Applications of veterinary medicine to *in situ* conservation efforts

William B. Karesh and Robert A. Cook

Wildlife conservation efforts are increasingly faced with declining, overcrowded or fragmented populations, environmental contamination, and the introduction of new species of either competitors or pathogens. These efforts are coming under increased public scrutiny in their attempt to balance human social and economic needs with those of wildlife. The integration of veterinary medicine as part of a multidisciplinary approach to conservation can assist in the successful planning, implementation and evaluation of conservation projects. Beyond the role of immobilizing animals, veterinarians can contribute to assessing and monitoring the health of wild populations, and can train others in modern approaches to working with and caring for wildlife.

Introduction

The successes of modern conservation efforts are clearly associated with the use of multidisciplinary approaches to resolve social, economic, political and biological issues. However, veterinary participation from inception to completion of conservation projects is still rare. This is partly due to the common misconception that veterinarians deal only with individual animals. The fact that veterinarians are actively involved with population, environmental and epidemiological approaches is often overlooked. This is partly due to use of different terminology such as 'herd health', or due to the segregation of information inherent to scientific publication. Integration of veterinary medicine into conservation has the potential to enhance the biological, social and economic components of many projects.

In recent years, the benefits of veterinary involvement in the translocation of endangered species has been demonstrated for a number of high-profile species such as the Arabian oryx *Oryx leucoryx* (Woodford and Koch, 1991) and the black-footed ferret *Mustela nigripes* (Thorne and Williams, 1988; Williams *et al.*, 1992). In rare instances, semicomprehensive health-care programmes have been established for select populations of a single wild species such as the mountain gorilla *Gorilla gorilla beringei* (Foster, 1988). More extensive programmes for species or for broad taxonomic groups maintained in captivity have been developed during the last decade (Munson and Cook, 1993; Bush *et al.*, in press). Veterinary involvement in government conservation activities in Kenya, Zimbabwe and South Africa serve as good examples of the value of interdisciplinary approaches.

Veterinarians can provide the expertise to augment wildlife conservation efforts in a number of tangible ways. In addition to clinical and pathology services, all wildlife health-related disciplines such as epidemiology, nutrition, genetics, toxicology and reproductive studies can be used to enhance conservation efforts. Wildlife health care can include: (i) identifying critical health factors, (ii) monitoring health status, (iii) crisis intervention, (iv) developing and applying new technologies, (v) addressing animal handling and welfare concerns, and (vi) training.

Critical health factors

Identifying critical health-related factors affecting wildlife populations is the first step in

https://doi.org/10.1017/S0030605300021232 Published online by Cambridge University Press

understanding the role of disease in population dynamics. A knowledge of these factors is essential to making many conservation management decisions. Over the last decade, the impact and potential impact of health and disease on conservation efforts has been discussed and promoted by leaders in a variety of disciplines (Anderson and May, 1979; Dobson and Hudson, 1986; May, 1988; O'Brien and Evermann, 1988; Scott, 1988).

A number of studies have identified health-related factors or disease-causing agents affecting a population of a particular species (Hudson and Dobson, 1989; Mech and Goyal, 1993; Woolf *et al.*, 1993). These studies are typically focused on either the mechanics or the ecological role of one specific factor or pathogen. Given the complex inter-relationships of factors affecting health, single-factor studies seldom provide the assessment needed in conservation projects and may result in misleading conclusions. For example, if the effects of an infectious agent are studied without assessing the presence of viruses or toxins that are known to interfere with immune system function, then the significance of any findings could easily be misinterpreted.

Complete health surveys including bacterial, viral, fungal, nutritional, metabolic, genetic and toxicological problems are needed but lacking for most threatened and endangered species, or even related sympatric species. When correlated with data on population dynamics, health-factor information collected in comprehensive surveys could be used to guide management plans and monitoring programmes. Dobson and Hudson (1986) provide compelling examples of the interactions of infectious disease, wildlife populations and anthropogenic effects. Although their models were simplistic because they included only two types of disease classes (micro- and macroparasites), they clearly demonstrated the complexity and importance of these interactions. A decade later, there is still a vast deficit in the amount of information collected and analysed for key species, communities, or ecosystems in many parts of the world. In addition to the suggestion of Dobson and Hudson (1986) that molecular biologists and immunologists collaborate with ecologists to address this knowledge deficit, veterinarians and other wildife health professionals should be included in the team and undertake the task of collecting and compiling complete health profiles on wildlife populations to provide critically needed data.

