Evermann JF, Laurenson MK, McKeirnan AJ, Caro TM. 1993. Infectious Disease Surveillance in Captive and Free-Living Cheetahs: An Integral Part of the Species Survival Plan. Zoo Biology 12(1):125-33.

Keywords: Acinonyx jubatus/captive breeding/cheetah/disease/free-ranging/health/herpesvirus/ management/survival/veterinary

Abstract: During the formulative stages of developing the Species Survival Plan (SSP) for the cheetah, the impact of infectious disease upon its survival in captivity was of prime consideration, together with genetics, nutrition, physiology, and behaviour. This paper summarizes the results of an infectious disease surveillance program, initially designed to monitor the infectious agent associated with clinically normal and clinically ill cheetahs in captivity, but subsequently supplemented with data from free-living cheetahs. The focus was on two viral infections, feline infectious peritonitis (FIP) and feline rhinotracheitis virus. Results indicated that between 1989 and 1991, there was a n increase in the seroprevalence (number antibody-positive animals) of cheetahs to feline coronavirus from 41% to 64% in captivity. During this same time period, there were only two documented cases of FIP in cheetahs in the United States. The results suggest that feline coronavirus (feline enteric coronavirus-feline infectious peritonitis group) or a closely related coronavirus of cheetah is becoming endemic in the captive cheetah population. Further serologic results from 39 free-living cheetahs demonstrated that there was a high seroprevalence (61%) to feline coronavirus, although serum antibody titers were considerably lower than those encountered in captive cheetahs. The observation of a high percentage of free-living cheetahs, which were seropositive to feline herpesvirus (44%), was unexpected, since it has been generally regarded that this infection is primarily associated with cheetahs in captivity.

van der Ingh, TS.G.A.M.; Zwart, P. Helstab, A. Veno-occlusive disease (VOD) of the liver in cheetahs and snow leopards. SCHWEIZ ARCHIVE TEIRHEILKE 123:323–327, 1981.
Wildt, D.E.; Bush, M.; Howard, J.G.; O'Brien, S.J.; Meltzer, D., Van Dyk, A.; Ebedes, H.; Brand, D.J. Unique seminal quality in the South African cheetah and a comparative evaluation in the domestic cat. BIOLOGY OF REPRODUCTION 29;1019–1025, 1983.
Wildt, D.E.; Brown, J.L.; Bush, M.; Barone, M.A.; Cooper, K.A.; Grisham, J.; Howard, J.G. Reproductive status of cheetahs (*Acinonyx jubatus*) in North American Zoos: The benefits of physiological surveys for strategic planning. ZOO BIOLOGY, 12:45–80, 1993.

Zoo Biology 12:125–133 (1993)

Infectious Disease Surveillance in Captive and Free-Living Cheetahs: An Integral Part of the Species Survival Plan

James F. Evermann, M. Karen Laurenson, Alison J. McKeirnan, and T. M. Caro

Department of Veterinary Clinical Medicine and Surgery and Washington Animal Disease Diagnostic Laboratory, Washington State University, Pullman (J.F.E., A.J.M.); Department of Zoology, University of Cambridge, Cambridge, United Kingdom (M.K.L.); and Department of Wildlife and Fisheries Biology, University of California, Davis (T.M.C.)

During the formulative stages of developing the Species Survival Plan (SSP) for the cheetah, the impact of infectious disease upon its survival in captivity was of prime consideration, together with genetics, nutrition, physiology, and behavior. This paper summarizes the results of an infectious disease surveillance program, initially designed to monitor the infectious agents associated with clinically normal and clinically ill cheetahs in captivity, but subsequently supplemented with data from free-living cheetahs. The focus was on two viral infections, feline infectious peritonitis (FIP) and feline rhinotracheitis virus. Results indicated that between 1989 and 1991, there was an increase in the seroprevalence (number antibody-positive animals) of cheetahs to feline coronavirus from 41% to 64% in captivity. During this same time period, there were only two documented cases of FIP in cheetahs in the United States. The results suggest that feline coronavirus (feline enteric coronavirus–feline infectious peritonitis group) or a closely related coronavirus of cheetahs is becoming endemic in the captive cheetah population.

