BAYLISASCARIS TRANSFUGA IN CAPTIVE AND FREE-RANGING POPULATIONS OF BEARS (FAMILY: URSIDAE)

DISSERTATION

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By
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ABSTRACT

Baylisascaris transfuga, the bear roundworm is an ascaroid parasite that has been reported in all species of bears (giant panda, *Ailuropoda melanoleuca*; Maylayan sun bears, *Helarctos malayanus*; sloth bears, *Melursus ursinus*; American black bears, *Ursus americanus*; brown bear, *Ursus arctos*; polar bears, *Ursus maritimus*; Asiatic black bear, *Selenarctos thibetanus*; and Andean bears, *Tremarctos ornatus*). This ubiquitous nematode of bears is particularly problematic for captive populations. *Baylisascaris* species have been implicated in clinical and subclinical disease in natural hosts including bears, as well as lethal larval migrans syndromes in a number of domestic species, alternative livestock, and captive and free ranging incidental hosts, including humans. Eradication or improved control measures for addressing contaminated bear enclosures will heighten biosecurity for this infectious pathogen and reduce the risk of potential public health threats associated with *Baylisascaris* species. Impediments to control efforts include ineffective sanitation and disinfection of contaminated and re-contaminated exhibits, and concerns regarding the development of parasite resistance in helminth parasites of bears treated routinely with anti-helminthic pharmacological agents. The development of naturalistic exhibits and environmental enrichment programs in zoos and other captive wildlife facilities, enhances the educational mission of zoos and captive wildlife display facilities, but impedes husbandry practices and preventive medicine programs aimed at prevention, control and eradication of infectious pathogens in captive enclosures. The first objective of this study was to obtain information on husbandry and preventive health programs from captive bear-holding facilities for evaluating factors which influence parasite contamination, persistence, and transmission among individual bears, bears species, other collection animals and people. The second objective was to obtain data on coprodiagnostic tests used by institutions to detect parasite ova prevalence in captive collections and conduct baseline studies of current roundworm prevalence and intensity levels in bear holding collections. For this second objective, two coprodiagnostic techniques were employed to compare sensitivities of tests typically employed by captive facilities and more sophisticated tests known to yield higher recoveries of parasite ova. A final objective was to compare the prevalence and intensity levels of roundworms among wild populations of bears and between captive and free-ranging populations.

DEDICATION

This dissertation is dedicated to my father Samuel William Schaul, my mother, the late Dana Monus Schaul, my sister Samantha Schaul Kaplan, my brother Andrew Schaul, and my aunt, Judith Schaul Neuger. Without my family's love, unyielding support, and commitment to me, this dissertation would not have been possible. My parents have encouraged me to pursue my dreams and their support exceeds comprehension.

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1.1 Introduction

The over-exploitation of large carnivores and the destruction of wild habitat continue to decimate populations of mega-predators. Currently many species of mega-carnivores exist as metapopulations withdrawn to fragmented habitats. As a result of human encroachment, communicable diseases that were at one time considered relatively insignificant to the conservation of large carnivore populations are now pathogens that have been implicated in the extirpation of predator species in all or parts of their historic range

The perceived threat of bears to humans and livestock has caused the killing of many bears in areas where indigenous peoples continue to cultivate crops and manage livestock. In North America, bears in particular, have emerged as peri-domestic nusisance animals (i.e., black bear in parts of North America), and the frequency of human-bear confrontations continue to arise. Even remote areas that were at one time inaccessible are now considered popular ecotourism destinations for wildlife enthusiasts. And in zoos and sanctuaries where captive bears are maintained for conservation education or propagation programs, human animal contact has increased through husbandry training programs in which handlers are directly exposed to their charges with much more regularity than in years past. Human exposure to bears through the handling of individual animals has increased. Routine training programs in captivity fosters the potential transmission of disease agents between bears and people to a greater degree than ever before, as does the handling of animals for the management of wild populations (i.e., translocation, euthanasia).

Infectious agents pose serious threats to the future stability of these predator populations (Murray et al. 1999). Captive or free-ranging metapopulations may be particularly vulnerable to epizootics of communicable diseases. They are also vulnerable to regional extinction. Some populations may be rendered extinct in the wild, whereas others face potential extinction in areas where populations can no longer sustain themselves. To maintain genetic viability and prevent inbreeding depression species often require continual gene flow among metapopulations and the recruitment of individuals through breeding or movement of individuals from one population to another.

Ursids and canids, as well as strict carnivores (i.e. felids) require a vast expanse of land and core or high quality habitat to survive and carry out species-specific life history patterns. Hence, the conservation of bears and other large carnivoran predators inherently contributes to the conservation of the diverse flora and fauna which comprise the habitat in which these keystone and umbrella species are indigenous to. Bears, similar to other large omnivores and carnivores require a large expanse of land and a multitude of ecotypes. Hence, the preservation of bears provides protection for a multitude of other species which are distributed throughout a variety of ecosytems. Thus, bear conservation and management greatly influences the status of rich communities of wildlife, particularly in biodiverse regions of the world.

Bears are not particularly susceptible to infectious diseases which have significantly impacted other carnivore species. Consequently, they serve as sentinels for the presence of many infectious diseases agents, which otherwise decimate populations of carnivores. They are very useful in monitoring wildlife disease epizoototics. Disease surveillance in ursids may also be of benefit to public health practicioners concerned with zoonoses as well as emerging infectious diseases. Many such diseases have the potential to move from animal to human hosts, particularly as the human population continues to access remote habitat creating opportunities for human –animal contact to increase in both rural and urban areas.

Sustainable management and the long-term survival of bears species requires genetic and demographic management of bear populations, as well as a high regard for the health and well-being of individual animals. The development of sound husbandry practices and preventive health measures have contributed to the success of self–sustaining captive populations. However, the effects of climate change on disease patterns, trends in mixed species exhibition, and management of animals in naturalistic enclosures are influential factors that may compromise the health of captive populations.

All of these factors may contribute to pathogen contamination and persistence. Although bears have few health problems in captivity, they continue to be plagued with infectious disease agents, particularly ascarid nematodes.

1.2 Parasite Host Coevolution

Evolutionary biologists consider communicable pathogens to be significant regulators of populations of large harmacolog which are not limited by predators (May, 1983). Furthermore, infectious diseases often have a very significant impact on metapopulations which are inherently vulnerable to high disease transmission rates, including zoo populations. Although small, isolated populations of a threatened species were once considered at low risk for epizootic diseases, conservation biologists now consider small or fragmented populations at greater risk for disease outbreaks as a result of genetic deficiencies among metapopulations (Allendorf, 1986; Mcallum and Dobson, 2002). Alternatively, hosts which carry infectious agents, but are not particularly susceptible to diseases, may transmit diseases regardless of population size or disease transmission rates (Begon and Bowers, 1995; McCallum and Dobson, 1995). Although bears are not particularly susceptible to many of the infectious disease agents that afflict other carnivoran mammals, bear metapopulations in particular, have become increasingly vulnerable to epizootics, a characteristic of fragmented populations which persist with an increasing loss of heterogeneity. The vulnerability of a metapopulation is also due in part to the small population's ability to carry infectious agents and sustain the reinfection of a population.

Movement patterns in wild animals as well as seasonal migrations are considered taxon specific behavioral adaptions, which in some cases have evolved as social barriers to pathogen transmission (Loehle, 1995). Hence, dense populations of wildlife species which are not regulated by predation are often regulated by pathogens. Rate of contact between individuals, an artifact of group size and social behavior, directly influences pathogen transmission. Bears are typically solitary animals. With the exception of seasonal aggregations at salmon runs or garbage dumps, these mega-omnivores do not typically aggregate in large numbers year round. When reared in captivity where they are rarely induced into torpor they are in frequent contact with conspecifics in a relatively small and confined area. This artificial social environment promotes high transmission rates of communicable diseases, particularly those pathogens which contaminate the environment and persist as viable agents of disease. Captive bears unlike their solitary conspecifics in the wild, are often confined in close quarters with other individuals. Hence, they are perpetually exposed to pathogens passed in feces and continually infected with roundworms. These artificial conditions do not offer the same kind of geographic dilution and environmental destruction of parasite ova that occurs in the wild (find feral pig study). Repeated exposure to embryonated ascaroid parasite ova, creates the potential for heavy burdens and thus requires routine treatment for ascariasis

(Abdelrasoul and Fowler, 1979). Control of round worms may require prophylactic treatment with antihelminthics, and post infection treatment of infected animals, as well as proper sanitation and available disinfection. The ova of these nematode parasites are nearly impossible to eliminate, once they are shed into the environment (Partridge, 1992). They are both hardy, persistent and prolific helminth parasites which heavily contaminate zoo enclosures. Ascarid infections play an important economic role in zoo carnivore and primate collections and their impact on animal health is contingent to a degree upon the host species, the age of the host, as well as environmental conditions, husbandry programs, hygiene and parasiticide treatment schedule (Okulewicz et al. 2002).

1.3 Larval Migrans Syndrome

Larval migans syndromes in humans have become a major health concern in regions where raccoons occur. In the past few decades raccoons have emerged as a peri-domestic pest, well adapted to both sylvatic and urbans dwelling. Although host to viral and bacterial zoonoses, they are also definitive hosts for the zoonotic ascarid parasite *Baylisascaris procyonis*. Although this agent rarely impacts definitive hosts, recent evidence suggests that aberrant migrations of ascaroid parasites outside the intestines of definitive carnivoran hosts suggest they can produce potentially lethal diseases in both definitive (Bwangamoi, 1973; Prociv 1990; Pietsch et al. 2002; Laus etal. 2003) and aberrant hosts including humans. Exposure to substrates and other environmental surfaces contaminated with raccoon feces are dangerous for children with an inclination for geophagia or pika, or other humans with compromised hygiene. The raccoon roundworm, and to a lesser extent the skunk roundworm, *Baylisascaris columnaris* have, been implicated in larval migrans syndromes in humans non-human primates and more that 90 other bird and mammal species. Raccoons are well established as a peridomestic species throughout their historic range, in areas where their range has expanded and within and outside the nearctic where they have been introduced. Because of their proximity to human dwellings, their *Baylisascaris procyonis*, the raccoon roundworm is of great public health concern. Early treatment with antihelminthics can prevent serious disease. However, the larval tropisms for the CNS tissues, and undetectable migrations of *B. procyonis* to central nervous system, often preclude early detection and permant brain damage. Death and neurological symptoms have been reported in over a dozen people, the majority of which were very young children and infants (reviewed by Kazacos, 1997, 2001; Rowley et al. 2000; Gavin et al. 2002; Kazacos et al. 2002) Zoonotic asacriasis in adults which have manifested in non-neural larval migrans have been caused by less aggressive, and slower growing ascarid species as well as by *Baylisascaris* spp with tropisms for visceral and ocular tissues in addition to neural tissues of the CNS. Although visceral and occasionally ocular larval migrans have been reported from *Toxocara* spp., ocular larval migrans has been most frequently reported in association with *Baylisascarisasis procyonis* (Kazacos et al., 1985; Goldberg et al. 1993;

and Mets et al., 2003). *Baylisascaris* induced diffuse acute neuro retinitis has been reported in adults with unilateral visual impairment and blindness. Although migrating *Baylisascaris* species have been implicated in clinical opthamologic pathologies, their less traumatic larval migrations through visceral tissues are less descript and perhaps harmacologic or misdiagnosed.

Baylisascaris transfuga, the bear round worm is a ubiquitous parasitic nematode of captive and free- ranging bears. Although *B. transfuga* is prevalent in free ranging populations of bears, the parasite is a particularly important pathogen in captive populations. To prevent clinical health concerns associated with heavy parasite burdens, routine parasiticidal treatment of bear collections is typically necessary to keep worm burdens at safe levels. The persistence of *B. transfuga* in the environment precludes the eradication of the roundworm from captive enclosures, once introduced. Reports of larval migrans syndromes associated with *Baylisascaris* spp. In zoo avian, primate, and small mammal collections warrants investigations of roundworm transmission in captive wildlife collections. The emergence of the raccoon roundworm *B. procyonis*, has been implicated in the deaths of human and animal species and warrants improved biosecurity regarding known captive reservoirs of *Baylisascaris* spp. Including bears. Investigations regarding the pathogenicity and zoonotic potential of the bear roundworm and other *Baylisascaris spp.* will aid in the development of preventive medicine programs for animal collections as well as animal handlers.

Bears are considered poor candidates for reintroduction programs (Clark et al., 2002, Schaul 2006) due to low fecundity, their exposure to high environmental variation in wild habitat, small founder population sizes, relatively low genetic variability (Manlove et al., 1980, Wathen et al., 1985), strong homing instincts (Beeman and Pelton, 1976; Miller and Ballard, 1982; Rogers, 1987). They are also overly habituated release candidates and have been subjects of poorly managed reintroduction programs (Clark et al., 2002; IUCN Reintroduction Specialist Group, 1998). However, depleted wild populations and growing captive populations have elicited recents discussions concerning prospects for reintroduction initiatives. Criswell and Fuller (2006) argue that although many consider reintroduction as a last resort for the implementation of *in situ* conservation programs captive bears may serve to supplement or perhaps serve to reestablish wild populations. Concern for the translocation of diseases in translocation, reintroduction, and repatriation projects for native species have been largely overlooked despite the potential for diseases to not only impede conservation efforts, but nullify their effect or perhaps further decimate native populations (Thorne and Williams 1988; Munson, 1991; Davidson & Nettles; Ballou 1993; Kirkwood 1993; Lyles & Dobson, 1993; Munson & Cook, 1993; Viggers et al. 1993; Woodford 1993; Woodford & Rossieter, 1993; McCallum and Dobson, 1993; Gulland 1995). Of particular concern is the reintroduction of animals that have been maintained in captivity (Cunningham 1996). The success of captive translocation programs can be enhanced through diseases surveillance of free-ranging wildlife in the areas designated for animal translocations. Futhermore, pathogens non-endemic to the area of reintroduction should be eliminated before animals are released into the wild (Viggers et al. 1993). These pre release protocols may prevent the catastrophic effects of disease introduction to target species and other wildlife endemic to translocation sites. To reduce pathogen transmission in captive animals intended for reintroduction, Woodford (1993) reccommended that animals be maintained as close to the release site as possible, and for as short a time as possible. The author also recommended minimizing direct and indirect contact between conspecifics and other species and adhering to husbandry protocols that reduce the transmission of pathogens from keepers to animals and transmission via contaminated or infected foodstuffs.

