Addressing Disease Risks When Recovering Species at Risk

JOSEPH K. GAYDOS[1] AND KIRSTEN V. K. GILARDI[2]

[1]The SeaDoc Society, U.C. Davis Wildlife Health Center–Orcas Island Office, 982 Deer Harbor Road, Eastsound, WA 98245, U.S.A., email jkgaydos@ucdavis.edu
[2]The SeaDoc Society, U.C. Davis Wildlife Health Center, School of Veterinary Medicine, One Shields Avenue, Davis, CA 95616, U.S.A.

Abstract: Infectious and noninfectious diseases have had major impacts on free-ranging wildlife populations, and are especially important when recovering species at risk. For example, disease has hindered recovery of the black-footed ferret (*Mustela nigripes*), bighorn sheep (*Ovis canadensis*), Florida panther (*Puma concolor coryi*), pygmy rabbit (*Brachylagus idahoensis*), wood bison (*Bos bison athabascae*), and southern sea otter (*Enhydra lutris nereis*). Additionally, disease brought the peregrine falcon (*Falco peregrinus*) to the brink of extinction in the 1970s, and caused the extinction of a *Partula* spp. terrestrial snail in the early 1990s. When a single disease can extirpate a remnant population, or when managers are forced to use tools such as translocation or captive breeding, which may increase the risk of disease impacts, managers must be proactive about disease risks. We suggest using a multi-tiered process when addressing disease concerns for species at risk:

- When planning species recovery, consider disease as a factor that can impact the success of recovery efforts.
- Evaluate potentially important infectious and noninfectious diseases.
- Be cognizant about the risk of introducing diseases when translocating species or when propagating species at risk in captivity. *It is easier to prevent the introduction of a disease than to manage or eradicate it.* Exercise the precautionary principle, recognizing that there can be diseases of concern that have not yet been documented for the species in question.
- Keep in mind that treatment of individuals or vaccinations are not the only strategies available for disease management. Disease in a population can be managed by manipulating one or more of the following: the pathogen or toxin, the population, the environment, or human activities.
- Monitoring disease management strategies is important to assess efficacy.

Key Words: disease, translocation, species recovery, disease monitoring

Introduction and Methods

Disease is a major ecological force and should always be considered as a factor that can impact the recovery of species at risk. There is no doubt that the role of disease in wildlife conservation was "radically underestimated" (Leopold 1933) by early conservationists. Even though determining the impact of disease can be difficult (McCallum 1994), we have since learned that disease has the potential to directly affect host survival and cause catastrophic die-offs (Young 1994), and also that it can indirectly affect host survival by increasing host susceptibility to predation or by reducing competitive fitness (Scott 1988).

Addressing disease concerns for species at risk is challenging and can seem overwhelming. Often very little is known about diseases of species at risk. Even when there is a considerable body of knowledge about diseases in a particular species, disease in a population is not static, and anthropogenic factors (Harvell et al. 1999; Daszak et al. 2001) and climate change (Harvell et al. 1999, 2002) influence disease risk. Complicating the matter further, more work is still needed to take what we know about wildlife diseases and conservation medicine and integrate it into practical actions that will help conserve wildlife more effectively (Deem et al. 2001).

We suggest that managers use a multi-tiered process when addressing disease concerns for species at risk. We use examples to illustrate this process. While these examples focus on wildlife diseases, we recognize that diseases also can affect plants (e.g., sudden oak death: Rizzo and Garbeletto 2003) and invertebrates (e.g., withering syndrome of abalone: Richard and Davis 1993; Alstatt et al. 1996), and hope that this process will still be helpful for mangers working with non-vertebrate taxa at risk.

We recommend five points for addressing disease concerns:

1. When planning species recovery, consider disease as a factor that can impact the success of recovery efforts.
2. Evaluate potentially important infectious and noninfectious diseases.
3. Be cognizant about the risk of introducing diseases when translocating species or when propagating species at risk in captivity. *It is easier to prevent the introduction of a disease than to manage or eradicate it.* Exercise the precautionary principle, recognizing that there can be diseases of concern that have not yet been documented for the species in question.
4. Keep in mind that treatment of individuals or vaccinations are not the only strategies available for disease management. Disease in a population can be managed by manipulating one or more of the following: the pathogen or toxin, the species at risk, the environment, or human activities.
5. Monitoring disease management strategies is important to assess efficacy.

