and 67 occurrences per vertebrate species. The broad distribution of some federally listed vertebrates heavily influences these figures, however. Just 12 vertebrate species (e.g., bald eagle) account for 12,121 occurrences, representing 49% of the total for all species. Excluding these 12 vertebrates, the average number of occurrences for vertebrates drops to 20 and the overall average to 17.

Conclusions

This analysis puts in perspective the relevance of federal land management for the protection of federally listed threatened and endangered species. Agencies that manage federal lands have substantial responsibilities and opportunities for protecting listed species, particularly those that are found exclusively, or mostly, on federal lands. An example of a plant entirely restricted to federal lands is Ruth's golden aster (*Pityopsis ruthii*), and an animal found exclusively on federal lands is the Laysan duck (*Anas laysanensis*), which lives only on national wildlife refuges.

Federal agencies can also provide substantial, permanent conservation of the listed species that have more than half of all occurrences on their lands. For example, most populations of both the white-haired goldenrod (*Solidago albopilosa*) and white birds-in-a-nest (*Macbridea alba*) are on national forest lands.

For many listed species with less than 50% of their occurrences on federal land, federal agencies may still be able to provide important protection and recovery opportunities. For example, the Karner blue butterfly (*Lycaeides melissa samuelis*), with less than one-quarter of its occurrences on federal lands, still can substantially benefit from federal management actions, such as restoration of the pine and oak savanna habitat on which this butterfly depends.

This study found, however, that fully 50% of federally listed species are not known to occur on federal lands, and that for all listed species, 64% of known occurrences are on nonfederal lands. This strongly points to the need for developing and strengthening federal efforts for protecting these species through cooperative efforts and incentive programs with state and local agencies, private conservation organizations, and private landholders.

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For further information:

Bruce A. Stein
The Nature Conservancy
1815 N. Lynn St.
Arlington, VA 22209

Increased Avian Diseases With Habitat Change

by
Milton Friend
National Biological Service

Changes in disease patterns and trends reflect changing relationships between the affected species (host) and the causes of disease (agent). Host-agent interactions are closely linked to environmental factors that either enhance or reduce the potential for disease to occur. As a result, wildlife disease patterns and trends are, to a substantial extent, indicators of environmental quality and changing host-agent interactions within the environment being evaluated. The types, distribution, and frequency of diseases causing major avian die-offs have changed greatly during the 20th century. Too little is known to assess the changes of most avian diseases that result in chronic attrition rather than major die-offs, or about those that affect reproductive success, reduce body condition, or affect survival in other indirect ways. Nevertheless, the changing patterns and trends in highly visible avian diseases provide notice of problems needing attention.

Information on the status of disease in wild birds was obtained from National Wildlife Health Center (NWHC) evaluations of the cause of death for more than 30,000 carcasses from across the United States during the past two decades, reports of avian mortality received from collaborators, the scientific literature, and NWHC field investigations of bird mortality. Comprehensive assessments of causes of wild bird mortality, magnitude of losses, and geographic distribution of specific diseases are not possible from these data, although we can identify general relationships for waterfowl and some other species.

Changes in Disease Patterns

The occurrence of disease involves three factors: a susceptible host, presence of an agent capable of causing disease, and suitable environmental conditions for contact between the host and agent in a manner that results in disease. Environment is often the dominant factor in this relationship (Fig. 1).

Avian Botulism

The most dramatic example of geographic expansion of a noninfectious indigenous disease is avian botulism, caused by the bacterium *Clostridium botulinum*. In 1914 a Bureau of Biological Survey researcher began investigating catastrophic die-offs that had begun in 1910 and in which millions of waterbirds along the Great Salt Lake, Utah, had died. Later studies revealed that avian botulism was responsible for those die-offs. Historically, avian botulism was referred to as "western duck disease" because of its rather limited geographical distribution of occurrence (Kalmbach and Gunderson 1934; Fig. 2)

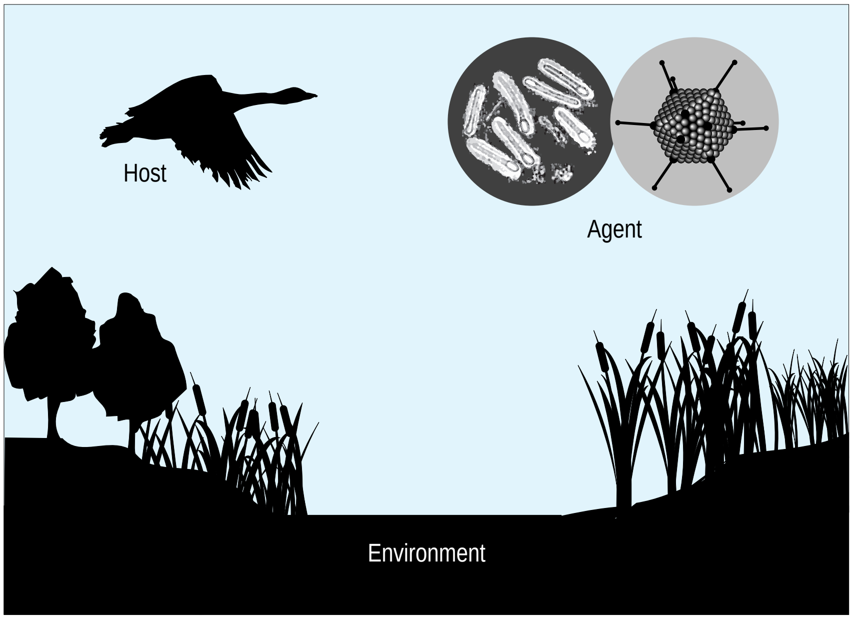

Fig. 1. Common factors required for disease to occur. Environmental factors greatly influence occurrence of disease by changing the amount and type of host-agent interactions.

Avian botulism now occurs all over the United States (Fig. 2) and in many other countries as well. Because of the visibility of massive die-offs, avian botulism is probably the best-documented nonhunting waterfowl mortality (Stout and Cornwell 1976). The continued reporting of avian botulism die-offs since the early 1900's makes researchers suspect that much of the disease's geographic expansion is of recent origin. Also, most (15 of 21) initial outbreaks of avian botulism in countries other than in North America have occurred since 1970.

Avian Cholera

Avian cholera, caused by the bacterium *Pasteurella multocida*, has been recognized as an important infectious disease of domestic poultry in the United States since at least 1867 (Rhoades and Rimler 1991). Therefore, it is noteworthy that a 1930 evaluation of the status of waterfowl commented on the lack of documentation of avian cholera in wild waterfowl (Phillips and Lincoln 1930). In 1944, however, the disease was documented in wild waterfowl in the United States (Quortrup et al. 1946). Limited geographical expansion of avian cholera in wild waterfowl occurred during the 1940's and 1950's, and sporadic occurrences were documented at a few new locations during the 1960's (Fig. 3). By the end of the 1960's, though, avian cholera was reported as established in the Central and Pacific flyways. Outbreaks in the Mississippi Flyway were unusual, and only two outbreaks had occurred in the Atlantic Flyway. With the exception of a single instance during the breeding season, outbreaks occurred in winter (Stout and Cornwell 1976). During the 1970's, avian cholera became established as a major cause of waterfowl mortality in all four flyways within the United States and as a recurring cause of waterfowl mortality in Canada (Fig. 3). Geographic expansion of die-off locations continues, and outbreaks now occur during all seasons of the year (Friend 1987).

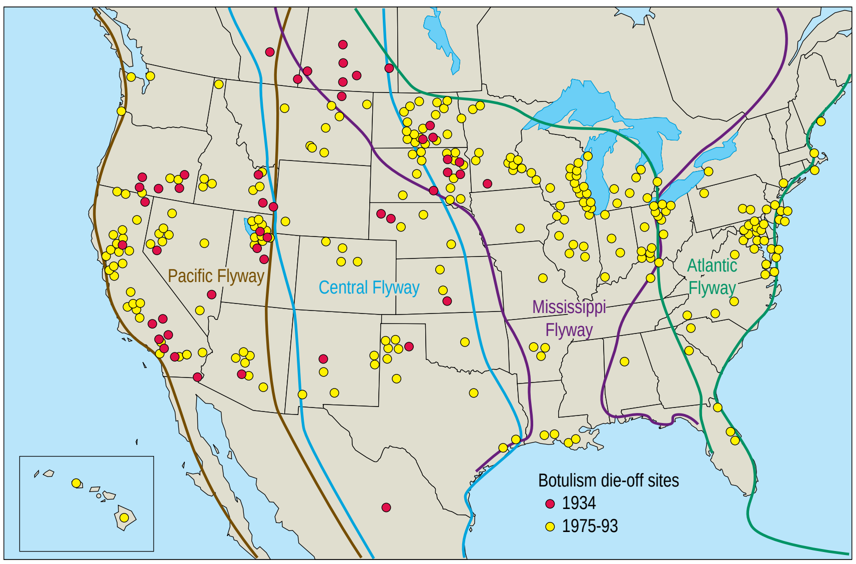

Fig. 2. Known distribution of "western duck sickness" (avian botulism) in North America, 1934 (Kalmback and Gunderson 1934), and from 1975 to 1993.

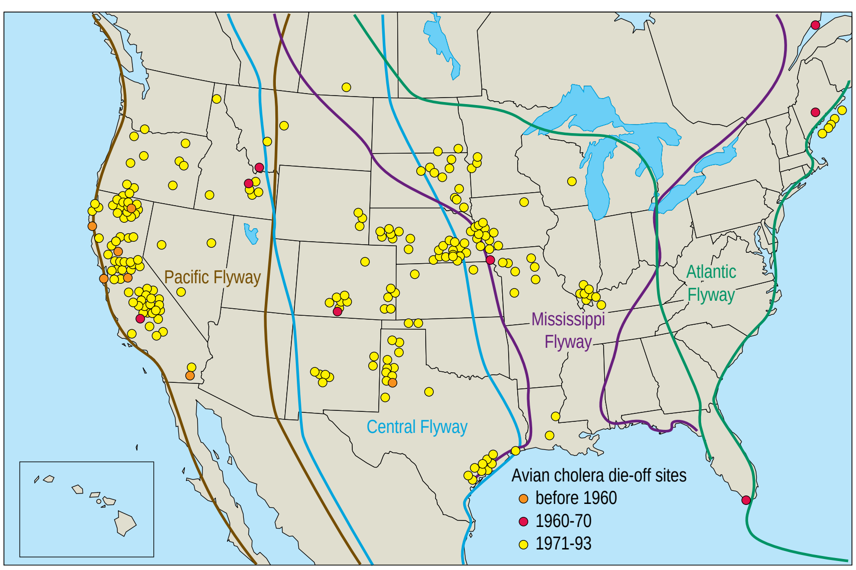

Fig. 3. Geographic distribution of avian cholera in wild waterfowl within the United States, before 1960 (first outbreak in 1944), during the 1960's, and after 1970, when disease spread (National Wildlife Health Center files).

Duck Plague

Duck plague is another emerging disease of North American waterfowl. This herpesvirus infection first appeared on the North American continent in 1967 when it caused large-scale losses in the domestic duck industry and losses of a small number of wild waterfowl (Leibovitz and Hwang 1968). The first major die-off involving wild waterfowl occurred during January 1973 at the Lake Andes National Wildlife Refuge in South Dakota (Friend and Pearson 1973). Duck plague has expanded throughout North America since the initial outbreak, along with an increasing number of outbreaks in each decade (Fig. 4). Nearly all occurrences of duck plague have involved nonmigratory waterfowl (captive, tame, and resident waterfowl that do not undergo traditional migratory movements). A February 1994 outbreak in the Finger Lakes region of New York State involving mallards (*Anas platyrhynchos*) and American black ducks (*A. rubripes*) is the first major outbreak involving migratory waterfowl since the January 1973 Lake Andes outbreak.

Other Diseases

Other diseases affecting wild birds are newly recognized, are occurring with increasing frequency, or have expanded their geographic

Disease	Cause	Species	First occurrence in species		Major expansion	Current status
			Year	Location		
Avian botulism	Bacteria	Waterbirds	1910	UT	1970's	Widespread; major problem
Avian cholera	Bacteria	Waterbirds	1944	TX,CA	1970's	Widespread; major problem
Duck plague	Virus	Waterfowl	1967	NY	1990's	Expanding
Avian pox	Virus	Waterfowl	1978	AK	1990's	Expanding
		Bald eagle	1978	AK	1980's	Stable
Salmonellosis	Bacteria	Songbirds	Historical	MA	1980's	Major problem of urban environments (bird feeders)
Canine parvovirus	Virus	Wild carnivores	1978	TX	1980's	Widely distributed
Canine heartworm	Parasite	Wild carnivores	Historical	Southeastern U.S.	1960's	Continuing spread northward from southeastern U.S.
Fibropapilloma	Unknown	Marine turtles	1938	FL	1980's	Major geographic spread; increased frequency of occurrence

Table 1. Changes in patterns of diseases affecting wildlife.

