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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Increased Avian Diseases With Habitat Change

by
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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)

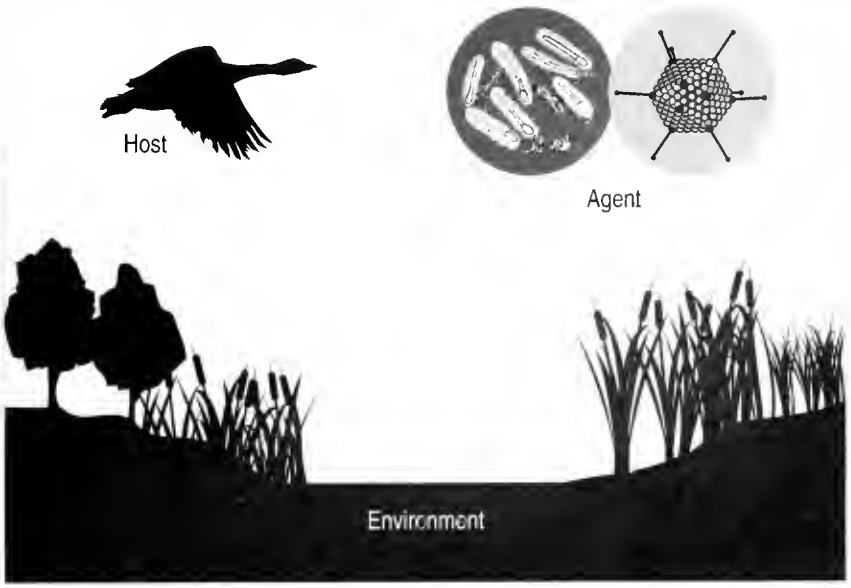

Fig. 1. Common factors required for disease to occur. Environmental factors greatly influence occurrence of disease by changing the amount and type of host-agent interactions.

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).

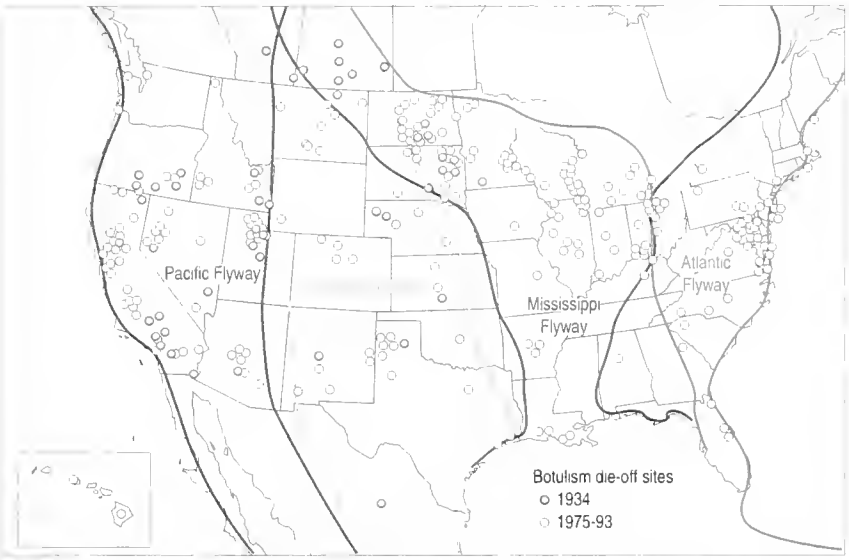

Fig. 2. Known distribution of "western duck sickness" (avian botulism) in North America, 1934 (Kalmback and Gunderson 1934), and from 1975 to 1993.