Results and Discussion

When Planning Species Recovery, Consider Disease as a Factor That Can Impact the Success of Recovery Efforts

When drafting a plan for recovery of a threatened or endangered species, it is customary to identify historic and current threats to the species of concern, and to mitigate those threats through specific activities that maximize the population's short- and long-term viability. In addition to factors such as habitat availability and quality, food availability, anthropogenic threats, population fecundity and genetic heterogeneity, disease must also be considered as a factor that has the potential to impact the success of a recovery effort (Wolfe and Seal 1993; Hess 1994; Simonetti 1995). Disease has hindered recovery of the black-footed ferret (*Mustela nigripes*) (Thorne and Williams 1988; Williams et al. 1988); peninsular bighorn sheep (*Ovis canadensis*) (U.S. Fish and Wildlife Service 2000); Florida panther (*Puma concolor coryi*) (Roelke et al. 1993; Cunningham et al. 1999); pygmy rabbit (*Brachylagus idahoensis*) (Mansfield et al. 2003); wood bison (*Bos bison athabascae*) (Tessaro et al. 1990); and southern sea otter (*Enhydra lutris nereis*) (Kreuder et al. 2003). Additionally, disease brought the peregrine falcon (*Falco peregrinus*) to the brink of extinction in the 1970s (Risebrough 1986), and caused the extinction of a *Partula* spp. terrestrial snail in the early 1990s (Cunningham and Daszak 1998).

Wildlife health specialists can provide assistance with matters relating to disease and population health, and should be consulted or utilized by species recovery teams throughout the recovery process. Although they are only a small part of the conservation team, wildlife health specialists bring diagnostic skills needed to determine the causes of sickness and death in wild animals, evaluate the impact of identified diseases and parasites on the population at risk, help define the disease interrelationships between wildlife and domestic animals, and ultimately, devise ways to prevent, control, or eliminate major disease problems for threatened or endangered species (Nettles 1992).

Evaluate Potentially Important Diseases

As a starting point, it is important for managers to determine which disease agents are threats to populations of concern. This can be difficult because some species have not been well studied from a disease perspective. For example, a recent review of infectious disease threats to a small declining population of killer whales (*Orcinus orca*) revealed only three infectious agents reported from free-ranging killer whales and only 13 more pathogens reported in captive killer whales (Gaydos et al. 2004). With so little information, it is difficult to assess disease risk. For other species, disease information is more abundant. A health protocol used to evaluate disease risk for translocating elk (*Cervus elaphus*), for example, identified 190 infectious agents and ectoparasites (Corn and Nettles 2001).

Regardless of the scarcity or abundance of available information, it is important for managers to develop a list of potential disease risks for the species of concern. This list should include noninfectious causes such as toxins and environmental contaminants, infectious diseases to which the animals are known to be susceptible, and potential infectious diseases that are known to infect closely related domestic animals or sympatric wild animals (Gaydos and Corn 2001).

Once developed, the list of potential disease risks should be evaluated to determine which diseases pose a threat to the recovery or long-term viability of the population. Mitigation or prevention strategies should be developed for these high-risk diseases. It is important to stress that the goal is prevention or control of diseases that may impact the population, not to develop a disease-free population. For very small populations and when captive propagation is used as a tool for recovery, population viability can depend on the performance of key individuals. In these cases, treatment of individual animals can become an integral component of population health (American Association of Zoo Veterinarians 1993).

Recovery teams need to make efforts to collect ongoing information about diseases in threatened and endangered species and to use this information to continually reassess the list of potential disease risks. When individual animals are captured and handled, the opportunity should be used to collect blood or other tissues, which can be evaluated for exposure to infectious and noninfectious diseases. Additionally, collection and complete necropsy of all dead animals is a critical component of collecting information about diseases of concern. We strongly recommend that all dead animals receive a comprehensive gross necropsy examination; a microscopic evaluation of tissues (histopathology) conducted by a pathologist experienced in wildlife diseases; ancillary testing for bacteria, viruses, and fungi; and screening for heavy metals and contaminants.