Further serologic results from 39 free-living cheetahs demonstrated that there was a high seroprevalence (61%) to feline coronavirus, although serum antibody titers were considerably lower than those encountered in captive cheetahs. The observation of a high percentage of free-living cheetahs, which were seropositive to feline herpesvirus (44%), was unexpected, since it has been generally regarded that this infection is primarily associated with cheetahs in captivity.
© 1993 Wiley-Liss, Inc.

Key words: coronavirus, herpesvirus, management

Received for publication July 17, 1992; revision accepted November 10, 1992.

Address reprint requests to James F. Evermann, Department of Veterinary Clinical Medicine and Surgery, College of Veterinary Medicine, Washington State University, Pullman, WA 99164.

© 1993 Wiley-Liss, Inc.

INTRODUCTION

Cheetahs are endangered in the wild as a result of increasing human agricultural encroachment on their habitat and direct persecution of them and their prey. In order to provide a buffer to dwindling wild populations, a concerted effort has been launched by North American zoos to keep a self-sustaining population in captivity. Unfortunately, low reproductive rates and continued depletion from adult mortality has made this goal difficult to attain at present. However, in November, 1989, the Cheetah Species Survival Plan (SSP) was started to investigate problems of maintaining a viable population in captivity [Grisham and Lindburg, 1989; Marker and O'Brien, 1989].

One protocol was to monitor the health of captive cheetahs and to sample them for the occurrence of infectious microorganisms which may have a negative impact upon their survival in captivity. During the initial phase of the disease surveillance study, serum samples, together with swabs and/or tissues from normal and diseased cheetahs, were solicited for viral antibody determination and viral culture.

The purposes of this paper are to bring together the serological results compiled over the past three years and to present perspectives on the ecology of infectious agents in the cheetah's environment. Although emphasis will be placed upon two viral infections, feline infectious peritonitis (FIP) and feline rhinotracheitis, other infectious agents may also have a detrimental effect upon the survival of the cheetah in captivity [Barr et al., 1989; Baxby et al., 1982; Letcher and O'Conner, 1991; Sabine and Hyne, 1970].

MATERIALS AND METHODS

Serum Samples

Serum samples were collected from captive and wild-caught cheetahs as previously reported [Evermann et al., 1988; Heeney et al., 1990]. The serum was separated from the blood clot, and stored at −20°C until used in serologic assays.

Serologic Assay

The indirect immunofluorescent antibody (IFA) serologic assay was used to evaluate cheetah serum for antibodies to the feline coronavirus group (feline infectious peritonitis/feline enteric coronavirus/canine coronavirus/transmissible gastroenteritis virus). The IFA had been shown to correlate well with western blot serology comparing coronavirus antibody titers in domestic cats and in cheetahs [Heeney et al., 1990]. IFA antibody titers ≥ 1:25 were regarded as positive. The virus neutralization (VN) assay was used to determine antibody titers to feline herpesvirus (FHV) type 1. VN antibody titers ≥ 1:2 were regarded as positive. Earlier work had demonstrated that FHV was closely related to the herpesvirus isolated from cheetah cubs with advanced facial cutaneous ulcers [Junge et al., 1991; Scherba et al., 1988], and from adult cheetahs succumbing to diseases heretofore unrelated to herpesvirus infection [Evermann and McKeirnan, 1991].

TABLE 1. Summary of the seroreactivity* of captive cheetahs to feline coronavirus

Year	Number of accessions	Number of zoo facilities	Total number seropositive	Total number tested[a]	% Seropositive
1989	48	19	42	102	41.2
1990	65	29	106	164	64.6
1991	81	22	125	194	64.4

*Based upon IFA for feline/cheetah coronavirus group specific antibodies.
[a]May include samples from same zoologic facility submitting serum on different occasions.

RESULTS

Status of Feline Coronavirus Infection in Cheetahs

The SSP surveillance of feline coronavirus infection in captive cheetahs commenced in 1989. Table 1 presents a summary of the seroreactivity of captive cheetahs to the feline coronavirus group. In 1989, there were 48 accessions which amounted to 102 samples tested, 42 (41.2%) of which were seropositive. In 1990, there were more accessions for a total of 164 serum samples tested, of which 106 (64.6%) were seropositive. In the third year of the study, 1991, there were 81 accessions and 194 serum samples tested. Of these, 125 (64.4%) were seropositive to the feline coronavirus group.