Disease	Cause	Species	Occurrence in species		Ecosystem type
			Year	Location	
Inclusion body disease of cranes	Virus	Exotic cranes	1978	WI	Terrestrial (captive-propagation flock)
Eastern equine encephalitis	Virus	Whooping crane	1984	MD	Terrestrial (captive-propagation flock)
Mycotoxicosis (Trichothecenes)	Fungus	Sandhill crane	1982	TX	Agricultural (peanuts)
Coccidioidomycosis	Fungus	California sea otter	1976	CA	Marine
Upper respiratory disease syndrome	Bacteria?	Desert tortoise	1987	NV	Desert
Avian tuberculosis	Bacteria	Whooping crane	1982	CO	Mixed; wetlands and agricultural fields
Neoplasia	Unknown	Mississippi sandhill crane	1975	MS	Mixed; wetlands and agricultural fields
Velogenic Newcastle disease	Virus	Double-crested cormorants	1990	Canada	Aquatic
			1992	Great Lakes	
Woodcock reovirus	Virus	American woodcock	1989	NJ	Forest
Seal plague	Virus	Marine mammals	1987	Russia	Inland sea
			1988	Europe	Marine
			1990	U.S.	Marine

Table 2. Emerging diseases of wildlife.

occurrence during the 20th century. Changes in disease patterns in wild birds are consistent with such changes in other species, including humans, and reflect environmental changes that foster the eruption of disease and the spread of infectious agents (Tables 1 and 2).

Magnitude of Losses

Changes over time in the frequency of wild bird die-offs and losses from disease cannot be precisely determined because no appropriate data base exists. Also, changes in surveillance and reporting confounds interpretation of existing data. Nevertheless, with the exception of rare catastrophic events, available information suggests that substantially greater numbers of wild birds are dying from diseases now than in earlier periods of the 20th century. The yearly average of 55,066 reported waterfowl deaths from disease during 1930-64 (Friend 1992) has been exceeded or nearly exceeded by single events since 1964. Several disease outbreaks, for example, have killed between 25,000 and 100,000 waterfowl; die-offs of 5,000 to 10,000 waterfowl are common.

The number of avian die-offs in the NWHC data base with reported mortality of 1,000 or more is sufficient to support the contention of increased numbers of birds dying from disease compared with the period before 1965. The annual number of avian die-offs is an additional indicator of the relatively high frequency of avian disease during the late part of the 20th century (Fig. 5).

Habitat and Human Interactions

Causes of major bird die-offs during the past decade and their geographic distribution are shown in Table 3. Composite data indicate a relation between bird concentrations and the occurrences of avian disease. Those states with large concentrations of migratory birds on migrational staging and wintering areas tend to have the most disease outbreaks. Preliminary assessments suggest that habitat quantity and quality are important factors in this relation.

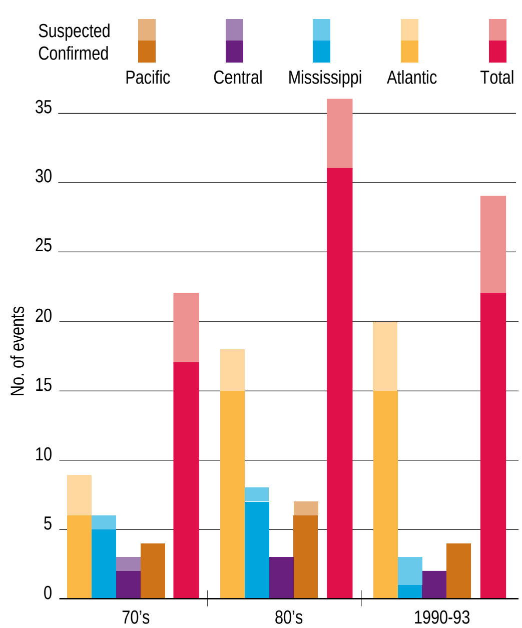

Fig. 4. Number of duck plague outbreaks in waterfowl in the United States, by flyway (suspect cases have pathology consistent with duck plague but lack isolation of the virus to confirm the diagnosis), and total number of outbreaks by decade.

Table 3. Geographic distribution of major (>500 birds) die-offs of wild birds by cause, 1983-93.

Disease	Cause	States (number of events)		
		<5	5-9	>9
Aspergillosis	Fungus	CO(1), VT(1)		
Avian botulism	Bacteria	AR(1), CO(2), KS(2), LA(2), MD(2) MI(1), MN(1), NM(1), NY(1), OH(2) OK(1), OR(4), WI(3)	ID(7) NB(5) NV(5)	CA(80), MT(14) ND(25), SD(14) UT(11)
Avian cholera	Bacteria	CO(3), IA(4), ID(1), ME(1), MN(3) OR(1), NM(4), NV(1), SD(1)	MO(5)	CA(21), NB(13) TX(18)
Chlamydiosis	Bacteria	ND(1)		
Erysipelas	Bacteria	MD(1)		
Mycotoxicosis	Fungus	TX(3)		
Myocardiopathy	Unknown	CA(1)		
Necrotic enteritis	Bacteria?	ND(3), SD(1)		
Newcastle disease	Virus	MN(1), ND(2), SD(1)		
Salmonellosis	Bacteria	CA(2), VT(1), WA(1)		
Toxicosis	Environmental contaminants	AZ(1), CA(2), IL(1), NV(1), VA(1)		
Trichomoniasis	Parasite	CA(1), NM(1)		

Wetland losses, for example, are well documented and clearly a contributing factor in the spread of avian cholera. California, a focal point for the occurrence and spread of avian cholera in waterfowl, lost 91% of its historical wetland acreage by 1980 (Dahl 1990). A similar situation exists in the Rainwater Basin of Nebraska where avian cholera first appeared in waterfowl in 1975; this area has subsequently become a focal point for spread to other areas. About 90% of historical wetland acreage within the Rainwater Basin has been lost (Farrar 1980). The association between wetland losses and spread of infectious disease is due to the interactive factors that aid disease transmission.

Habitat (environment) loss often results in crowding birds on the remaining habitat, thereby enhancing the potential for transmission of infectious agents. Movement patterns of infected birds can spread the disease to other locations and populations and help establish the disease as a recurring problem.

High concentrations of birds for prolonged periods of time on limited habitat often degrade the quality of habitat through fecal contamination and damage to vegetation. Deposition and survival of pathogenic parasites and microbes are aided by such environmental conditions and can result in enhanced disease maintenance and spread.

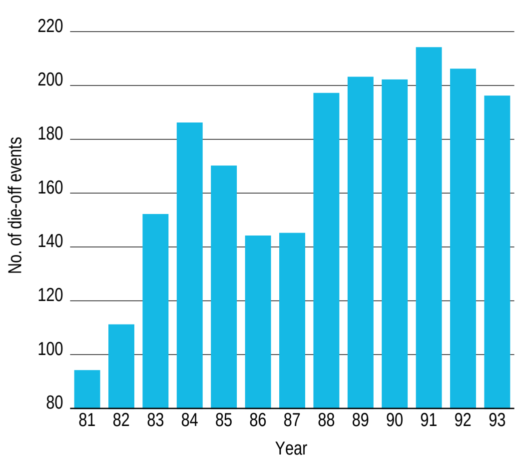

Fig. 5. Number of wild bird die-off events listed in the National Wildlife Health Center data base, 1981-93.

Habitat degradation due to human-caused factors is also important. For example, although the bacterium responsible for avian botulism is a common inhabitant of wetland substrates, the production of the botulinum toxin that causes botulism is dependent on specific environmental factors such as ambient temperature, pH, oxygen depletion, and other factors (Locke and Friend 1987). Discharges into wetlands of sewage, agricultural chemicals, and poultry wastes from factories have frequently been associated with eruptions of avian botulism, although cause and effect relationships have not been clearly established.

Prevention of Avian Diseases

Diseases affecting wild birds can be prevented and controlled despite the challenges of dealing with species and populations that are often highly mobile and spend much or all of their lives in remote areas.

Methodical monitoring and surveillance programs are needed to provide early detection of emerging problems so that intervention can begin when problems are most manageable. Accurate diagnostic assessments of the causes of morbidity and mortality are essential for focusing control efforts. Also, greater emphasis is needed on studies of disease ecology to provide enhanced understanding of host-agent-environment relationships for specific diseases. This information serves to identify weak links where disease-control and prevention efforts will be most effective. Molecular biology and the associated field of genetic engineering will greatly assist these efforts.

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For further information:

Milton Friend
National Biological Service
National Wildlife Health Center
6006 Schroeder Rd.
Madison, WI 53711

Captive Propagation, Introduction, and Translocation Programs for Wildlife Vertebrates

by
Joshua Dein
Kathryn Converse
National Biological Service
Christy Wolf
University of Wisconsin

Captive propagation, introduction, and translocation (relocation) programs for many animals have been undertaken by federal, state, and private agencies for more than 20 years. These programs help aid the recovery of endangered and threatened species, reestablish lost species, augment declining populations, increase recreational opportunities, reduce nuisance species, and introduce non-native species. Davidson and Nettles (1992) discuss translocation as a component of successful early restorations of game species including wild turkey (*Meleagris gallopavo*) and white-tailed deer (*Odocoileus virginianus*), and recovery of endangered species such as the peregrine falcon (*Falco peregrinus*). Despite some successes, the total number of translocations that occur yearly is unknown, as is the success and effects of these programs, because there is rarely appreciable monitoring after release (Griffith et al. 1989; Gogan 1990). This report focuses on trends in the use of translocation programs and disease transmission following translocation of wildlife vertebrates other than fish.

In the absence of a national data base on wildlife translocations, a search for publications with information on translocations was performed by using *Wildlife Review* and the U.S. Fish and Wildlife Reference Service CD-ROM data bases for the 20-year period, 1971-91. In addition, personnel from multiple federal, state, and private agencies that conduct propagation and translocation programs were contacted for supplemental information and literature. Increasing numbers of books (Neilsen and Brown 1988), journals (Ullrey 1993), and meetings (Junge 1992; Wolff and Seal 1992) discuss wildlife translocations and many contain information on the effects of translocations on animals and their environment.

Trends

Of 292,628 citations reviewed, 1,431 addressed translocations. There were relatively high percentages of citations that included translocation programs in the early 1970's and again in the late 1980's with a general increasing trend overall (Fig. 1). Although the number of publications probably underestimates the true extent of translocation programs, it does demonstrate the trend of continued interest, research, and publication over the past 20 years.

Griffith et al. (1989) published a comprehensive survey that estimated an average of 515 translocations per year (414 programs) of terrestrial vertebrates occurring in the United States, Canada, New Zealand, and Australia between 1973 and 1989; 98% were conducted in the United States and Canada. Birds were most frequently (59%) translocated (Fig. 2); 92% of the translocations involved game species, 7% endangered and threatened species, and 1% nongame species (Griffith et al. 1993). Of the 261 translocations in the United States reported by Griffith et al. (1993), wild species were most frequently translocated, and the Southeast had the greatest number of translocations (Table 1).

In 1985 Boyer and Brown (1988) surveyed the 50 state conservation agencies; 29 confirmed they were translocating mammals (56% native game species, 5% nongame species, and 5% endangered species). In addition, 19 states reported that mammals were translocated by private agencies in their states.

A 1993 follow-up to the Griffith et al. (1993) survey suggests that many of the 414 programs originally surveyed were still releasing animals (C. Wolf, University of Wisconsin, unpublished data). The average duration of these translocation programs was 4.8 years, an increase from

Captive-reared whooping crane chicks released in Kissimmee Prairie, Florida, 1993.

the 3 years estimated by Griffith et al. (1989). Boyer and Brown (1988) reported that 40 states projected either no change or an increase in translocation activity.

It is impossible to estimate the total number of animals released throughout the United States, but Maryland provides an example of an ongoing and intensive propagation and release program for mallard ducks to augment the natural population. The state released 409,838 mallards from 1967 to 1991. An estimated 100,000-150,000 ducks per year are also released in Maryland by private parties onto regulated shooting areas (L. Hindman, Maryland Department of Natural Resources, personal communication).

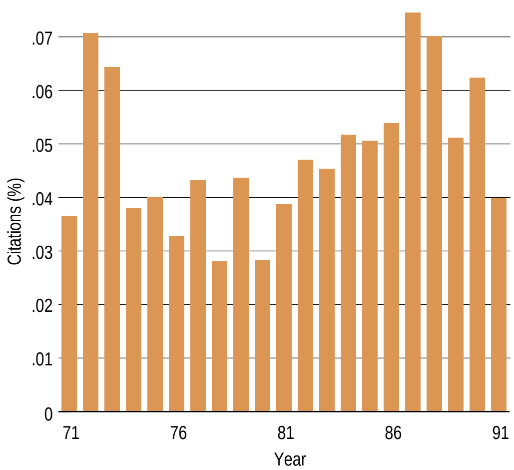

Fig. 1. Percentage of citations relating to translocations, 1971-91. Sample size = 292,628.

Disease

Every animal represents a living micro-ecosystem containing bacteria, viruses, fungi, and parasites. Wildlife scientists now recognize the translocation of a wild animal never represents movement of a single species (Davidson and Nettles 1992). Unless health-monitoring programs for source populations are in place, the risk is greater that hazardous disease agents may be moved and released into new environments along with the species of interest.

Table 1. Percentages of translocations by geographic area and source of translocated animals, 1973-86 (Griffith et al. 1993).

Geographic area U.S. regions	Wild (%)	Captive (%)*	Total no. translocations
Northwest	85	15	53
Southwest	88	12	24
Central	82	18	40
Southeast	62	38	61
Northeast	89	11	46
Rocky Mountain	81	19	37

*May include some wild-caught animals.

This threat also exists in reverse, of course: animals for which a significant amount of money has been spent on their production may be decimated by a disease agent existent at the release site. Success of a whooping crane (*Grus americana*) reintroduction program in Idaho was limited by disease, and the current whooping crane reintroductions in Florida face similar challenges.

Williams et al. (1992) documented the importance of overcoming disease problems to have a successful reintroduction program. Table 2 summarizes other documented incidents of disease introduction into new environments via animal translocations. These diseases have substantial effects on wildlife, domestic animals, and humans.