The use of radio transmitters to monitor species at risk can be an excellent opportunity for biologists and disease specialists to collaborate and learn more about diseases in the population of concern (Spalding and Forrester 1993). Samples can be taken when animals are handled, and if radio-tagged animals are followed until death, they can be retrieved in a relatively rapid and systematic manor and submitted for postmortem necropsy.

The Florida panther recovery program provides a good example of how to evaluate potentially important disease risks and incorporate them into a recovery plan. It also provides an example of the value of remaining open and willing to alter plans based on continual assessment of diseases and disease risk. Low population numbers, increased human presence, diseases and parasites, and reduced prey base are recognized threats to the survival of the Florida panther (U.S. Fish and Wildlife Service 1987). During early recovery planning, a comprehensive list of infectious disease agents that might affect the panther was developed (Roelke et al. 1991). Samples collected from live and dead panthers helped to create a list of 61 contaminants, tumors, anomalies, parasites, and infectious disease agents in this subspecies (Forrester 1992). Veterinarians assisted with chemical capture and immobilization and sample collection for disease screening. They also provided treatment to injured and ill animals, and performed postmortem necropsies. Three viruses and one parasite were targeted for intervention, and panthers were vaccinated and dewormed on an annual or biannual basis depending on the capture interval (Roelke and Glass 1992). Additionally, because postmortem necropsies demonstrated that road mortality was a major mortality factor (Maehr et al. 1991), road underpasses were constructed, which significantly reduced mortality at one major highway site (Maehr 1997).

Translocation and Disease Risk

Translocation of genetically similar individuals to establish a new population or augment an existing population is sometimes used as a recovery tool. Source animals can come from more robust but separate wild populations or from captive breeding. Such translocation efforts should not be undertaken without first addressing disease risks.

Several good reviews address different aspects of disease and translocation, and warrant review by managers who are considering translocation as a tool for species recovery (Davidson and Nettles 1992; Jessup 1993; Griffith et al. 1993; Wolfe and Seal 1993; Cunningham 1996; Gaydos and Corn 2001). Briefly, risks include the movement of a disease agent into a release area, exacerbation of an existing disease problem by introduction of additional pathogens, and exposure of translocated wildlife to diseases already present at the release area (Gaydos and Corn 2001). By far, the greatest hazard is the introduction of a new disease through translocation. A well known example of this was the translocation of 6000 plains bison (*Bos bison bison*) to an area with an established wood bison herd numbering about 1500. That translocation inadvertently introduced bovine brucellosis (*Brucella abortus*) and bovine tuberculosis (*Mycobacterium bovis*) into the wood bison herd (Tessaro et al. 1990; Carbyn and Watson 2001). Because there are no effective treatment or immunization methods for either disease, the introduction of these diseases and the hybridization that also occurred with this translocation remain political and biological problems for managing wood bison 75 years after the translocation.

A comprehensive disease risk assessment will help managers evaluate the potential for introducing pathogens and exposing animals to new pathogens at a release site, and a risk reduction protocol can facilitate safer translocation. Remember, however, there can always be diseases of concern that have not yet been documented for the species in question, so from a disease perspective, there is no such thing as a risk-free translocation. Because it is easier to prevent the introduction of a disease than to manage or eradicate it, managers should exercise the precautionary principle when translocating animals.

Disease Management Options

When considering disease as a factor that can impact the success of a recovery effort, managers will ultimately be faced with the question of what can or should be done to mitigate for diseases that are determined to be important. Disease management in wildlife can be categorized into three categories: prevention, control, and eradication (Wobeser 1994). For each of these options, treatment or action can occur at the level of the individual animal or at the level of the population and can be directed at manipulating the disease agent, the host population, the environment, human activities, or a combination of these (Wobeser 1994).

