Endangered Species UPDATE

Including a Reprint of the latest USFWS
Endangered Species Technical Bulletin

July 1989 Vol. 6 No. 9

THE UNIVERSITY OF MICHIGAN
School of Natural Resources

In this Issue:

Infectious Diseases and Endangered Species Management

U.S. Bans Ivory Imports

Three Mammals and Two Plants Listed

Agriculture, Wetlands and Endangered Species: The Food Security Act

Infectious Diseases and Endangered Species Management

by

Andrew Dobson and Dan Miller

Disease can play a pivotal role in the population dynamics of endangered species. The mountain gorillas of Virunga recently suffered an epidemic of respiratory illness which infected an estimated ten percent of the population and led to the death of six gorillas (Sholley 1989). The causative pathological agent was identified as measles, presumably introduced through contact with an infected human. Luckily an inoculation campaign was quickly mounted, and large scale vaccination of potentially susceptible individuals prevented a full epidemic. In a less fortunate incident, North Sea populations of harbour seals (*Phoca vitulina*) were struck by a viral epidemic last summer which led to the deaths of more than 14,000 animals (Anon 1989). Such epidemics are not confined to vertebrates. Crayfish plague, a disease caused by a fungal pathogen, threatens the endangered white-clawed crayfish (*Austropotamobius pallipes*) in its last stronghold in the lakes of central Ireland (Reynolds 1988).

These examples suggest that an understanding of the population dynamics of pathogens, and the diseases they cause, is essential to the management of populations of both endangered and apparently healthy populations. In this short review we outline some important features of the population biology of infectious diseases and discuss their implications for the conservation of endangered populations.

The dynamics of parasites and pathogens are intrinsically difficult to study in endangered species because of small population sizes and the concern for protecting the remaining populations of a species. However, studies on non-endangered species can be used as a means of gaining a basic understanding of the types of pathogens that pose a threat to endangered populations. Several important general principles have emerged from the resurgence of interest in the ecology of parasites and disease of the last decade (Anderson and May 1979, May 1988, Scott and Dobson 1989). The greatest level of sophistication and detail is available for models of infectious diseases in human populations, where mathematical models have become increasingly prominent as tools for the study of disease dynamics. Many of the important epidemiological features of these models can be applied to systems where less comprehensive data are available.

Types of Pathogens

Parasites and pathogens can be conveniently classified on epidemiological grounds as microparasites and macroparasites (Anderson and May 1979). Microparasites include viruses, bacteria, fungi, and many protozoans; these pathogens are characterized by their small size (invisible to the naked eye), their ability to reproduce directly in infected hosts, and their ability to induce sustained immunity to reinfection in their hosts. Macroparasites, which include the parasitic helminths, ticks, and fleas, are characterized by their larger size (visible to the naked eye), and their relative inability to reproduce directly within infected hosts.

black-footed ferret (*Mustella nigripes*) Photo: WCI

This classification makes sense when the characteristic patterns of the two types of infection are considered. Essentially, hosts acquire macroparasites as discrete numbers of infective larvae which give rise to an infrapopulation of adult parasites in each infected host; these parasites induce a limited immune response in the host that may diminish the rate of acquisition of subsequent challenge infections. In contrast, microparasites tend to infect hosts that either succumb to the infection or, more characteristically, recover after some short time and then remain immune, or are resistant to subsequent infection, for the remainder of their lives.

Two important parameters define the epidemiology of macro- and microparasitic infections. R_0 is the basic reproductive rate, which measures the potential reproductive capacity of the pathogen. For microparasites, this is defined as the number of secondary infections generated by an infected individual in a population of susceptibles (Anderson and May 1982a), and for macroparasites as the average number of female offspring produced through the lifetime of a mature female in the absence of density dependent constraints (Anderson and May 1982b). In both cases, R_0 must be equal to or greater than one in order for the infection to persist. N_T is the threshold density of susceptibles required for a disease to establish in a population. R_0 and N_T generally have an inverse relationship; if R_0 is large, then a smaller N_T is required for establishment of a pathogen. Thus, particularly virulent species require large populations to sustain them; when a pathogen species is highly specific towards its host species, it is unlikely to be the ultimate cause of extinction in an endangered population, because the pathogen itself is likely to become extinct when host population density falls below N_T through host mortality or reductions in fecundity (Dobson and May 1986, 1989).