Monitoring

Monitoring the health of wildlife populations over time can provide information that can be used to implement or modify conservation strategies. Disease-monitoring programmes can serve as sensitive indicators of environmental degradation by elucidating potential threats and actual changes in the health of populations. Such changes often occur prior to changes in population size or structure. For example, exposure to toxins or infectious agents, or the presence of metabolic, genetic or nutritional disorders can be detected in a population as a part of routine health-monitoring programmes. Woolf *et al.* (1993) demonstrated the serological presence of tularemia in cottontail rabbits *Sylvilagus floridanus* prior to a population decline from this disease. Such early detection allowed the prediction of seasonal survival.

Assessment and monitoring of population health would provide valuable qualitative and quantitative data to population viability analysis (PVA) programmes. The viability of a population is inseparable from the health of a population. PVAs performed in the absence of up-to-date health information are weakened in the same way that remote sensing surveys are weakened by a lack of ground truthing. In contrast with a conclusion made from visual observations indicating good health in four species of duikers *Cephalophus* spp. in the Ituri forest of Zaire, a health-assessment study demonstrated antibody titres to a variety of serovars of leptospirosis in 25 per cent of individuals tested, bovine herpesvirus 1 in approximately half, and bluetongue virus in roughly 90 per cent (Karesh *et al.*, in press). All these pathogens are known to cause reproductive problems in other ruminants and leptospirosis has been seen to cause stillbirths in captive duikers. Population modelling could overestimate productivity of these heavily harvested species (Hart, 1978) if based on reproductive potential without estimates of reproductive failure.

Eco-tourism and multiple-use land management have the potential for enhancing conservation efforts in some situations. While the benefits of these programmes are always stressed, there are also risks to the health of wildlife, domestic animals and human populations. Examples indicating these risks include diseases shared by: humans and great apes – measles, tuberculosis, hepatitis and respiratory viruses (Acha and Szyfres, 1980; Martin, 1986; Ott-Joslin, 1986; Kalter and Heberling, 1990; Hastings *et al.*, 1991; Shellabarger, 1991; Sajuthi *et al.*, 1992); wild and domestic ungulates – foot and mouth disease, parainfluenza-3, bluetongue virus, bovine herpesvirus, tuberculosis, brucellosis and pasteurellosis (Chow and Davis, 1964; Thorsen *et al.*, 1977; Hamblin and Hedger, 1978; Nyaga *et al.*, 1981; Thomas, 1981; Anonymous, 1990; Callan *et al.*, 1991; Sadi *et al.*, 1991); and, more recently, mortalities associated with canine distemper virus in the lions *Panthera leo* of the Serengeti (Morell, 1994) and black-footed ferrets in the United States (Thorne and Williams, 1988).

Conservation programmes, therefore, cannot be evaluated completely without assessing the impact on the health status of the wildlife populations. Baseline data collection will provide information needed for preventing the introduction or spread of new diseases. These data, coupled with routine monitoring, will enable the early detection of potentially serious health problems arising from changes in land-use practices.

Health assessment and monitoring also provide data on the presence of zoonotic diseases in wildlife populations that are used for eco-tourism. A conservation programme based on the financial rewards of animal viewing could be devastated by the illness of animals from a tourist-spread disease or the illness of tourists from an animal-spread disease. The potential for either problem needs to be identified and mitigated prior to an unfortunate episode. In 1988 an outbreak of respiratory disease in mountain gorillas in Rwanda resulted in the emergency implementation of a measles vaccination programme (measles is commonly manifested as severe pneumonia in apes). Follow-up studies demonstrated serological and histopathological findings consistent with measles virus or another closely related morbillivirus in one case and with a bacterial pneumonia in others (Hastings *et al.*, 1991). Although the behaviour of the animals had been studied for over 20 years, no baseline health sampling had been performed. Evidence of prior presence of the virus without mortality may have indicated no need for vaccination. In addition, the absence of prior presence of the virus would have indicated the introduction of a new pathogen. Having the baseline information would have simplified and expedited the decision making by project personnel.