The management of lead poisoning in waterfowl is an example of controlling disease by manipulating the disease agent: lead shotgun pellets and human activities. Ducks and other aquatic birds can ingest lead shot while feeding, and at one time, lead poisoning was estimated to kill over one million birds annually (Wobeser 1997). To manage this noninfectious disease, a steel shot was developed and was mandated for use for waterfowl hunting.

The control of rinderpest in African wildlife is an example of managing disease by manipulating a combination of the agent and the host population. Rinderpest is an infectious disease caused by a morbillivirus. Since its introduction into Africa in the late 1800s rinderpest has caused catastrophic losses of wildlife and livestock (Plowright 1982). Large populations of susceptible animals are necessary to sustain the virus, which has moved between wildlife and domestic animals, especially between African buffalo (*Syncerus caffer*) and domestic cattle, since being introduced to Africa (Rossiter 2001). The development of a safe and efficacious vaccine for cattle allowed for widespread cattle vaccination campaigns (Plowright 1982). By effectively decreasing the threshold of susceptible animals needed to sustain the rinderpest virus, the cattle vaccination campaigns have effectively eradicated the virus from both cattle and wildlife and stopped outbreaks in certain regions (Rossiter 2001).

Monitor Management Efficacy

Attempts to manage disease in species at risk should always be combined with plans for monitoring and evaluating management efficacy. By deciding at the onset how management actions will be monitored and what will determine success, managers can more effectively determine if management attempts are beneficial and whether or not management actions should be continued or altered. This can be difficult, as often threatened or endangered populations are small and the importance of every individual can prohibit division of animals into treatment and no-treatment categories. For example, 65 mountain gorillas (*Gorilla gorilla beringei*) in the Virunga volcanoes region of central Africa were vaccinated during a measles-like respiratory outbreak in 1988 (Hastings et al. 1991). Dividing animals into vaccinated and non-vaccinated groups to monitor vaccine efficacy was not realistic due to the extremely small size of the population and the importance of all individuals to the population; consequently, all gorillas except pregnant ones were vaccinated. Signs of respiratory disease ceased after the vaccination program was initiated, however, the role of vaccination in preventing spread of the disease really could not be adequately evaluated. Despite potential difficulties in assessing disease management efficacy, assessment of action should be planned and conducted as a part of all disease management efforts.

Conclusions

Considering disease as a potential threat to the long-term viability of threatened or endangered species at the onset of recovery planning is the first step in averting disease-related problems during recovery. Managers also need to continually assess disease risks and impacts during the recovery process. When diseases of catastrophic potential are identified, disease management actions should be undertaken and evaluated for success. Disease is a major ecological force, and identifying and mitigating disease risks are critical components of recovering species at risk.

Acknowledgments

We thank the SeaDoc Society, a marine ecosystem health program of the U.C. Davis Wildlife Health Center for supporting this project. We thank S. Raverty and G. Massey for providing comments that improved the manuscript.

References

Allstatt, J.M., R.F. Ambrose, J.M. Engle, P.L. Haaker, K.D. Lafferty, and P.T. Raimondi. 1996. Recent declines of black abalone (*Haliotus cracherodii*) on the mainland coast of Central California. Marine Ecology–Progress Series **142**:185–192.

American Association of Zoo Veterinarians. 1993. Proceedings of the international conference on implications of infectious disease for captive propagation and reintroduction of threatened species. Journal of Zoo and Wildlife Medicine **24**:229–408.

Carbyn, L.N., and D. Watson. 2001. Translocation of plains bison to Wood Buffalo National Park: economic and conservation implications. Pages 189–204 in D.S. Maehr, R.F. Noss, and J.L. Larkin, editors. Large mammal restoration: ecological and sociological challenges in the 21st century. Island Press, Covela, California.

Corn, J.L., and V.F. Nettles. 2001. Health protocol for translocation of free-ranging elk. Journal of Wildlife Diseases **37**:413–426.

Cunningham, A.A. 1996. Disease risks of wildlife translocation. Conservation Biology **10**:349–353.

Cunningham, A.A., and P. Daszak. 1998. Extinction of a species of land snail due to infection with a microsporidian parasite. Conservation Biology **12**:1139–1141.