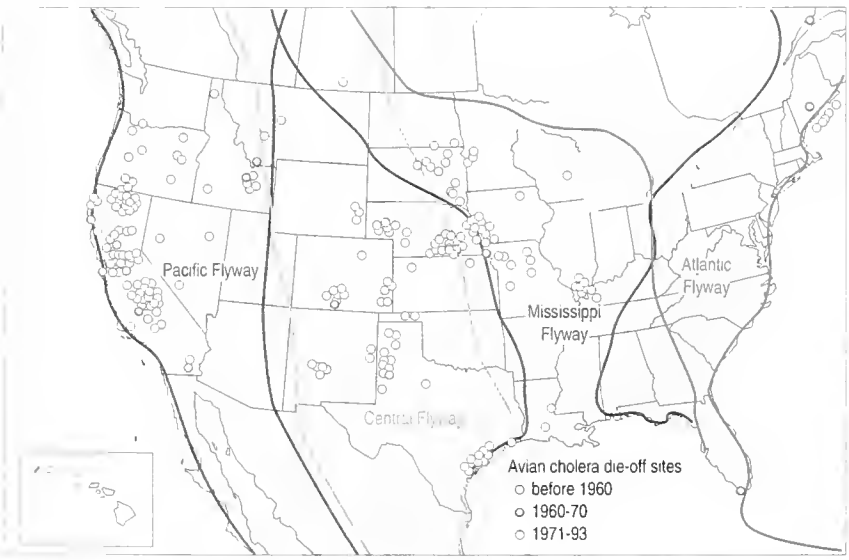

Fig. 3. Geographic distribution of avian cholera in wild waterfowl within the United States, before 1960 (first outbreak in 1944), during the 1960's, and after 1970, when disease spread (National Wildlife Health Center files).

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.

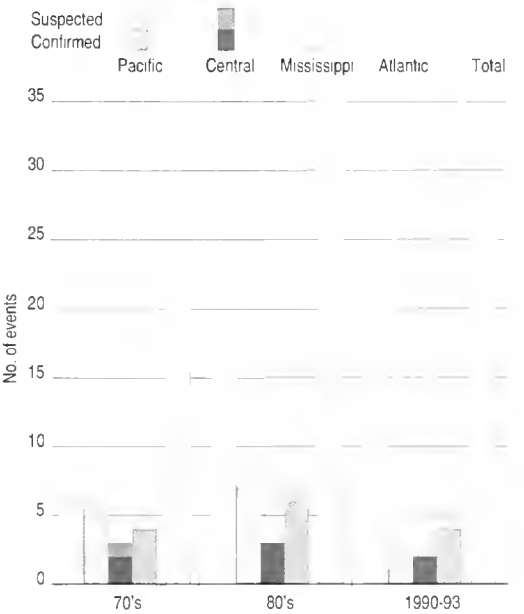

Fig. 4. Number of duck plague outbreaks in waterfowl in the United States, by flyway (suspect cases have pathology consistent with duck plague but lack isolation of the virus to confirm the diagnosis), and total number of outbreaks by decade.

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.

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.

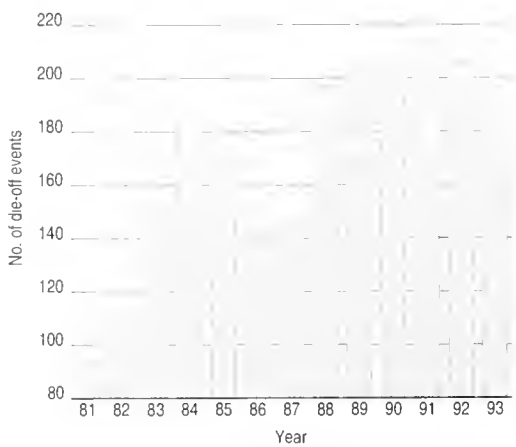

Fig. 5. Number of wild bird die-off events listed in the National Wildlife Health Center data base, 1981-93.

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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Captive Propagation, Introduction, and Translocation Programs for Wildlife Vertebrates

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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.

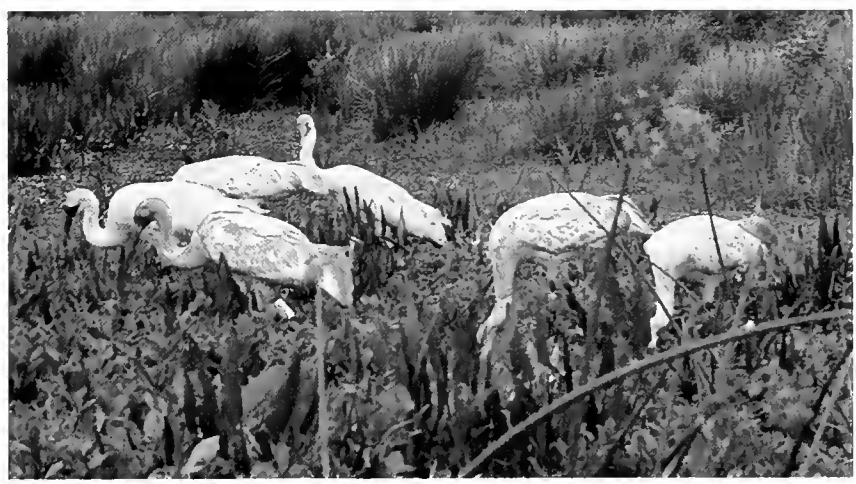
Trends

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



Courtesy International Crane Foundation

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