Several helminth parasites of carnivores are potential etiological agents of ocular, visceral and neural larval migrans syndromes (Beaver 1969; Beaver et al.1984; Kazacos 1991, 1996, 1997, 2000; Smyth 1995). Helminth zoonoses associated with larval migrans syndromes include ascarids, and hookworms and other helminth parasites, including gnathostomes, *Spirometra* and *Alaria, among others* (Kazacos 2001). Humans become infected following accidental ingestion of embyonated ova of roundworms which contaminate the environment when infected animals defecate (Overgauuw, 1997). A paucity of research has been conducted on risks associated with environmental exposure to zoonotic ascarid ova (Dubin et al., 1975; Dada and Linquist, 1979; Surgan et al., 1980;

Smith and Hagstad, 1984; Childs et al. 1985, Paul et al., 1988; Chorazy and Richardson, 2005). Among the ascarids *Baylisascaris* spp. are most often implicated as roundworms of zoonotic concern.

1.4 Human-Bear Conflict

Aside from the loss of habitat and the poaching of bears for medicinal markets, bear populations all over the globe continue to decline as bears continue to be perceived as threats to human life and livestock or both. Perceived threats to human life following confrontations with polar bears have been discussed by Gjertz and Persen (1987) and from human confrontations with North American brown bears and black bears by Herrero (1985). Similarly, the fear of human or livestock predation by sloth bears (Rajpurohit and Krausman, 2000), Asiatic black bears (Chauhan, 2003) and Andean bears (Goldstein, 2002) has instilled a negative perception of bears among agricultural communities and has been the impetous for the hunting of these opportunitic carnivores. Grizzlies and black bears in North America raid apiaries, crops, orchard fruits, and garbage dumps (Ambrose and Sanders, 1978, Garshelis et al., 1999) and can inflict considerable damage on timber stands (Stewart et al., 1999). Grizzlies and black bears in North America and Andean bears have beer reported to prey on livestock (Knight and Judd, 1983; Goldstein 2002). Asiatic black bears have been reported to have raided orchards and crops as well as fish farms (Azuma and Torri, 1980; Huygens and Hayashi, 1999). Iswariah (1984) reported that sloth bears raid sugarcane and groundnut plantations in India. Sun bears have been reported to raid newly planted crops in Indonesian, Borneo (Fredriksson, 2005)

1.5 Systematics, Natural History, and Conservation Status of Ursidae

The eight living species of bears are recognized and distributed on four continents representing 65 countries (IUCN/SSC Bear Specialist Group, 1998) and represent the largest species of extant carnivoran mammals, as well as some of the largest living land animals. The family Ursidae (Waldheim 1817) is one of the smallest families classified within Carnivora. Carnivora, itself is a relatively small order represented today by only two suborders, three superfamilies, and ten families (Wozencraft, 1989a; McKenna, and Bell, 1997).

Although bears comprise a small clade of three subfamilies ((Ursinae: American black bear,*Ursus americanus*; brown bear, *Ursus arctos*; polar bear, *Ursus maratimus* Asiatic black bear, *Ursus thibetanus*; sun bear, *Helarctos mayalanus*; and the sloth bear *Melursus ursinus*; Tremarctinae: Andean bear, *Tremarctos ornatus*; and Ailuropodinae: Giant panda, *Ailuropoda melanoleuca* (Garshelis, 2001) ursidae is recognized as a major monophyletic group within the order Carnivora (Delisle and Strobeck, 2004).

The body lengths of ursids range from 1000 mm to 2800 mm, with tail lengths of 65 mm to 210 mm, and weights ranging from 27 to 780 kg. On average males are 20 percent larger than females. Giant panda, Asiatic black bear, American black bear and

Andean bears are comparable in regard to body size (Garshelis, 2001; Zhi, 2001). Bears have large heads, large heavily built bodies, short powerful limbs, short tails, small eyes, and small ears which are round and erect. The dental formula for most species is: (incisors 3/3, carnassials 1/1 premolars 4/4 molars 2/3) X 2 = 42. Bear incisors are not specialized, and the canines are enlongate. The first three premolars are reduced or absent. The molars have broad, flat and tubercular crowns (Nowak, 1991). Bears have a shuffling gait, walk plantigrade with the heel of their foot touching the ground, and can walk on their hind legs for short periods of time. Arboreal species or those that climb tend to have naked soles, while terrestrial species have hairy soles (Nowak, 1991).

Natural history and conservation data remains sparse or fragmentary for several species of bears, and for some species, a paucity of information exists in regions throughout much of their current range (Servheen, 1989). Bears have adapted to a variety of habitats ranging from the circumpolar arctic to equatorial regions of the neotropics (Nowak 1991, and Joshi et al 1999). Sympatry is commonly reported for populations of giant panda and Asiatic black bears (Nowak 1999), as well as for populations of brown bears and American black bears (Derocher 2000). However, giant panda and Asiatic black bears exhibit some syntopy, as their activity schedules and budgets overlap to some degree, as do their use of space, but their feeding ecologies differ dramatically (Schaller et al., 1989). American black bears and brown bears are exhibit both syntopy in certain regions where they overlap in distribution (Derocher 2000), but brown bear activity patterns may differ substantially from the more crepuscular and nocturnal black bears. Some species which occur in open areas often dig dens, while others find shelters in caves, hollow logs, or dense vegetation. Although, most species of bears are opportunistic omnivores some are specialists.

Recent impacts on bear populations have been attributed to habitat loss, whereas historic decimation of populations had been attributed to direct kills (Servheen, 1990). Unfortunately, in recent years, human encroachment and loss of habitat have led to an increase in bear-human interactions, many of which have resulted in the killings of nuisance bears. Increased exposure to human-related foods (Fredriksson, 2005), have resulted in human–bear conflicts for most bear species, and many are now considered nuisance animals in much of their current range which is also inhabited by people. People and bears continue to compete for resources (e.g. space) wherever bears and humans exist together (Servheen, 1990). Human encroachment and manipulation of bear habitat, in twenty years following Cowan’s review (Cowan, 1972) of the conservation status of bears, have significantly impacted the population stability for six of the eight species of bears. Although the grizzly has certainly recovered in parts of the conterminous United States, only black bear and polar bear populations were considered stable in the late 1980s (Servheen, 1990) and in more recent years. The management of bears requires that humans permit bears to continue to access resources that promote sustainable populations, and in some cases sustainable harvests of bears. Unfortunately, so little is known about the populations of some species of bears that intervention to mitigate human-animal conflicts is particularly challenging (Servheen, 1990).

1.5.1 Polar Bears (*Ursus maritimus*)

Extensive data has been collected on the polar bear (*Ursus maritimus*), the polar, and circumpolar species whose southern range is determined by the extent of ice pack formation in the Arctic ocean and ice formation off the northern coasts of the continents (Demaster and Stirling 1981; and Nowak, 1999). Polar bears use ice both as a platform for hunting and traveling (Stirling and Archibald, 1977; Smith, 1980). Nineteen populations of polar bears have been recognized in the polar and circumpolar regions of the Arctic since the five nation (Canada, Greenland , Denmark, Norway, USA and USSR) Agreement on the Conservation of Polar Bears was negotiated for management and research of polar bears in 1973 (IUCN/SSC Polar Bear Specialist Group, 1998). These include Western Hudson Bay, Southern Hudson Bay, Foxe Basin, Davis Strait-Labrador, Baffin Bay, Kane Basin, Lancaster Sound, Wrangel Island and western Alaska; Northern Alaska; the Canadian Arctic Archipelago; Greenland; Svalbard-Franz Joseph Land, Gulf of Boothia, M'Clintock Channel, Viscount Melville Sound, Norwegian Bay, Queen Elizabeth Islands, Northern Beautfort Sea, Southern Beatfort Sea, Chuchki Sea, Laptev Sea, Franz Josef L.-Novaja Z., Svalbard, and East Greenland; and the Central Siberian population). Some patterns of genetic discontinuities have evolved within these populations and are attributed to seasonal distribution patterns affected by changes in sea ice distribution and seal abundance (Paetuk et al., 1999). Polar bears primarily hunt ringed seals (*Phoca hispida*), as well as bearded seals, (*Erignathus barbatus*), and harp seals (*Phoca groenlandicus*) while their prey surface at breathing holes, are hauled out on ice, or prey on seals in birth lairs (Stirling and Archibald, 1977; Smith, 1980).

1.5.2 Brown Bears (*Ursus arctos*)

More is known about population structure and distribution of brown bears than any other ursid species (Servheen, 1990). Brown bears currently range throughout Europe, Asia, and North America (Servheen, 1990; Nowack, 1991; Hofreiter et al., 2004). At one time taxonomists using morphometric studies of brown bear cranial and dental characteristics, recognized more than 90 subspecies of brown bears in North America (Merriam 1918), and over 270 subspecies in Eurasia (Ognev, 1931). Brown bear populations exist in arid regions of the Middle East & Asia, boreal forest, taiga and tundra of circumpolar regions of the Northern hemisphere (Paetkau et al., 1998). Systematic investigations of brown bears, in North America have generated much debate, particularly with regard to the phylogenies of bears on islands in southeast Alaska, the Kodiak Archipelago, Alaskan coastal bears and the grizzlies of the interior, including populations distributed through out the North American Continent. Early morphometric studies led to the systematic description and recognition of the Kodiak brown bears

(*Ursus arctos middendorffi*) a subspecies found only on the Kodiak Archipelago and considered at first to be the only distinct subspecies of Alaskan brown bears aside from *Ursus arctos horribilis,* represented by island, coastal bears, as well as bears of the Alaska interior and the continental populations, often referred to as “grizzlies” (Rausch, 1963). Molecular data supports the sub-specific classification of Kodiak bears which, like coastal bears are larger in size, relative to ‘grizzlies,’ but unlike coastal populations Kodiak bears have distinctly broad skulls (Paetkau et al., 1998).

Through further systematic splitting, Kurten (1973), classified the large Alaskan coastal brown bears, the bears of Admiralty, Baranof and Chicagof islands, and the coastal populations of British Columbia as the distinct subspecies, *Ursus arctos dalli.* More recent molecular data using nuclear microsatellite data indicate that the bears of Admiralty, Baranof and Chicagof islands are apart of the continuous continentally distributed populations of North America brown bears or ‘Grizzly bears’ (Paetkau et al., 1998).

1.5.3 American Black Bears (*Ursus americanus*)

The American black bear (*Ursus americanus* Pallas 1780) occurs throughout all Canadian provinces and territories except Prince Edward Island and throughout the United States except in arid regions of the South West (Kolenosky and Strathearn, 1987). *Ursus americanus* also occurs in the forests of Mexico’s Sierra Madre Occidental and

Sierra Madre Oriental. Currently 16 subspecies of American black bears are recognized *Ursus americanus altifrontalis* (Pacific Northwest); *Ursus arctos amblyceps* (Southwestern states), *Ursus arctos americanus* (Alaska to the Atlantic coast), *Ursus arctos californiensis* (Interior of California), *Ursus arctos carlottae* (Queen Charlotte islands of British Columbia), *Ursus arctos cinnamomum* (Wyoming, eastern Colorado, Idaho, western Montana, southwestern Alberta, southeastern British Columbia), *Ursus arctos emmonsii* (coastal AK from Glacier Bay to Prince William Sound), *Ursus arctos eremicus* (northeastern Mexico and the Big Bend area of Texas), *Ursus arctos floridanus* (Florida, southern Georgia, southern Alabama), *Ursus arctos hamiltoni* (Newfoundland), *Ursus arctos kermodei* (portion of coastal BC), *Ursus arctos luteolus* (southern Louisiana and southern Mississippi), *Ursus arctos machetes* (northwestern Mexico), *Ursus arctos perniger* (Kenai Peninsula of AK), *Ursus arctos pugnax* (southeastern Alaska), *Ursus arctos vancouveri* (Vancouver Island) (******). Taxonomists update subspecies classifications as they learn more about regional differences in DNA, body form, and behavior. The American black bear is an opportunistic predator of moose (Austin et al. 1994, Schwartz and Franzman, 1991) and requires a variety of habitats producing seasonal foods, as well as extensive and secluded areas for denning.

Both Grizzly bears and American black bears are opportunistic omnivores that can become food conditioned, nuisance animals if exposed to human-related foods. Both of these species feed on orchard fruits, crops apiaries, garbage and livestock (Ambrose and Sanders, 1978; Knight and Judd, 1983; and Garshelis et al., 1999)

1.5.4 Asiatic Black Bears (*Ursus thibetanus*)

Asiatic black bears (*Ursus thibetanus*) are distributed throughout mainland of South East Asia, but little is known about the population structure of this species (Amano et al., 2004). Asiatic black bears occur in Thailand, north of Vietnam, and south of China on the main land of Southeast Asia. To the west they occur north of Pakistan, south of Afghanistan, and east of the Himalayans (Kanchanasakha et al., 1998). The Japanese Asiatic Black bear is widely distributed throughout the three major islands of the Japanese archipelago, with the exception of the island of Hokkaido (Hazumi, 1999; Horino and Miura, 2000). Seven species of Asiatic black bears have been described (Ellerman and Morrison-Scott, 1951). *Ursus thibetanus japonicus* (Schlegel, 1857) is found on the Japanes archipelago and are typically smaller than bears found on the mainland (Pocock, 1933). *Ursus t. formosanus* is a Taiwanese subspecies described by Swinhoe (1964). This race is intermediate in size. Individuals are reported to be larger than *U. t. j.* but smaller that *U. t. t.* *Ursus t. gedrosianus* was described by Blanford (1877) from an individual from Baluchistan. The Chinese subspecies *U. t. mupinensis* was described by Pocock (1933). Pocock (1933) also described a northern Chinese and Korean race, *U. t. ussuricus.* This subspecies was also distributed throughout Manchuria.