Conclusions

Data presented here show a consistent if not increasing trend in the number of translocation programs between 1971 and 1991. Multiple disease problems have been documented in animals moved in similar programs. We are alarmed because many of these programs will continue and probably increase in the future, and because most programs do not monitor or follow up to detect ecosystem change caused by translocations. Griffith et al. (1989) found only 27% of the agencies that responded to their survey followed specific protocols for collecting and recording information during translocations. These data indicate a need for a national

Raccoon Rabies: Example of Translocation, Disease

The spread of raccoon (*Procyon lotor*) rabies in the eastern United States is an excellent example of disease transmission through the movement of animals (Winkler and Jenkins 1991).

The first reported raccoon rabies occurred in Florida in the early 1950's. Between the 1950's and 1977, rabies spread by raccoon-to-raccoon transmission primarily within Florida and Florida to Georgia.

More than 3,500 raccoons were trapped in Florida and transported to Virginia between 1977 and 1981 to restock raccoon populations and provide increased hunting opportunities. Rabid raccoons were confirmed in shipments of animals to Virginia and North Carolina from Florida.

After these shipments, between 1977 and 1994, mid-Atlantic rabies outbreaks spread north to Virginia, Maryland, Pennsylvania, District of Columbia, Delaware, New York, New Jersey, Connecticut, Massachusetts, Vermont, and New Hampshire, and south to North Carolina (Jenkins et al. 1988; Rupprect and Smith 1995).

Studies of rabies viruses have shown great similarity between rabies virus isolates from raccoons collected between 1950 and 1977 in Florida and Georgia and the mid-Atlantic outbreaks (Winkler and Jenkins 1991). There is increased public health concern about human contact with the rabid animals that are common in densely populated urban and suburban areas.

Table 2. Some diseases transmitted by or to translocated animals in the United States (adapted from Woodford 1993).

Species translocated	Source*	Disease or agent	Release area	Species affected	Reference
Desert tortoise	Pet shops, w/c	*Mycoplasma*	Mojave Desert	Desert tortoise	Jacobson et al. 1991
Whooping crane	MD, c/b	Avian tuberculosis	ID	Whooping crane	Snyder et al. 1991
Waterfowl	Various, c/b	Duck plague	Various	Waterfowl	Brand 1987
Wild turkey	Various, w/c, c/b	*Mycoplasma*	Various	Wild turkey	Davidson et al. 1982
Parrot	Central, S. Am., w/c	Newcastle disease	CA	Domestic poultry, pet birds	Utterback 1973
Raccoon	FL, w/c	Rabies	VA	Raccoon; 6 other spp.	Winkler and Jenkins 1991
	TX, w/c	Parvovirus	WV	Skunk, raccoon	Nettles et al. 1980
Red fox	OH, other states	*Echinococcus multilocularis*	SC	Unknown	Davidson et al. 1992
Bighorn sheep	Los Angeles Co., CA, w/c	Contagious ecthyma (Orf)	Ventura Co., CA	Human	Jessup et al. 1991
	ID, w/c	Scabies (mange mite)	OR	Human	Thorne et al. 1992
Tule elk	CA, w/c	Paratuberculosis	Pt. Reyes, CA	Tule elk (from contact with domestic cattle)	Jessup et al. 1981
Elk, caribou	Various, w/c	Brainworm	Various, w/c	Elk, caribou (from contact with wild white-tailed deer)	Samuel et al. 1992

*w/c—wild caught, c/b—captive bred.

data base and monitoring program for propagation, introduction, and translocation programs. This data base should be readily available to managers planning similar programs and should provide a mechanism for assessing the positive and negative effects of these programs.

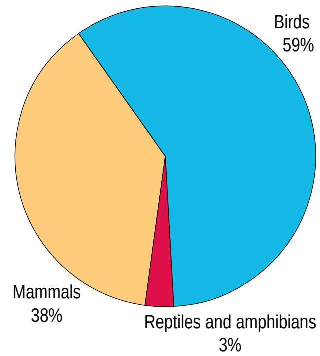

Fig. 2. Percentage of translocated animals by classes, 1971-86; average number of translocations per year was 515 (Griffith et al. 1993).

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For further information:

Joshua Dein
National Biological Service
National Wildlife Health Center
6006 Schroeder Rd.
Madison, WI 53711

Contaminants in Coastal Fish and Mollusks

by
Donna Turgeon
Andrew Robertson
National Oceanic and Atmospheric Administration

Historically, U.S. coastal fish and shellfish have been plentiful, supporting native carnivores such as ospreys, bald eagles, striped bass, sharks, sea lions, porpoises, and whales in ecosystem food webs. Since the 1960's, however, the capacity of coastal ecosystems to produce abundant fish and shellfish has declined. Increasingly frequent reports of closures of shellfish beds and bathing beaches, contamination of living resources and habitats by toxic chemicals, decreases in commercial fish stocks, shallow-water strandings of porpoises and pilot whales, losses of wetland habitat, and spread of toxic and nuisance algal blooms indicate there has been widespread environmental degradation.

As part of the national response to concerns over the deteriorating health of our coastal ecosystems, several federal and state programs monitor changes in the levels of toxic chemicals in select organisms at coastal sites. In general, contaminant levels have been found to be holding steady or, in the case of several contaminants, decreasing in coastal areas over the past few years, reversing the trends of contaminant increases that occurred in the first two-thirds of this century.

The National Oceanic and Atmospheric Administration (NOAA) initiated its National Status and Trends (NS&T) Program in 1984 with its National Benthic Surveillance Project. The project monitors concentrations of about 70 chemical contaminants (Table) in fish livers and sediments and investigates some of the effects of these chemicals on fish (e.g., liver tumors, reproductive impairment, fin loss) from nearshore waters of the Atlantic, Gulf of Mexico, and Pacific coasts, including Alaska. In 1986, the NS&T Program began its Mussel Watch Project to monitor concentrations of the same contaminants in the tissues of bivalve mollusks (primarily mussels and oysters) and sediments. More than 350 coastal sites (Fig. 1) of the continental United States, off Hawaii, several Caribbean islands, and in the Great Lakes are regularly monitored. Since 1986 the NS&T Program also has conducted intensive studies of the magnitude and extent of contaminant effects on selected indicator species from the most contaminated U.S. estuaries (Wolfe et al. 1993).

Methods

All sites are located away from known point sources and dumpsites (Lauenstein et al. 1993). Sites are sampled every 1-2 years for biota and less frequently for sediments. Sediments for chemical analyses are collected from the top 2 cm (0.75 in) of grab samples. Mollusks (e.g., oysters, clams, and mussels) are dredged from deep subtidal zones or hand-collected in intertidal to shallow subtidal zones. Fish are sampled by otter trawl tows in depths of 1-70 m (3-230 ft). Details of sampling protocols and methods of analysis are described elsewhere (Lauenstein and Cantillo 1993).

Sediment contaminant concentrations have been adjusted for particle size to account for differences in concentrations due to variations in physical properties of absorption surfaces among large-grained sands, fine muds, and sediment mixtures (NOAA 1988). Measurements for individual chemicals have been combined for groups of related compounds. Thus total PCB (polychlorinated biphenyl) is based on the sum of the concentrations of 20 PCBs; total PAH (polycyclic aromatic hydrocarbon) is the sum of 24 PAH compounds; total DDT (1,1'-[2,2,2-trichloroethylidene]bis[4-chlorobenzene]) is the sum of the concentrations of DDT and its metabolites; and total chlordane is the sum of the concentrations of two major constituents of chlordane mixtures (*cis*-chlordane and *trans*-nonachlor) and two minor components (heptachlor and heptachlorepoxide).

The primary species of mollusks monitored are the eastern oyster (*Crassostrea virginica*), the northeastern and west coast species of mussels (*Mytilus edulis*, *M. trossulus*, and *M.*

Table. Chemicals measured in the National Oceanic and Atmospheric Administration's National Status and Trends Program.

Chemicals measured		
DDT and its metabolites	**Polycyclic aromatic hydrocarbons**	**Major elements**
2,4'-DDD	*2-ring*	Aluminum
4,4'-DDD	Biphenyl	Iron
2,4'-DDE	Naphthalene	Manganese
4,4'-DDE	1-Methylnaphthalene	Silicon
2,4'-DDT	2-Methylnaphthalene	
4,4'-DDT	2, 6-Dimethylnaphthalene	
	1,6,7-Trimethylnaphthalene	
Tetra-, tri-, di-, and monobutyltins	*3-ring*	**Trace elements**
	Flourene	Antimony
	Phenanthrene	Arsenic
	1-Methylphenanthrene	Cadmium
Chlorinated pesticides other than DDT	Anthracene	Chromium
Aldrin	Acenapthene	Copper
Chlordanes	Acenaphthylene	Lead
cis-Chlordane		Mercury
trans-Nonachlor	*4-ring*	Nickel
Heptachlor	Fluoranthene	Selenium
Heptachlor epoxide	Pyrene	Silver
Dieldrin	Benz[*a*]anthracene	Tin
Hexachlorobenzene	Chrysene	Zinc
Lindane (gamma-HCH)		
Mirex	*5-ring*	
	Benzo[*a*]pyrene	
	Benzo[*e*]pyrene	**Toxaphene at some sites**
	Perylene	
Polychlorinated biphenyls	Dibenz[*a,h*]anthracene	**Related parameters**
PCB congeners 8, 18, 28,	Benzo[*b*]fluoranthene	Grain size
44, 52, 66, 77, 101, 105,	Benzo[*k*]fluoranthene	Total organic carbon (TOC)
118, 126, 128, 138, 153,		*Clostridium perfringens* spores
179, 180, 187, 195, 206, 209	*6-ring*	
	Benzo[*g,h,i*]perylene	
	Indeno[1,2,3-*cd*]pyrene	

californianus), and the Great Lakes zebra mussel species *(Dreissena polymopha)*. The six primary fish species monitored nationwide are winter flounder (*Pleuronectes americanus*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), flathead sole (*Hippoglossoides elassodon*), white croaker (*Genyonemus lineatus*), and starry flounder (*Platichthys stellatus*).

Status and Trends

Contaminants in Sediments (1984-90), Bivalves (1986-90), and Fish (1984-88)

Nationwide, the highest concentrations of the chemicals measured in coastal sediments were found near urbanized areas of the Northeast (New York City, Boston, and Baltimore) and the west coast (San Diego, Los Angeles, and Seattle). An NS&T inventory revealed that more than 90% of the coastal and estuarine areas have concentrations below "High" (the geometric mean plus one standard deviation of all NS&T site means). The greatest number of sites with concentrations greater than five times the "High" ("5 x High") was near densely populated areas in poorly flushed water bodies (e.g., harbors and intracoastal waterways) of the Northeast and Gulf of Mexico. The most common chemicals in the inventory at these "5 x High" levels were metals in decreasing frequency: mercury, cadmium, tin, and silver. Total PAH was the organic compound group most commonly found in the "5 x High" range, a finding important to the consumption of fish and mollusks taken near highly contaminated sites. According to the U.S. Environmental Protection Agency, 22 states had advisories warning against consumption of fish and shellfish from coastal waters in 1992 (Fish Consumption Database 1993).

Mollusks accumulate many organic and inorganic contaminants. Although tissue concentrations of organic contaminants did not vary by species, tissue concentrations of several inorganic contaminants were species-dependent (O'Connor 1993). Mercury was used to illustrate the national spatial distribution of contamination in mollusks because differences in tissue concentrations are not species-dependent (Fig. 2). Mercury concentrations in mollusks from sites with corresponding high sediment concentrations off Texas, Florida, and California were among the highest measured. The highest concentrations of organic contaminants in molluscan tissues were found at sites with corresponding high sediment concentrations, near Boston, New York City, Mobile, San Diego, San Francisco, and Los Angeles (O'Connor 1992).

Levels of silver, lead, and the organic compounds (total DDT, total chlordane, and total PCBs) in fish livers have been found to be positively correlated with sediment concentrations (i.e., high levels of contaminants in sediments and high levels in fish livers from the same site; Turgeon et al. 1993). Figure 3 illustrates the distribution of mean concentrations of lead and total DDT in the livers of fish from sites along the east, Gulf of Mexico, and west coasts. Concentrations of lead were highest in winter flounder from Casco Bay in Maine, in Atlantic croaker from the Elizabeth River in Virginia, and in white croaker from San Diego and San Pedro bays in California. Concentrations of total DDT were highest in white croaker from San Pedro Bay and winter flounder from the Hudson-Raritan Estuary in New York and New Jersey.

Contamination assessments have been made for selected regions and compared with sites nationwide (e.g., Turgeon et al. 1989; Gottholm and Turgeon 1992; Gottholm et al. 1993). For example, mean concentrations of total DDT in sediment from 213 sites, mussel tissue from 111 sites, and fish liver from 118 sites nationwide were compared to mean concentrations at 14 Hudson-Raritan Estuary and coastal New Jersey sites (Gottholm et al. 1993). Among these sites, concentrations in sediments were all above the national median, whereas concentrations in mussel tissues were at or above the median at most sites. Advisories (Fish Consumption Database 1993) were in effect warning against consumption of fish and shellfish collected from much of the Hudson-Raritan Estuary area. NS&T-sampled sites with high levels of contaminants were within the fish-consumption advisory area (Fish Consumption Database 1993) and a health advisory area (New York State Department of Health 1993).