Pathogens As A Threat to Endangered Species

One characteristic of most endangered species is small population sizes. These small populations are often found at artificially high densities in reserves, thereby often facilitating the rapid spread of pathogens that may be introduced into these populations, even if the population density is below the threshold density required to maintain an endemic infection. A classic example of this effect may be the outbreak of canine distemper that nearly eradicated the black-footed ferret (*Mustella nigripes*) shortly after its rediscovery in 1981 near Meeteetse in Wyoming (Thorne and Williams 1988). The free-ranging ferret population, which peaked at 129 individuals in 1984, was reduced to six individuals by the end of 1985 by an epizootic of the disease (Forrest *et al.* 1988).

Where small populations have reduced genetic variability due to past bottleneck effects and inbreeding, the loss of genetic diversity at such loci as the major histocompatibility complex and other immune system loci may increase population susceptibility to a disease epidemic (Allendorf 1986, O'Brien and Evermann 1988). Similarly, epidemics often break out when a population is disturbed or stressed; these outbreaks may reduce the population to sizes where demographic stochasticity or Allee effects prevent recovery, Such effects may be compounded by artificially increased levels of aggression in high density populations, which in turn reduce levels of immunocompetence. For example, in a captive population of macaques (*Macaca mulatta*), clinically confirmed tetanus accounted for approximately 25 percent of the 230 deaths which occurred during a five-year study (Rawlins and Kessler 1982). The tetanus organism, which is found in the feces of infected animals, enters the body through puncture wounds, postpartum contamination of the uterus, or umbilical infections. Peak levels of annual mortality occurred during the mating season when levels of aggression were at a peak and infection could occur through septic wounds.

Diseases That Infect Multiple Host Species

Pathogens that can utilize a range of host species present the greatest threat to endangered species. The presence of reservoir host species allows generalist pathogens to establish and maintain infections in populations otherwise too small to sustain them (Dobson and May 1989). Where the pathogen is more virulent towards rarer species, extinction of a susceptible population may be facilitated by the presence of a more common coexisting host. In many cases the impact of the pathogen results from differences in the lengths of time for which the various host species have had to develop a resistance to the pathogen. The establishment of pathogens of this type is often the result of the introduction of a non-native host species which acts as a reservoir for the disease while remaining comparatively immune to it. A classic example of this type of introduction has occurred in Hawaii where the extinction of several species of endemic landbirds was facilitated by the introduction of a suitable vector for transmissions of avian malaria. The pathogen had little impact on

Endangered Species
UPDATE

A forum for information exchange on endangered species issues
July 1989
Vol. 6 No. 9

Rob Blair...................Editor
Suzanne Jones............Assistant Editor

Instructions for Authors:
The *Endangered Species UPDATE* welcomes articles related to species protection in a wide range of areas including but not limited to: research and management activities for endangered species, theoretical approaches to species conservation, and habitat protection and preserve design. Book reviews, editorial comments, and announcements of current events and publications are also welcome.

Readers include a broad range of professionals in both scientific and policy fields. Articles should be written in an easily understandable style for a knowledgeable audience.
Manuscripts should be 10-12 double spaced typed pages. For further information please contact Rob Blair at the number listed below.

Subscription Information:
The *Endangered Species UPDATE* is published approximately ten times per year by the School of Natural Resources at The University of Michigan. Annual subscriptions are $15 each ($18 outside the U.S.). Send check or money order (made payable to The University of Michigan) to:

Endangered Species UPDATE
School of Natural Resources
The University of Michigan
Ann Arbor, MI 48109-1115
(313)763-3243

Cover:
Elk *(Cervus elaphus canadensis)*

Photo: Colorado Department of Natural Resources, Wildlife Division

Table 1. Tactics taken in pathogen control may depend on the primary host.