In contrast to enhancing conservation efforts, the lack of health-monitoring data has resulted only in speculation and accusations regarding the significance of disease findings on the decline of populations. In the case of the mountain gorillas, unconfirmed reports of a high incidence of human measles in neighbouring Zaire implicated human encroachment into the parks or possibly poor management of tourism programmes. Some biologists working in South America attribute the decline of white-lipped peccaries *Tayassu pecari* and brocket deer *Mazama* spp. in specific localities to the introduction of domestic livestock and their diseases such as foot-and-mouth disease and/or an unidentified swine disease (A. Taber, J. Fragoso, pers. comms., Silvius, 1995). Without pre-exposure and post-exposure data, it is impossible to validate any of these potentially inflammatory speculations.

It is critical to address the potential for disease transmission to local human or domestic animal populations. With this information, one can better assess the social and economic benefits of multiple-use management or community-based conservation strategies. Wildlife reservoirs for diseases affecting humans and

© 1995 FFI, *Oryx*, **29** (4), 244–252

domestic animals have been reported for decades. Rabies (Sikes, 1981), yellow fever (Felsenfeld, 1972; Seymour and Yuill, 1981), foot-and-mouth disease (Hedger, 1981; Bengis *et al.*, 1986), avian influenza (Gerlach, 1994) and Newcastle's disease (Gerlach, 1994) are just some examples of diseases in wildlife that can have profound effects on humans and domestic animals. Hull (1963) lists 104 diseases transmitted from wild mammals and birds to humans. Many of those listed have seldom occurred or been reported due to the remoteness of the areas in which they exist. A project to support people and their domestic animals to settle new areas or live in proximity to wildlife accomplishes nothing if the disease risks are not addressed.

One other function of monitoring and assessment programmes for wildlife health is to assist in determining the suitability of wildlife populations for translocation, restocking, reintroduction or restoration ecology programmes. The success of these programmes can be greatly enhanced if proper steps are taken to evaluate the health risks existing in an area or in a particular group of animals. Animals to be introduced to an area need to be evaluated for diseases they may be harbouring and for their immunity to agents to which they may be exposed during the process. The areas that are selected for receipt of animals need to be assessed for the presence of diseases that may threaten the new arrivals and also for risks to existing populations by the introduction of new pathogens. Obviously, a disease-free state is not obtainable and probably not desirable, but documentation of health factors would be extremely helpful in decision making and in the evaluation of project methodology.

Many of the well-known examples of wildlife health problems have arisen from the movement of animals, such as the introduction of rinderpest to the African continent via cattle (Plowright, 1982), the introduction of a variety of avian diseases to Hawaii (Holmes, 1982), and the introduction of tuberculosis and brucellosis to bison *Bison bison* populations in Canada (Anonymous, 1990). Woodford (1993) provides a review of this topic and cites 15 other examples.

After decades of problems, this area of conservation work is now the most open to veterinary involvement. In 1992 a symposium was attended by over 150 participants to discuss the implications of infectious diseases in the captive propagation, reintroduction and translocation of wildlife, and the papers presented were published in the *Journal of Zoo and Wildlife Medicine* (1993). Davidson and Nettles (1992) and Woodford and Rossiter (1993) thoroughly describe infectious disease concerns that have arisen from the translocation of wildlife. The black-footed ferret recovery programme, which was severely hampered by exposure to canine distemper virus, currently has veterinarians involved in several areas (Thorne and Williams, 1988; Williams *et al.*, 1992). The golden-lion tamarin *Leontopithecus rosalia* (Bush *et al.*, in press), Arabian oryx (Woodford and Koch, 1991), whooping crane *Grus americana* (Langenberg, 1992), and California condor *Gymnogyps californianus* (Shima and Gonzales, 1991) programmes have all benefited by integrating veterinary specialists into their activities. The risks of introducing tuberculosis and hepatitis to wild orangutan *Pongo pygmaeus* populations during the release of confiscated pets in Indonesia are now being addressed by a team of veterinarians (Sajuthi *et al.*, 1993). The potential of introducing new diseases or exposing animals to new environmental pathogens in proposed strategies such as interactive management of small wild and captive populations (Foose, 1993) will require an even greater involvement of veterinarians in the movement of wildlife.

Crisis intervention

Making a diagnosis during a health crisis or wildlife die-off has been a traditional role of veterinarians in wildlife conservation. The *Supplement to the Journal of Wildlife Diseases (Wildlife Disease Newsletter)* provides a quarterly report on wildlife die-offs in North America, frequently listing cases with mortalities in the thousands. Disease outbreaks in endangered species such as mountain gorillas

(Hastings *et al.*, 1991), or black-footed ferrets (Thorne and Williams, 1988) have drawn attention to the potential impact of disease on small populations.