The Pakistani sub species was described from black bear specimens from Kashmir and Punjab. This race distributed in the Western range of the Asiatic black bear was named *U.t. laniger.* This species is threatened by commercial hunting, which supports traditional medicine (e.g. poaching for gall bladders) as well as nuisance kills, to protect humans, and crops. In Japan, Asiatic black bears commonly raid crops, orchards and fish farms (Huygens and Hayashi, 1999). Deforestation is additional threat to Asiatic black bears, as it continues to fragment populations and eliminate habitat (Hazumi, 1999).
Schlegel, 1857; Pocock 1933; Swinhoe 1964; Blanford 1877

1.5.5 Malayan Sun Bears (*Helarctos malayanus*)

Two subsepecies of sun bears are currently recognized (Ellerman and Morrison-Scott, 1951; Medway 1978). *Helarctos malayanus malayanus* is distributed on the mainland of South East Asia and the island of Sumatra. A The subspecies, *H. m. eurspilus,* is found on the island of Borneo (Pocock, 1933. A paucity of information exists for the Malayan sun bear (*Helarctos Malayanus*) and even today sun bears remain the least studied of the eight extant species of bears. Basic data on reproductive biology, foraging ecology and home range size is scarce and only recently have investigators conducted studies on population structure (genetics) and densities (Meijaard, 1997; Servheen, 1999). The smallest of the ursids, adult sun bears weigh 27-65 kilograms and attain a length of 120 to 150 centimeters. Sun bears occur in in fragments of primary and logged forests (Wong et al., 2003) of their historic range. This includes forests of Bangladesh, Myanmar, Thailand, Laos, Kampuchea, Vietnam, Southern China, Peninsular Malaysia and the islands of Borneo and Sumatra (Stirling, 1993). Although human-rood related incidents with sun bears have not been well documented, historical accounts from early colonialism suggest that sun bears began crop-raiding soon after attractive foods were planted near forest habitat (O- Viri, 1925, Ellerman and Morrison-Scott, 1951; Medway 1978; Pocock 1933)

1.5.6 Sloth Bears (*Melursus ursinus*)

Two subspecies of sloth bears are recognized (Ellerman and Morrison-Scott, 1951). *Melursus ursinus ursinus* if found on the Indian subcontinent and *M. u. inornatus* is found in Sri Lanka and distinguished by an absence of chest markings that are found on the mainland population (Pocock, 1933). The sloth bear (*Melursus ursinus*) occurs in India, Nepal, Bhutan, Bangladesh and Sri Lanka. Due to human encroachment and the cultivation of coffee and tea, they are now found only in northern and eastern lowlands of Sri Lanka (Santiapillai and Santiapillai, 1990). This unique looking ursid attains body lengths of 1400-1800 mm, with a tail length of 100-125 mm and a weight of 55-145 kg. Males weigh approximately 80-145 kg and females weigh approximately 55-95 kg (Garshelis, 1999). The species has long shaggy black hair with no underfur and is the only species with long hair on its ears (Garshelis, 1999) and a several structural modifications associated with its insectivorous feeding habits. These opportunistic myrmecaphagous omnivores feed primarily on termites (white ants), but also feed on other insects, honey, grubs, carrion, and vegetation consisting of flowers, grass and fruits. They have naked, protrusible, or prehensile lips, and nostrils that may be closed voluntarily. With a hollow upper palate and an absence of two front upper incisors, these bears are specialized insectivores, capable of blowing off residual dust and dirt from dug up termite nests. They can then vacuum feed upon termites.

Sloth bears inhabit rocky outcrops of dry and moist forests (Nowak, 1991). They occur in grasslands, thorn scrub, moist evergreen forest and sal (*Shorea robusta*) forest (Garshelis, 1999). Studies in Nepal indicate that bears moved to uplands which permitted feeding on termites and returned to lowlands during the dry season, a period when excavation of termites was hampered by dry soil conditions in the highlands (Davidar, 1983). In India, sloth bears were reported to rely less on termites and foraged more on fruit, given a greater abundance a non-insect food sources and a longer fruiting season (Gokula, 1995).

Sloth bears considered to be nocturnal they have been reported to be active at all periods of the day. During cool periods they tend to seek out areas of dense vegetation or shallow caves, but are not known to hibernate.

Because sloth bears occasionally have attacked people in defense, they are thought to be dangerous. However, they are not generally considered dangerous, but are rather defensive when approached closely by people. Human encounters are relatively frequent because of the suspected poor hearing and eyesight of the bears, leading to surprise encounters. Hunting of sloth bears has been attributed to fear of sloth bear attack and crop damage associated with bears. They are vocal ursids. Intraspecific vocalizations are associated with intraspecific agonistic and aggressive behaviors (e.g. roars, howls, screams and squeals) and make sloth bears easy targets for human hunters.

1.5.7 Andean Bears (*Tremarctos ornatus*)

The Spectacled bear *Tremarctos ornatus* is an intermediate sized bear, with adult males reaching lengths of 1.5 m to 2.0 m and weights measuring between 140 kg and 175 kg (Mondolfi 1971 and Peyton 1980), the only extant species of short-faced bears. Similar to giant pandas, the spectacled bears have large zygomaticulomandibularis muscles and short muzzles relative to their body size (Davis 1955). These features permit herbivorous feeding habitats and ability to grind fibrous vegetation in both spectacled bears and pandas. Unlike the other ursids the Andean bears have underdeveloped proconids on their fourth premolars, an adaptation for tearing flesh in other species (Kurten 1966). They also have a unique chromosome number (2n=52) among bears (Nash and O'Brien 1987). Spectacled bears are active in the montane cloud forests both during the day and night and there is no evidence that they hibernate at any time of year (Peyton 1999). In Peruvian deserts they rest in covered day beds. In forest canopies theis arboreal species creates elevated platforms or tree nests out of crushed branches (Peyton 1987). Spectacled bears are generally solitary, but have been observed feeding in *Opuntia* cactus groves and cornfields in groups of up to nine bears. They feed on, palms, leaf petiole bases of bromeliads (*Puya, Tillandsia*, and *Guzmani*a ssp.), frailejon (*Espeletia* spp.), and orchid pseudobulbs, when fruit is unavailable. Similarly, they feed on the meristematic tissues of bamboo and desert tree species (Peyton 1999). As opportunistic omnivores they feed on invertebrates, rodents, birds and livestock (Peyton 1980, 1987; Jorgenson and Rodriguez 1986; Suarez 1988; Brown and Rumiz 1989, Goldstein 1989). Cubs often remain with their mothers for a year post-parturition.

1.5.8 Giant Panda (*Ailuropoda melanoleuca*)

Giant pandas (*Ailuropoda melanoleuca*) currently range throughout central china. Their historic range includes much of eastern China to the south of the Huang River, but today they occur in the central provinces of Gansu, Shaanxi, and Sichuan (Schaller et al., 1985). Giant pandas range in body length from 1200-1500 with a tail length of approximately 127 mm and a body weight of 75-160 kg. Giant pandas have a thick and wooly white coat with black eyes patches, black ears, legs and a black shoulder band (Nowak, 1991). Giant pandas have scent glands under their tail. *Ailuropoda* shares several character traits with the lesser panda (*Ailiurus*). It has been suggested that both species should be placed in the family Ailiuropodidae or Ailiuridae or classified separately in these distinct families, on the basis of certain morphological, reproductive, and behavioral characters (Schaller et al 1985). Several characters are common to members of both the raccoon (Procyonidae) and bear (Ursidae) families, but evidence suggests that both species are more closely related to the latter (Schaller et al. 1985). However, lesser pandas have most recently been classified as members of Procyonidae and giant pandas as members of the family Ursidae on the basis of anatomical, paleontological, anatomical and biochemical evidence (Schaller et al., 1985).

Giant pandas are primarily a crepuscular and nocturnal species occurring in dense montane forests with an abundance of bamboo stands. Their primary food sources are bamboo shoots and roots. Giant pandas also feed on other plants including gentians, irises, crocuses, and tufted grasses. They will also feed opportunistically on fish, pikas and small mammals.They are not considered arboreal, but can climb trees. Although they do not utilize permanent dens they do shelter in caves, rock crevices and hollow trees. They are not arboreal, but can climb trees. Although they do not hibernate they do descend as low as 800 meters in the winter. Giant panda have expanded zygomatic arches which support well-developed masticatory musculature. Their second and third molars and premolars are larger than those of other ursids. The pads on their forelimbs have unique accessory lobes for grasping bamboo (Garshelis 2001).

1.6 Evolution and Phylogenetics of Ursidae

The bears are thought to have evolved from a transitory group of late Oligocene carnivores 15-20 Million Years ago (Thenius, 1959; Kurten, 1968; Thenius, 1982; and Waites et al., 1998). The eight extant species and the extinct subfamily Agriotheriinae likely derived from Ursavus, the earliest known bear during the harmac (Thenius, 1959; Kurten, 1968; Thenius, 1982; Goldman et al., 1989; Waites et al., 1998).

1.6.1 Evolution and Phylogenetics of the Family Ursidae

Despite extensive paleontological (Kurten, 1968; Thenius, 1982), cytological (Nash and O'Brien, 1987), immunological, DNA hybridization, isozymal (Obrien et al., 1985 and Goldman et al., 1987) mitochondrial DNA studies generated over a near half century, controversial taxonomic placement persists for ursine species and related carnivoran phylogenies (Waites et al., 1998; Paab, 2000; Delisle and Strobeck, 2004; and Li Yu et al., 2004). These phylogenetic ambiguities persist, as unresolved polytomous relationships for the familial carnivoran clades and within ursid phylogeny at sub-familial, interspecific and, subspecific levels. Although monophyly continues to be been challenged within Carnivora, recent molecular genetic study indicates that Ursidae along with Pinnipedia ((Otariidae, eared seals; Odobenidae, walrus; and Phocidae, earless seals) and Musteloidea (Mustelidae, weasles, Procyonidae, raccoons; Ailiuridae, lesser panda) are the major monophyletic clades within the dog-like carnivoran clade, Arctoidea (Delisle and Strobeck, 2004).

1.6.2 Current Taxonomic Placement of Bear Species Within Ursidae

Current taxonomic placement within the family ursidae depends upon the methods employed to resolve phylogenetic relationships, and hence morphological and molecular data continues to challenge taxonomic classification of bear species, leaving bear phylogeny largely unresolved (Talbot and Shields, 1996; Paabo, 2000) . Mitochondrial DNA sequencing has enhanced phylogenetic resolution and has warranted subsequent reclassification in recent years. At one point, each of the six ursine species was placed within its own genus (Eisenberg, 1981) and later each was re-classified in the genus ursus (Nowak, 1991). Separate placement of the sloth bear, *Melursus ursinus* into a distinct genus (Honacki et al., 1982; and Corbet and Hill, 1991) was based on genetic and morphological determinants. Giant pandas, are considered early devergents from Ursidae (Zhi, 2001**),** on the basis of morphometric (Pierlot, and Jiao, 1985), molecular genetic (Wurster-Hill and Bush, 1980) and hematologic studies (Hoffman and Braunitzer, 1987). The Andean bear (Subfamily: Tremarctinae) is consider the closest sister taxon to giant panda (Subfamily: Aluropodinae) on the basis of hematologic studies (Hoffman and Braunitzer, 1987; Hoffman et al. 1987), and hence, links pandas to the ursine clade. Polar bears and brown bears are sister taxa and breeding has occurred between these closely related ursine taxa (Stirling, I. 2001; Pers Comm., J. Clark, 2006). Although American black bears were considered most closely related to Asiatic black bears, molecular phylogeneticists have inferred from sequences of ursine mitochondrial DNA that *Ursus Americanus* is most closely related to Malayan sun bears (Garshelis, 2001; Zhang and Ryder, 1994), the species considered to be the oldest member of the family Ursidae (Thenius, 1965; Leyhausen and Thenius, 1993).

Despite unsuccessful attempts to resolve phylogenies within the carnivoran clade and within the ursid family, in particular, recent evidence from molecular studies support earlier attempts to establish phylogeny, by other methods. Seven fissipedal dog-like families of carnivorans (i.e., Canidae, dogs; Mustelidae, weasles; Mephitidae, skunks and Procyonidae, raccoons) and the extinct family of bear dogs Amphycionidae have been taxonomically placed in the super family Canoidea (Arctoidea). The remaining eight families include fissipedal cat- like carnivoran (Felidae, cats; Herpestidae, mongooses; Hyaenidae, hyenas; Viverridae, civets, and the extinct family Nimravidae (paleofelids). Three pinnipedal carnivoran families (Otariidae, eared seals; Odobenidae, walrus; and Phocidae, earless seals) are often placed in the subfamily Pinnipedia with, (families have been placed in the superfamily Feloidea (Aleuroidea). Ursidae has been taxonomically placed in the superfamily Canoidea or Arctoidea which is comprised of four other extant families ((i.e., Canidae (dogs); Mustelidae (weasles); Mephitidae (skunks) and Procyonidae (raccoons); and the extinct family of bear dogs Amphycionidae).

CHAPTER 2

REVIEW: PARASITIC DISEASES OF BEARS

2.1 Microparasites

Parasites of ursine species were reviewed in 1935 by Stiles and Baker. Since that publication extensive data has been collected on the parasitic organisms of bears with at least 43 new species having been reported in ursids. Coccidia spp. (*Eimeria albertensis & Eimeria borealis*) which have reportedly caused clinical illness in bears (Couturier, 1954) were reported in free-ranging American black bears (Hair and Mahrt, 1970) and (*Eimeria ursi*) in brown bears from the USSR (Yakimoff and Matschoulsky, 1935; 1940). A Babesia species was reported in a captive bear from a florida zoo (Stiles and Baker, 1935).

2.2 Trematodes (flukes)

Trematodes reported in bears include *Dicrocoelium lanceatum* in Asiatic black bears in the USSR (Bromlei, 1985) and *Echinistoma revolutum* in Grizzly bears in Montana (Worley et al., 1976). The metacercariae of the fluke *Nanophytes salminocolo* was reported in salmonids eaten by bears. These larval trematodes vector two species of rickettsial organisms. Experimental infections in black bears demonstrated clinical disease (Farell, 1968).

2.3 Cestodes (tapeworms)

Bears serve as both definitive and intermediate hosts for cyclophyllidean tapeworms. Several taeniid tapeworms have been reported in captive and free-ranging bear species. In Alaska, *Taenia krabbei* and *Taenia hydatigena* were recovered from captive black bears (Rausch 1954; Rausch et al., 1956). Choquette et al. (1969) also reported *T. krabbei* in wild grizzlies in Northwestern Canada. In the contiguous 48 states, *Taenia saginata* (Jonkel and Cowan, 1971) was reported in black bears in northwestern Montana, *Taenia pisiformis* from a black bear in Colorado (Hortsman, 1949). Taeniid cestodes have also been reported in a captive Asiatic black bear in India (Stiles and Baker, 1935). Rogers (1975) reported *Multiceps serialis*, a cestode normally found in an intermediate mammalian host, the snowshoe hare.