	Wild Host	Domestic Host
Reservoir Host	Controlled culling of wild host often seen as cheapest viable means of control.	Control is likely if economic losses in domestic animals are important.
Pathological Host	May exclude domestic livestock from "wild" areas.	Mortality in wild species may go unnoticed.

the large variety of exotic bird species previously imported to the island, yet endemic Hawaiian species with no previous exposure to the pathogen succumbed rapidly to infection (Warner 1968, van Riper *et al.* 1986).

Pathogens that infect both wild and domestic species of hosts are of particular concern for conservation biologists and managers of wild habitats. The control of these pathogens can lead to conflicts between interest groups, primarily livestock and wildlife managers. The problems that arise are often dependent upon whether domestic or wild animals are the primary host of the pathogen (Table 1). In essence, if the pathogen is predominantly present in domestic animals, it is in everyone's best interest to control it. However, if infections are maintained in wild animals, then it may be easier to control interactions between wild and domestic animals by reducing the size of the wild host population.

As examples of these two different scenarios, we can compare and contrast brucellosis with rinderpest — two microparasitic diseases which infect wild and domestic ungulate populations in the savanna grasslands of United States and East Africa, respectively. The causative agent of brucellosis is the bacterium *Brucella abortus*, while rinderpest is caused by a *Morbillivirus*. Both pathogens cause problems around the borders of nature reserves where domestic livestock come into contact with wild ungulates.

Brucellosis

Brucellosis is a major disease of domestic livestock that results in economic loss through abortions, infertility, and loss of domestic animal products. It also poses a health risk to those who work with infected animals (Thimm 1982). In the prairie regions of northwestern Wyoming, elk and bison are reservoirs of the disease, with transmission between elk occurring primarily through contact with aborted fetuses. Infected elk have been present in Yellowstone National Park since at least 1917 (Tunnicliff and Marsh 1935), and infected animals are found in at least 15 of the 23 herds that visit the winter feeding grounds in northwestern Wyoming (Thorne *et al.* 1979). The disease is most likely maintained because of the unnaturally crowded conditions resulting from winter feeding programs; non-feedground elk that have been tested have shown no evidence of disease (Thorne *et al.* 1981).

Brucellosis in free-ranging elk has several implications for the management of elk. It causes abortion of the first pregnancy following infection, and occasionally causes abortion of the second. The net result is a 7 to 12 percent reduction in herd productivity, and a reduction in the potential sustainable yield harvested by hunters (Boyce 1989, Thorne, *et al.* 1979). Also, infected elk pose a health problem for hunters handling infected animals (Thorne *et al.* 1981, Kistner *et al.* 1982).

More complex problems arise when elk feed alongside cattle during the period that abortions are occurring, thus providing a potential source of infection for brucellosis-free cattle herds. Circumstantial evidence has implicated elk in two cases of brucellosis arising in cattle in northwestern Wyoming (Boyce 1989, Tessaro 1986). In the spring of 1989, an outbreak of bovine brucellosis which occurred near Dubois, Wyoming, was likely transmitted by infected elk and bison that were feeding with this particular herd (E.T. Thorne *pers. comm.*).

A vaccination program at several feedgrounds was begun to control brucellosis in the elk. This control program will help ease the conflicts between wildlife and livestock managers, and, if successful, will set precedents for similar programs involving other species.

The bison of Yellowstone National Park are also a reservoir of brucellosis (Tessaro 1986, McCorquodale and DiGiacomo 1985, Meagher 1973), as are the hybrid woods-plain bison (*Bison bison athabascae X Bison bison bison*) in Wood Buffalo National Park, Alberta (Broughton 1987). Like elk, the presence of brucellosis in bison offers several management problems. The fear of transmission of brucellosis from bison to cattle is such that all bison migrating north across the Yellowstone Park border are shot (Meagher 1989).