Cunningham, M.W., M.R. Dunbar, C.D. Buergelt, B.L. Homer, M.E. Roelke-Parker, S.K. Taylor, R. King, S.B. Citino, and C. Glass. 1999. Atrial septal defects in Florida panthers. Journal of Wildlife Diseases **35**:519–530.

Daszak, P., A.A. Cunningham, and A.D. Hyatt. 2001. Anthropogenic environmental change and the emergence of infectious diseases in wildlife. Acta Tropica **78**:103–116.

Davidson, W.R., and V. F. Nettles. 1992. Relocation of wildlife: identifying and evaluating disease risks. Transactions of the North American Wildlife and Natural Resources Conference **57**:466–473.

Deem, S.L., W.B. Karesh, and W. Weisman. 2001. Putting theory into practice: wildlife health in conservation. Conservation Biology **15**:1224–1233.

Forrester, D.J. 1992. Parasites and diseases of wild mammals in Florida. University Press of Florida, Gainesville, Florida. 459 pp.

Gaydos, J.K., and J.L. Corn. 2001. Health aspects of large mammal restoration. Pages 149–162 in D.S. Maehr, R.F. Noss, and J.L. Larkin, editors. Large mammal restoration: ecological and sociological challenges in the 21st century. Island Press, Covela, California.

Gaydos, J.K., K.C. Balcomb, III, R.W. Osborne, and L. Dierauf. 2004. Evaluating potential infectious disease threats for southern resident killer whales, *Orcinus orca*: a model for endangered species. Biological Conservation **117**:253–262.

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1993. Animal translocations and potential disease transmission. Journal of Zoo and Wildlife Medicine **24**:231–236.

Harvell, C.D., K. Kim, J.M. Burkholder, R.R. Colwell, P.R. Epstein, D.J. Grimes, E.E. Hofmann, E.K. Lipp, A.D.M.E. Osterhaus, R.M. Overstreet, J.W. Porter, G.W. Smith, and G.R. Vasta. 1999. Emerging marine diseases-climate links and anthropogenic factors. Science **285**:1505–1510.

Harvell, C.D., C.E. Mitchell, J.R. Ward, S. Altizer, A.P. Dobson, R.S. Ostfeld, and M.D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. Science **296**:2158–2162.

Hastings, B.E., D. Kenny, L.J. Lowenstine, and J.W. Foster. 1991. Mountain gorillas and measles: ontogeny of a wildlife vaccination program. Pages 198–205 in Proceedings of the annual conference of the American Association of Zoo Veterinarians, Calgary, Alberta.

Hess, G.R. 1994. Conservation corridors and contagious disease: a cautionary note. Conservation Biology **8**:256–262.

Jessup, D.A. 1993. Translocation of wildlife. Pages 493–499 in M.E. Fowler, editor. Zoo and wild animal medicine, current therapy 3. W. B. Saunders Company, Philadelphia, Pennsylvania.

Kreuder, C., M.A. Miller, D.A. Jessup, L.J. Lowenstine, M.D. Harris, J.A. Ames, T.E. Carpenter, P.A. Conrad, and J.A.K. Mazet. 2003. Patterns of mortality in southern sea otters (*Enhydra lutris nereis*) from 1998–2001. Journal of Wildlife Diseases **39**: 495–509.

Leopold, A. 1933. Game management. Scribner's, New York. 481 pp.

Maehr, D.S., E.D. Land, and M.E. Roelke. 1991. Mortality patterns of panthers in southwest Florida. Pages 201–207 in A.G. Eversole, editor. Proceedings of the annual conference of the southeastern fish and wildlife agencies. White Sulphur Springs, West Virginia.

Maehr, D.S. 1997. The Florida panther: life and death of a vanishing carnivore. Island Press, Washington D.C. 261 pp.

Mansfield, K., M. Finnegan, L. Harrenstien, D. Hays, L. Shipley, J. Steele, and N. Woodford. 2003. Disease as a factor limiting Columbia Basin Pygmy Rabbit recovery. Page 43 in Proceedings of the Wildlife Disease Association annual meeting. Saskatoon, Saskatchewan.