Among other adult cyclophyllidean tapeworms recovered from bears, *Pentorchisarkteios*, was reported in a sun bear in Burma (Meggitt, 1927). Adult taeniid cestodes have also been recovered from captive bears, including *Taenia harma*, from a captive brown bear at the Copenhagen zoo (Linstow, 1893) and *Taenia ursi-maritimi* from captive polars bears elsewhere in Europe (Rudolphi, 1810; Linstow, 1878). Bears also harbor larval cyclophyllidean cestodes (Meggitt, 1924), including Batsches* (1786) report of hydatid cysts in ursine species and a specific report of *Cysticercus cellulosae* cysticerci in a brown bear presumably from the old world (Diesing, 1851). Among pseudophyllidean tapeworms reported in North American bears, only members of the genus *Diphyllobothrium* have been reported. These tapeworms are associated with fish eating mammals which have consumed fish harboring the larval plerocercoids (Rausch, 1954).

Dyphyllobothrium latum (Skinker, 1931; Rush, 1932), *Dyphyllobothrium cordatum* (Scott, 1932) and *Dyphyllobothrium cordiceps* (Rausch, 1954) have all been identified and occasionally re-identified in wild black bears from Yellowstone National Park. *Dyphyllobothrium latum* was also reported in a captive polar bear in Minnesota (1949). Bromlei (1965) reported *Dyphyllobothrium latum* and *Dyphyllobothrium cordatum* in brown bears from southeastern USSR. *Bothriocephalus ursi* was reported in a brown bear from a German zoo (Landois, 1877) and in a polar bear from a zoo in Ireland (Foot, 1865).

2.4 Nematodes (roundworms)

Sprent (1968) reclassified the ursine ascaridoid nematodes of the genera *Ascaris* and *Toxascaris* into *Baylisascaris,* a genus reported in all bears species except spectacled bears. *Baylisascaris* has been reported in grizzly bears in northwestern Canada (Choquette et al., 1968), and in black bears in Ontario (Sprent, 1950; 1951), Alaska (Rausch 1961), Minnesota (Rogers, 1975), Montana (Worley et al., 1976) and Wyoming (Rush, 1932). *Baylisascaris tranfuga*, has been reported in bears from south–eastern USSR (Oshmarin, 1963), Japan (Okoshi et al., 1962), Caucasus, Baikal, Chukotka, Indonesia, Syria, and Tibet (Bromlei, 1965).

2.5 *Baylisascaris* (ascaridoid nematodes)

Baylisascaris transfuga has also been reported in captive bears. The ascarids were collected from captive polar bears in Australia (Sprent, 1968). Two more ascarids reclassified as *Baylisascaris* sp. Include *Baylisascaris schroederi* (McIntosh, 1939) collected from the giant panda and *Baylisascaris melursus* collected from the sloth bear (Khera, 1951). *Baylisascaris multipapillata* was collected from a captive black bear in Germany (Kreis, 1938). Other ascarids reported in bears include *Toxocara canis and Toxocara mystax* collected from captive bears in Germany (Couturier, 1954)

2.6 Strongyles and Miscellaneous Endoparasitic Mematodes

Baylis and Daubney (1922) reported four hookworms of the genus Ancylostoma from captive sloth bears in India (*Ancylostoma brasiliens, Ancylostoma ceylanicum, Ancylostoma malayanum* and *Ancylostoma caninum*) and reported *Ancylostoma malayanum* in a captive sun bear from India. Lane (1916) also reported *Ancylostoma malayanum* in Asiatic black bears and from a captive sun bear from India. Ursine *Uncinaria* species, originally described as *Dochmius ursi* (Dujuardin, 1845) were collected from a polar bear and later reported in *Ursus arctos caucasicus*. Northern carnivore hookworms (*Uncinaria stenocephala*) were reported in brown bears near the Caspian Sea (Rukhliadev and Rukhliadeva, 1953; Sadykhov, 1962). Wolfgang (1956), described a new species of hookworms in the genus *Uncinaria. Uncinaria yukonensis* was described on the basis of samples collected from two black bears from the Yukon territory. Choquette (1969) reported *Uncinaria yukonesis* in Yukon Grizzlies. In Alaska, *U. yukonensis* was reported in both black and brown bears (Rausch, 1961: 1968) as was a newly described species, *Uncinaria rauschii* (Olsen 1968). Canavan (1929) reported the unique finding of *Haemonchus contortus* in the enteric tract of a polar bear at the Philadelphia zoo. An avian cyathastome (*Cyathostoma bronchiale*) in a captive brown bear was reported from the same zoo by Stiles and Baker (1935).

2.7 Extra-intestinal Helminths

A number of extra-intestinal nematodes have been described and/ or reported in ursids. Gmelin (1790) reported *Taenia ursi* as a parasite of bears, and Diesing (1850) reported *T. ursi* (*Nematoideum ursi*) in *Ursus arctos.* A new species of *Crenosoma* lungworms were reported in wild, but not captive black bears (King et al 1960). Among spirurid infections black bears were reported to have been infected with the eye worm *Thelazia ursi* in California. Hosford et al. (1942) and Hutrya et al. (1946) reported the finding of a kidney worm (*Dictophyma renale*) in the abdominal cavity of an unidentified bear. *Gongylonema pulchrum*, a common parasite of ungulates was found in an emaciated black bear from Pennsylvania (Chandler, 1950). In more recent accounts, Crum et al. (1978) and Conti et al. (1983) reported that the prevalence of *Gonglyonema pulchrum* can be high. The high prevalence of gravid females reported in Pennsylvania black bears (Kirkpatrick, 1986) suggested that ursids are natural hosts for the spururid. Rudolphi (1819) reported the presence of *Spiroptera ursi* in the European brown bear, as was *Gongylonema contortum* reported for the same host species (Molin, 1860).

Yamaguti (1941) first described *Dirofilaria ursi* from an Asiatic black bear from Japan. Subsequent reports include infections of the filarial worm in Siberian brown bears (Petrov and Krotov, 1954) and from a brown bear in south-eastern USSR (Oshmarin, 1963). The filarial worms were also reported in black bears from Ontario and Quebec (Anderson, 1952; Choquette, 1952) and from black bears in Michigan (Rogers, 1975) and

Minnesota (Rogers 1975; Rogers and Seal unpublished). King et al. (1960) reported both adult filarial worms and microfilariae in black bears from New York. Worley et al. (1976) reported *Dirofilaria* in grizzly bears from Montana, and Jonkel and Cowan (1971) reported filarial worms from black bears sampled from the same state. Rogers (1975) reported that *Dirofilaria ursi* is common in Alaskan brown bears and they were collected from Alaskan black bears by Rausch (1961). Choquette et al. (1969) reported the filarial worms in grizzly bears from north-western Canada.

Trichinella spiralis was recovered from captive polar bears in German zoos (Bohm, 1913), the Philadelphia Zoo (Canavan, 1929; Brown et al., 1949) and the London Zoo (Leiper, 1938). More recently *Trichinella harma* infections were reported in a polar bear from the Knoxville Zoo (Sleeman et al., 1994) and from a polar bear at the Chapultepec Zoo in Mexico City. *Trichinella* infections in wild polar bears were reported from the following regions: Alaska (Rausch et al., 1956; Fay, 1960), Canada (Cameron, 1960; Brown et al., 1948); Greenland (Thorborg et al., 1948; Roth, 1950; Madsen, 1961); Svalbard (Brown et al., 1949; Connell, 1949); Nowegian and Barents Seas (Thorshaug and Rosted, 1956); Rudolph Land (Kozemjakin, 1959); Palearctic (Brusilovskiy, 1957); N. E. Siberia (Ovsjukova, 1965). *Trichinella* infections in wild brown bears were reported from the following regions: Alaska (Rausch et al., 1956); Idaho, Wyoming, and Montana (Winters 1969; Worley et al., 1969; Worley, 1974); California (Walker, 1932); N.W. Canada (Choquette et al., 1969); USSR (Lukashenko et al., 1971); N. E. Siberia

(Ovsjukova 1965); E. Siberia (Toschev, 1963); N. Siberia (Gubanov, 1964); Caucasus mountains (Rukhliadev and Rukhliadev, 1953); Azerbaijan (Sadhykov, 1962); Germany (von Bockum-Dolffs, 1888). *Trichinella* sp. Larvae were collected from grizzly bears (*Ursus arctos horribilis*) in British Columbia (Schmitt et al., 1976; Schmitt et al., 1978) and from brown bears in northwestern Alberta and grizzlies in the province east of the Rocky Mountains (Dies and Gunson, 1984). *Trichinella* infections in wild black bears were reported from the following regions: New York (King et al., 1960); Vermont (Babbott and Day, 1968; Roselle et al., 1965); New England (Harbottle et al., 1971); Michigan, Wisconsin, Minnesotta; Colorado, New Mexico, Arizona, Wyoming, Idaho, Oregon, California, Alaska (Zimmerman, 1974); California isonsin and Idaho (Zimmerman, 1977); California (Ruppanner et al., 1982) Montana (Worley et al., 1976); S. Alaska (Rausch et al., 1956); Quebec (Frechette and Rau, 1977); Ontario (Addison et al 1978); Arizona (Le Count 1981); Pennsylvania (Quinn, 1981). Schad et al., 1986 reported high intensity levels of *Trichinella spiralis* in black bears from Pennsylvania. The high intensity levels in some bears evoked concern for potential single source epizootics of human trichinosis. *Trichinella* was also reported in an Asiatic black bear from Thailand (Doege, 1969). *Trichinella* was recently reported in a black bear from New Hampshire, following a reported case of tricinellosis in a human who had consumed bear meat (Hill et al., 2005)

2.8 Ectoparasites

Among arthropods, the louse, *Trichodectes pinguis pinguis* was collected from European brown bears (Burmeister, 1838; Werneck, 1948) and from a captive Asiatic black bear in a Parisan zoo (Neumann, 1913). *Trichodectes pinguis euarctidos* was described from lice obtained from black bears in British Columbia and Ontario (Hopkins, 1954) and reported in black bears from Michigan (Rogers, 1975), New York (King et al. 1960), Montana (Jonkel & Kowan, 1971), and Minnesota (unpublished data). The flea *Chaetopsylla setosa* was reported from bears in the following states and provinces of North America: Black bears from British Columbia (Rothschild 1906, Hopkins and Rothschild (1956) and Montana (Hubbard, 1947); and brown bears from British Columbia (Jellison and Good, 1942; Ewing and Fox, 1943; Holland, 1949). The larger flea, *Chaetopsylla hiberculaticeps ursi* was also reported in the in brown bears (Worely et al., 1976) and black bears from various provinces and states in North America: black bears: black bears from south central Alaska (Jellison and Khols, 1939); Montana (Hubbard, 1947; Jonkel and Cowan, 1971); from brown bears in Southern Alberta (Rothschild, 1906, Hopkins and Rothschild, 1956); southern British Columbia (Holland, 1949); and Alaska (Rausch, 1961). *Chaetopsylla tuberculaticeps tuberculaticeps* were collected from Norweigan, Russian, and Italian populations of brown bears. *Thrassis spenceri* was collected from a brown bear from British Columbia and *Pulex irritans* were collected from black bears in California. An unidentified *Pulex* species was also collected from black bears from Montana (Worely et al., 1976).

Orchpeas caedens were collected from a bear's den in Minnesota after it had been vacated by the bear (Rogers and Rogers, 1976).

CHAPTER 3

CAPTIVE BEAR HUSBANDRY

3.1 Cleaning, Sanitization, & Disinfection

Removal of organic and inorganic debris from exhibit and holding enclosure surfaces must be comleted prior to sanitation and disinfection. In zoological parks, the daily removal of urine, feces, and bedding contaminated with excrement is a common practice. This must be done prior to sanitation with detergents or cleaning agents. Some detergents include sterilizing agents. These compounds and other detergents must be rinsed thoroughly washed and removed from surfaces prior to the administration of disinfectants. Exposure of some disinfectants to residual detergents may produce volatile chemical reactions which can severly harm animals and their caretakers. Hot water (140-150) is perhaps the safest disinfectant, but many synthetic chemicals ha ve been produced commercially to target a narrow or broad spectrum of pathogens. With proper and comprehensive sanitation, disinfection can be administered with less frequency. Husbandry professionals in zoos are often required to attend training sessions to become familiar with occupation hazards associated with exposure to potent and often volatile chemical agents used in the routine disinfection of animal enclosures. This may include intensive training in occupational safety with regard to the use and storage of disinfection agents. Orientations and training sessions often address directions for use and other specifications detailed on Material Saftey Data Sheets (including shelf life and permissible parameters for the diluting and mixing of auqueous agents). Proper storage, specifics for administration on the basis of corrosion potential (corrosiveness); solution strengths; “kill times”; and ”kill rates”), and disposal of chemical agents are reviewed, along with specifications for safe and appropriate use of Personal Protective Equiptment. First aid practices may also be reviewed to address occupational health hazards associated with dangerous chemicals.are also often reviewed. Due to the variety of pathogenic agents encountered in zoos, and the multitude of surfaces found in animal enclosures, a broad spectrum of microbicidal agents are used by zoo husbandry personnel. Common disinfectants are o-phenylphenol salts. Popular cleaning and sanitation agents that have been selected for routine use are quaternary ammonium compounds and sodium hypochlorite or chlorine bleach (Heuschele , 1995).

3.2 Disinfectants

3.2.1 Sodium Hypochloride

Chlorine solution (bleach) (1:4) is a broadspectrum disinfectant which is effective in killing bacterial, fungal and viral pathogens. It also removes the shell of ascarid ova. The kill time increases with solution temperature. Halogens (e.g. iodine and bromide) are both bacterialcidal and mycobacterialcidal, as well as virucidal. They are sporocidal (bacilli) and also effectively kill protozoan cysts.

3.2.2 Phenols

Phenols are highly corrosive, potentially carcinogenic and have minimal virucidal properties. They are primarily used in clinical and quarantine facilities and are not recommended for use in conventiaonal animal enclosures.

3.2.3 Quaternary Ammonia Compounds

Quaternary ammonia compounds are broad spectrum disinfectants which effrectively penetrate cell walls, killing most microbes. They are not particularly corrosive and therefore are quite versatile biocidal agents. However, they can not be mixed with other agents and this precludes their use in non-clincal animal settings.

3.2.4 Alcohol

Alcohol is quite corrosive and is typically restricted for use in clinical settings as an antiseptic bacterialcidal agent with a rapid kill time. At higher concentrations it can be utilized as a viralstatic agent.

3.2.5 Chlorhexidine

Chlorhexidine is commonly used in animal settings because it has a wide margin of safety, but it is a narrow spectrum disinfectant, with bacterialcidal properties limited to ly on gram negative and gram positive bacteria, common in zoos and aquariums where hosing fecal material is a daily job task.