Rinderpest

In many ways rinderpest presents an obverse example to brucellosis. With rinderpest, domestic livestock act as the reservoir from which the pathogen can invade wild animals (Scott 1970, Plowright 1982). The pathogen caused a major pandemic in both cattle and wild game when first introduced into East and Southern Africa at the end of the 19th century.

The development of a relatively effective vaccine in the 1940s led to large scale inoculation schemes for domestic livestock. However, these vaccines were only effective in animals that were devoid of colostral immunity (partial immunity conferred on newly-

(Continued on UPDATE page 4)

born offspring by immune mothers). Because vaccination campaigns were carried out only once a year, substantial populations of immature susceptible animals built up, and these were large enough to sustain rinderpest infections in many areas (Plowright 1982). The development of a culture-attenuated virus vaccine in the late 1950s produced a vaccine that was effective in cattle of all ages, and this facilitated the international campaign which attempted to completely control rinderpest in African livestock. In areas of Africa where this campaign was successfully mounted it had the additional side-effect of removing the source of infection for wild animals, and many populations consequently increased in numbers. In the Serengeti region of Tanzania, numbers of buffalo and wildebeest have increased by almost a factor of five since the control of rinderpest (Sinclair 1977).

In areas of Africa where wars or economic problems make administration of an effective vaccination scheme impossible, rinderpest continues to affect both wild and domestic ungulate populations (Rossiter *et al.* 1987). These economically troubled areas serve as primary loci of infection from which rinderpest can occasionally spread with the movement of infected cattle or game, and cause outbreaks in areas free from infection. These outbreaks are potentially devastating because the majority of populations of game animals in rinderpest-control areas contain few immune individuals once the pathogen has been controlled for several years.

Anthrax

Pathogens can also have effects on the structure of ecological communities that lead to changes in the numbers of species that are not infected by the disease. A long term study of predator-prey relationships in Etosha National Park has shown that providing water by digging waterholes and gravel pits has led to an epidemic of anthrax in several ungulate species (Berry 1981; Ebedes 1976). The waterholes were dug to provide a source of water for ungulates during the dry season, which was required because fencing around the park boundary prevented the game populations from making their normal migration. The presence of large populations of ungulates throughout the year and the alkaline conditions of the pools proved ideal for the survival of anthrax spores; the mortality from anthrax accounts for an estimated 60 to 70 percent of diagnosed wildebeest deaths. The presence of large numbers of readily available corpses has led to an increase in the density of scavenging predators in the park, which in turn has led to increased predation and disturbance of uninfected prey species (Berry 1981). Ratios of predator to prey in the area are thus significantly higher than they are in other comparable habitats.

Controlling Pathogens In Wild Populations

Once it is realized that artificially high population densities and association with potential reservoir hosts are major causes of disease outbreaks, it is possible to make recommendations about the steps that should be taken to prevent outbreaks.

It is important to differentiate between pathogens introduced from interactions with other species and those that are normally present in host populations. If pathogens are introduced from other species it is important to minimize the opportunity for chance introductions, which may be done isolating the endangered population from contact with potential sources of infection. For example, in cases where pathogens affect both wild and domestic species, fencing can be used to control diseases such as trypanosomiasis and foot-and-mouth disease in Africa (Taylor and Martin 1987). However, the cost of fences can be expensive and may disrupt the normal migration routes of wild species, as in Etosha.

Where pathogens directly threaten the welfare of endangered species, isolation may seem an attractive option. However, it may ultimately prove detrimental because the absence of exposure to other common pathogens relaxes selection for resistance to pathogens, and lowers herd immunity. Re-exposure — which is inevitable given a sufficiently long time horizon — will ultimately resort in higher levels of mortality. It is therefore important not to keep populations of endangered species in conditions where they lose natural immunity to common infections. Indeed, in the very long term, selection by parasites may help to maintain population genetic variation. Thus, the threat of exposure to pathogens is one of the strongest arguments that can be made for subdividing populations of endangered species into different isolated nature reserves.