These results were analyzed further by comparing the distribution of serum antibody titers amongst the three years (Table 2). There were three categories established based upon the serum titer levels. These were seronegative (IFA titers < 1:25); seropositive, normal range (IFA titers 1:25 to 1:3,125); and seropositive, "watch" (IFA titers ≥ 1:15,625). It was observed that there was a change in serum antibody titer distribution from the first year (1989) of the study compared with the succeeding two years. The number of seronegative cheetahs dropped from 58.8% in 1989 to 35.9% in 1990. This percentage remained constant throughout 1991. Concurrent with the decrease in seronegative cheetahs was the increase in seropositive cheetahs in the normal serum titer range (35.2% in 1989 to 59.7% in 1990 and 62.8% in 1991). The number of cheetahs in the "watch" category decreased from 6 in 1989 to 3 in 1991. During this period of time, there were 2 deaths attributed to FIP; both animals had serum titers in the "watch" category.

In a parallel study of free-living cheetahs, immobilized and sampled in the course of radio collaring [Caro, in press; Laurenson and Caro, in press], samples were collected from 39 cheetahs. Sixty-one percent were seropositive to feline coronavirus (Table 3).

Status of Feline Herpesvirus Infection in Cheetahs

Only free-living cheetahs were included in this portion of the study, since the majority of captive cheetahs in the United States are vaccinated with combination vaccines containing feline herpesvirus, feline calicivirus, and feline panleukopenia virus [Wack, 1991]. The results (Table 3) indicated that there was a high rate of seropositivity to feline herpesvirus (43.6%).

DISCUSSION

The surveillance of infectious disease microorganisms affecting the cheetah has focused upon just two agents, on the basis of prior disease epizootics with FIP and the

TABLE 2. Comparison of coronavirus serum antibody titers in captive cheetahs, 1989–1991

Year		Serum titer	Number tested	Serum %
1989	Neg[a]	<25	60	58.8
		25	17	
	Normal range[b]	125	7	
		625	8	35.2
		3125	4	
	Watch[c]	≥15,625	6	5.8
	Total		102	
1990	Neg	<25	59	35.9
		25	32	
	Normal range	125	38	59.7
		625	15	
		3125	13	
	Watch	≥15,625	7	4.3
	Total		164	
1991	Neg	<25	69	35.5
		25	61	
	Normal range	125	30	62.8
		625	18	
		3125	13	
	Watch	≥15,625	3	1.5
	Total		194	

[a]<25 seronegative.
[b]Seropositive, normal range 25–3,125.
[c]Seropositive, "watch" ≥ 15,625.

TABLE 3. Survey of free-living cheetahs sampled in the Serengeti ecosystem, Tanzania

	Total seropositive			
Total tested	Feline coronavirus[a]	%	Feline herpesvirus[b]	%
39	24	61.5	17	43.6

[a]Mean titer 1:25, range <25 to 1:625, IFA.
[b]Mean titer 1:8, range <2 to 1:64, VN.

isolation of feline herpesviruses from several cases during the course of the current study [Evermann et al., 1988, 1989; Evermann and McKeirnan, 1991; Junge et al., 1991]. The results of the coronavirus serology reflected a trend toward a more endemic infection occurring in the captive cheetah populations of the United States. Infection rates of 64.4% are similar to those observed in some domestic cats housed in catteries (40–85%) [Pedersen, 1991]. During the course of this study there were only two cases of FIP reported in the cheetah population, which may indicate one of several things. This low level of FIP mortality may be indicative of the control efforts that have been used in various cheetah collections (based upon serologic-directed quarantine); the changing virulence of the feline–cheetah coronavirus in nature; the lowered number of coronavirus-naive cheetahs in captivity; or a combination of the above.

The earlier findings of feline herpesvirus infection being associated with clinically ill as well as clinically normal cheetahs is compatible with our knowledge of the pathogenesis of this virus in domestic cat populations [Povey, 1986]. The isolation of feline herpesvirus from a clinically normal cheetah confirms that asymptomatic shedding can occur and may account for the infection of susceptible animals, especially cubs [Evermann and McKeirnan, 1991].