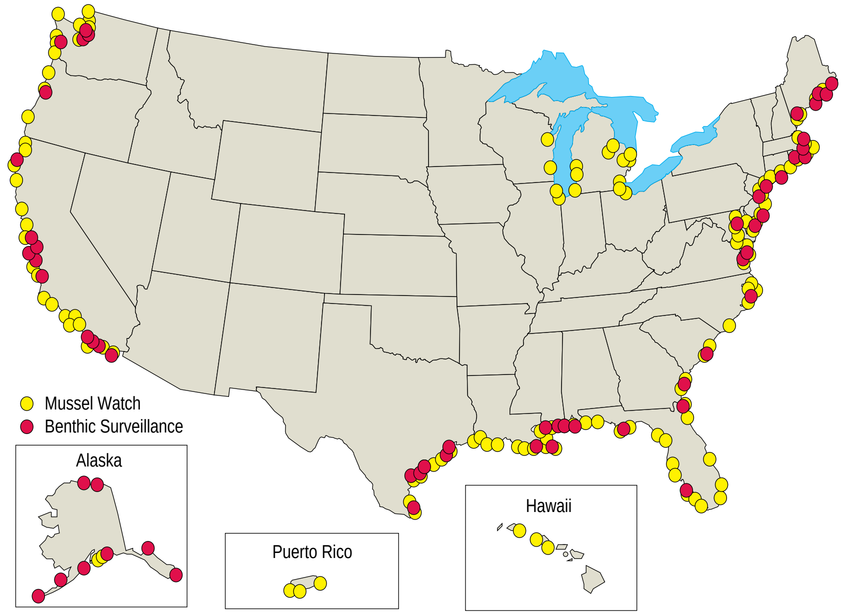

Fig. 1. The National Oceanic and Atmospheric Administration's National Status and Trends Program monitors more than 350 sites nationwide for chemical contaminants in fish livers, bivalve molluscan tissues, and associated sediments. Yellow symbols depict Mussel Watch Project (molluscan and sediment monitoring) and red symbols depict National Benthic Surveillance Project (fish and sediment monitoring) sites.

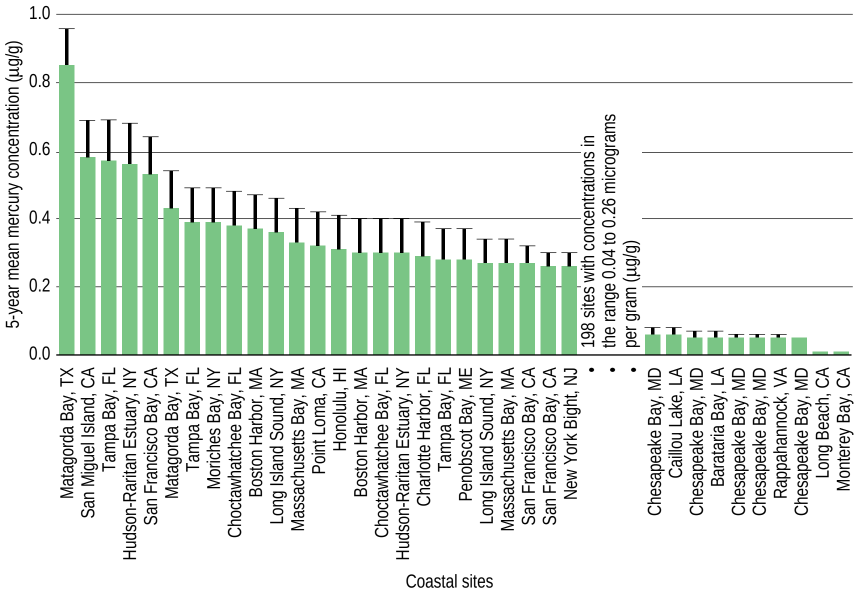

Fig. 2. Mercury in molluscan tissues from the National Oceanic and Atmospheric Administration's National Status and Trends Program coastal sites. Bar graphs are 5-year (1986-90) mean concentrations (mercury measurements in micrograms per gram dry weight) and standard deviations ("T" symbols on bars).

Contaminants in Surface Sediments, Bivalves, and Fish

Recent national and regional trends for certain contaminants have been identified in data from fish livers (McCain et al. 1992), surface sediments (O'Connor 1990; Wade et al. 1992), and molluscan tissues (O'Connor 1992). A statistical test (Spearman rank-correlation) was used to detect trends in annual mean concentrations of 14 chemicals at 141 sites with 4 or 5 years of molluscan monitoring data (O'Connor 1992). Among 1,974 chemical-site combinations, there were 239 occurrences (152 decreasing and 87 increasing) with strong correlations between those concentrations and time. The hypothesis was offered that similar trends among sites in an area corroborate that the trend is real and areawide. For example, at nine Long Island Sound (New York) sites, decreases occurred in copper at six sites, cadmium at five, silver at four, and zinc at three. An apparent 20-year decreasing trend in annual concentration of total PCB in mussels has been recorded at Palos Verdes, California.

Contaminants Determined from Dated Sediment Cores

Trends in contamination can also be detected from contaminant profiles in dated estuarine and coastal sediment cores. Since 1989 the NS&T Program has sponsored projects that use sediment cores to reconstruct the history of contamination in U.S. coastal waters (Hudson-Raritan Estuary, Long Island Sound, Chesapeake Bay, Savannah River, southern California Basin, San Francisco Bay, and Puget Sound). In 1994 sediment cores were analyzed for sites in the Mississippi River Delta and Galveston Bay. Generally, results show a slow increase in contamination in the late 1800's, followed by an acceleration of pollution in the mid-1900's. Maximum contamination was reached around the mid-1970's, and in most areas a decrease has been observed for anthropogenic contaminants (e.g., antimony, lead, DDT, and PCBs; Valette-Silver and O'Connor 1989; Valette-Silver et al. 1994).

Selected Studies in Highly Contaminated Coastal Areas

Liver neoplasms (cancerous tumors) were found in 10 fish species collected from 1984 to 1988 from sites near urban centers along the west and northeast coasts (Turgeon et al. 1992). Scientists concluded that the contaminants most likely to be factors in the development of these tumors were the PAHs, PCBs, and DDTs (Myers et al. 1993).

Although incidences of cancerous tumors are generally low in fish from U.S. coastal waters, other liver disease conditions, some of which may progress to neoplasms, occur more frequently in areas where contaminants are high. Neoplasms and pre-neoplasms (pre-cancerous tumors) were found in up to 15% of the winter flounder from sites in Boston Harbor (Murchelano and Wolke 1991). Along the west coast, neoplasm incidences are well below 10% in most fish species (Myers et al. 1993). Relatively high incidences of nontumorous disease conditions occur in fish from contaminated sites. For example, in English sole (*Parophrys vetulus*) from Elliott Bay, Washington, incidences of 42% for specific degeneration and necrosis (SDN) of liver cells and 13% proliferative disorders (cells duplicating out of control) have been recorded; and in white croaker from San Pedro Outer Harbor, California, 22% SDN and 7% for proliferative disorders have been found (Varanasi et al. 1989; Myers et al. 1993). At Morris Cove, a highly contaminated site in New Haven, Connecticut, up to 90% of the cells in winter flounder livers have been found to be vacuolated cells (large areas of apparently empty, nonfunctioning cells; Gronlund et al. 1991).

Although fin erosion (fish with reduced fins or in extreme stages of disease with no fins) has been found in all species at all sites, this condition is still unusual, except in a few highly contaminated areas. Eroded fins occurred in 27% of the black croaker (*Cheilotrema saturnum*) and 22% of barred sand bass (*Paralabrax nebulifer*) from the West Harbor site in San Diego Bay, California (McCain et al. 1989). Up to 90% of Atlantic croaker, 100% of sand seatrout (*Cynoscion arenarius*), and 17% of spot sampled from the Houston Ship Channel at Green Bayou, Texas, experienced fin loss due to disease (P. Hanson, National Marine Fisheries Service, personal communication).

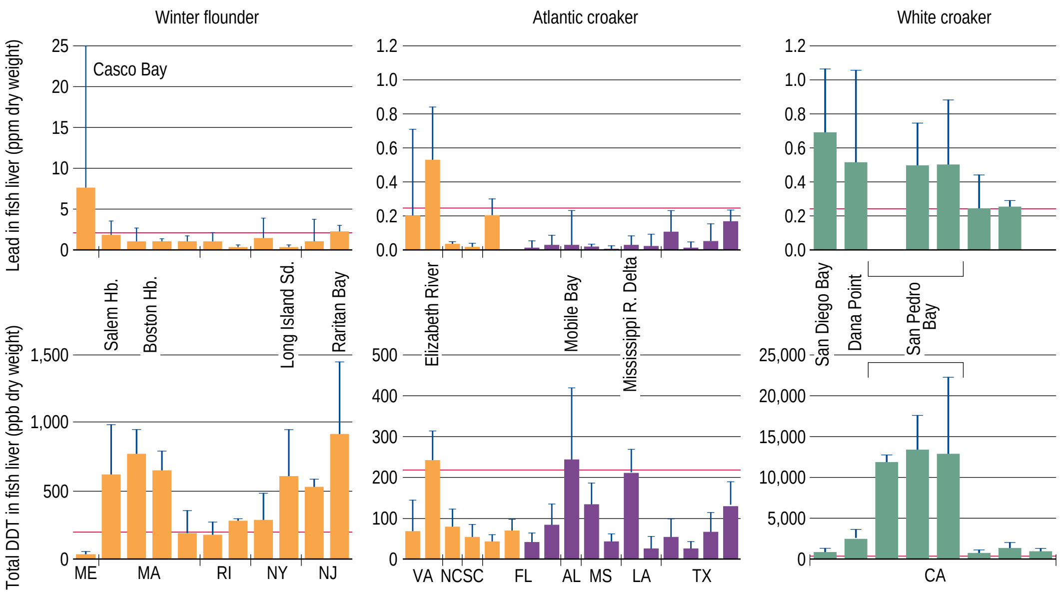

Fig. 3. Lead (Pb) and total DDT in fish livers from the National Oceanic and Atmospheric Administration's National Status and Trends Program coastal sites. Bar graphs are 5-year (1984-88) mean concentrations (Pb measurements in parts per million dry weight; total DDT in parts per billion dry weight) and standard deviations ("T" symbols on bars).

Reproductive impairment occurred in fish from Eagle Harbor and Duwamish Waterway in Puget Sound, San Francisco and San Pedro bays, and in Morris Cove. Significantly lower levels of estradiol (a reproductive hormone) and vitellogenin (yolk protein critical to the development of fertile eggs for reproduction) have been found in English sole from contaminated sites in Puget Sound than those at relatively clean sites (Johnson et al. 1989). Also, a significant proportion of fish from contaminated sites failed to produce yolked eggs and undergo normal ovarian development. Moreover, fewer English sole spawned from the Duwamish Waterway (54%) in comparison with those from Port Susan during the 1987 and 1988 reproductive seasons (Casillas et al. 1991).

White croaker from a site near Los Angeles and kelp bass (*Paralabrax clathratus*) from San Pedro Bay had lower reproductive succcess than those from less contaminated sites at Dana Point and Santa Catalina Island (Cross and Hose 1989). In this study, the percentage of spawning fish was 24%-68% lower, batch fecundity (number of eggs produced) was 36%-44% lower, and the proportion of eggs fertilized was 14%-45% lower at the contaminated site. Gonadally mature female starry flounders from an urbanized central San Francisco Bay site off Berkeley had a reduced proportion of floating eggs and poorer fertilization success than those captured at a site in northern San Pablo Bay (Spies and Rice 1988). In Long Island Sound, embryo abnormalities were most frequent and hatching success was lowest in female winter flounders from more contaminated sites near Milford and New Haven; larvae were smallest off Deer Island, a highly contaminated site in Boston Harbor (Nelson et al. 1991). Thus, we conclude that at contaminated sites the observed lower reproductive success of sampled benthic fish could have long-term effects on spawning populations from contaminated sediments.

Impacts of Contaminants on Coastal Ecosystems

Results from NS&T monitoring have helped define the body burdens of toxic contaminants, evaluate trends in these contaminant data, and assess certain related biological effects in fish and shellfish from more than 350 estuarine and coastal sites over the past 10 years. Contaminant levels have been found to be quite low in most U.S. coastal areas, although substantially elevated levels of a number of contaminants have been measured near most major urban centers. Some biological effects associated with contaminants have been found near these same urban centers, but there is little indication of widespread acute biological effects on benthic fishes and bivalves associated with toxic contaminants throughout most of the U.S. coastal waters. Overall, contaminant levels have been stable or, for a few contaminants, decreasing in the past few years.

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For further information:

Donna Turgeon
National Oceanic and Atmospheric Administration
National Status and Trends Program
N/ORCA 22, Bldg. SSMC4
1305 East-West Highway
Silver Spring, MD 20910

Persistent Environmental Contaminants in Fish and Wildlife

by
C.J. Schmitt
C.M. Bunck
National Biological Service

The publication of *Silent Spring* (Carson 1962) highlighted the potential for dichlorodiphenyl trichloroethane (DDT) and other pesticides that persist in the environment to accumulate in and to harm fish, wildlife, and the ecosystems upon which they depend. The federal government responded in the mid-1960's by establishing a multi-agency program to monitor the concentrations of pesticides and, later, other long-lived toxic contaminants in all segments of the environment.

The U.S. Fish and Wildlife Service (USFWS) participated in this program by periodically measuring contaminant concentrations in freshwater fish and birds (Johnson et al. 1967). Fish were selected for monitoring aquatic ecosystems because of their tendency to accumulate pesticides and other contaminants. The European starling (*Sturnus vulgaris*) was selected for monitoring contaminant levels in terrestrial habitats because of its varied diet and wide geographic distribution. Following a successful pilot study (Heath and Prouty 1967), the wings of hunter-killed ducks were used to monitor contaminants in duck populations of the major flyways, and thereby to also provide an assessment of contaminant levels in wetlands. The USFWS maintained this National Contaminant Biomonitoring Program into the 1980's, with the objective of continuing the documentation of temporal and geographic trends in contaminant concentrations (Prouty and Bunck 1986; Bunck et al. 1987; Schmitt and Brumbaugh 1990; Schmitt et al. 1990).