Veterinarians are frequently called upon to provide an immediate response in the face of disease outbreaks. Although intervention is not always necessary, the need to understand the processes at work is an essential part of preparation for times when intervention may be appropriate. The lack of previous monitoring data often confounds the interpretation of diagnostic information, but veterinarians can still provide a list of possible diagnoses to consider and investigate in addressing the problem. If consulted early in the course of a health problem, wildlife veterinarians can help to formulate a diagnostic plan to expedite the identification of the cause and source of the problem. Due to their knowledge of disease processes and treatment in other species, a veterinarian is the best qualified professional for arriving at a therapeutic plan for a health crisis situation. Equally important is the veterinarian's ability to develop long-range health management plans to avoid future disease outbreaks for the population in question and to identify other species at risk. Wobeser (1994) and Geraci and Lounsbury (1993) provide very detailed, comprehensive, and practical information on approaching the management of disease outbreaks.

New technologies

New techniques and approaches to working with wildlife are needed in conservation to improve the efficiency and success of expanding efforts. Due to the hands-on nature of veterinary training combined with extensive education into the anatomical and physiological function of animals, veterinarians are well suited for developing and applying new technologies to enhance wildlife research, conservation and management. Teamed with other field conservationists, veterinarians can devise solutions to technological limitations and improve the safety and effectiveness of currently used techniques and equipment. For example, the development of a remote biopsy dart (Karesh *et al.*, 1987) has facilitated the gathering of specimens for genetic analysis and eliminated the need for capture or chemical immobilization to obtain samples (Georgiadis *et al.*, 1990, 1994). Veterinary involvement in developing and evaluating new anaesthetics and capture techniques such as the use of inhalation anaesthesia for pinnepeds (Work *et al.*, 1992), or improving diagnostic sample collection methods such as the development of transport media for respiratory bacteria infecting bighorn sheep *Ovis canadensis* (Foreyt and Lagerquist, 1994), or the development of new treatment or vaccination modalities such as the oral rabies vaccine for carnivores (Blancou *et al.*, 1986; Artois *et al.*, 1990) are continually improving the capabilities of the wildlife conservation team.

Animal handling and welfare

Projects that require the handling of wildlife benefit from inclusion of a veterinarian from the onset. A veterinarian can: reduce costs by providing expertise in selecting appropriate equipment and techniques, improve efficiency, and minimize the potential for animal injuries during the start-up of a project. Veterinarians can rapidly evaluate the health risks of techniques and also have the background to adjust methodology to improve effectiveness.

Once techniques have been developed, the veterinarian can train field personnel to continue the programme without further assistance. Veterinarians can also broaden the information gathered during animal handling by performing health examinations, collecting samples for laboratory evaluations and training field staff in these techniques. For example, health examinations added to an ecological study of guanacos *Lama guanaco* in Chile by providing a simple predictive index of calf survival (Gustafson and Franklin, 1995). Serological tests from blood samples collected during ecological studies of raccoons *Procyon lotor* revealed the presence of a variety of infectious diseases (Rabinowitz and

Potgieter, 1984). In many cases, samples collected opportunistically during the handling of animals for other project purposes would provide the first data on the health and disease status of wild populations.

A related area of concern is animal welfare. In addition to ethical issues being raised in the study of wildlife (Farnsworth and Rosovsky, 1993), there are government regulations, policy statements of scientific organizations, and institutional guidelines that mandate attention to animal welfare (Marine Mammal Protection Act, 1972; Animal Welfare Act, 1976; Canadian Council on Animal Care, 1984; American Ornithologist's Union, 1988; Orlans, 1988; Cooper 1993). Typically, veterinarians serve as institutional animal welfare officers. The same concerns as to the welfare of research animals in the laboratory or captive setting also apply to free-ranging wildlife. Veterinarians are trained to critically evaluate the impact of manipulation on the well-being of animals. These skills can be used to enhance the performance and validity of wildlife projects. Once the difficult decision has been made to take the risks associated with handling wild animals, maximizing the information obtained and reducing the impact on the individuals is not only an ethical imperative but also enhances a project's image. Political support is frequently affected by this component and requires the same attention as other aspects of a conservation project.