"In many cases the efficacy of vaccination and other disease control schemes is determined by who foots the bill..."

In situations where pathogens are naturally present in wild and domestic populations, there will always be inherent difficulties in controlling them; brucellosis, for example, may be controlled fairly readily in elk, but not in bison due to differences in feeding habits, locale, and the effects of the vaccine on the animals. Similarly, although it is possible to vaccinate several thousand cattle a day with rinderpest vaccine, it is impossible to vaccinate more than 20 to 30 wild buffalo (Plowright 1982); even vaccinating this many buffalo would involve considerable risk of physical injury to the workers doing the vaccination. Under these circumstances it is highly unlikely that sufficient levels of herd immunity would be attained in the wild population to come anywhere near controlling the disease.

Economics of Disease Control

In many cases the efficacy of vaccination and other disease control schemes is determined by who foots the bill for control (May 1988). The economic problems involved here are further compounded by the rate at which different interest groups discount the future. Many farmers, wildstock managers, and even politicians are as concerned for the future of different game species as are conservation biologists and wildlife managers. However, the financial incentive determining how much each group should pay towards the control of a specific disease is highly dependent upon both the benefits that each receives from the control and the length of time those benefits last. Unfortunately, there is often an inverse relationship between the finance base of each of these organizations and the length of time for which they plan. The economic decisions made by the financially more vociferous agricultural and political lobbies are usually determined by events that occur on a timescale of months and years. In contrast, the relatively impoverished environmental organizations are concerned with timescales that are measured in decades and centuries. Thus, financial aid is often made available to control epidemic outbreaks of disease where immediate profits are threatened, but little financial incentive exists to continually monitor the possibility of outbreaks in wild species of limited economic value. Perhaps the present epidemic of AIDS and the resurgence of malaria — diseases whose economic and social effects will be felt on the timescale of decades — will alter the perspectives of politicians from their present short-term focus to one that promotes a longer term approach to rational disease control. This change in attitude is essential if the major breakthroughs in epidemiological theory of the last 10 years are to be capitalized upon in the control of infectious diseases in both wild and domestic populations.

> **"Perhaps the present epidemic of AIDS and the resurgence of malaria...will alter the perspectives of politicians from their current short-term focus..."**

Acknowledgements

Andrew Dobson is an assistant professor, and Dan Miller is a graduate student, at the Department of Biology, University of Rochester, in Rochester, NY. Their work on wildlife diseases is supported by a grant from Wildlife Conservation International.

Literature Cited

Allendorf, F. W. 1986. Genetic drift and the loss of alleles versus heterozygosity. Zoo Biology 5:181-190.

Anderson, R. M. and R. M. May. 1979. Population biology of infectious diseases: Part I. Nature 280:361-367.

Anderson, R. M. and R. M. May. 1982a. Directly transmitted infectious diseases: control by vaccination. Science 215:1053-1060.

Anderson, R. M. and R. M. May. 1982b. Population dynamics of human helminth infections: control by chemotherapy. Nature 297:557-563.

Anon. 1989. Death in the North Sea. Oryx 23:5-6.

Berry, H. H. 1981. Abnormal levels of disease and predation as limiting factors for wildebeest in the Etosha National Park. Madoqua 12:242-253.

Broughton, E. 1987. Diseases affecting bison. Pages 34-38 in H. W. Reynolds and A. W. L. Hawley, eds. *Bison ecology in relation to agricultural development in the Slave River lowlands, NWT*. Occ. Paper No. 63. Canadian Wildlife Service.

Boyce, M. S. 1989. *The Jackson Elk Herd*. Cambrige University Press, New Rochelle.

Dobson, A. P., and R. M. May. 1986. Disease and Conservation. Pages 345-365 in M. Soulé, ed. *Conservation Biology: The Science of Scarcity and Diversity*. Sinauer Associates, Sunderland, MA.