The serologic profile of the 39 free-living cheetahs points to several interesting observations. First, it exemplifies the use of serologic testing for surveillance purposes to assess the degree of infection within a given population of animals [Hancock, 1988; Heeney et al., 1990; Horzinek and Osterhaus, 1979; Munson, 1991]. Second, the high seroprevalence of feline coronavirus antibodies (61.5%) indicates that a coronavirus of cheetahs is endemic in at least one cheetah population living in East Africa. This observation supports the earlier reports of coronavirus seropositive cheetahs in the wild [Evermann et al., 1988; Horzinek and Osterhaus, 1979]. The fact that certain populations of cheetahs, either in captivity or in the wild, have remained seronegative to feline coronavirus may be reflective of the lack of exposure to a cheetah coronavirus or to the other coronaviruses known to cross-react with the feline coronaviruses, i.e., porcine coronavirus and canine coronavirus [Spencer, 1991].

The third observation indicates a high seroprevalence of free-living cheetahs to feline herpesvirus (43.6%), previously considered to be predominantly an infection and disease of captive cheetahs. The occurrence of seroreactive cheetahs in the wild raises many questions in regards to the ecology of these viruses and the practicality of trying to maintain colonies of cheetahs that are free of infection. It is clear that more needs to be known about the ecology of these viruses in nature in order to implement control measures for their control in captive cheetah populations [Morse, 1991].

ECOLOGY, PATHOGENESIS, AND EPIDEMIOLOGY

Anderson [1991] recently posed the question pertaining to populations and infectious diseases of whether one should refer to it as ecology or epidemiology. In reality, it is both, since there is considerable overlap. When studying the ecology of a virus, the questions asked are how does the virus persist in nature at the cellular level, host animal level, and at the population level [Anderson and May, 1986; Mahy, 1985]. Pathogenesis refers to the potential for the virus to cause disease at the host animal level, which invariably involves target organs and preferential cells for virus replication. Epidemiology is the study of the ecology of an infectious agent in order to understand the pathogenesis, and ultimately control it. Control may occur by culling of infected animals, segregation to reduce infection, and thereby minimize disease, and vaccination if one exists. Table 4 presents the ecology of feline infectious peritonitis virus and feline herpesvirus, based upon current information.

Control Efforts

The control of feline coronavirus infections in domestic cats and cheetahs has historically relied upon initial serologic testing, segregation, and periodic serologic testing to monitor the effectiveness of the control program [Addie and Jarret, 1990; Evermann et al., 1988, 1991; Hoskins, 1991; Pedersen, 1991]. The placement of domestic cats in small family units of five to six animals has also been an effective

TABLE 4. Ecology of selected viral infections of cheetahs

	Feline infectious peritonitis	Feline rhinotracheitis
Nature of the virus	Coronavirus SS-RNA (+) envelope (cross-reacting antigens with feline, porcine, and canine coronaviruses)	Herpesvirus DS-DNA envelope (limited cross-reactivity with canine herpesvirus)
Natural host	Cats, wild felidae	Cats, wild felidae
Clinical signs	Immune-mediated vasculitis, 100% fatal	Conjunctivitis, rhinitis, pneumonia, corneal and oral ulceration
How spread?	Ingestion, aerosol? Injection via bite?	Aerosol, licking (saliva)
Attack rate	2–60%	5–80%
Mechanisms of persistence		
a. Cell	a. Unknown (macrophage?)	a. Nucleus (trigeminal ganglia)
b. Host	b. Localized GI infection, mucosal IgA	b. Localized URT infection, mucosal IgA
c. Population	c. Concurrent infection with feline enteric coronavirus, interferes with FIP/mutation occurs?	c. Concurrent infection with feline calcivirus
d. Environment	d. Very labile outside host, wildlife reservoir probable?	d. Very labile outside host, wildlife reservoirs? canids?
Control	Good sanitation, separate kittens/cubs from older animals (4 mos), discourage crowding. MLV(ts) vaccine available for domestic cats*, 2×/yr. FeLV, FHV, FCV, FPL regarded as synergistic infections	Good sanitation, separate kittens/cubs from older animals, discourage crowding. Vaccine (MLV and killed) available for domestic cats, 2× to 4×/yr multiple animal facilities.

*This vaccine has not been licensed for use in cheetahs as of this date.

control measure for control of FIP in endemic catteries [Evermann and Ott, unpublished data]. The apparent increase in seroprevalence of captive cheetahs from 1989 to 1991 suggests that segregation may not be totally effective in reducing infection. However, there has been a noticeable reduction in the clinical cases of FIP, which may reflect a form of natural immunization with a feline–cheetah coronavirus, as the infection becomes more endemic in captive cheetahs.