Training

One of the most important roles for veterinarians in conservation today is the training of colleagues, field biologists and wildlife managers. The task of understanding the role that health plays in the population dynamics within ecosystems will require the efforts of a multitude of individuals. The key to success is to provide the necessary skills to as many people as possible. Training can be customized to the needs of individuals and accomplished in the field, in the classroom and laboratory, at a captive wildlife facility or a combination of these settings. For example, field biologists at the authors' institution commonly use training opportunities in our veterinary facilities or integrate them into their field projects and overseas training programmes (Cook and Karesh, 1990; Rabinowitz, 1993). In our experience, training in the field, using locally available resources combined with follow-up interactions, results in a higher level of implementation and usage of new approaches than other training methods. Because we cannot anticipate a huge increase in the number of veterinarians available to participate in every conservation project in the near future, an informal network of trained wildlife professionals world-wide could provide the intellectual and physical force needed to begin unravelling the complex relationships of pathogens, hosts, vectors and the environment.

Conclusion

Veterinary sciences could contribute to *in situ* conservation programmes in the ways listed below.

1 Identifying health factors having or potentially having a significant impact on wildlife population dynamics.

2 Providing objective data for use in assessing and monitoring populations.

3 Providing guidelines for monitoring and mitigating the impact of interactions of humans, domestic livestock and wildlife.

4 Improving sampling and animal handling methodology and reduce project start-up time.

5 Maximizing the information learned about a species or population when animals are being handled for other purposes.

6 Demonstrating a regard for the well being of wildlife consistent with the project's overall goals.

7 Addressing the regulatory obligations concerning research on animals.

8 Training field personnel to expand current capabilities for addressing wildlife health issues.

The role of veterinary medicine in modern conservation efforts needs to expand rapidly to meet the needs of governmental and non-governmental programmes around the world.

The efficiency and effectiveness of conservation efforts can be significantly enhanced by incorporating animal health considerations into the planning, implementation and evaluation phases of almost all programmes involving wildlife. Due in part to their higher level of success, multidisciplinary approaches to conservation are being used more frequently. Veterinary medicine can serve as another valuable resource to strengthen these approaches and expand their impact.

Acknowledgements

We thank William G. Conway, John R. Robinson, Alan Rabinowitz and Andrew P. Dobson for their insights and input into the development of this manuscript, and the suggestions and contributions of two anonymous referees from *Oryx*.

References

Acha, P.N. and Szyfres, B. 1980. Zoonoses and communicable diseases common to man and animals. *Pan American Health Org. Sci. Pub.* No. 354.

American Ornithologist's Union. 1988. Report of committee on use of wild birds in research. *Auk*, **105** (1, Suppl.), 1A–41A.

Anderson, R.M. and May, R.M. 1979. Population biology of infectious diseases. *Nature*, **280**, 361–367, 455–461.

Animal Welfare Act 7 USC 2131-2155. 1976. United States Department of Agriculture, Washington.

Anonymous. 1990. Northern diseased bison. In *Report on the Environmental Assessment Panel*, pp. 4-7. Federal Environmental Assessment Office, Quebec.

Artois, M., Charlton, K.M., Tolson, N.D., Casey, G.A., Knowles, M.K. and Campbell, J.B. 1990. Vaccinia recombinant virus expressing the rabies virus glycoprotein: safety and efficacy trials in Canadian wildlife. *Can. J. Vet. Res.* **54**, 504–507.

Bengis, R.G., Thomson, G.R., Hedger, R.S., De Vos, V. and Pini, A. 1986. Foot and mouth disease and the African Buffalo (*Syncerus caffer*). I. Carriers as a source of infection for cattle. *Onderspoort J. vet. Res.* **53**, 69–73.

Blancou, J.M., Kieny, P., Lathe, R., Lecocq, J.P., Pastoret, P.-P., Soulebot, J.P. and Desmettre, P. 1986. Oral vaccination of the fox against rabies using a live recombinant vaccinia virus. *Nature*, **332**, 373–375.

Bush, M., Montali, R.J. and Kleiman, D.G. In Press. Medical management of the golden lion tamarin. In *The Biology of the Golden Lion Tamarin* (ed. D. G. Kleiman). Smithsonian Press, Washington.

Callan, R.J., Bunch, T.D., Workman, G.W. and Mock, R.E. 1991. Development of pneumonia in desert bighorn sheep after exposure to a flock of exotic wild and domestic sheep. *JAVMA*, **198** (6), 1052–1056.

Canadian Council on Animal Care. 1984. *Guide to the Care and Use of Experimental Animals*, Volume 2. Ottawa.