Dobson, A. P. and R. M. May. 1989. Parasites, cuckoos and avian population dynamics. In C.M. Perrions, ed. *Bird Population Studies: Their Relevance to Conservation and Management*. Oxford University Press (in press).

Ebedes, H. 1976. Anthrax epizootics in Etosha National Park. Madoqua 10:99-118.

Forrest, S. C., D. E. Biggins, L. Richardson, T. W. Clark, T. W. Campbell III, K. A. Fagerstone, and E. T. Thorne. 1988. Population attributes for the black-footed ferret (*Mustela nigripes*) at Meeteetse, Wyoming, 1981-1985. J. Mammal. 69:261-273.

Kistner, T. P. 1982. Diseases and parasites. Pages 181-218 in J. Thomas and D. E. Toweill, eds. *Elk of North America: ecology and management*. Stackpole Books, Harrisburg, PA.

May, R. M. 1988. Conservation and disease. Cons. Bio. 2:28-30.

McCorquodale, S. M., and R. F. DiGiacomo. 1985. The role of wild North American ungulates in the epidemiology of bovine brucellosis. J. Wildl. Dis. 121:351-357.

Meagher, M. 1989. Evaluation of boundary control for bison of Yellowstone National Park. Wildl. Soc. Bull. 17:15-19.

Meagher, M. 1973. The Department of Agriculture, the Department of the Interior, brucellosis, and the farmer. BioScience 23:311-312.

Plowright, W. 1982. The effects of rinderpest and rinderpest control on wildlife in Africa. Symp. Zool. Soc. Lond. 50:1-28.

O'Brien, S. J., and J.F. Evermann. 1988. Interactive influence of infectious disease and genetic diversity in natural populations. Trends Ecol. Evol. 3:254:259.

Rossiter, P. B., W. P. Taylor, B. Bwangamoi, A. R. H. Ngereza, P. D. S. Moorhouse, J. M. Haresnape, J. S. Wafula, J.. F. C. Nyange, and I. D. Gumm. 1987. Continuing presence of rinderpest virus as a threat in East Africa, 1983-1985. Veterinary Record 120:59-62.

Scott, G. R. 1970. Rinderpest. Pages 20-35 in J. W. Davis, L. H. Karstad and D. O. Trainer, eds. *Infectious Diseases of Wild Mammals*. Iowa State University Press, Iowa.

Scott, M. E., and A. Dobson. 1989. The role of parasites in regulating host abundance. Parasitology Today 5:176-183.

Sinclair, A. R. E. 1977. *The African Buffalo: A Study of Resource Limitation of Populations*. University of Chicago Press, Chicago, IL.

Sholley, C. R. 1989. Mountain gorilla update. Oryx 23:57-58.

Rawlins, B. G. and M. J. Kessler. 1982. A five-year study of tetanus in the Cayo Santiago Rhesus monkey colony: behavioral description and epizootiology. Am. J. Primatology 3:23-29.

Reynolds, J. D. 1988. Crayfish extinctions and crayfish plague in central Ireland. Biol. Cons. 45:279-285.

Taylor, R. D., and R. B. Martin. 1987. Effects of veterinary fences on wildlife conservation in Zimbabwe. Environ. Manage. 11:327-334.

Tessaro, S. V. 1986. The existing and potential importance of brucellosis and tuberculosis in Canadian wildlife: a review. Can. Vet. J. 27:119-124.

Thimm, B. M. 1982. *Brucellosis: Distribution in Man, Domestic, and Wild Animals*. Springer-Verlag, Berlin.

Thorne, E. T., and E. S. Williams. 1988. Disease and endangered species: the black-footed ferret as a recent example. Conserv. Biol. 2:66-74.

Thorne, E. T., J. K. Morton, and W. C. Ray. 1979. Brucellosis, its effect and impact on elk in western Wyoming. Pages 212-220 in M. S. Boyce and L. D. Hayden-Wing, eds. *North American Elk: Ecology, Behavior, and Management*. The University of Wyoming, Laramie, WY.