Status and Trends

During the two decades spanned by USFWS contaminant monitoring, the use of persistent insecticides such as DDT was greatly curtailed, and concentrations in fish and wildlife declined. In the environment, DDT breaks down gradually into several different toxic metabolites, of which dichlorodiphenylethylene (DDE) is the most stable and most toxic. A downward trend was clearly evident for DDE in all three networks (Fig. 1), indicating that the total DDT burden in North America declined. In fish, DDE increased from about 70% of total DDT in 1976 to about 74% in 1986 (Fig. 2).

As existing DDT is metabolized, DDE increases proportionally if DDT inputs are reduced; the proportional change evident in fish therefore provides additional evidence of reduced inputs to North American ecosystems. A similar trend toward increasing percentages of DDE relative to DDT has been noted elsewhere (Aguillar 1984), indicating that the global DDT burden is also declining.

In the United States, the bioaccumulation (*see* glossary) of DDT led to eggshell thinning in fish-eating birds such as the bald eagle (*Haliaeetus leucocephalus*). The resulting decline in recruitment of young to bald eagle populations caused the near extirpation and subsequent listing of this species as endangered in the conterminous states (Federal Register 1978). The downward trend of DDT concentrations documented in fish, starlings, and duck wings (Figs. 1 and 2) was paralleled by declining DDE concentrations in bald eagle eggs, and eagle eggshell thickness increased (Wiemeyer et al. 1993). Corresponding increases in recruitment have led to bald eagles repopulating many areas (Fig. 2), and reclassification of the bald eagle from endangered to threatened has been proposed for most of the conterminous states (Federal Register 1994).

In addition to the effects of DDT and its metabolites on eggshell thickness, these compounds, as well as PCBs (polychlorinated biphenyls) and other contaminants, are reported to interfere with other reproductive and maturation processes in fish and wildlife (e.g., Fry and Toone 1981). Although overall concentrations have declined, residues of DDT, other insecticides, and PCBs remain widespread, and problem areas are still evident. In the United States, concentrations of DDT (mostly as DDE) remain highest in fish and wildlife from areas in the South, Southwest, and Northwest where DDT was used to protect cotton and orchards from insects; in the Northeast, where it was used to control mosquitos; and near former centers of DDT production and formulation. Areas affected by former production centers include northern Alabama, near the former Red Stone Arsenal—now Wheeler National Wildlife Refuge (O'Shea et al. 1980); and the Arkansas, Tombigbee, Alabama, and Tennessee rivers (Fig. 3).

Concentrations of other persistent insecticides that are no longer in widespread use, such as heptachlor, dieldrin, endrin, and chlordane, have also declined in all three networks (Prouty and Bunck 1986; Bunck et al. 1987; Schmitt et al. 1990). Nevertheless, residues of chlordane remain sufficiently high in fish from some areas of the Midwest to warrant the issuance of human consumption advisories by state health agencies. Concentrations are also high in Hawaii, where chlordane and other chemically similar compounds were used against termites and agricultural pests, as they were in the Midwest.

Chlordane is a mixture of structurally similar compounds that decompose at different rates over time. The composition of the chlordane mixture present in fish has changed during the 1980's in a manner indicative of an overall

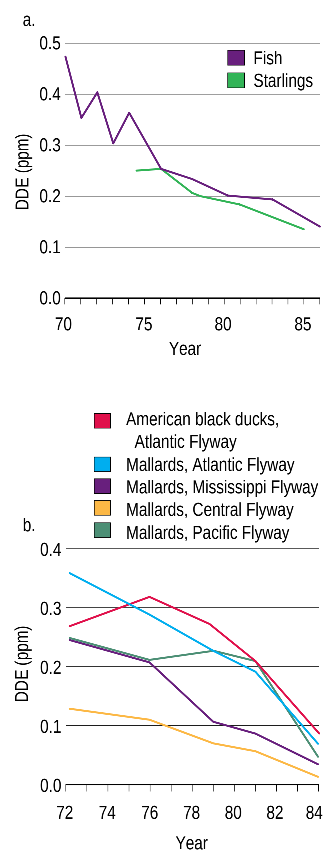

Fig. 1. Mean concentrations of DDE in U.S. Fish and Wildlife Service monitoring networks: (a) fish and starlings and (b) flyway populations of mallards and American black ducks.

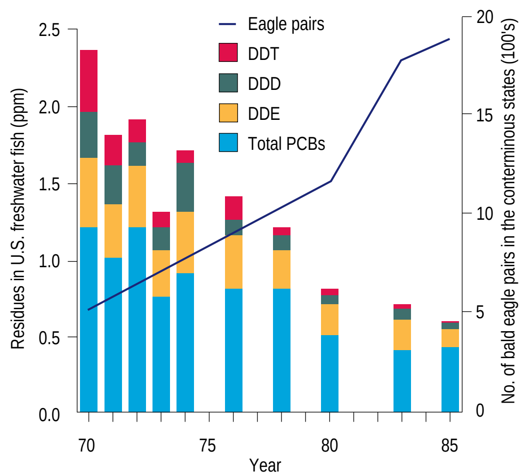

Fig. 2. Mean concentrations of DDT and its primary metabolites, DDE and DDD (TDE—dichlorodiphenyldichloroethane), and of total polychlorinated biphenyls (PCBs), in fish,1970-86. Also shown are the estimated number of bald eagle pairs in the conterminous United States during the same period (Federal Register 1994).

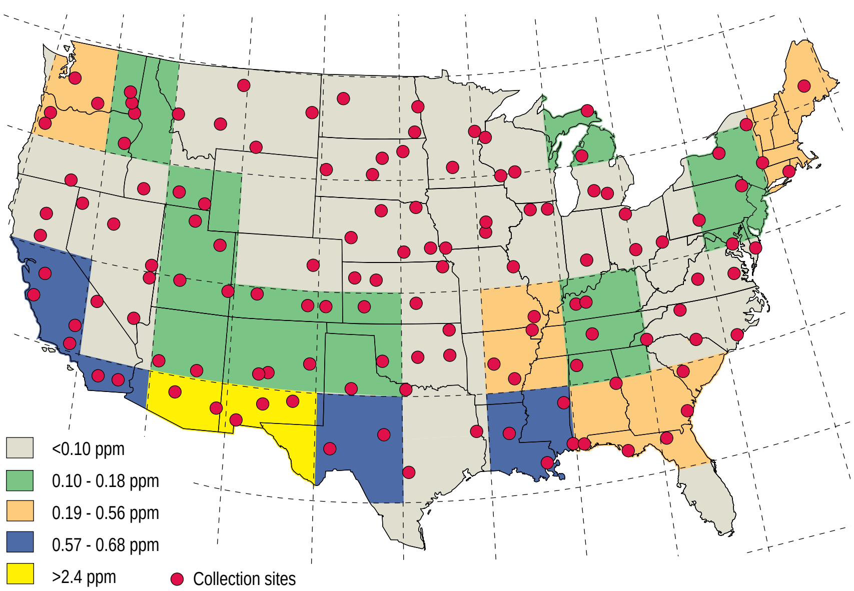

Fig. 3. Geographic distribution of DDE residues in starlings collected in 1985. Also shown are boundaries of the 5-degree (latitude and longitude) sampling blocks and collection sites.

decline (Schmitt et al. 1990). Concentrations of toxaphene, an insecticide that replaced DDT in cotton farming and many other applications, have also declined in fish since 1980, when its registration was canceled (Schmitt et al. 1990). Toxaphene does not accumulate in birds and was not measured in either starling or duck-wing samples.

Polychlorinated biphenyls (PCBs) are also complex mixtures of chemicals. Comprising as many as 209 different compounds, various PCB formulations were used historically as lubricants, hydraulic fluids, and fire retardants; as heat transfer agents in electrical equipment, including fluorescent light ballasts; and as a component of carbonless copy papers. Much like DDT, many PCBs are persistent and toxic. Large quantities were discharged directly to waterways, including Lakes Michigan and Ontario and the Hudson, Mississippi, Kanawha, and Ohio rivers. PCBs are also often present in landfills and urban runoff. These discharge and disposal patterns are reflected in the geographic trends evident for PCBs in fish and wildlife; greatest concentrations generally occur in the urban-industrial regions of the Midwest and Northeast (Fig. 4). By 1980, the direct discharge of PCBs to waterways had been greatly restricted, and total PCB concentrations generally declined in U.S. fish and wildlife (Bunck et al. 1987; Schmitt et al. 1990). Residual PCBs nevertheless remain a problem in some areas, as evidenced by human consumption advisories in effect for fish from the Great Lakes, Lake Champlain, the Hudson River, and elsewhere.

Some highly toxic PCBs are long-lived and are selectively accumulated by aquatic organisms. Fish samples collected in 1988 from some regions, especially the Great Lakes, still contained toxic PCBs at concentrations great enough to be harmful to fish-eating birds (C.J. Schmitt, National Biological Service, unpublished data, 1993). Indeed, PCBs and other contaminants in Great Lakes fish are believed to limit the reproduction of bald eagles and other fish-eating birds, mink (*Mustela vison*), and river otters (*Lutra canadensis*) in coastal areas of the Great Lakes (Wren 1991; Giesy et al. 1994). PCBs, along with DDE and other contaminants, including chlorinated dioxins, may also be involved in the failure of lake trout (*Salvelinus namaycush*) to reproduce naturally in Lake Michigan (USFWS 1981; Spitsbergen et al. 1991). In spite of discharge restrictions, the concentrations of PCBs and chemically similar compounds in the Great Lakes will likely remain elevated because of atmospheric transport and the internal cycling of contaminants already present in the lakes.

The primary sources of mercury to U.S. waters were discharges from chemical facilities that manufactured caustic soda (sodium hydroxide). These discharges have been regulated since the 1970's. Other historical sources included paper mills, gold and silver mines, and the production and use of mercury-containing pesticides. Concentrations of mercury in fish declined significantly from 1969 through 1974 as a result of restrictions on these historical uses, but concentrations have not changed appreciably since 1974. Concentrations in fish from heavily contaminated waters, such as Lake St. Clair, declined the most (Schmitt and Brumbaugh 1990). Despite these declines, fish consumption advisories remain in effect for some waters. Recent findings have highlighted the importance of atmospheric transport and the accumulation of mercury in natural sinks, such as Lake Champlain (e.g., Driscoll et al. 1994) and the Everglades, in the maintenance of elevated concentrations (Zillioux et al. 1993).

Lead concentrations in fish declined from 1976 to 1986 (Schmitt and Brumbaugh 1990), paralleling a trend reported for U.S. rivers (Smith et al. 1987). This decline has been attributed to reductions in the lead content of gasoline and to discharge restrictions at smelters and other industrial sources (Smith et al. 1987).

Selenium is a trace element required by plants and animals; it is toxic at high concentrations. Concentrations of selenium in fish declined in some areas of the United States. In some parts of the West, however, where concentrations were historically elevated, levels either increased or remained unchanged (Schmitt and Brumbaugh 1990). Selenium is a natural component of soils and is present at high concentrations in some arid areas of the U.S. West. The dissolution of selenium and other potentially toxic elements from soils and their accumulation in ecosystems are accelerated by irrigation. Elevated selenium concentrations, induced by irrigation, are responsible for the widely publicized wildlife deaths and deformities at Kesterson National Wildlife Refuge in California (Lemly 1993).

In general, U.S. concentrations of persistent contaminants that accumulate in fish and wildlife are lower now than at any time for which accurate data exist, although problem areas remain. These results imply that direct inputs of many toxic substances to the environment have been reduced through the regulation of industrial discharges and pesticide use. Declining concentrations of DDT and other contaminants in North America have permitted the return of predatory birds, such as bald eagles, to some areas from which they had been eliminated (Fig. 2).

The persistence of contaminant problems, despite curtailment of direct discharges to waterways and restrictions on the uses of persistent pesticides, has highlighted the importance of global and ecosystem processes such as atmospheric transport and internal cycling. The accumulation of selenium in California, and mercury in the Everglades, has resulted from natural processes—the leaching of elements from soils and vegetation. The rates of these processes have been accelerated by irrigation and other activities associated with agriculture. Atmospheric transport also represents an important source of PCBs to the Great Lakes; it has also been linked to the accumulation of mercury in Lake Champlain (*see* Glaser, this section; Baker et al. 1993) and other northeastern lakes (Driscoll et al. 1994).

The exposure of migratory birds such as peregrine falcons (*Falco peregrinus*) to contaminants on their wintering grounds outside of the United States (Henny et al. 1982), where DDT and other persistent compounds are still used, also remains a problem. Moreover, the curtailment of organochlorine pesticide use in North America has led to increasing reliance on so-called soft pesticides—highly toxic organophosphate, carbamate, and synthetic pyrethroid compounds—that are difficult to monitor because they are short-lived and do not accumulate. Evidence of the increasing use and potential adverse effects of these chemicals is highlighted by increasing occurrences of wildlife mortality attributable to them (*see* Glaser, this section). Additionally, chemical analysis has demonstrated the presence of highly toxic contaminants such as the chlorinated dioxins. No long-term monitoring data exist for these compounds, which may affect fish and wildlife at extremely low concentrations (Giesy et al. 1994). New approaches and technologies, capable of detecting chemical exposure and its effects at all levels of biological organization, will be required to monitor and assess highly toxic chemicals and those that do not accumulate in fish and wildlife before concentrations reach harmful levels.