Chow, T.L. and Davis, R.W. 1964. The susceptibility of mule deer to infectious bovine rhinotracheitis. *Am. J. Vet. Res.* **25**, 518–519.

Cook, R.A. and Karesh, W.B. 1990. Veterinary Field Program. In *Proc. Annu. Meet. Am. Assoc. Zoo Vet.* pp. 154–156. AAZV, Philadelphia.

Cooper, M.E. 1993. Legal implications for the management of infectious disease in captive breeding and reintroduction programs. *J. Zoo and Wildl. Med.* **24** (3), 296–303.

Davidson, W.R. and Nettles, V.F. 1992. Relocation of wildlife: identifying and evaluating disease risks. *Trans. 57th NA Wildl And Nat Res Conf*, **1992**, 466–473.

Dobson, A.P. and Hudson, P.J. 1986. Parasites, disease and the structure of ecological communities. *Trends in Ecology and Evolution*, **1** (1), 11–15.

Farnsworth, E.J. and Rosovsky, J. 1993. The ethics of ecological field experimentation. *Conservation Biology*, **7** (3), 463-472.

Felsenfeld, A.D. 1972. The arboviruses. In *Pathology of Simian Primates, Part II: Infectious and Parasitic Diseases* (ed. R. N. T-W-Fiennes), pp. 523–536. S. Karger, Basel.

Foose, T.J. 1993. Interactive management of small wild and captive populations. In *Orangutan Population and Habitat Viability Analysis Workshop Briefing Book* (eds R. Tilson, K. Traylor-Holzer and U. Seal), pp. 12–19. Captive Breeding Specialist Group, Apple Valley.

Foreyt, W.J. and Lagerquist, J.E. 1994. A reliable transport method for isolating *Pasteurella haemolytica* from bighorn sheep. *J. Wild. Dis.* **30** (2), 263–266.

Foster, J.W. 1988. A health management plan for the mountain gorilla. In *Proc. Joint Conf. Am. Assoc. Zoo Vet. and Am. Assoc. Wildl. Vet.*, pp. 106. AAZV, Philadelphia.

Georgiadis, N.J., Kat, P.W. and Oketch, H. 1990. Allozyme divergence within the bovidae. *Evol.* **44** (8), 2135–2149.

Georgiadis, N., Bischof, L., Templeton, A., Patton, J., Karesh, W. and Western, D. 1994. Structure and history of African elephant populations I: eastern and southern Africa. *J. Heredity*, **85** (2), 100–104.

Geraci, J.R. and Lounsbury, V.L. 1993. *Marine*

 © 1995 FFI, *Oryx*, **29** (4), 244–252

Mammals Ashore: A Field Guide for Strandings. Texas A&M Sea Grant Publication, Galveston.

Gerlach, H. 1994. Viruses. In *Avian Medicine: Principles and Application* (eds B. W. Ritchie, G. J. Harrison and L. R. Harrison), pp. 862–948. Wingers Publishing, Inc., Lake Worth.

Gustafson, L. and Franklin, W. 1995. Predictors of neonatal mortality in the guanacos of Torres del Pine, Chile, a pilot study in adaptive modeling of wildlife population health. In *Ecosystem Monitoring and Protected Areas* (eds T. Herman, S. Bondrup-Nielsen, J. H. M. Willison and N. W. P. Munroe), pp. 285–289. Science and Management of Protected Areas Association, Halifax.

Hamblin, C. and Hedger, R.S. 1978. Neutralizing antibodies to parainfluenza-3 virus in African wildlife, with special reference to the cape buffalo (*Syncerus caffer*). *J. Wildl. Dis.* **14,** 378–388.

Hart, J.A. 1978. From subsistence to market: A case-study of the Mbuti net hunters. *Hum. Ecol.* **6,** 325–335.

Hastings, B.E., Lowenstine, L.J. and Foster, J.W. 1991. Mountain gorillas and measles: ontogeny of a wildlife vaccination program. In *Proc. Annu. Meet. Am. Assoc. Zoo Vet.* pp. 198–205. AAZV, Philadelphia.

Hedger, R.S. 1981. Foot-and-mouth disease. In *Infectious Diseases of Wild Mammals*, 2nd edn (eds J. W. Davis, L. H. Karstad and D. O. Trainer), pp. 87–96. Iowa State University Press, Iowa.