Thorne, E. T., T. J. Walthall, and A. Tebaldi. 1981. The incidence and importance of brucellosis in elk in northwestern WyOming. Job Comp. Rep. Wyo. Game and Fish Comm., Laramie, WY.

Tunnicliff, E. A., and H. Marsh. 1935. Bang's disease in bison and elk in the Yellowstone National Park and on the National Bison Range. J. Am. Vet. Med. Assoc. 86:745-752.

van Riper III, C., S. G. van Riper, M. L. Goff and M. Laird. 1986. The epizootiology and ecological significance of malaria in Hawaiian landbirds. Ecol. Monogr. 56:327-344.

Warner, R. E. 1968. The role of introduced diseases in the extinction of the endemic Hawaiian avifauna. Condor 70:101-120.

Opinion

Invertebrate Subspecies and the Endangered Species Act

by Dennis D. Murphy

Taxonomists' decisions can have enormous impact on our estimates of rates of vanishing biological diversity and our ability to employ the Endangered Species Act. In the original Act, Congress legislated "species" protection that could be extended to individual populations. An amendment in the 1978 reauthorization of the Act restricted protection for invertebrates to subspecies or higher taxonomic entities (species, genera, etc.) that are threatened or endangered in their *entirety*. With that amendment, Congress created a source of unending controversy, and, certainly unintentionally, granted taxonomists the power to determine which among the world's millions of invertebrates can be considered for federal protection.

While the subspecies designation is generally recognized as a valuable tool for describing infraspecific geographic variation, it is also recognized as an often arbitrary taxonomic construct that conveys little genetic or evolutionary information. Wilson and Brown (1953, Sys. Zool. 2:97-111) long ago noted that the use of different sets of physical characters can result in the division of species into different numbers of subspecies. Thus, all taxonomic treatments below the species level are particularly subject to disagreement.

The U.S. Fish and Wildlife Service, short on staff and appropriations, and faced with thousands of candidates for endangered species protection, understandably attempts to avoid initiating the listing process for controversial candidates—exemplars of which are organisms whose taxonomic status cannot be resolved with even the best available scientific evidence. In this context, otherwise innocuous infraspecific taxonomic decisions can have far-reaching consequences. The implications of this new-found power of taxonomists to influence application of the Endangered Species Act to invertebrates is well-illustrated by the case of the callippe silverspot butterfly (*Speyeria callippe callippe*).

Known from just three relict populations around San Francisco Bay, the silverspot was an inarguably strong candidate for endangered status. As time came for the USFWS to render its "biological opinion" on the proposal, a manuscript purporting to "revise" (reassign) the subspecies names of *Speyeria callippe* was circulated. Using principal components analysis, Arnold (1985, Pan. Pac. Ent. 61:1-23) drew the conclusion that the species *Speyeria callippe* consisted of not the 16 traditionally accepted, narrowly distributed subspecies, but just three broadly distributed subspecies.

Principal components analysis is a valuable tool for assessing variation, but use of this technique does not guarantee unequivocal taxonomic assignments. Biological insight is required in choosing appropriate characters and in interpreting the results. In the case of the silverspot, from an essentially infinite pool of phenetic, genetic, and ecological characters, Arnold selected for analysis but eight characters, all wing markings. Based on ventral hindwing color, nine otherwise highly morphologically and ecologically distinct subspecies distributed from Mexico to Oregon were lumped as one—*Speyeria callippe callippe.* Since this study was published, specialists have indicated that the characters chosen for the analysis would not have separated full species within the genus *Speyeria*, and that individuals of species other than *Speyeria callippe* appear to have been used in the original analysis. Nonetheless, following that treatment, the silverspot would not qualify for protection, and the pending publication of the paper alone was adequate to squelch the listing. One of the remaining populations has become surrounded by housing developments, thus the future of *Speyeria callippe callippe* (*sensu lato*) is now in additional jeopardy.