McCallum, H. 1994. Quantifying the impact of disease on threatened species. Pacific Conservation Biology **1**:107–117.

Nettles, V.F. 1992. Wildlife diseases and population medicine. Journal of the American Veterinary Medical Association **200**:648–652.

Plowright, W. 1982. The effects of rinderpest and rinderpest control on wildlife in Africa. Pages 1–28 in M.A. Edwards, and U. McDonnell, editors. Animal disease in relation to animal conservation. Academic Press, London, England. 336 pp.

Richard, D.V., and G.E. Davis. 1993. Early warnings of modern population collapse in black abalone *Haliotus cracherodii*, Leach, 1814, at the California Channel Islands. Journal of Shellfish Research **12**:189–194.

Risebrough, R. 1986. Pesticides and bird populations. Current Ornithology **3**:397–427.

Rizzo, D.M., and M. Garbelotto. 2003. Sudden oak death: endangering California and Oregon forest ecosystems. Frontiers in Ecology and the Environment **1**:197–204.

Roelke, M.E., D.J. Forrester, E.R. Jackobson, and G.V. Kollias. 1991. Rationale for surveillance and prevention of infectious and parasitic disease transmission among free-ranging and captive Florida panthers (*Felis concolor coryi*). Pages 185–190 in Proceedings of the annual conference of the American Association of Zoo Veterinarians. Calgary, Alberta.

Roelke, M.E., and C.M. Glass. 1992. Strategies for the management of the endangered Florida panther (*Felis concolor coryi*) in an ever shrinking habitat. Pages 38–43 in Proceedings of the joint meeting of the American Association of Zoo Veterinarians and the American Association of Wildlife Veterinarians. Oakland, California.

Roelke, M.E., J.S. Martenson, and S.J. O'Brien. 1993. Consequences of demographic reduction and genetic depletion in the endangered Florida panther. Current Biology **3**:340–350.

Rossiter, P. 2001. Rinderpest. Pages 37–45 in E.S. Williams and I.K. Barker, editors. Infectious diseases of wild mammals. Iowa State University Press, Ames, Iowa. 558 pp.

Scott, M.E. 1988. The impact of infection and disease on animal populations: implications for conservation biology. Conservation Biology **2**:40–56.

Simonetti, J.A. 1995. Wildlife conservation outside parks is a disease-mediated task. Conservation Biology **9**:454–456.

Spalding, M.G., and D.J. Forrester. 1993. Disease monitoring of free-ranging and released wildlife. Journal of Zoo and Wildlife Medicine **24**:271–280.

Tessaro, G.V., L.B. Forbes, and C. Turcotte. 1990. A survey of brucellosis and tuberculosis in bison in and around Wood Buffalo National Park, Canada. Canadian Veterinary Journal **31**:174–180.

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

U.S. Fish and Wildlife Service. 1987. Florida panther (*Felis concolor coryi*) recovery plan. Prepared by the Florida Panther Interagency Committee for the U.S. Fish and Wildlife Service, Atlanta, Georgia. 75 pp.

U.S. Fish and Wildlife Service. 2000. Recovery plan for bighorn sheep in the Peninsular ranges, California. U.S. Fish and Wildlife Service, Portland, Oregon. 251 pp.

Williams, E.S., E.T. Thorne, J.G. Appel, and D.W. Belitsy. 1988. Canine distemper in black-footed ferrets (*Mustela nigripes*) in Wyoming. Journal of Wildlife Diseases **24**:385–398.

Wobeser, G.A. 1994. Investigation and management of disease in wild animals. Plenum Press, New York. 265 pp.

Wobeser, G.A. 1997. Diseases of wild waterfowl, 2nd edition. Kluwer Academic Publishers, New York. 336 pp.

Wolfe, P.L., and U.S. Seal. 1993. Implications for infectious disease for captive propagation and reintroduction of threatened species. Journal of Zoo and Wildlife Medicine **24**:229–230.

Young, T.P. 1994. Natural die-offs of large mammals: implication for conservation. Conservation Biology **8**:410–418.