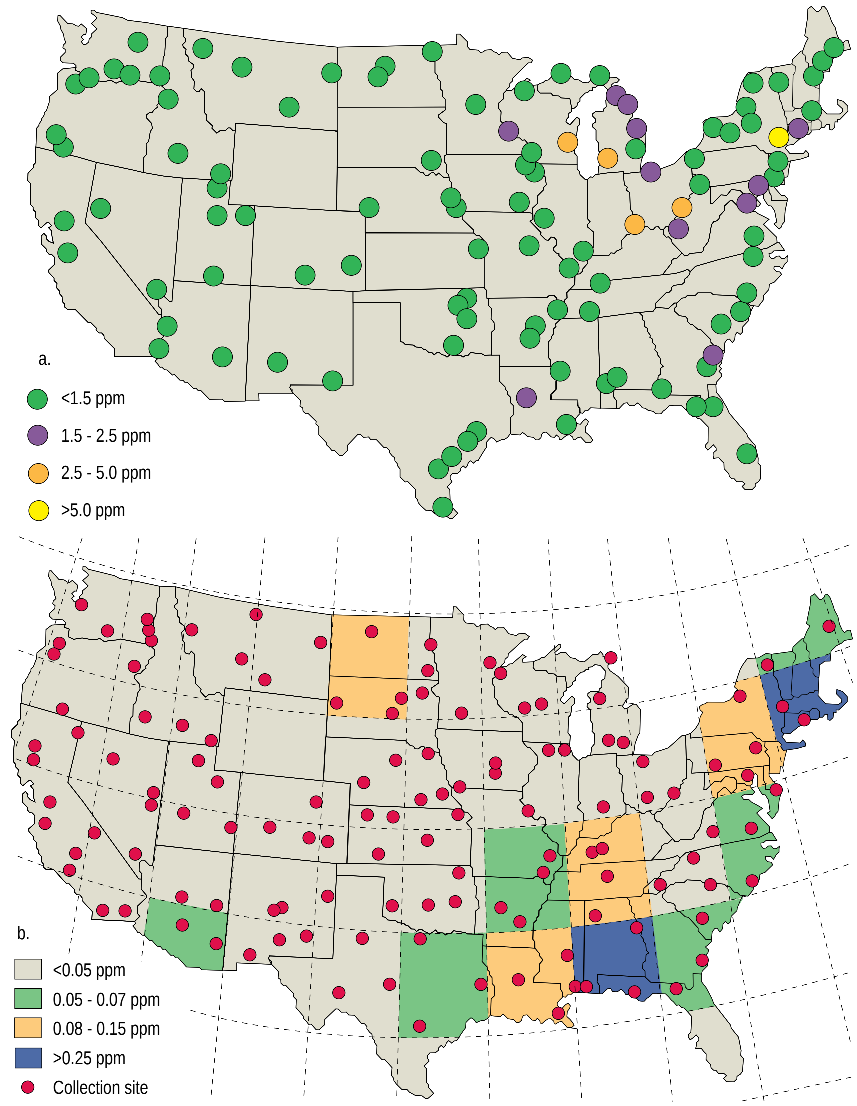

Fig. 4. Geographic distribution of PCB residues in U.S. Fish and Wildlife Service monitoring networks: (a) PCB concentrations in fish collected in 1986 from the indicated sites. Not shown are stations in Alaska and Hawaii, at which PCB concentrations were < 1.5 parts per million (ppm) at all sites; (b) PCBs in starlings collected in 1985. Also shown are boundaries of the 5-degree (latitude and longitude) sampling blocks and collection sites.

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For further information:

C.J. Schmitt
National Biological Service
Midwest Science Center
4200 New Haven Rd.
Columbia, MO 65201

Wildlife Mortality Attributed to Organophosphorus and Carbamate Pesticides

by
Linda C. Glaser
National Biological Service

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.

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

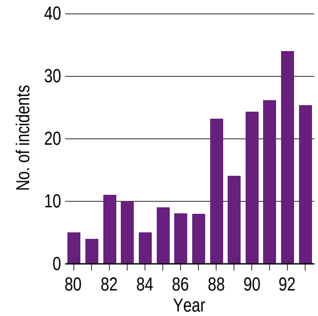

Fig. 1. Number of organophosphorus and carbamate pesticide-related wildlife mortality incidents, 1980-93.

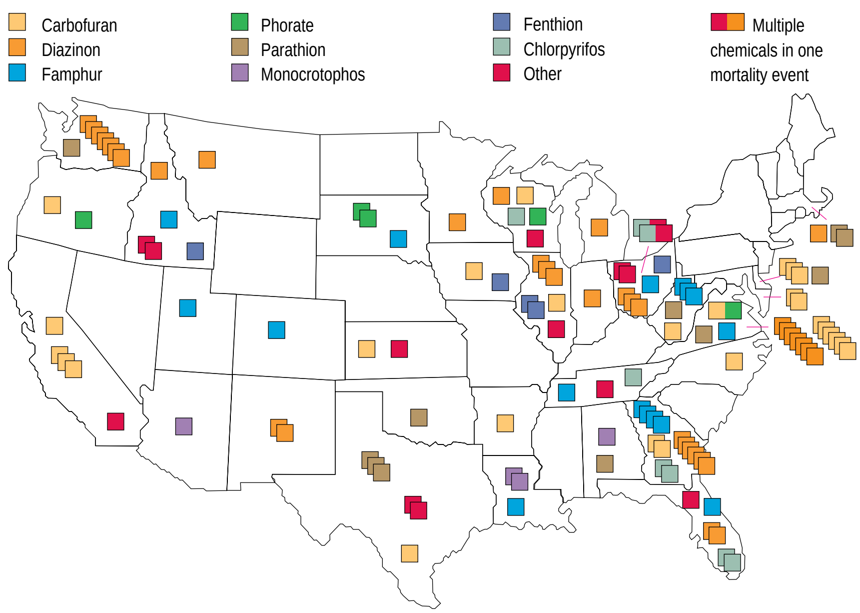

Fig. 2. Location by state of organophosphorus and carbamate compounds in pesticide-related wildlife mortality incidents, 1980-93.

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.

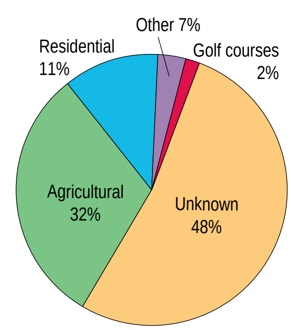

Fig. 3. General type of application associated with organophosphorus and carbamate pesticide-related wildlife mortality incidents, 1980-93.

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.

For further information:

Linda C. Glaser
National Biological Service
National Wildlife Health Center
6006 Schroeder Rd.
Madison, WI 53711

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Acidic Deposition (“Acid Rain”)

by
Kent Schreiber
National Biological Service

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

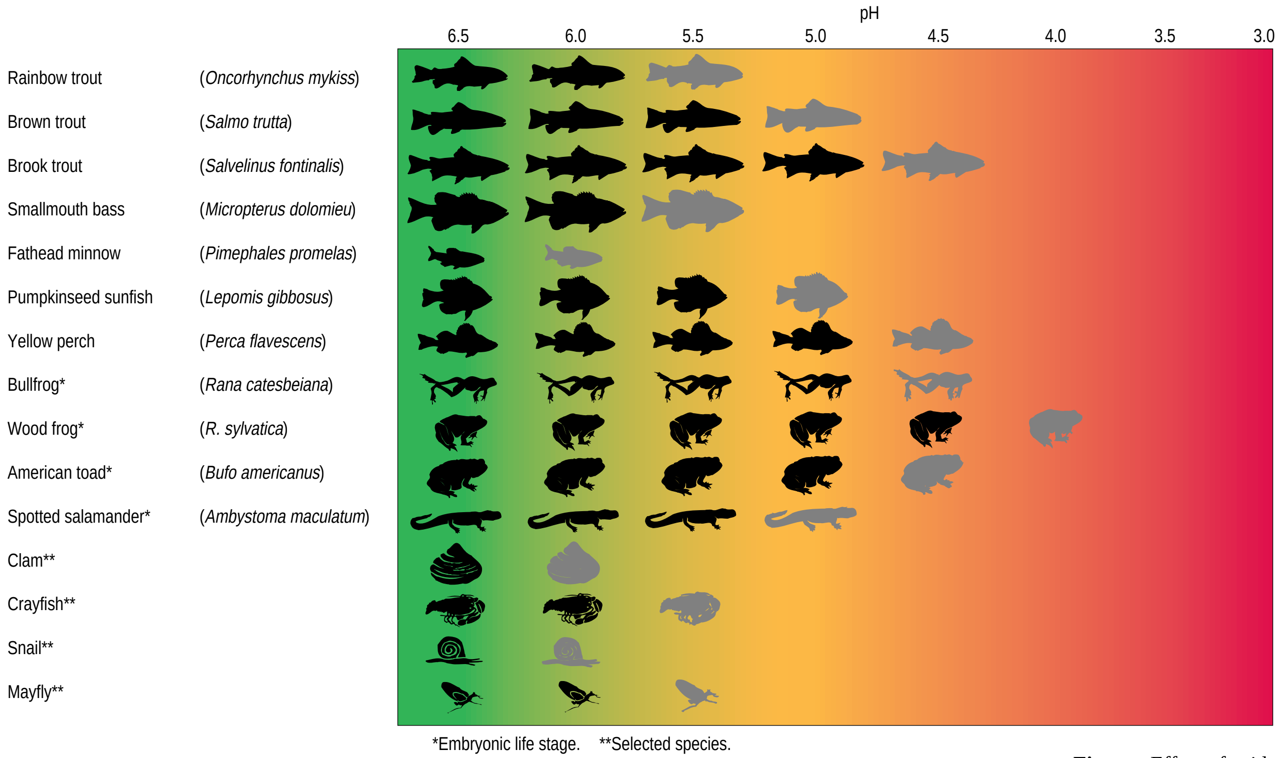

Figure. Effect of acid rain on some aquatic species. As acidity increases (and pH decreases) in lakes and streams, some species are lost (gray).

effects from acidification. Comparison of information for 274 lakes surveyed between 1929 and 1934 and again between 1975 and 1985 showed 80% of the lakes had declined in their capacity to neutralize acidity (Driscoll et al. 1991). Surveys for fish in 1,469 Adirondack lakes during 1984-87 showed 24% without fish, with a high percentage (61%) of these fishless lakes located in the southwestern portion of the region where buffering of acid input is limited by the local geology. These lakes are generally small, shallow, and at relatively high elevations. Although fish species demonstrated a wide range of tolerance to acidity, studies found that the number of species in a lake declined as pH declined. Comparisons with historical information demonstrated that populations of brook trout (*Salvelinus fontinalis*), a relatively acid-tolerant species, had disappeared from 44 of 409 lakes (11%), and acid-sensitive minnows were lost from 33 of 170 lakes (19%) surveyed (Baker et al. 1993).

Surveys in the mid-Appalachian and mid-Atlantic Coastal Plain regions indicate many streams that are vulnerable to acidic deposition. Acidic deposition influences an estimated 3,000 km (1,865 mi) of trout streams in Pennsylvania (Carline et al. 1992). Of 344 streams surveyed in western Virginia, nearly all (93%) are considered sensitive and nearly half are considered extremely sensitive because of their low buffering capacity. Ten percent of the surveyed streams in this area are acidic (Cosby et al. 1991). Waters farther south in the Blue Ridge province presently show little or no effects from atmospheric acidity, but the potential for damage exists because of their low buffering capacity. Evidence suggests that the ability of the watersheds to neutralize the acidic input is declining, and future acidification of surface waters is a continuing concern.

In the extreme south, Florida has the distinction of having the greatest number of acidic lakes of any U.S. region; however, many of the fish species commonly found in these lakes are tolerant of low pH levels. Other regions, such as the upper Midwest and western states, have waters with low buffering capacity and, although existing information does not indicate biological problems, they remain vulnerable to acidity.

Acidification of the aquatic environment can also affect vertebrate species other than fish. For example, studies show acidic deposition can affect the diet, foraging, distribution, and reproduction of bird species that depend on the aquatic environment (Table). Such indirect effects are often difficult to interpret, but they could potentially lead to fundamental changes in the ecosystem.

Terrestrial Species

Acidic deposition affects terrestrial wildlife species by damaging habitat and by reducing or contaminating food sources through uptake of toxic levels of metals (Schreiber and Newman 1988). Species such as amphibians, which

Table. Bird species studies that either did (yes) or did not (no) yield evidence that acidic deposition affected the birds (modified from Longcore et al. 1993).

Species	Diet/foraging		Breeding distribution		Reproductive measures	
	Yes	No	Yes	No	Yes	No
Common loon (*Gavia immer*)	x		x**	x**	x	x
Arctic loon (*Gavia arctica*)						x
Common merganser (*Mergus merganser*)			x		x	
Belted kingfisher (*Ceryle alcyon*)			x			
Osprey (*Pandion haliaetus*)	x		x		x	
American black duck (*Anas rubripes*)	x		x		x*	
Common goldeneye (*Bucephala clangula*)			x*			
Ring-necked duck (*Aythya collaris*)	x				x	
Eastern kingbird (*Tyrannus tyrannus*)				x	x	
Tree swallow (*Tachycineta bicolor*)	x			x	x	

*Beneficial effect.
**Evidence of both an effect and no effect.

require both aquatic and terrestrial environments, are perhaps most at risk. For example, in the acid-sensitive areas of eastern Canada, 16 of the 17 amphibian species have more than 50% of their ranges affected by acidic deposition (Clark 1992). Monitoring amphibian populations could provide a biological indication of changes in acid deposition (Freda et al. 1991).