The control of FIP in domestic cats has been augmented by the recent development of a modified-live temperature-sensitive FIP virus vaccine [Postorino et al., 1992]. The vaccine appears to be safe, and the effectiveness ranges from 40 to 80% depending on the strain of FIP virus that is used to challenge the cats. The vaccine has not yet been tested for safety in cheetahs. The efficacy of such a vaccine should only be studied in a collection of captive cheetahs that is endemic for feline coronavirus, due to the hazards of experimental challenge in an endangered species [Evermann and McKeirnan, 1991].

The control of feline herpesvirus infections has been dependent upon a combination of good hygiene, decreased population density, and an aggressive vaccination program (at least twice per year) [Evermann and McKeirnan, 1991; Povey, 1986; Wack, 1991]. The feline herpesvirus is usually shed when the cats have clinical signs, such as rhinitis and conjunctivitis [Povey, 1986]. The pathogenesis of feline herpesvirus in cheetahs appears to be similar to that described in domestic cats [Evermann and McKeirnan, 1991]. The immune response to the feline herpesvirus is dependent upon maternal antibodies for the first 8 to 12 weeks, and then for continual boosting from either natural exposure or vaccination to maintain protective levels of immunity [Spencer and Burroughs, 1991, 1992; Wack, 1991].

CONCLUSIONS

The experiences observed with infectious diseases of cheetahs, in particular the feline coronavirus and feline herpesvirus infections, raises some questions pertaining to the factors which influence the susceptibility of these animals to infection and the severity of disease in selected individuals. According to Pedersen [1991], there are many factors which influence the outcome of infections. These include: the host response; the environment in which the host lives; and microbial agents to which the host is exposed. Of particular interest with regard to the cheetah are those factors of the host response, primarily those pertaining to developmental and heritable anomalies of the immune system. O'Brien and Evermann [1988] reviewed reports on the genetic homogeneity of the cheetah and postulated that this homozygosity may reflect lack of immunologic diversity to infectious agents. In a series of experiments, the immune response of the cheetah has been reported as being suboptimal, based on the lack of rejection of skin grafts and the lack of demonstrable neutralizing antibodies to FIP virus [McKeirnan and Evermann, unpublished data; O'Brien et al., 1985].

Pedersen [1987] cautions against the use of skin testing for measuring the effectiveness of delayed-type hypersensitivity reactions in domestic cats. Although cats do not respond well to some antigens, they have been shown to develop measurable levels of delayed hypersensitivity to certain chemicals. Nonetheless, there appears to be some differences in the cell-mediated immune response of domestic cats as measured by decreased lymphocyte reactivity to T-cell mitogens, and this observation may apply to cheetahs as well. Recent evidence now supports the altered T-cell function of the cheetah [Miller–Edge and Worley, 1992]. In that study, there was a decrease in T-cell responsiveness of cheetah peripheral blood mononuclear cells, when compared with domestic cats, when the cells were cultured with inactivated feline herpesvirus. These experiments, as well as those of other investigators, suggest that the susceptibility of the cheetah to viral infections and the severity of disease are the result of an immune-compromised host [Miller–Edge and Worley, 1991]. This understanding will allow for us to pursue strategies for augmenting the cheetah's immune response, which should include genetics as well as managing cheetahs to reduce the risk of high exposure to potentially fatal pathogens, and the development of effective and safe vaccines to aid in the control of such diseases [Hohdatsu et al., 1991; Lin, 1992].

ACKNOWLEDGMENTS

We express our gratitude to Dr. Melody Roelke, who saw a disease situation, and not only pursued a diagnosis, but advocated corrective management strategies as a means of long-term prevention. We would also like to thank those investigators who have shared their research findings with us, in particular Dr. Michael Worley and Dr. Ray Wack. We greatly appreciate those zoo veterinarians, curators, and staff who

have cooperated in and assisted with the collection of samples from the cheetahs. Continued thanks to Dr. Tony Gallina for his support of the diagnosis of animal diseases. We extend our appreciation to the Government of Tanzania, Serengeti Wildlife Research Institute, and Tanzania National Parks for permission to conduct research. Biological material was collected and transported in full compliance with federal fish and wildlife permits (CITES: endangered and threatened species) issued to the National Cancer Institute by the U.S. Fish and Wildlife Service of the Department of the Interior.