Holmes, J.C. 1982. Impact of infectious disease agents on the population growth and geographical distribution of animals. In *Population Biology of Infectious Diseases* (eds R. M. Anderson and R. M. May), pp. 37–51. Dahlem Konferenzen, Springer Verlag, New York.

Hudson, P.J. and Dobson, A.P. 1989. Population Biology of *Trichostrongylus tenuis*, a parasite of economic importance for red grouse management. *Parasitology Today,* **5** (9), 283–291.

Hull, T.G. 1963. The role of different animals and birds in diseases transmitted to man. In *Diseases Transmitted from Animals to Man* (ed. T. G. Hull), pp. 876–924. Charles C. Thomas, Springfield.

Journal of Zoo and Wildlife Medicine. 1993. **24** (3), 229–415.

Kalter, S.S., and Heberling, R.L. 1990. Primate viral diseases in perspective. *J. Med. Primatol.* **19,** 519–535.

Karesh, W.B., Smith, F. and Frazier-Taylor, H. 1987. A remote method for obtaining skin biopsy samples. *Conservation Biology,* **1** (3), 261–262.

Karesh, W.B., Hart, J.A., Hart, T.B., House, C.H., Torres, A., Dierenfeld, E.S., Braselton, W.E., Puche, H. and Cook, R.A. In press. Health evaluation of five sympatric duiker species (*Cephalophus* spp.). *J. Zoo Wildl. Med.*

Langenberg, J. 1992. Health management for the whooping crane propagation and reintroduction program. In *Proc. Joint Conf. Am. Assoc. Zoo Vet. and Am. Assoc. Wildl. Vet.* pp. 2–9. AAZV, Philadelphia.

Marine Mammal Protection Act 16 USC 1361-1407. 1972, 1976, and Supp. V. 1981. National Marine Fisheries Service, Washington, DC.

Martin, D.P. 1986. Infectious diseases. In *Zoo and Wild Animal Medicine,* (ed. M. E. Fowler), 2nd edn, pp. 669–673. W. B. Saunders, Co., Philadelphia.

May, R.M. 1988. Conservation and disease. *Conservation Biology,* **2** (1), 28–30.

Mech, L.D. and Goyal, S.M. 1993. Canine parvovirus effect on wolf population change and pup survivial. *J. Wildl. Dis.* **29** (2), 330–333.

Morell, V. 1994. Serengeti's big cats going to the dogs. *Science,* **264,** 1664.

Munson, L. and Cook, R.A. 1993. Monitoring, investigation, and surveillance of diseases in captive wildlife. *J. Zoo Wildl. Med.* **24** (3), 281–290.

Nyaga, P.N., Kaminjolo, J.S., Gathuma, J.M., Omuse, J.K., Nderu, F.M.K. and Gicho, J.N. 1981. Prevalence of antibodies to parainfluenza-3 virus in various wildlife species and indigenous cattle sharing the same habitats in Kenya. *J. Wildl. Dis.* **17** (4), 605–608.

O'Brien, S.J. and Evermann, J.F. 1988. Interactive influence of infectious disease and genetic diversity in natural populations. *Trends in Ecology and Evolution,* **3** (10), 254–259.

Orlans, F.B. (ed.) 1988. *Field Research Guidelines.* Scientists Center for Animal Welfare, Bethesda.

Ott-Joslin, J.E. 1986. Viral diseases in nonhuman primates. In *Zoo and Wild Animal Medicine,* (ed. M. E. Fowler), 2nd edn, pp. 674–697. W. B. Saunders, Co., Philadelphia.

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

Rabinowitz, A.R. 1993. *Wildlife Research and Conservation Training Manual.* NYZS/The Wildlife Conservation Society, New York.

Rabinowitz, A.R. and Potgieter, L.N.D. 1984. Serologic survey for selected viruses in a population of raccoons, *Procyon lotor,* in the Great Smoky Mountains. *J. Wildl. Dis.* **20** (2), 146–148.

Sadi, L., Joyal, R., St-Georges, M. and Lamontagne, L. 1991. Serologic survey of white-tailed deer on Anticosti Island, Quebec for bovine herpesvirus 1, bovine viral diarrhea, and parainfluenza 3. *J. Wildl. Dis.* **27** (4), 569–577.

Sajuthi, D., Pamungkas, J., Iskandriati, D., Lelana, R.P.A., Knitter, G.H. and Karesh, W.B. 1992. The incidence of Tuberculosis and Hepatitis B in orangutans confiscated by the Indonesian Government in 1991. In *Proc. Joint Conf. Am. Assoc.*

Zoo Vet. and Am. Assoc. Wildl. Vet. p. 17. AAZV, Philadelphia.