3.3 Ascaricidal Agents

Although Akao et al. (1995) demonstrated that benzalkonium-ion intercalated aluminium triphosphate (BIAT) had larvacidal properties when applied in vitro to pre-embryonated eggs of *Toxocara canis*, BIAT was not effective as a larvicidal agent for embryonated inffective eggs of *T. canis.* In an earlier studyBurg et al. (1987) demonstrated that the following disinfectants were not at all effective in killing embryonated or unembryonate ascarid eggs: Chlorine; phenol; cresol; sodium and potassium hydroxide, quaternary ammonium compounds; and glutaraldehyde or paraformaldehyde). A more recent study demonstrated the efficacy of halogens as effective disinfecting agents for ascarids eggs. Aycicek et al. (2001) evaluated different concentrations of several classes of disinfectants and their efficacies in rendering embryonated eggs of *T. canis* non-motile. An evaluation of “kill time” and “kill rates”: for iodine, glutaraldehyde, benzalkonium chloride, sodium hypochloride, potassium permanganate, ethyl alcohol, potassium hydroxide and phenol solutions demonstrated that the only class of disinfectants which successfully rendered ascarid larva non- motile was the halogen, Iodine. Historically chlorine (Sodium hypochloride) was recommended as a disinfection agent for use in animal facilitities, but this recent study of halogens suggests that Iodine should be used for the disinfection and decontamination of ascarids in animal enclosures.

CHAPTER 4

PREVENTIVE MEDICINE AND PARASITE CONTROL

4.1 Prophylactic and Post-Infection Treatment

Several chemotherapeutic agents have long been recognized as effective in the prophylactic and post infection treatment of ascariasisin definitive hosts (Katz, 1977). Treating larval migrans in definitive or aberrant hosts has been much less successful, and depends greatly on the location, number and pathogenic index of the species of migrating larva. Laser surgery can reverse ocular damage produced by larvae which have migrated through the retina. Much more documentation exists for the treatment and elimination of raccoons with *Baylisascaris*

4.2 Parasiticidal Agents

The most effective parasiticidal agents used in the treatment and control of raccoon roundworms include piperazine, fenbendazole, pyrantel pamoate, levamisole and the organophosphate dichlorovos. Kazacos (2001) successfully cleared raccoons of adult worms with single administrations of piperazine citrate (120–240 mg/kg), pyrantel pamoate = embonate (6–10 mg/kg) and fenbendazole given at 50–100 mg/kg for 3–5 days. Bauer and Gey (1995) demonstrated the efficacy of six ant-helminthics (pyrantel embonate = pamoate; 20 mg base/kg; ivermectin (1 mg/kg); moxidectin (1 mg/kg);

albendazole (50 mg/kg daily for 3 days); fenbendazole (50 mg/kg daily for 3 days); and flubendazole (22 mg/kg daily for 3 days)) at necropsy seven days post treatment. Ivermectin delivered to raccoons at 2 mg/kg was also highly effective in treating adult worms as determined by subsequent coprodiagnostic study (Hill et al., 1991). Veracruse et al., (1976) harmacologi treated 5 polar bears with Menbendazole.

4.3 Drugs: Mechanisms of Action

Mechanisms of action for anti-helminthics used in the treatment of Balisascaris and other helminthic infections in natural hosts include a variety of biostatic and biocidal modalitities which do not effect biochemical pathways of hosts, but successfully target and interrupt biological function of adult worms, larvae and their eggs. The mechanisms of action of these drugs include the inhibition of microtubules which induces an irreversible blockage of glucose uptake, rendering the parasite metabolically impaired. The inhibition of tubulin polerimization precludes microtubule formation. Fenbendazole (Panacur), a member of the benzimidazole class of antihelminthics is commonly administered to raccoons and bears in captive collections to eliminate nematodes, cestodes, trematodes and protozoa. Fenbendazole is not readily absorped in the gut. The drug is largely passed in feces and some of the drug which is metabolized to oxfendazole in the liver, is returned to gut in bile. The drug is totallyeliminated in 48 hours. Another commonly used benzimidazole is mebendazole (Telmintic powder). Febantel (Drontal

Plus also contains pyrantel pamoate and praziquantel) is a pro-benzimidazole has a similar mechanism of action to benzimidazoles. Tetrahydrapyrimidines depolarize the neuromuscular blockade, and the inhibit cholinesterase, which disrupts neural pathways, and subsequently paralyze the targeted pathogens. Pyrantel embonate and Pyrantel pamoate belong to the chemical class of agents known as Imidazothiazole. As an acetylcholine agonist and hence, depolarizing neuromuscular blocking agent, this class of drugs induce rigid muscle contractions of the muscles. Imidazothiazole derivatives like target nerve ganglia and impair nematode muscle cell membranes. These salts effectively treat ascarids and other nematodes. Vacuolization of the schistosome tegument, Increased cell membrane permeability, resulting in intracellular calcium loss and Increased cell membrane permeability to chloride ions via chloride channels precludes physiological processes required to sustain life.

4.3.1 Macrocyclic Lactones

Macrocyclic lactones are a broadspectrum, relatively non-toxic class of anti-helminthics which have emerged as perhaps the most effective parasiticides for treatments of human and animal parasites. The macrolides are antibiotics derived from streptomycete microorganisms. They bind to glutamate gated chloride channels, and trigger an influx of chloride ions (Arena et al 1991, Martin 1993; Shoop et al. 1995).

This mechanism of action hyperpolarizes the neuron of parasites and precludes the normal conductance of action potentials. Subsequently, the macrolides paralyze and kill the parasites. Ivermectin is marketed under several trade names. Heartgard Plus which also contains Pyrantel Pamoate was developed for canids and effectively treats *Toxocara canis.* It is less effective in the treatment of *Toxascaris* spp.. The combination of ivermectin and pyrantel pamoate has been marketed under the proprietary name HeartGard 30- Plus and has been reported to effectively treat and control *Toxocara canis* and *Toxascaris*..

Selemectin was formulated as a semi-synthetic derivative of Doramectin (Dectomax), an avermectin labeled for use in the treatment and control of bovine and swine parasites. Hence, Selemectin is a modified form of a mutant strain of the fermentation product *Streptomyces avermitilis* (Bishop et al. 2000). In cats, it has shown to be effective in the treatment and and control of *Toxocara cati* and McTier et al. (2000) reported its efficacy in the control and treatment of *Toxocara canis* and *Toxocara leonine* in dogs.

Milbemycin oxime is derived from the fermentation of *Streptomyces hygroscopicus aureolacrimosis* and has both a similar structure and mechanism of action as Avermectins. It has shown efficacy against Toxocara canis in experimentally infected dogs (Bowman et al., 1988; Bowman 1992).

4.3.2 Benzimidazoles

Benzimidazoles are another group of broadspectrum class of antihelminthics that have been used in the control and treatment of human and animal helminthiasis (Cambell, 1990, Lacey 1990, McKellar and Scott, 1990). However, reports of helminth resistance to benzimidazoles have been reported in many species and albendazole, mebendazole, and oxfendazoles are known teratogens, precluding their uses in pregnant animals (Lynn, 2003). Benzimidazoles selectively bind to Tubulin molecules of nematodes, exhibiting a much lower affinity for binding to Tubulin of mammals. Tubulin binding precludes microtubule formation and subsequently disrupts cell division (Frayha et al. 1997; Reinemeyer and Courtney, 2001). Through its inhibition of fumarate reductase, benzimidazoles deplete parasites of energy, through the blockage of mitochondrial function (Lynn, 2003). Febantel, a nonbenzimidazole is metabolized to fenbendazole, which is approved for use in zoo animals and oxfendazole, a benzimidazole which is used to treat harmacolo in bovids and equids. Fenbantel, praziquantel, a cestocidal agent, and pyrantel have been formulated as a broad-spectrum antihelminthic under the trade name Drontal Plus. As an ascaracidal agent it effectively treats *Toxocara canis, Toxascaris leonine*, and *Toxocara vulpis* (Bowman and Arthur, 1993; Cruthers et al., 1993).

4.3.3 Tetrahydropyrimidines

Several salts of Pyrantel, morantel, and oxantel represent the class of Tetrahydropyrimidines. Tetrahydropyrimidines are very potent nicotinic agonists. They induce tonic paralysis through the disruption of neuromuscular function in nematodes (Aubrey et al. 1970; Eyre, 1970, Martin 1993). Pyrantel is the most commonly used tetrahydropyrimidine. Pyrantel pamoate, marketed under the trade name Nemex is labled for use in dogs for the treatment of *Toxocara canis* and *Toxascaris leonine.*

4.3.4 Heterrocyclics

Piperazine and its analogue diethylcarbazine have central heterocyclic rings. They disrupt GABA neurotransmission through the production of a neuromuscular blockade. Piperazine has shown to be effective against *Toxocara canis*, *Toxocara cati* and *Toxascaris* spp. (English and Sprent, 1965; Sharp et al. 1973; Jacobs 1987; Jacobs 1987). Diethylcarbamazine is marketed under the trade names Filaribits and Nemacide and shows some efficacy in the treatment of *Toxocara canis*, *Toxocara cati* and *Toxascaris leonine* (Arundel et al., 1985).

4.3.5 Combinations

Several broad-spectrum combinations are now available for treatment of nematodes and other helminth parasites. Trivermicide worm capsules contain both a cestocidal and nematocidal agent. Trivermicide contains the nematocidal agent methylbenzene and dichlorphene as the cestocidal agent. This compound successfully treats *T. canis*..

4.3.6 Trade Names

Iverheart Plus, Ivomec), Moxidectin (PROHEART, Proheart 6),) Selamectin (Revolution, Milbemycin oxime (Interceptor, Sentinel also contains Lufenuron) are commonly administered Macrocyclic lactones. Selamectin the newest of the Macocyclic Lactones and is marketed under the trade name Revolution. It is labeled for use in domestic canids and effectively treats *Toxocara cati* (McTier et al., 2000*)*. In carnivores the half life of the drug is 24-36 hours. With the exception of adult heartworms, Ivermectin is used to treat adult nematodes and mites. It is not effective against cestodes. Dichlorvous, marketed under the trade name Task, is an organophosphate which inhibits acetycholinesterase. Normally acetycholinesterase removes acetycholine from post synaptic junctions. The accumulation of acetycholine in gap junctions induces continued depolarization of neurons and subsequently results in paralysis of the parasite (Fest and Schmidt, 1982). Piperazine is marketed under the following proprietary names: Pipa-tabs, Tasty Paste, WRM Rid. It is a GABA agonist. Hence, like the neurotransmitter GABA, piperazine effectively induces the hyperpolarization of nerve membranea and subsequently causes flaccid paralysis of nematodes. As with the induction of paralysis by other antihelminthic agents the worms are removed by normal peristalsis of host gut musculature.

Diethylcarbamazine citrate is commonly used in dogs as a heartworm prophylactic and is also used to treat *Toxocara* spp. and *Toxascaris*.. It is marketed under the the following proprietary names: Filaribits Plus w/ oxibendizole; Filaribits; Nemacide. This herterocyclic compound is closely related to piperazine citrate.

CHAPTER 5

NUTRITIONAL EVALUATIONS FOR CAPTIVE BEARS

5.1 Nutritional Assessments for Captive Wildlife

Zoo animal nutritional assessments and service departments have emerged as integral contributors to management and preventive health programs for captive wildlife (Marques and Maslanka 2005). Although several zoo animal collections may benefit from nutritional assessments conducted by staff nutritionists, a paucity of rigorously designed nutritional research studies have been initiated for zoo animals. Consequently, the nutritional needs of great proportion of captive wildlife species are largely unknown (Crissey et al 2001).

Nutritional assessments based on haematological parameters are the most practical means for establishing nutritional requirements for threatened and endangered captive wildlife, but few such studies have been initiated to date (Crissey et al. 2001). Despite the frequent collection of blood samples for a variety of serum chemistry profiles required for animal health management and for use in research relevant to ongoing reproductive and behavioral endocrinological studies, few nutritional assays have been performed with any regularity to aid in the establishment of nutritional requirements. Furthermore, zoos frequently quantify animal consumption to monitor growth weight in juveniles and to asses body condition in adult and geriatric animals, but few institutions monitor specific nutrient parameters despite access to crude intestinal tract digestibility and nutrient availability. Dietary regiments continue to be formulated through extrapolations based on nutritional requirements for domestic species, remain quite variable among captive facilities, and may continue to contribute to health problems for zoo animals (Slifka et al. 1999; Hatt 2005).

5.2 Nutrional Management of Captive Omnivores

Very few studies have examined nutritional status in some of the most common zoo species. Nutritional requirements for captive canids and ursids have not been established, despite the considerable data available on domestic canid nutrition requirements (Crissey et al. 2001). Limitations of available and appropriate animal models may preclude progress in developing nutritional guidelines for zoo omnivores, as do contradictory reports of dietary consumption in wild animals. The complexity of wild animal nutritional ecologies that best serve as models for reference are helpful resources, but may be very impractical for use in zoos.

Dietary parameters selected for criteria in re-examining phylogenies of carnivoran clades indicate that strict carnivores are represented by all members of the family felidae and select species of mustelidae, ursidae, procyonidae, hyaenidae and canidae (Munoz-Garcia and Williams 2005). Hence, among the carnivoran clade most species are classified as omnivores with the exception of felids (Munoz-Garcia and Williams 2005). Advances in zoo nutrition for strict carnivores include attempts to elicit more natural feeding behaviors from felids to perhaps mimic the energetic, digestive and metabolic biology of strict carnivores and ultimately improve efficiency of nutrient absorption and metabolism (Altman et al. 2005). However, data on the energetic ecology of wild omnivores complicates and perhaps, prohibits the possibility of utilizing nutrition of free ranging mammalian omnivores as models for developing dietary guidelines for captive species (McNabb 1992). Programs aimed at providing food stuffs that best mimic and elicit the dynamic feeding behavior and nutritional ecologies of highly opportunistic and omnivorous mega-carnivoran taxa face a multitude of constraints. The implementation of fasting days, the rotation of processed and whole carcass food offerings, the changes in food rations, and the induction of torpor do elicit some physiological responses that mimic the energetic and metabolic biology of wild omnivores, but these methods are often impractical for managing zoo animals in climates that provide selective pressures that are far removed from what dictates aspects of the nutritional ecology of wild animals. For example, polar bears maintained at the Cairo Zoo were often subjected to temperatures exceeding 107 degrees F and tropical bears of South East Asia have been maintained in temperate and circumpolar facilities of the Canadian High Arctic. Although these animals must receive dietary provisions to sustain life, extreme modifications in diet are warranted to promote health and welfare.