REFERENCES

Addie, D.D.; Jarrett, O. Control of feline coronavirus infection in kittens. VETERINARY RECORD 126:164, 1990.

Anderson, R.M. Populations and infectious diseases. Ecology or epidemiology? JOURNAL OF ANIMAL ECOLOGY 60:1–50, 1991.

Anderson, R.; May, R. The invasion, persistence and spread of infectious diseases within animal and plant communities. PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON [BIOL] 314:533–570, 1986.

Barr, M.C.; Calle, P.P.; Roelke, M.E.; Scott, F.W. Feline immunodeficiency virus infection in nondomestic felids. JOURNAL OF ZOO AND WILDLIFE MEDICINE 20:265–272, 1989.

Baxby, D.; Ashton, D.; Jones, D. An outbreak of cowpox in captive cheetahs: Virological and epidemiological studies. JOURNAL OF HYGIENE 89:365–372, 1982.

Caro, T.M. CHEETAHS OF THE SERENGETI PLAINS: GROUPING IN AN ASOCIAL SPECIES. Chicago, Illinois, University of Chicago Press, in press.

Evermann, J.F.; Heeney, J.L.; McKeirnan, A.J.; O'Brien, S.J. Comparative features of a coronavirus isolated from a cheetah with feline infectious peritonitis. VIRUS RESEARCH 13:15–28, 1989.

Evermann, J.F.; Heeney, J.L.; Roelke, M.E.; McKeirnan, A.J.; O'Brien, S.J. Biological and pathological consequences of feline infectious peritonitis virus infection in the cheetah. ARCHIVES OF VIROLOGY 102:155–171, 1988.

Evermann, J.; McKeirnan, A. Infectious disease surveillance in the cheetah with primary emphasis upon feline coronavirus and feline herpesvirus infections. AMERICAN ASSOCIATION OF ZOO VETERINARIANS PROCEEDINGS 1991:191–197, 1991.

Evermann, J.F.; McKeirnan, A.J.; Ott, R.L. Perspectives on the epizootiology of feline enteric coronavirus and the pathogenesis of feline infectious peritonitis. VETERINARY MICROBIOLOGY 28:243–255, 1991.

Grisham, J.; Lindburg, D. Cheetah master plan. Pp. 3–10 in AMERICAN ASSOCIATION OF ZOOLOGICAL PARKS AND AQUARIUMS SPECIES SURVIVAL PLAN PROGRAM. Oklahoma City, Zoological Park Publishing, 1989.

Hancock, D.D.; Blodgett, D.; Gay, C.C. The collection and submission of samples for laboratory testing. VETERINARY CLINICS OF NORTH AMERICA: FOOD ANIMAL PRACTICE 4:33–60, 1988.

Heeney, J.L.; Evermann, J.F.; McKeirnan, A.J.; Marker-Kraus, L.; Bush, M.E.; Wildt, D.E.; Meltzer, D.G.; Colly, L.; Lukas, J.; Mantan, J.; Caro, T.; O'Brien, S.J. Prevalence and implications of feline coronavirus infections of captive and free-ranging cheetahs (*Acinonyx jubatus*). JOURNAL OF VIROLOGY 64:1964–1972, 1990.

Hohdatsu, T.; Okada, S.; Koyama, H. Characterization of monoclonal antibodies against feline infectious peritonitis virus type II and antigenic relationship between feline, porcine, and canine coronaviruses. ARCHIVES OF VIROLOGY 117:85–95, 1991.

Horzinek, M.C.; Osterhaus, A.D.M.E. Feline infectious peritonitis: A worldwide serosurvey. AMERICAN JOURNAL OF VETERINARY RESEARCH 40:1487–1492, 1979.

Hoskins, J.D. Coronavirus infection in cats. COMPENDIUM ON CONTINUING EDUCATION FOR THE PRACTICING VETERINARIAN 13:567–588, 1991.

Junge, R.E.; Miller, E.; Boever, W.J.; Sherba, G.; Sundberg, J. Persistent cutaneous ulcers associated with feline herpesvirus type 1 infection in a cheetah. JOURNAL OF THE AMERICAN VETERINARY MEDICAL ASSOCIATION 198:1057–1058, 1991.

Laurenson, M.K.; Caro, T.M. Monitoring the effects of non-trivial handling in free-living cheetahs. ANIMAL BEHAVIOR in press.