Needless to say, this soft underbelly of the Act has not been lost on the development interests that perceive themselves threatened by specific invertebrate listing proposals. Defense contractor United Technologies Corporation, for example, recently hired Arnold to make a similar taxonomic argument to stop the listing of the bay checkerspot butterfly, *Euphydryas editha bayensis.* That attempt ultimately failed, but during the more than two year delay that it caused, several populations of the butterfly declined and one went extinct.

Both of the above examples clearly indicate that irresponsible revisions that lump subspecies compromise the ability of the USFWS to fulfill the Congressional mandate to protect Earth's biological diversity, including diversity within species. A better Endangered Species Act would confer federal protection upon invertebrate populations—for it is on that level that the genetic diversity of invertebrate species is shaped and must be preserved. But, until the Act is improved, taxonomists will continue to bear a heavy conservation responsibility—lumping of subspecies as a by-product of studies of infraspecific variation could well mean the extinction of threatened or endangered populations. With that in mind taxonomists: do feel free to continue to study infraspecific variation but, *please*, lump subspecies only after *all* factors are considered.

Dennis Murphy is director of The Center for Conservation Biology at Stanford University.

Bulletin Board

Restoration Conference

The second annual conference of the Society for Ecological Restoration will be held in Chicago on April 29-May 3, 1990. The program will include several special sessions and a full program of contributed papers, lectures, workshops, and field trips to facilitate communication among restorationists, decision makers, and the general public. Special session topics will include: prairie and savanna restoration, restoration and global climate change, setting standards for monitoring restoration projects, restoration and recovery of endangered species, and restoration philosophy. The Society invites submission of paper abstracts on these topics in particular, as well as other aspects of ecological restoration. Deadline for submission is January 15, 1990. Submission forms may be obtained from the Society's offices: S.E.R., 1207 Seminole Highway, Madison, WI 53711; (608) 263-7889.

Rare Lichens Project

A project to determine the conservation status of the lichens of Hawaii and North America north of Mexico was recently begun by Mason E. Hale, Jr. and Sherry K. Pittam of the Smithsonian Institution, in cooperation with The Nature Conservancy. The project's goal is to generate a list of rare and endangered lichens, along with the information necessary to provide protection for these species as needed. This information will then be made available to The Nature Conservancy, as well as other conservation organizations and land management agencies. Those interested are invited to submit the names of potentially rare or endangered lichen species, along with any supporting information. Please send to: Sherry K. Pittam, Rare Lichens Project, Smithsonian Institution, Botany/NHB 166, Washington, DC 20560; (202) 357-2545.

Conservation of Biological Diversity Program

The World Wildlife Fund, the World Resources Institute, the Center for International Development and Environment, and The Nature Conservancy, are implementing a centrally-funded U.S. Aid for International Development (USAID) program for the Conservation of Biological Diversity. The program will promote sustainable economic development in developing countries through better conservation and use of biological resources.

The project is composed of five major parts: 1) technical assistance offered to AID missions, host country institutions, local private volunteer organizations and the Peace Corps; 2) a small grants program for specific research issues relevant to AID's worldwide conservation activities; 3) training for local scientists in identifying research priorities and preparing proposals; 4) an information and evaluation network on USAID conservation activities linked with other relevant databases; and 5) pilot demonstration projects funded largely by USAID mission and regional bureau buy-ins. For more information, contact: Dr. Gary S. Hartshorn, Biodiversity Director, World Wildlife Fund, 1250 24th Street, NW, Washington, DC 20037; (202) 778-9600.

Bulletin board information provided in part by Jane Villa-Lobos, Smithsonian Institution.

Endangered Species UPDATE

School of Natural Resources
The University of Michigan
Ann Arbor, MI 48109-1115

Non-Profit
Organization
U.S. POSTAGE
PAID
Ann Arbor, MI
Permit No. 144