Sajuthi, D., Lelena, A. and Karesh, W. 1993. Updated recommendations on medical procedures during quarantine for orangutans intended for reintroduction. In *Orangutan Population and Viability Analysis Workbook*, pp. 45–48. Captive Breeding Specialist Group, Apple Valley.

Scott, M.E. 1988. The impact of infection and disease on animal populations: implications for conservation biology. *Conservation Biology*, **2** (1), 40–56.

Seymour, C. and Yuill, T.M. 1981. Arboviruses. In *Infectious Diseases of Wild Mammals*, (eds J. W. Davis, L. H. Karstad and D. O. Trainer), 2nd edn, pp. 54–86. Iowa State University Press, Ames.

Shellabarger, S. 1991. Overview of primate viral zoonotic diseases and their prevention. In *Proc. Annu. Meet. Am. Assoc. Zoo Vet.* pp. 224–234. AAZV, Philadelphia.

Shima, A. and Gonzales, B. 1991. Veterinary involvement in the California and Andean condor recovery and release projects. In *Proc. Annu. Meet. Am. Assoc. Zoo Vet.* pp. 90–97. AAZV, Philadelphia.

Sikes, R.K. 1981. Rabies. In *Infectious Diseases of Wild Mammals*, (eds J. W. Davis, L. H. Karstad and D. O. Trainer), 2nd edn, pp. 3–17. Iowa State University Press, Ames.

Silvius, K. 1995. Conservation Hotline: Where have all the peccaries gone? *Wildlife Conservation*, **98** (3), 10.

Thomas, F.C. 1981. Hemorrhagic Disease. In *Diseases and Parasites of White-Tailed Deer*, (eds W. R. Davidson, F. A. Hayes, V. F. Nettles and F. E. Kellogg), pp. 87–96. Southeastern Cooperative Wildlife Disease Study, Athens.

Thorne, E.T. and Williams, E.S. 1988. Disease and endangered species: the black-footed ferret as a recent example. *Conservation Biology*, **2** (1), 66–74.

Thorsen, J., Karstad, L., Barrett, M.W. and Chalmers, G.A. 1977. Viruses isolated from captive and free-ranging wild ruminants in Alberta. *J. Wildl. Dis.* **13**, 74–79.

Williams, E.S., Thorne, E.T., Kwiatkowski, D.R. and Oakleaf, B. 1992. Disease management in the black-footed ferret (*Mustela nigripes*) reintroduction program in Wyoming. In *Proc. Joint Conf. Am. Assoc. Zoo Vet. and Am. Assoc. Wildl. Vet.* pp. 10–11. AAZV, Philadelphia.

Wobeser, G.A. 1994. *Investigation and Management of Disease in Wild Animals.* Plenum Press, New York.

Woodford, M.H. 1993. International disease implications for wildlife translocation *J. Zoo Wildl. Med.* **24** (3), 265–270.

Woodford, M.H. and Kock, R.A. 1991. Veterinary considerations in re-introduction and translocation projects. In *Beyond Captive Breeding, Re-introducing Endangered Mammals to the Wild* (ed. J. H. W. Gipps), pp. 101–110. Oxford University Press, Oxford.

Woodford, M.H. and Rossiter, P.B. 1993. Disease risks associated with wildlife translocation projects. *Rev. sci. Tech. Off. int. Epiz.* **12** (1), 115–135.

Woolf, A., Shoemaker, D.R. and Cooper, M. 1993. Evidence of tularemia regulating a semi-isolated cottontail rabbit population. *J. Wildl. Mgmt*, **57** (1), 144–157.

Work, T.M., DeLong, R.L. and Spraker, T.R. 1992. The use of halothane anaesthesia as a method of immobilizing free-ranging California sea lions (*Zalophus californianus*). In *Proc. Joint Conf. Am. Assoc. Zoo Vet. and Am. Assoc. Wildl. Vet.* p. 57. AAZV, Philadelphia.

William B. Karesh, Wildlife Health Sciences, The Wildlife Conservation Society, 185th and Southern Blvd., Bronx, New York 10460, USA.

Robert A. Cook, Wildlife Health Sciences, The Wildlife Conservation Society, 185th and Southern Blvd., Bronx, New York 10460, USA.