Letcher, J.D.; O'Conner Jr., T.P. Incidence of antibodies reacting to feline immunodeficiency virus in a population of Asian lions. JOURNAL OF ZOO AND WILDLIFE MEDICINE 22:324–329, 1991.

Lin, D-S. Feline immune system. COMPARATIVE IMMUNOLOGY, MICROBIOLOGY AND INFECTIOUS DISEASES 15:1–11, 1992.

Mahy, B.W.J. Strategies of virus persistence. BRITISH MEDICAL BULLETIN 44:50–55, 1985.

Marker, L.; O'Brien, S.J. Comparative breeding of the cheetah (*Acinonyx jubatus*) in North American zoos (1871–1986). ZOO BIOLOGY 8:3–16, 1989.

Miller-Edge, M.; Worley, M. In vitro mitogen responses and lymphocyte subpopulations in cheetahs. VETERINARY IMMUNOLOGY AND IMMUNOPATHOLOGY 28:337–349, 1991.

Miller-Edge, M.A.; Worley, M.B. In vitro responses of cheetah mononuclear cells to feline herpesvirus-1 and Cryptococcus neoformans. VETERINARY IMMUNOLOGY AND IMMUNOPATHOLOGY 30:261–274, 1992.

Morse, S.S. Emerging viruses: Defining the rules for viral traffic. PERSPECTIVES IN BIOLOGY AND MEDICINE 34:387–409, 1991.

Munson, L. Strategies for integrating pathology into single species conservation programs. JOURNAL OF ZOO AND WILDLIFE MEDICINE 22:165–168, 1991.

O'Brien, S.J.; Evermann, J.F. Interactive influence of infectious disease and genetic diversity in natural populations. TRENDS IN ECOLOGY AND EVOLUTION 3:254–259, 1988.

O'Brien, S.J.; Roelke, M.E.; Marker, L.; Newman, A.; Winkler, C.A.; Meltzer, D; Colly, L.; Evermann, J.F.; Bush, M.; Wildt, D.E. Genetic basis for species vulnerability in the cheetah. SCIENCE 227:1428–1434, 1985.

Pedersen, N.C. Basic and clinical immunology. Pp. 146–181 in DISEASES OF THE CAT. Vol. 1. 1st ed. J. Holzworth, ed. Philadelphia, W.B. Saunders Co., 1987.

Pedersen, N.C. Common infectious diseases of multiple-cat environments. Pp. 163–208 in FELINE HUSBANDRY. N.C. Pedersen, ed. Goleta, California, American Veterinary Publications, Inc., 1991.

Postorino, N.C.; Pollock, R.V.H.; Thurber, E.T. Long-term follow-up study of cats vaccinated with a temperature-sensitive feline infectious peritonitis vaccine. CORNELL VETERINARIAN 82:117–123, 1992.

Povey, R.C. Persistent viral infection. The carrier state. VETERINARY CLINICS OF NORTH AMERICA: SMALL ANIMAL PRACTICE 16: 1075–1095, 1986.

Sabine, M.; Hyne, R. Isolation of a feline picornavirus from cheetahs with conjunctivitis and glossitis. VETERINARY RECORD 87:794–796, 1970.

Scherba, G.; Hajjar, A.M.; Pernikoff, D.S.; Sundberg, J.P.; Basgall, E.J.; Leon-Monzon, M.; Nerurkar, L.; Reichmann, M.E. Comparison of a cheetah herpesvirus isolate to feline herpesvirus type 1. ARCHIVES OF VIROLOGY 100:89–97, 1988.

Spencer, J.A. Lack of antibodies to coronaviruses in a captive cheetah (Acinonyx jubatus) population. JOURNAL OF THE SOUTH AFRICAN VETERINARY ASSOCIATION 62:124–125, 1991.

Spencer, J.A.; Burroughs, R. Antibody response of captive cheetahs to modified-live feline virus vaccine. JOURNAL OF WILDLIFE DISEASES 27:578–583, 1991.

Spencer, J.A.; Burroughs, R. Decline in maternal immunity and antibody response to vaccine in captive cheetah (Acinonyx jubatus) cubs. JOURNAL OF WILDLIFE DISEASES 28:102–104, 1992.

Wack, R. The response of cheetahs to routine vaccination. M.S. Thesis, Ohio State University, 1991.