5.3 Nutrional Ecology of Bears and Captive Management Implications

Among Carnivora, the family Ursidae, represented by eight extant species, may exhibit the widest range of nutritional and feeding ecologies. Four species (North American black bear, *Ursus americanus;* Asiatic black bear, *Ursus thibetanus;* Sun bear, *Helarctos Malayanus;* Andean Bear, *Tremarctos ornatus*) are considered to be opportunistic omnivores feeding on plant matter, fruit, arthropods, small to large vertebrates, and carrion and share craniodental features that are intermediate between carnivores and herbivores. Although wild bear diets change from season to season, year to year to year and vary from one geographic area to another (Hwang et al 2002), plant consumption typically composes more than 80 % of their dietary intake for these omnivorous species. North American black bear (*Ursus americanus),* Asiatic black bear (*Ursus thibetanus),* and subspecies of brown bears (*Ursus arctos* spp.) occasionally prey on ungulates, small mammals, birds, reptiles, amphibians, fish and invertebrates, but feed primarily on plant material (Hwang et al. 2002; Robbins et al. 2004). The sun bears (*Helarctos malayanus)* are considered highly frugivorous and insectivorous. (Hoffman et al. 2005). Similarly spectacled bears feed predominantly on a number of broad leafed neotropical flora and fruits, but also consume a great number insects (Troya et al. 2004). The giant panda (*Ailuropoda melanoleuca*), polar bear (*Ursus maritimus*), grizzly bear brown bear (*Ursus arctos horribilis*) and sloth bear (*Melursus ursinus*) have specialized diets (Sacco and Van Valkenburgh 2004). Polar bears (*Ursus maritimus)* are considered hypercarnivores, feeding almost exclusively on ringed seals, but will forage on birds, grasses and berries (Stirling 1988). Grizzly bears, a subspecies of brown bears can exhibit a predilection for carnivory (Craighead and Mitchell 1982). Sloth bears (*Melursus ursinus*) are considered highly specialized for myrmecophagy, but relative to other termite specialists they are considered moderately myrmecophagous (Redford 1987). Recent studies suggest that at times their dietary consumption is composed of a high percentage of animal matter (Bargali et al. 2004). The giant panda (*Ailuropoda melanoleuca*) feeds almost exclusively on bamboo (Schaller et al. 1985) Unlike carnivore diets, with the exception of commercial polar bear feeds current bear diets formulated for captive bears consist of commercial dog food or an omnivore diet supplemented with vitamin enriched meat or fish and fruits and vegetables (Lintzenich et al. 2005). The diets rarely reflect the species specific nutritional ecology of individual bear species. The giant panda (*Ailuropoda melanoleuca*) an obligate herbivore can survive on an omnivore diet and such food provisions have apparently met the dietary requirements for growth, maintenance and reproduction in this species (Dierenfeld et al. 1994). However, giant panda diets are currently standardized for much of the captive population. Crissey et al. (2001) analyzed serum levels for Vitamin A, D and E metabolites (A, E, and D) in an attempt to link dietary intake to nutritional status.

CHAPTER 6

CAPTVE BEAR POPOULATION GENETICS

Zoos serve as models for investigations of small and fragmented population biology and have emerged as genetic refuges for captive wild life (Rabb, 1996). Although not all captive carnivores are ideal candidates for reintroduction programs, zoos strive to maintain genetic diversity in captive populations to prevent inbreeding depression in captive collections and eliminate potential factors that might compromise population persistence for reintroduction programs. Captive breeding histories vary by species and hence, breeding and propagation program should be tailored to specific genetic and demographic characteristics for each species. (Earnhardt, 1999) Inbreeding depression has been a concern for captive populations of bears and other captive wildlife. Concern for hereditary disorders such as albinism in captive bears will strongly influence management programs. Laikre et al. (1996) reported reduction in litter size for Eurasian brown bears and high incidence of albinism in a relatively inbred captive population of brown bears in Swiss zoos. Sophisticated analyses of both genetic and demographic data are required to manage self –sustaining populations of captive wildlife (Faust et al. 2003).

CHAPTER 7

ANIMAL WELFARE

7.1 Enclosure Effects on Welfare

In the last century zoological parks have emerged as conservation centers (Moriarty, 1998). Archaic exhibitions of exotic animal menageries have evolved into captive wildlife sanctuaries and propagation facilities, whereby collections have been significantly reduced in size; enclosures have been greatly enlarged and constructed as naturalistic exhibits. None-the-less, the exhibition of captive bears and other wildlife species has evoked increasing concern regarding the welfare of confined animals (Rietschel, 2002) which must adapt to artificial enclosures designed by man (Altmann-Langwald, 1996). In the past two decades, zoo animal welfare has been scrutinized to nearly the same degree as biomedical and agricultural livestock populations. Criticism has largely developed as a result of new legislation, societal pressures, and from psychological issues elucidated by the emerging field of applied ethology (Kreger, 1997). The mission of zoos is to maintain wildlife in captivity for conservation, research, education, and recreation (Tudge, 1991). These objectives are typically justifiable from ethical perspectives, if animal welfare standards are adhered to (Wickins-Dražilová, 2006). Primary criticisms, both justifiable and unwarranted include critiques of holding conditions, space, feeding and health status (Rietschel, 2002). More general criteria for meeting welfare standards include reproductive success, longevity, and physical health (Wickins-Dražilová, 2006). In terms of physical health, evaluations of both preclinical and clinical conditions must be considered (Dawkins, 2003). Fowler (1996) asserts that both housing and feeding programs are suboptimal and species specific concerns are often overlooked or misunderstood. Zoo managers must consider not only the natural history of the species, but the individual history of each animal and enclosure constraints in offering species specific provisions for environmental enrichment as a means of enhancing psychological welfare (Mellen and MacPhee, 2001).

Enclosure design catering to species-specific behaviors for Andean bears was considered the primary factory influencing animal welfare, aside from health care practices and has become the most influential factor contributing to captive carnivore welfare (Mallapur et al., 2002). For instance the enclosure design, for the Zurich zoo Andean bear collection, along with appropriate environmental enrichment and stimuli were standardized by Swiss animal welfare law and animal welfare regulations to optimize the physical and psychological well-being of captive carnivores (Rubel, 1996). Forthman and Baker (1992) reported that social factors including rearing history and conspecific composition, as well as environmental factors influenced social activity patterns among captive sloth bears. The authors recommended that social and enclosure variables be considered with regard to improving health management and propagation management programs. They also encourage that such biotic and abiotic factors be considered for the purposes of increasing the educational value of captive bear exhibition (Forthman and Baker, 1992; Reade and Waran, 1996). In a behavioral assessment of mother –reared polar bear at the Roger Williams Zoo, Greenwald & Dabek (2003) observed significant changes in behavior following exposure to environmental enrichment and husbandry training. Most recently, aberrant behaviors in bears and other wide ranging carnivores has been attributed to enclosure size. Animals with larger home ranges were reported to exhibit more stereotopies than species with smaller home ranges (Clubb and Mason, 2003). Commonly reported aberrant behavior in captive bears include excessive inactivity as well as stereotypic behaviors which include but are not limited to pacing, head swing, and patterned swimming in polar bears. Polar bears may be the species most commonly reported to exhibit stereotypic behaviors (Meyer- Holzapfel, 1968; van keulen Kromhout, 1978; Jakobi, 1990; Ames, 1991; Carlstead et al. 1991; Weschler 1991) All of these reports indicate that various factors induce these manifestations of aberrant behavior and the episodes vary in length and severity among individuals. Extrinsic factors include seasonality, photoperiods, feeding time, keeper interaction and other stimuli (e.g., loud noises). The reproductive status or management of oestrous has been implicated as an inductor of male stereotypic behaviors. Although feeding enrichment programs reduce stereotypic behaviors, they do not extinguish them. Stereotypic behaviors often resume when the animal has ceased feeding (Altman, 1999). Altman (1999) reported species specific responses to environmental enrichment. Access to manipulability inedible objects and enrichment devices reduced stereotypic behaviors in Andean bears, increased stereotypic behaviors in captive bears, and elicited no response from sloth bears. Andean bears displayed a limited range of their species typical behavioral repertoire with respect to ethograms developed for behavioral evaluations of captive bears. Along with exhibiting a restricted subset of behaviors, they utilized a limited amount of space within the enclosure. The introduction of climbing structure for these arboreal ursids increased the diversity of behavioral activity as well as the uses of the enclosure (Renner and Lussier, 2002). A recent multi-institutional study of stereotopies in European brown bears showed that stereotopies were most common in medium aged animals that were housed in small exhibits. Stereotypic pacing was most frequently observed in animals, where keepers inadvertently reinforced pacing with food rewards. Older animals spent more time resting (Montaudouin and Pape, 2004). Vickery and Mason (2004) reported age and species specific differences in stereotypic behaviors as well as potential motivating factors for appetitive stereotopies in two different species of Asian bears. Hence, the authors recommend that evaluations of aberrant behaviors be evaluated in greater detail to determine factors influencing behaviors in specific age, gender and species cohorts.

For US zoos, the need to follow regulations set forth by the 1999 Animal Welfare Act (USDA-Aphis) has served prompted captive wildlife managers to reevaluate the psychological welfare of exotic collections. Some aspects of psychological behavioral welfare have been re-evaluated in the context of behavioral training and enrichment, and enclosure design (Tresz, 2006). Swaisgood and Shepherdson (2005) report that studies on stereotypic behaviors in zoo animals indicate that environmental enrichment reduces captivity-induced aberrant behavior, but more rigorous studies on larger samples sizes are warranted to predict the effects of enrichment as a husbandry tool to reduce and or eradicate stereotypic behaviors.

Mother reared and peer reared studies in captive pandas suggest that non-mother reared individuals lag behind in development in comparison to mother reared individuals. As a consequence, conspecific rearing programs should be tailored to provide social stimulation from sows (Snyder et al. 2003). More recently, a prevalence study of bone fracture disease in polar bears suggested nutritional deficiencies in the captive population and elicited concern regarding enclosure design in terms the physical well-being of polar bears maintained in captivity (Lin et al., 2005).

7.2 Environmental Enrichment

Although new naturalistic exhibits are typically beneficial for their inherent educational value, they also mitigate behavioral problems and enrich the lives of confined animals. Older exhibits have also been modified to increase the biofunctional value of an exhibit. Large tree-trunks, sand, mulch and bark litter substrates have been placed in designated substrate pits to stimulate more complete behavioral repertoires for bear species including polar bears (Ames, 1992). Enrichment programs have included changes in feeding routines and play provisions (e.g., toys, enrichment devices) to elicit exploratory behaviors (Law 1985; Ames 1991). Ames (1992) recommends that polar bears be offered at least 10 enrichment objects, including non-edible enrichment devices of various shapes, color and texture, as well as bark covered logs and leafy branches as a source of food and play enrichment provisions. More general recommendations suggest that bears be managed as other ursids first and as arctic mammals second. Enrichment programs should reflect these management priorities, and enclosures should cater to animals which often spend several months on beaches and inland tundra and on topography with overgrown vegetation bedding with straw, woodchips and woodwool on raised platforms.

CHAPTER 8

REVIEW OF DISEASES OF CAPTIVE BEARS

8.1 Abstract

Integrated health management of captive and free-ranging bears is critical to ursid conservation management initiatives. Proactive disease surveillance programs for endemic communicable diseases, emerging infectious diseases, and chronic diseases, as well as other health concerns of captive bear populations provide invaluable data for the holistic management of captive and free-ranging endangered species. Although the eight extant species of bears are considered less susceptible to infectious and non-infectious diseases of carnivores, a growing number of serological surveys indicate that bears are susceptible to a broader spectrum of infectious diseases than previously recognized. Disease outbreaks depend on ecological or epizootiological factors, such as those associated with declining host populations or susceptibility to disease. As a result of their limited susceptibility to many carnivoran diseases and their declining populations in most regions of the world, bear metapopulations increasingly serve as sentinels for many emerging and re-emerging infectious diseases, including zoonoses. Previous reviews of carnivore diseases have been restricted, in taxonomic scope, to diseases of wild or captive species, or in terms of disease category. In this review, a comprehensive account of bear

health concerns is presented, including parasitic, bacterial, fungal, and viral agents of disease along with non-infectious diseases of captive and wild bears.

8.2 Introduction

To help mitigate the future decline of the eight species of bears, it is important to identify and improve surveillance programs for disease agents of significance to ursids, including non-infectious diseases that impact metapopulations of free-ranging bears and captive populations of particularly threatened bear species. Bears also serve as excellent sentinels for many diseases including several zoonoses and hence increased recognition and surveillance of bear diseases may contribute to domestic animal, wild animal and public health surveillance programs. In a review of select infectious pathogens of wild carnivores, Murray et al. (1999) indicated that the most common infectious diseases reported were, viral infections, followed by bacterial, and protozoal agents.

8.3 Degenerative Diseases of Bears

Age associated degenerative diseases have been investigated to some degree in non-human mammals. Cork et al. (1988) reported a neurological degenerative disease in a brown bear and a polar bear, citing cytoskeletal abnormalities in these animals. Bilateral degenerative joint disease was reported in a European brown bear with a craniodorsal luxation of the right femoral head (Witz et al 2001).

8.4 Dental Pathologies of Bears

Aside from castration, dental procedures are the most common surgical operations necessitating anesthetic intervention for captive bears (Foreir 1975; Wedlich 1982). Dental pathology is a significant problem for captive animals. Dental health problems, reduce food intake, negatively impact body condition, and expose animals to recurrent sepsis. In captivity, deposits of calcified dental calculus are more common than in free-ranging bears, a finding attributed to limited opportunities for natural dental cleansing and inappropriate diets. Canine tooth and secondary alveolar lesions are attributed to stereotypical chewing. Older bears were also reported to have a higher frequency of apical and combined apical-marginal lesions of alveoli from radiographic studies of perialveolar ostyolytic processes (Wenker et al.,1998, Wenker et al.,1999). Sheels (2004) more recently reported that trauma, periodontal disease, decay and soft tissue lesions are the most common dental pathologies in polar bears.

8.5 Degenerative Disorders and Injuries of Bears

Spinal spondylosis and acute intervertebral disc prolapse was reported in a European brown bear (Wagner et al. 2005). Spinal decompression from a ruptured intervertebral disc was reported in a black bear (Nichols et al. 1980). Bone fractures are not uncommon in polar bears. Lin et al. (2005) reported antebrachial fractures in polar bears.