Forest damage attributed to acid deposition, such as the maple dieback, can change the biomass of invertebrates available to birds. Species such as the red-eyed vireo (*Vireo olivaceus*) and least flycatcher (*Empidonax minimus*), which forage in the overstory, may have fewer prey because of habitat loss. Other species, though, including the wood thrush (*Hylocichla mustelina*) and ovenbird (*Seiurus aurocapillus*), which are associated with shrubs and ground-feeding, may benefit from an increased biomass of invertebrates in their foraging areas (DesGranges 1987). Such effects could result in changes in the ecosystem; however, little direct evidence of population-level changes is available.

Future Conditions

Legislation to reduce emissions that form acid rain has been enacted in both the United States and Canada. There is evidence that acidic deposition in some areas has started to decline and that water quality has improved (Gunn and Keller 1990). Monitoring over a decade at 81 selected sites in the Northeast and upper Midwest has shown that most of the lakes and streams there have decreased in sulfate levels, coinciding with the general decrease (about 11%) in national emissions of sulfur dioxides (NAPAP 1993). Results from modeling the effects of 30 years of emission controls (i.e., 1980 to 2010) on 2,500 affected lakes in the Adirondacks suggest improvements will occur in water chemistry and fish habitat in up to 150 lakes (Rubin et al. 1992).

Control measures take time to implement, and it is too early to determine their overall ecological effects. Episodes of acidification continue to adversely affect fish populations and invertebrates. To prevent loss of fisheries and aquatic biota in some severely affected localities, limestone, a neutralizing agent, is being applied to reduce acidity levels (Olem 1991). It is important to continue monitoring the status of species and populations in sensitive areas to evaluate the effect of emission controls and to ensure healthy ecosystems.

For further information:

R. Kent Schreiber
National Biological Service
Leetown Science Center
1700 Leetown Rd.
Kearneysville, WV 25430

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Atmospheric Deposition and Solute Transport in a Montane Mixed-Conifer Forest System

by
Daniel A. Everson
David M. Graber
National Biological Service

In 1981 a long-term, cooperative study of ecosystems in the southern Sierra Nevada was begun to address concerns over high levels of air pollutants. Atmospheric pollutants are generated throughout California and because of topography, wind patterns, and a Mediterranean climate, they eventually concentrate in the San Joaquin Valley, west of the study area. Baseline ecosystem data—chemical and biological—were collected to determine basic system structure and function. This collection was followed by long-term measurements of pollutants to assess their present and potential effects on terrestrial and aquatic ecosystems. Studies included measurement of precipitation chemistry, dry deposition, stream hydrology, aquatic chemistry and biology, soil chemistry, meteorology, nutrient fluxes, watershed response to fire disturbance, and vegetation structure and dynamics.

Methods

Research was designed to take advantage of the striking elevation gradient by including measurements at three core areas:

Elk Creek is a low-elevation, 750-m (2,460-ft) foothill site dominated by chamise chaparral (*Adenostoma fasciculatum*). Precipitation averages 66 cm (36 in) annually, nearly all falling as rain in winter. Precipitation chemistry and volume are collected weekly from a site at Ash Mountain, 3 km (1.9 mi) south of the site. An intermittent first-order tributary, Chamise Creek, is sampled when possible.

Log Creek is a mid-elevation 2,100-m (6,890-ft) montane mixed conifer forest site dominated numerically by white fir (*Abies concolor*); however, giant sequoia (*Sequoiadendron giganteum*) contribute the greatest basal area. Mean annual precipitation is 100 cm (39.4 in); more than 85% falls as snow during the winter. Precipitation chemistry and volume are collected weekly. Paired watersheds, Tharp's and Log creeks, are sampled biweekly.

Emerald Lake is a subalpine 3,000-m (9,840-ft) cirque (*see* glossary), largely treeless but including lodgepole pine (*Pinus contorta*), western white pine (*Pinus monticola*), foxtail pine (*Pinus balfouriana*), and red fir (*Abies magnifica*). Annual precipitation varied between 70 cm (28 in) and 300 cm (118 in) in the past decade, nearly all as snow during the winter. Precipitation depth is estimated by using snow-water equivalents; precipitation chemistry is collected as the opportunity arises.

Inputs

Precipitation and discharge at all three sites vary greatly from year to year. As a result, annual ion input and export also vary considerably in each watershed. There was a general increase in precipitation and a decrease in ion concentration with elevation. Most precipitation falls during the winter as snow above 1,800 m (5,900 ft).

Unlike the eastern United States, where the major source of acidification of lakes and streams is sulfur deposition, the southern Sierra Nevada is considered to be most exposed to nitrogen. At the Log Creek and Elk Creek sites, over the sampling period the mean loading of nitrogen, expressed as NO_3^-, was 16.77 kg ha^{-1} yr^{-1}, with 74% contributed from wet deposition. The mean loading of sulfur (S), expressed as SO_4^{2-}, was 5.24 kg ha^{-1} yr^{-1}, with 67% contributed by wet deposition (Table). The dry deposition input estimates are conservative because the dry deposition sampling site appears more shielded from pollutant inputs than the wet sampling site.

The mean precipitation pH at the Log Creek site was 5.25, and at the Elk Creek site 5.37; there is not a chronic acid rain problem in the area. The frequency and volume of summer storms were fairly constant. Wet-deposition ion loading at Log Creek and Elk Creek was similar. Elk Creek, a somewhat more polluted site, received 57% as much precipitation as Log Creek, but ions were proportionately more concentrated (Blanchard and Tonneson 1993), yielding equivalent loading. Dry deposition loading in the Elk Creek site was not measured.

Emerald Lake received about 99% of its precipitation in the form of snow, with a mean pH of 5.3, meaning the site is only slightly acidic. Concentrations of individual ions were extremely dilute, usually less than 5 µEq L^{-1}. Mean wet deposition loading of nitrogen and sulfur, expressed as NO_3^- and SO_4^{2-}, was 2.15 kg ha^{-1} yr^{-1} and 0.78 kg ha^{-1} yr^{-1}, respectively (estimated from Dozier et al. 1987). No reliable estimate of annual dry deposition flux is available at Emerald Lake. Like Log Creek, Emerald Lake has no chronic acid precipitation problem.

Table. Log Creek site inputs of nitrogen and sulfur (kg ha^{-1} yr^{-1}).

Year*	NO^3		NH^4		Total N		SO^4		S	
	Wet	Dry	Wet	Dry	Wet	Dry**	Wet	Dry	Wet	Dry***
85	4.98	-	2.39	-	2.98	-	2.89	-	0.97	-
86	10.52	-	2.08	-	3.99	-	8.62	-	2.88	-
87	4.87	3.23	1.66	-	2.39	0.73	6.38	1.79	2.13	0.73
88	5.39	3.80	1.89	-	2.68	0.86	3.12	1.79	1.04	0.60
89	4.48	4.82	1.42	-	2.11	1.09	2.57	2.07	0.86	0.69
90	4.88	5.71	2.24	-	2.84	1.29	1.84	1.68	0.61	0.56
91	8.41	4.11	2.09	-	3.52	0.93	2.23	0.75	0.74	0.25
92	5.46	-	2.23	-	2.96	-	2.26	-	0.75	-
93	4.12	-	1.11	-	1.79	-	2.02	-	0.67	-
				Mean	**2.81**	**0.98**			**1.18**	**0.57**
				Standard deviation	**0.64**	**0.19**			**0.74**	**0.17**

* Hydrologic year is October 1 to September 30.
Wet deposition from National Atmospheric Deposition Program site.
Dry deposition from Wolverton National Oceanic and Atmospheric Administration site.
** Dry deposition N is HNO^3 and NO^3 reported as NO^3.
*** Dry deposition S is SO^2 and SO^4 reported as SO^4.

Trends in Input

Between 1981 and 1989, 29 precipitation events were highly acidic (pH values less than 4.5), with 22 of these events occurring in low-volume summer storm events from May through September. Since 1989 only one storm, in November 1991, had a pH below 4.5. A rise in mean precipitation pH was also recorded during this period at both the low-elevation and mid-elevation sites. The Elk Creek site mean precipitation pH rose from 5.23 before 1989 to 5.68, while the Log Creek site rose from 5.12 to 5.39. A beneficial downward trend in the total annual loading of sulfur occurred (Table), which was poorly explained by variation in precipitation (r = 0.397). The frequency of storm events with very high (> 2 mg L^{-1}) concentrations of sulfur was also reduced from 25 events from 1983 to 1988 to 6 events in the following 5 years. No apparent trend for nitrogen was seen. Emerald Lake precipitation chemistry data are insufficient to infer trends.

Effects on Stream and Lake Chemistry

Stream discharge peaks in February at the Elk Creek site, April at Log Creek, and June at Emerald Lake. The first is a direct response to maximum rainfall; the other two discharges reflect the peaks of snowmelt.

In the mixed-conifer Log Creek site, more than 99% of the nitrogen deposited was conserved. Mean discharge of nitrogen, expressed as NO_3^-, is 0.09 kg ha^{-1} yr^{-1}, virtually all of which was derived from the melting snowpack. Seventy-four percent of the annual loading of sulfur was conserved, with a mean discharge, expressed as SO_4^{2-}, of 0.93 kg ha^{-1} yr^{-1}, again mostly derived from melting snowpack. Acid-neutralizing capacity (ANC), expressed as HCO_3^- (bicarbonate), was many times greater than annual acidic loading at a mean of 320 µEq L^{-1}. At these levels, most sulfur and nitrogen are being conserved by the biota in the ecosystem, and the ecosystem's ability to neutralize acid is generally good except when extreme events occur.

Tharp's Creek, one of the paired watersheds in the mid-elevation Log Creek site, was burned by prescription in October of 1990, producing striking changes in stream output chemistry that continued through 1993. Although net retention of NO_3^- continued, discharge of NO_3^- increased from a pre-burn mean of 0.04 kg ha^{-1} yr^{-1} to 1.59 kg ha^{-1} yr^{-1} in the 3 years following the burn. Thus, the ability to retain nitrogen was decreased, and the system leaked nitrogen and sulfur. The SO_4^{2-} outputs exceeded inputs following the fire, increasing from a pre-burn mean of 0.35 kg ha^{-1} yr^{-1} to over 6.63 kg ha^{-1} yr^{-1}. Acid-neutralizing capacity also rose from a pre-burn mean of 21.16 kg ha^{-1} yr^{-1} to over 37.16 kg ha^{-1} yr^{-1}.

At the Elk Creek site, mean alkalinity (or ANC) expressed as HCO_3^- was 310.0 µEq L^{-1} with a mean stream pH of 6.61 (neutral). The creek flows intermittently, mostly between January and March. The water is cloudy with suspended clay particles, and debris flows are common after heavy rains.

The outflow of Emerald Lake had a mean pH of 6.17 (neutral) and mean HCO_3^- of only 30 µEq L^{-1}. Episodic acidification on the order of days to weeks was recorded at Emerald Lake under two scenarios: (1) during dirty summer storms, when buffering capacity was overwhelmed by low-pH stormwater flashing into the lake, and (2) during snowmelt, when NH_4^+, NO_3^-, and SO_4^{2-} were preferentially eluted from the snowpack, causing an acidic pulse (Williams and Melack 1991).

Discussion

We have found no long-term chronic acidification of lakes and streams in our study area, even though the hundreds of lakes in the region are considered to be the most poorly buffered in the western United States (Landers et al. 1987).

Emerald Lake, typical of subalpine lakes in the region, currently generates enough ANC, mostly through cation exchange (Williams et al. 1993a), to buffer two to five times the current annual acidic inputs (Sickman and Melack 1989). Very clean winter air and the large-volume, extremely dilute snowpack it produced were significant factors in maintaining the buffering capacity. Dirty summer storms and spring snowmelt that concentrate NO_3^- and SO_4^{2-} and deliver them quickly to the lake have caused episodic acidification, a phenomenon that we are studying. An increase in the frequency of storm events during the summer and fall would likely be harmful to subalpine lake basins if the chemistry of these events were to remain the same.

The low concentrations of nitrogen and sulfur in stream water indicate that neither reached saturation in soils and plants of the mixed-conifer forest (Williams et al. 1993b). The buffering capacities of low- and mid-elevation sites were many times greater than acidic inputs. But human-caused nitrogen and sulfur have been shown to stimulate the growth of ponderosa pines (*Pinus ponderosa*), which in turn increases vulnerability to high local ozone levels and potential for damages (Temple et al. 1992).

Precipitation and snowmelt pH levels were not low enough to mobilize aluminum (Dozier et al. 1987). Bradford et al. (1992) found that present pH levels in Sierran lakes and streams are not sufficient, directly or through aluminum mobilization, to affect indigenous amphibians.

The measured reductions in sulfur loading and decrease in frequency of low-pH storm events suggest that reduced pollutant emissions may be having a positive effect on the air quality of the southern Sierra Nevada. Continued monitoring and further research will be needed to determine if this trend will continue, given the tremendous rate of population growth in California.

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For further information:

David M. Graber
National Biological Service
Sequoia and Kings Canyon
Field Station
Three Rivers, CA 93271

Agricultural Ecosystems

by
Arthur W. Allen
National Biological Service

Approximately 45% of the U.S. land area is used for agricultural purposes, with 191 million ha (472 million acres) in cropland and 238 million ha (587 million acres) in range or pasture (Knutson et al. 1990). American agriculture has become the most productive in the world based on technology and increased specialization. Energy, machinery, agrochemicals, and irrigation are principal components of modern American agriculture, all of which potentially affect farm and off-farm environmental quality. In addition, government policies have pervasively affected U.S. agriculture, often precluding producers from responding to changing market conditions or affecting adoption of farm practices that potentially improve environmental quality (National Research Council 1989; Reichelderfer 1990).

Energy and technology have propelled American agriculture from pioneering conversion of the landscape to intensive, high-yield, monocultural production. The composition of agriculture in terms of farm numbers, size, and methods of production have changed dramatically throughout this century. The effects of the agricultural industry on the diversity, distribution, and abundance of wildlife continue to be profound.

Larger, more economically efficient producers that could tolerate smaller profit margins have absorbed the assets of smaller, less successful operations. In 1991 the U.S. human population on farms was less than one-tenth of what it was in 1920 (Haynes 1991). As the number of farms decreased by two-thirds during this same period, farm size increased. In response to fewer farms and the need to increase production efficiency, fields have become larger, crop diversity has decreased, crop rotation patterns have become simpler and less frequent, and agrochemicals play a major role in crop production. Over the last 30 years, these elements have had significant effects on environmental quality within agricultural ecosystems.

The Conservation Title of the Food Security Act of 1985, commonly referred to as the Farm Bill, was formulated in a time of commodity surpluses, economic stress within the agricultural community, and increasing public concern about environmental quality. The Conservation Reserve Program (CRP), a cornerstone of the 1985 Farm Bill, was enacted to remove highly erosive cropland from production. This legislation reflects an effective integration of economic support to the agricultural community with environmental policies advocated by a strong coalition of organizations representing a wide spectrum of the American public. The CRP has provided substantial benefits to wildlife populations across the nation. To appreciate the CRP's significance to wildlife, we must remember that tremendous changes in agriculture have influenced the abundance and quality of habitat in this century (Soil and Water Conservation Society 1994).

World War II, for example, brought an increased demand for American agricultural products. New technologies adopted in the post-war period reduced production costs and further escalated farm output. Tractors and farm machinery became more powerful and efficient. Time and energy savings decreased the amount of human labor needed to work larger fields. Advances in biological and chemical technologies further increased agricultural efficiency and crop yields. The use of nitrogen fertilizer increased from 197 million metric tons (217 million tons) in 1940 to 6,765 million metric tons (7,459 million tons) in 1970 (Haynes 1991). By the early 1970's, crop yields had skyrocketed to new records.

American agriculture entered the world market in the 1970's in response to increased global demands for agricultural products. American farmers expanded production by cultivating existing croplands more intensively and bringing new, less fertile and more fragile lands into production. The 1980's arrived with the farm industry in crisis due to overproduction, increased costs for fuels and fertilizers, elevated interest rates, declining land values, and decreased demand for export sales. The agricultural economic predicament, as well as heightened public concern about environmental quality, set the stage for the 1985 Farm Bill and establishment of the CRP.

Agricultural Effects on Wildlife Habitat

The effects of modern agriculture on wildlife are indisputable, ranging from habitat elimination to long-term effects of agrochemicals on water quality and reproductive success of ground-nesting birds (Capel et al. 1993). Habitat diversity in agricultural ecosystems has declined drastically as a consequence of the elimination of hay and pasture needed by draft animals and a shift to crop monocultures. In many regions, wetland drainage, consolidation of fields and farms, and elimination of fencerows and idle areas have reduced habitat diversity even further, thereby diminishing the ability of agricultural ecosystems to sustain viable populations of wildlife. The amount of undisturbed grass-dominated cover and non-cropped areas has decreased, resulting in lower availability of habitat and higher losses to predators for many nongame and game species of wildlife. In many agricultural regions, crucial wildlife habitat components such as undisturbed grassland have become dissected into small, isolated patches, or spatially segregated tracts. Increased agrochemical use has been implicated in the long-term decline of species such as the northern bobwhite (*Colinus virginianus*).

Monocultures, with minimal rotations between crops, have accelerated soil erosion and led to a greater dependence on chemical fertilizers and pesticides (Bender 1984) resulting in surface and groundwater contamination (Ribaudo 1989). Larger, heavier equipment used for tillage, planting, application of agrochemicals, and harvesting contributes to increased soil compaction and decreased soil tilth (suitability), further contributing to erosion. Agriculture has become the largest single nonpoint source of water pollution, delivering not only soil particles but also absorbed and dissolved nutrients and pesticides (National Research Council 1989).

The Conservation Reserve Program (CRP)

About 14.7 million ha (36.4 million acres) were removed from production for a minimum of 10 years during the 12 sign-up periods of the CRP (U.S. Department of Agriculture 1993). The percentage of each county area enrolled in the CRP is illustrated in Fig. 1. Grasses represent the vast majority of cover established on retired acres (Table). The most significant benefit to wildlife from the CRP is the more than 13 million ha (32 million acres) of grass interspersed with lands remaining in production. This grass cover has enhanced the quality and distribution of habitat for nongame and game species in both terrestrial and aquatic ecosystems. To document CRP-derived benefits to habitat quality, a cooperative study between the International Association of Fish and Wildlife Agencies and the U.S. Fish and Wildlife Service was initiated in 1987 (Farmer et al. 1988).

From 1987 to 1993 fish and wildlife agency personnel from 31 states collected vegetation

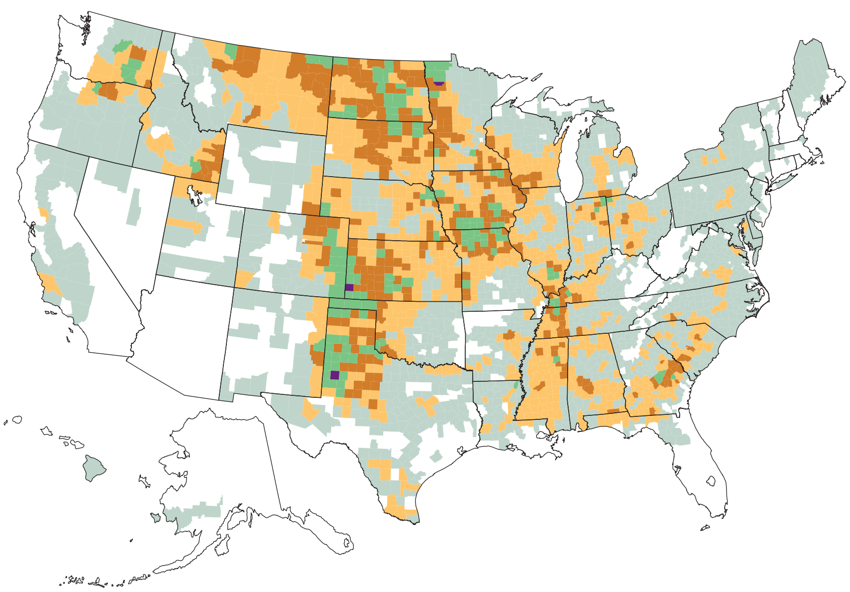

Fig. 1. Percentage of county area enrolled in the Conservation Reservation Program (CRP) through July 1992.

Table. Conservation Reserve Program (CRP) acres contracted in dominant conservation practices through the 12th sign-up period (U.S. Department of Agriculture 1993).

Conservation practice	Acres	Percent of all CRP acres
CP1 Tame grass	21,385,848	58.68
CP2 Native grass	8,459,343	23.21
CP3 Tree planting	2,321,290	6.37
CP4 Wildlife habitat	1,972,563	5.41
CP10 Existing grass	2,010,940	5.52
CP12 Wildlife food plots	18,449	0.05
CP13 Filter strips	52,931	0.15
All other conservation practices	221,408	0.61
Total	**36,442,772**	**100.00**

data in 501 counties under guidance of the U.S. Fish and Wildlife Service's National Ecology Research Center in Fort Collins, Colorado (now part of the National Biological Service). Study sites were based on environmental conditions and dominant agricultural practices before CRP enrollment. CRP fields in each region were sampled based on the conservation practice established (e.g., tame grasses, native grasses) and the year the CRP contract began.

Vegetation data were collected before spring growth (pre-greenup) and during midsummer (July-August) after the peak of the growing season. Visual obstruction readings (VOR) provide a simultaneous measure of vegetation height and density. Pre-greenup VOR are used to assess the amount of residual vegetation (i.e., dead material remaining from the previous growing season), and is an important indicator of habitat quality for ground-nesting birds, which often establish nests before significant growth of the current year's vegetation. Midsummer VOR provide evidence of the amount and quality of vegetative cover present during the peak growing season.

Data pertaining to vegetation height and density in CRP fields planted to tame and native grasses in the Southern Plains, Northern Plains, and Midwest regions portray some of the wildlife habitat realized under this program (Figs. 2 and 3). Pre-greenup VOR were essentially 0.0 cm in all fields before establishment of CRP cover, indicating an absence of reproductive and protective cover for grassland-dependent species.

Pre-greenup VOR in tame grasses (Fig. 2a) showed increased height and density of residual vegetation in the Southern Plains and Midwest regions for the first 4 years after establishment. In the Northern Plains, the vegetation response was more immediate, reaching a maximum of 31 cm (12.2 in) only 2 years after planting. Within all three regions, however, tame grass VOR eventually showed a declining or stable trend.

In comparison, pre-greenup VOR in native grasses indicated a slower response in the first 2 years after planting (Fig. 2b); however, these fields eventually showed greater height and density of vegetation across all three regions. In the Midwest, VOR in native grasses reached a maximum value of 65 cm (25.5 in) 5 years after planting.

Midsummer VOR in tame grasses showed rapid increases in value for the first 2 years after planting (Fig. 3a). In the Northern Plains, however, VOR decreased from 60 cm (23.5 in) to 36 cm (14.2 in) by 6 years after planting. Relatively constant increases in VOR values for tame grasses were evident in the Southern Plains and Midwest regions. Midsummer VOR measurements in native grasses indicated a slower response in terms of height and vegetation density (Fig. 3b). With the exception of the Southern Plains, long-term VOR values are generally higher for native grasses than tame grasses across all regions (Fig. 3b).

CRP Benefits

The CRP has provided substantial wildlife habitat with millions of acres planted to tame and native grasses. These millions of acres of high-quality habitat have, in turn, provided benefits to populations of both nongame and game wildlife (Allen 1993a, 1993b). Tame grasses appear to provide greater cover in initial years after planting, but height and density of residual and midsummer vegetation begin to decline in a few years. Conversely, native grasses appear to take longer to provide substantial benefits but provide habitat of higher quality for longer periods. Eventually, regardless of species composition, some type of management (e.g., burning, mowing, limited grazing, or haying) will be required to maintain stand vigor and long-term habitat quality in grass-dominated CRP fields.

Although the CRP's highest priorities were to reduce deficiency payments, decrease soil erosion, and provide economic support to the agricultural community, it also provides benefits to wildlife and their habitat. The restoration of more than 14 million ha (36 million acres) of cropland to long-term cover has provided an essential element of habitat stability and has helped repair the widespread deterioration in habitat and environmental quality experienced across the agricultural landscape. In contrast to the U.S. Department of Agriculture's annual set-aside programs, which typically have negative effects on wildlife (Berner 1988), the key beneficial element of the CRP to wildlife is the long-term provision of relatively undisturbed vegetation cover dispersed across agricultural ecosystems. Based on the propensity of American agriculture to overproduce selected commodity crops, the return of most CRP acres to production can be expected to result in

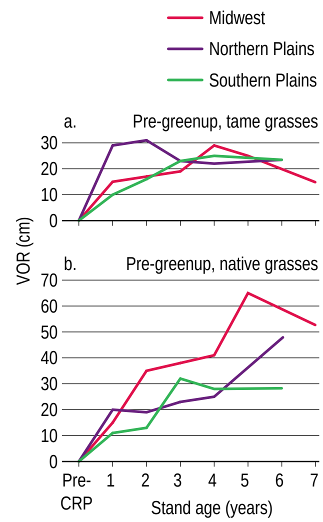

Fig. 2. Relationships between pre-greenup Visual Obstruction Readings (VOR) and stand age in Conservation Reserve Program fields planted with (a) tame grasses and (b) native grasses. VOR data were collected in spring before current season's vegetation growth (1 cm—0.4 in).

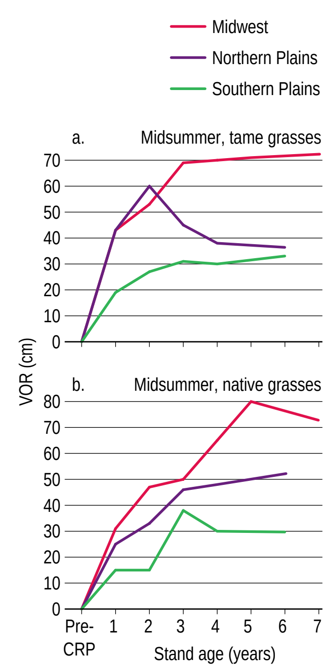

Fig. 3. Relationships between midsummer Visual Obstruction Readings (VOR) and stand age in Conservation Reserve Program fields planted with (a) tame grasses and (b) native grasses. VOR data were collected in midsummer after peak growth (1 cm—0.4 in).

greater dependence on annual set-aside programs that potentially have drastic negative effects on wildlife and environmental quality.

The CRP has provided environmental benefits, particularly in terms of water quality stemming from reduced amounts of soil erosion and reduced applications of agrochemicals. Agricultural production, environmental quality, and viable populations of wildlife in agricultural ecosystems are not mutually exclusive objectives. The Food Security Act of 1985 and the CRP have successfully integrated environmental and agricultural policies, providing public benefits on a national scale. Recent surveys indicate that most lands enrolled in the CRP will return to crop production upon the program's termination in 1995 (Dicks 1994). If this does occur and if remaining lands are subjected to uncontrolled haying and grazing, the many benefits to wildlife and environmental quality realized over 10 years will be lost.

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For further information:

Arthur W. Allen
National Biological Service
Midcontinent Ecological Science Center
4512 McMurry Ave.
Fort Collins, CO 80525