8.6 Vascular Diseases of Bears

Vascular diseases are uncommon in bears, and are often secondary to septicemia and bacterial infections. A polar bear was recently reported to have died of arterial sclerosis (McOrist, 2002). A polar bear from a zoo in Mexico infected with *Trypanasoma cruzi* died of acute Chagas' carditis (Jaime-Andrande 1996) and McBurney et al. (2000) reported bacterial valvular endocarditis in a wild black bear from Labrador, Canada.

8.7 Endocrinopathies of Bears

A thyroid adenocarcinoma was reported in a bear by Grunberg and Stavrou (1973). Other thyroid endocrinopathies reported in bears include a thyroid cystadenoma, colloid goiter and hypothyroidism in a black bear (Storms et al., 2004), hypothyroidism in a grizzly bear (Russel, 1970), and cretinism reported in a black bear (Duncan et al., 2002).

8.8 Malignancies of Bears

Certain cancers are frequently reported in captive bears. Hepatic neoplasia, billiary adenocarcinomas, pancreatic tumors and tumors of the thyroid are particularly common in captive bears, particularly tropical species (Hellmann et al. 1991). Tumors of the pancreas were the most common neoplasms reported in a zoo survey (Lombard and

Witte 1959) and have long been reported in bears (Stewart 1966). In an early review of neoplasms of zoo animals Halloran (1955) cited reports of billiary and hepatic carcinomas, pancreatic adenocarcinoma, mammary gland carcinoma, hemangioma, and renal hypernephroma and sarcoma in bears. Kloppel (1980) reported a hemangioma in the liver of a polar bear. More recent reports of hepatic neoplasms were reported in two polar bears, including cholangiocarcinoma, intrahepatic billiary neoplasm and hepatocellular carcinoma (Miller et al., 1985). Extrahepatic billiary neoplasms were reported in captive sun bears (Montali et al., 1981) and cholangiocarcinomas involving the bile duct have been commonly reported in sloth bears (Moulton 1961; Kronberger, 1962; Dorn 1964; Appleby et al. 1968; Gosselin and Kramer et al., 1985). Montali et al. (1981) also reported a leiomyoma and a lipoma in bears. Intestinal lymphosarcoma was reported in a captive grizzly bear by (Blanquaret et al., 1984) as well as in brown bear also reported to have a leiomyoma (Zwart et al., 1974). Lymphosarcomas were reported in a polar bear (Hubbard et al., 1983), a black bear (Montali et al., 1980), and have also been documented in bears by Zwart et al. (1974) and Effron et al. (1977). Fibromas were reported in a polar bear (Hubbard et al. 1983), a black bear (Karesh et al., 1982), and by Effron et al. (1977). Effron et al. (1977) also reported a case of a conjunctival myoxoma in a bear. Momotani et al. (1988) reported an osteosarcoma in a brown bear as did Ponomar'kov and Khutorianskii (1995) in a polar bear. Haemangiosarcoma of the conjunctiva was reported in a giant panda (Lopez et al. 1996).

Non malignant ocular pathologies were reported in giant pandas by Ashton (1976). Retinal astrocytic hamartomas were reported in giant panda on post-mortem examination (Mclean et al. 2003).

8.9 Nutritional Deficiencies and Metabolic Diseases of Bears

Nutritional deficiencies and metabolic bone disease have been reported in bears. In one instance captive polar bear cubs abandoned by their mother developed rickets while under the care of a zoo's husbandry staff (Kenny et al. 1999).

8.10 Infectious Diseases of Bears

Bears are not as highly susceptible to infectious diseases common in other carnivoran taxa, and mortality due to infectious diseases are not common in the wild. Rather, natural traumatic injury was reported to be the most common cause of death among free-ranging brown bears, followed by road collisions, starvation, and septicemia (Morner, 2005). Specifically, intraspecific infanticide was reported as a common cause of mortality in bears in Sweden (Swenson et al., 1997).

8.11 Viral Diseases of Bears

Among double stranded DNA viruses, adenovirus, the herpes virus, pseudorabies, and orthopoxivirus have been reported in bears. Two reports of epizootic adenovirus in captive American black bears provided some of early evidence of susceptibility to infectious canine hepatitis (Pursell et al., 1983; Collins et al., 1984). Mainka et al. (1994) reported canine adenovirus in captive giant pandas from a reserve in China.

Infectious canine hepatitis was reported in Alaskan brown bears (Zarkne and Evans, 1989; Chomel et al., 1998) and in polar bears and black bears from Canada (Philippa et al., 2004). Foreyt et al. (1986) reported serological indications of adenovirus in black bears from Washington State. A wild strain of canine adenovirus type 1 has been characterized from tissue samples of American black bears (Whetstone et al., 1988). Madic et al. (1993) reported evidence of exposure to human adenovirus in European brown bears. Adenovirus-like lesions were reported in a European brown bear (Kritsepi, 1996).

There is growing concern that transmission the transmission of another double stranded DNA virus, pseudorabies, a disease of domestic livestock, may continue to spread to wild bears with increasing frequency, as the interface between domestic livestock and wildlife broadens (Capua, 1997). Infections of pseudorabies have been reported in Florida black bears by Pirtle et al. (1986). Schultze et al. (1986) also reported pseudorabies infections in black bears. A captive Asiatic black bear, brown bear and polar bear from a circus reportedly died from Aujeskys disease virus (Banks et al. 1999), as did a collection of European Brown bears (Zanin et al., 1997). Serological data has also demonstrated ursine susceptibility to orthopoxvirus, as indicated by a report of anti-orthopoxivirus antibodies in a European brown bear (Tryland et al., 1998). Madic et al. (1993) also reported one case of cytomegalovirus in a brown bear.

There is a paucity of information on single stranded DNA viruses in wild carnivores (Steinel et al., 2001). Among ursidae, parvovirus has been reported in Florida black bears (Dunbar et al., 1998). Madic et al. (1993) and Marsilio et al. (1997) reported parvovirus in both captive and free-ranging European brown bears. Cockburn et al. (1947) first reported parvovirus infections in giant panda and Mainka et al. (1994) more recently reported evidence adenovirus infection in captive giant pandas at large reserve in China.

Among double stranded RNA viruses, members of the family reoviridae have been reported in serological surveys of bears. Blue tongue virus and epizootic hemorrhagic disease virus antibodies were reported in Florida black bears (Dunbar et al 1998). Baumeister et al. (1983) reported a rotavirus in a captive brown bear.

Among Paramyxoviridae, both terrestrial and marine morbilliviruses have been reported in ursids, and continue to emerge as significant cause of disease and mortality in free ranging carnivores (Saliki et al., 2002). The susceptibility of bears to canine distemper virus is still debated (Appel and Summers, 1995; Montali, 1987). Polar bears, in particular, have been linked to the evolutionary ecology of morbilliviruses, given their adaptations for both marine and terrestrial lifestyles (Amstrup and Demaster, 1988; Follmann et al., 1996). Non-specific morbillivirus exposure was first reported in Alaskan and Russian polar bear populations by Follman et al. (1996). Upon further investigation, serological evidence of canine distemper was reported for these polar bear populations (Garner et al. 2000). Although canine distemper is no longer commonly reported in zoo carnivores (Appel and Summers, 1995), epizootics are still reported. For instance, Marsilio et al. (1997) reported serological indication of canine distemper virus in both captive and free-ranging brown bears in Italy. Tryland et al. (2005) reported seroprevalence of canine distemper virus in polar bears sampled from a Norwegian population. In a serosurvey conducted in the interior of Alaska, Chomel et al. (1998) reported seroprevalence of canine distemper in brown bears, but not black bears. Dunbar et al. (1998) reported canine distemper in Florida black bears. Both canine distemper and phocine distemper were reported in polar bears from western Hudson Bay and Lancaster Sound populations (Cattet et al., 2004). Phillipa et al. (2004) reported prevalence of antibodies to morbilliviruses in polar, brown and black bears sampled from populations in Alberta & British Columbia. Canine distemper virus, dolphin morbillivirus and phocine distemper virus were all detected in both polar bears and brown bear populations. Seroprevalence of canine distemper virus and phocine distemper virus was reported in black bears with no evidence of exposure to dolphin morbillivirus. Mainka et al. (1994)

conducted a serological survey for viral pathogens in giant panda and reported a serological indication of canine distemper virus.

Another virus from the family paramixoviridae has been reported in ursidae. Phillipa et al. (2004) reported parainfluenza type 3 in black bears from Canada. Parainfluenza type 1 was reported in a captive European brown bear in Croatia (Madic et al., 1993).

Rabies and Dolphin rhabdovirus are the two rhabdoviruses that have been reported in bears. Patent rabies infections were reported in experimentally infected bears, *Ursus* spp. by Rausch (1975). Natural infections include a report of rabid black bears in Ontario (Waltroth, 1996). Mutinelli et al. (2001) detected antibodies in a brown bear and an observation of a rabid polar bear was reported reported in Canada (Loewen et al., 1990; Taylor et al. 1991). Waltroth et al. (1996) reported rabies in black bears in Ontario. Jadav et al reported a case of rabies in a sloth bear. Dolphin rabdovirus was reported in Canadian polar bears (Phlippa et al., 2004). Madic et al. (1993) reported serological evidence of Influenza A and B in European brown bears.

Serological evidence of emerging infectious diseases has recently been reported in bears. Among flaviviruses, St. Louis encephalitis virus and Western Equine Encephalitis have been reported in black bears from Idaho (Binninger et al., 1980) and in black bears from Florida (Dunbar et al., 1998). Farajollahi et al. (2003) detected West Nile Virus (WNV) antibodies in black bears from New Jersey. Madic et al. (1993) also reported serological evidence of WNV infection in Croatian brown bears, although the significance of WNV infections in bears requires further study. Serological indication of Bhanja virus, Tahyna virus, and Naples sandfly virus were also reported in European brown bears (Madic et al., 1993).

8.12 Bacterial Diseases of Bears

Serological evidence was reported for *Chlamydia psittaci* in European brown bears by Madic et al. (1993). Antibodies to *Francisella tularensis* were detected in black bears from Idaho (Binninger et al., 1980) and in black bears and brown bears from Alaska (Chomel et al., 1998).

Anti-*brucella* antibodies in polar bears were first reported from serosurveys conducted by Tryland et al. (2001) in Svalbard and the Barents Sea. Rah et al. (2005) reported a serological indication of *Brucella* spp. Infection in polar bears from the Beaufort and Chucki Seas. One suspected source of *Brucella* infection in polar bears are infected carrion and carcasses of animals (S.C. Amstrup, unpublished observations). Antibodies to *Brucella* species were reported in Alaskan brown bears by Zarkne et al. (1983) and brown bears from Alberta (Zarkne and Yuill, 1981). Although brucellosis is not a significant health threat to wildlife in California antibodies to brucellosis were reported in a black bear during a serological survey conducted between 1977 and 1989. Neiland and Miller (1981) inoculated a black bear and grizzly bears with *Brucella suis* type 4 and reported fulminant infections as well as induced antibody titers. More recently, Olsen et al. (2004) conducted experimental vaccinations on American black bears with *Brucella abortus* strain RB51 via oral inoculations.

Leptospirosis was reported in two populations of European brown bears from the Republic of Croatia and from a zoo in Croatia. Antibody titers implicated include the following *Leptospira interrogans* serovars: *australis, sejroe, canicola and icterohaemorrhagiae* (Modric and Huber, 1993). An earlier serosurvey of Croatian brown bears reported serovars to *gryppotyphosa*, *saxkoebing or sejroe* (Karlovic et al., 1985). Borcic et al. (1982) also reported evidence of *Leptospira* infections in bears from the Sava Valley, Croatia. *Leptospira* infections were detected following a serosurvey of Alaskan brown and black bears (Zarkne et al., 1983). Kathe and Mockman (1967) reiterated Kleinscmidt's report of antibodies to *icterohaemorrhagiae* in a captive bear from Germany. Antibodies to servovars *autumnalis* and *icterohaemorrhagiae* were reported in black bears by (Matula et al., 1980). In a serological study conducted on black bears in California indications of infections with serovars *australis, hyos*, and *mini* were reported (Ruppaner et al., 1982). Binninger et al. (1980) reported serological indications of infection with serovar *grippotyphosa* in black bears from Idaho. Anderson et al. 1978 reported that captive bear cubs were implicated as the source of infection for zoo animal keepers diagnosed with Leptospirosis (*Leptospira interrogans* serovar *icterohaemorrhagiae*)

Ruppaner et al. (1982) reported antibodies against *Yersinia pestis* in California black bears. Sasaki et al. (1989) recovered isolates of *Yersinia enterocilitica* serogroup O5A from a brown bear from a zoo in Tokyo.

Antibodies against *Coxiella burnetii* were detected in California black bears by Ruppaner et al. (1982), in black bears from Idaho (Binninger et al., 1980), and were reported in Alaskan brown and black bears by Zarnke (1983). Serological evidence of Q fever was also reported in European brown bears by Madic et al. (1993) and in Asiatic black bears (*Ursus thibetanus*) by Ejercito et al. (1993).

Ruppaner et al. (1982) reported antibodies against *Clostridium botulinum* in California black bears. *Clostridium difficile* and salmonella were recovered from a captive brown bear (Orchard et al., 1983). *Clostridium perferingens* type A strains were isolated from intestinal lesions in two Asiatic black bears (Greco et al., 2005)

Novel *Helicobacter* sequence types were characterized from fecal samples from captive polar bears at a marine park in Australia (Oxely et al., 2004). Kazmierczak et al. (1988) reported the first case of borreliosis in the family ursidae. Borrelia was isolated from tissues of black bears infested with *Ixodes dammini*, the primary vector of Lyme disease and *Dermacentor variabilis.* Titers to *Borrelia burgdorfi* were determined in whole blood or serum samples for grizzly bears, polar bears and black bears by Phillippa et al. (2004) and Brown et al. (2004).

Rickketsial organisms have also been reported in bears from serological evidence of Rocky Mountain Spotted Fever in a black bear from Idaho (Binninger et al., 1980). Brown et al. (2004) reported seropositivity to *Anaplasma phagocytophilum,* a pathogen transmitted by *Ixodes* species.

Escherichia coli and *Proteus mirabilis* were isolated from tissues of a black bear that had died from a pseudorabies infection (Schultze et al., 1986). Bacteriological cultures from skin scrapings of a polar bear with dermatophilus indicated the presence of saprophytic staphylococci and streptococci of Lancefield's group L, *Proteus* spp. and *Geotrichum* spp. (Smith & Cordes, 1972). *Proteus*, and *Escherichia coli* were isolated from tissues of a wild black bear that had died from a valvular endocarditis caused by *Staphlococcus aureus* (McBurney et al., 2000). *Pasturella multocida* was isolated from pleural and peritoneal lesions observed during a post-mortem evaluation of a polar bear with suppurative pleuritis and peritonitis (Newman et al., 1975)

The bacteriology of bear bites have warranted investigation in recent years as the number of bear-human encounters have increased. Deep wound cultures from a patient who sustained bites from a grizzly bear in Alberta, Canada produced *Serratia fonticola, Serratia marcescens, Aeromonas hydrophila, Bacillus cereus* and *Enterococcus durans.* Rose et al. (1982) reported bacteriology from three cases of bear maulings. Isolates of *Staphylococcus aureus* were cultured from wounds of one patient and *S. epidermidis* were cultured from wounds of a second individual. *Proteus vulgaris, Citrobacter* *diversus, Escherichia coli* and *S. epidermidis* were isolated from wound cultures in a third patient. *Mycobacterium fortuitum, Streptococcus sanguis, Neisseria sicca, Bacillus* spp. Were isolated from a brown bear bite wound (Lehtinen et al., 2005). Goatcher et al. (1987) reported that the microflora cultured from nasal, rectal, preputial and vaginal secretions were likely indicative of transient microbes "influenced by foraging habits and the surrounding environment." Mouth cultures from brown bears in Alaska produced isolates of *Staphylococcus epidermidis, Escherichia coli,* streptococci, diptheroids, pseudomonads, and unidentifiable gram-negative rods (Parry et al., 1983).

8.13 Mycotic Diseases of Bears

Fungal dermatitis, from an infection with the actinomycete *Dermatophilus congolensis* was first reported in polar bears by Smith et al. (1972). Subsequent reports include diagnoses by Smith (1973) and Newman et al. (1975). Saetz et al. (1979) reported *C. albicans* and other transient yeast species among the digestive flora of a giant panda. The yeast *Pityrosporum pachydermatis* was isolated from Alopecic tissues of a black bear cub (Salkin et al., 1978). Yeast phase lysate antigens from isolates of *Blastomyces dermatitidis* cultured from a polar bear were obtained for use in a blastomycosis serodiagnosis (Abuodeh et al., 2004).

8.14 Parasitic Diseases of Bears

Parasites of ursine species were reviewed in 1935 by Stiles and Baker. Since that publication extensive data has been collected on the parasitic organisms of bears with at least 43 new species having been reported in ursids. Coccidia sp. (*Eimeria albertensis* and *Eimeria borealis*) which have reportedly caused clinical illness in bears (Couturier, 1954) were reported in free-ranging American black bears (Hair and Mahrt, 1970). Coccidia were also reported in free-ranging grizzly bears by Gau et al. (1999). *Eimeria ursi* was reported in brown bears from the USSR (Yakimoff and Matschoulsky 1935; 1940). *Eimeria* spp. and *Isospora* spp. were reported in Eurasian brown bears (Craighead and Mitchell 1982) A *Babesia* species was reported in a captive bear from a Florida zoo (Stiles & Baker, 1935). Bemrick and O'Leary (1979) reported a coccidian from a grizzly bear. Coccidia were more recently reported in Grizzly bears in the central Canadian Arctic, the first finding of gastrointestinal harmacol in wild brown bears in North America (Gau et al., 1999). Cryptosporidiosis was reported in black bear from Virgina (Duncan, 1999) samples from the bear were used in the molecular characterization of a new genotype of *Cryptosporidium parvum* (Xiao et al., 2000).

Toxoplasma can infect most species of warm blooded vertebrates (Dubey and Beatie, 1988; Dreesen, 1990) *Toxoplasma gondii* cysts and antibodies were detected and isolates were characterized from tissue samples of black bears in Pennsylvania (Dubey et al., 1994; Dubey et al., 1995). Isolates from Pennsylvania black bears have been characterized as one of three *T. gondii* genotypes circulating among wild animals. (Dubey et al., 2004). Dunbar et al. (1998) detected antibodies to *Toxoplasma gondii* in Florida black bears (*Ursus americanus floridanus*), and Nutter et al. (1998) reported titers to *T. gondii* in hunter-killed black bears from North Carolina. Serological evidence of *Toxoplasma gondii* infection was reported in brown bears and black bears from Alaska (Chomel et al., 1995) and from black bears from Ontario (Quinn et al., 1976; Tizard et al. 1976). Serum antibody titers to *Toxoplasma gondii* were reported in brown bears (Zarnke et al., 1997) and black bears (Zarnke et al., 2000) from Alaska. Titers to *Toxoplasma gondii* and were determined in whole blood or serum samples for grizzly bears, polar bears and black bears (Phillippa, 2004). A serological indication of *toxoplasma* infection was reported as a concomitant infection with trichinosis from a human patient who had consumed raw bear meat from a black bear hunted in California.

In a study of endoparsitic fauna from black bears in six southeastern states (Virginia, West Virginia, Georgia, Tennessee, Florida, North Carolina), *Sarcocystis* sp. Were prevalent in tissues of 11 % of the bears examined (Crum et al., 1978).

Although the lifecycle of *Sarcosystis* has yet to be determined in bears, fatal sarcosystosis was reported in two polar bears from a zoo in Anchorage, Alaska (Garner, 1997). *Sarcosystis* spp. was also reported as an incidental finding in two male black bears from Oregon, being examined for the trematode *Prouterina wescotti (*Foreyt et al., 1999*).* Cheadle et al. (2002) recovered sarcocysts from muscle sections taken from Florida black bears (*Ursus americanus floridanus*). *Hepatazoon* spp. were reported in lungs of Japanese black bears (*Ursus thibetanus japonicus*).

Trematodes reported in bears include *Dicrocoelium lanceatum* in Asiatic black bears in the USSR (Bromlei, 1985) and *Echinistoma revolutum* in Grizzly bears in Montana (Worley et al., 1976). The metacercariae of the fluke *Nanophytes salminocolo* was reported in salmonids eaten by bears. These larval trematodes vector two species of rickettsial organisms. Experimental infections in black bears demonstrated clinical disease (Farell, 1968).

Bears serve as both definitive and intermediate hosts for cyclophyllidean tapeworms. Several taeniid tapeworms have been reported in captive and free-ranging bear species. In Alaska, *Taenia krabbei* and *Taenia hydatigena* were recovered from captive black bears (Rausch, 1954; Rausch et al., 1956). Choquette et al. (1969) also reported *T. krabbei* in wild grizzlies in Northwestern Canada. In the contiguous 48 states, *Taenia saginata* (Jonkel and Cowan, 1971) was reported in black bears in northwestern Montana, *Taenia pisiformis* from a black bear in Colorado (Hortsman, 1949). Taeniid cestodes have also been reported in a captive Asiatic black bear in India (Stiles and Baker 1935). Rogers (1975) reported *Multiceps serialis*, a cestode normally found in an intermediate mammalian host, the snowshoe hare.

Among other adult cyclophyllidean tapeworms recovered from bears, *Pentorchis arkteios*, was reported in a sun bear in Burma (Meggitt, 1927). Adult taeniid cestodes have also been recovered from captive bears, including *Taenia* spp. from a captive brown bear at the Copenhagen zoo (Linstow, 1893) and *Taenia ursi-maritimi* from captive polars bears elsewhere in Europe (Rudolphi, 1810; Linstow, 1878). Bears also harbor larval cyclophyllidean cestodes (Meggitt, 1924), including Batsches (1786) report of hydatid cysts in ursine species and a specific report of *Cysticercus cellulosae* cysticerci in a brown bear presumably from the old world (Diesing, 1851). Among pseudophyllidean tapeworms reported in North American bears, only members of the genus *Diphyllobothrium* have been reported. These tapeworms are associated with fish eating mammals which have consumed fish harboring the larval plerocercoids (Rausch, 1954).

Dyphyllobothrium latum (Skinker, 1931; Rush, 1932), *Dyphyllobothrium cordatum* (Scott, 1932) and *Dyphyllobothrium cordiceps* (Rausch, 1954) have all been identified and occasionally re-identified in wild black bears from Yellowstone National Park. *Dyphyllobothrium latum* was also reported in a captive polar bear in Minnesota (1949). Bromlei (1965) reported *Dyphyllobothrium latum* and *Dyphyllobothrium cordatum* in brown bears from southeastern USSR. *Dyphyllobothrium* spp. were reported from brown bears in the central Canadian Arctic (Gau et al., 1999). *Bothriocephalus ursi* was reported in a brown bear from a German zoo (Landois, 1877) and in a polar bear from a zoo in Ireland (Foot, 1865).

Spargana of *Spirometra mansonoides* were reported in an endoparasitic survey of black bears from the Southeastern United States (Crum, 1978).

The ancanthocephalen, *Macracanthorhyncus ingens,* was reported in black bears inhabiting coastal plains of the southeastern United States.

The digenetic trematode, *Prouterina wescotti,* was described in a black bear from Idaho, from specimens recovered from the bears brain, lungs and nasal sinuses (Foreyt et al., 1996).

Sprent (1968) reclassified the ursine ascaridoid nematodes of the genera *Ascaris* and *Toxascaris* into *Baylisascaris,* a genus reported in all bears species except spectacled bears. *Baylisascaris* has been reported in grizzly bears in northwestern Canada (Choquette et al., 1968) the central Canadian Arctic (Gau et al., 1999), and in black bears in Ontario (Sprent, 1950; 1951), Alaska (Rausch, 1961), Minnesota (Rogers, 1975), Montana (Worley et al., 1976) and Wyoming (Rush, 1932). *Baylisascaris tranfuga* was reported in black bears throughout the southeastern US (Crum, 1978) and has been reported in bears from south–eastern USSR (Oshmarin, 1963), Japan (Okoshi et al, 1962), Caucasus, Baikal, Chukotka, Indonesia, Syria, and Tibet (Bromlei, 1965).

Baylisascaris transfuga has also been reported in captive bears. The ascarids were collected from captive polar bears in Australia (Sprent, 1968). Two more ascarids reclassified as *Baylisascaris* sp. Include *Baylisascaris schroederi* (McIntosh, 1939) collected from the giant panda and *Baylisascaris melursus* collected from the sloth bear (Khera, 1951). *Baylisascaris multipapillata* was collected from a captive black bear in Germany (Kreis, 1938) and from captive bears in Louisisana (Clarki et al., 1969).

Gorman et al. 1986 reported *Baylisascaris* in brown bears, but not polar bears or black bears held at a zoo in Santiago, Chile. *Baylisascaris* spp. were recovered from a polar bear from a zoo in Worcester, MA (McOrist et al., 2002). Mozgovoi (1953) reiterated a report of bear mortality Baylisascariasis.

Other ascarids reported in bears include *Toxocara canis and Toxocara mystax* collected from captive bears in Germany (Couturier, 1954)

Baylis and Daubney (1922) reported four hookworms of the genus *Ancylostoma* from captive sloth bears in India (*Ancylostoma brasiliens*, *Ancylostoma ceylanicum, Ancylostoma malayanum* and *Ancylostoma caninum*) and reported *Ancylostoma malayanum* in a captive sun bear from India. Lane (1916) also reported *Ancylostoma malayanum* in Asiatic black bears. Setasuban and Vajrasthira (1975) collected *Ancylostoma malayanum* from a Malayan sun bear in Southern Thailand. *Ancylostoma caninum* was reported by Crum et al. (1978) in black bears from the southeastern United States. Ursine *Uncinaria* species, originally described as *Dochmius ursi* (Dujuardin, 1845) were collected from a polar bear and later reported in *Ursus arctos caucasicus.* Northern carnivore hookworms (*Uncinaria stenocephala*) were reported in brown bears near the Caspian Sea (Rukhliadev and Rukhliadeva, 1953; Sadykhov, 1962). Wolfgang (1956) described a new species of hookworms in the genus *Uncinaria. Uncinaria yukonensis* was described on the basis of samples collected from two black bears from the Yukon territory. Choquette (1969) reported *Uncinaria yukonesis* in Yukon Grizzlies.

In Alaska, *U. yukonensis* was reported in both black and brown bears (Rausch 1961, 1968) as was a newly described species, *Uncina*ria rauschii (Olsen 1968). The raccoon hookworm, *Arthrocephalus lotoris* was commonly found in black bears from the Southeastern United States (Crum, 1978). Canavan (1929) reported the unique finding of *Haemonchus contortus* in the enteric tract of a polar bear at the Philadelphia zoo. An avian cyathastome (*Cyathostoma bronchiale*) in a captive brown bear was reported from the same zoo by Stiles and Baker (1935).

Stongyloides species were recovered from black bears and were reported to be the third most prevalent nematode in a survey of endoparasites of black bears in the southeastern United States. The trichostrongylid *Molineus barbatus* was also recovered in the survey, and was collected from all study sites in six southeastern sites.

A number of extra-intestinal nematodes have been described and/ or reported in ursids. Gmelin (1790) reported *Taenia ursi* as a parasite of bears, and Diesing (1850) reported *T. ursi* (*Nematoideum ursi*) in *Ursus arctos.* A new species of *Crenosoma* lungworms were reported in wild black bears from New York, (King et al., 1960) and Ontario (Crum et al,. 1978). Among spirurid infections black bears were reported to have been infected with the eye worm *Thelazia ursi* in California. Hosford et al. (1942) and Hutrya et al. (1946) reported the finding of a kidney worm (*Dictophyma renale*) in the abdominal cavity of an unidentified bear. *Gongylonema pulchrum*, a common parasite of ungulates was found in an emaciated black bear from Pennsylvania (Chandler, 1950).

More recently, Crum et al. (1978) and Conti et al. (1983) reported that the prevalence of *Gonglyonema pulchrum* can be high. The high prevalence of gravid females examined in Pennsylvania black bears (Kirkpatrick, 1986) suggested that ursids are natural hosts for the spururid.

Rudolphi (1819) reported the presence of *Spiroptera ursi* in the European brown bear, as was *Gongylonema contortum* reported for the same host species (Molin, 1860). Immature species of *Physaloptera* and *Ggnathastoma* were reported with low prevalence in black bears in the southeastern US along with *Cyathospirura* sp. (Crum, 1978).
The dog heartworm, *Dirofilaria immitis* was reported in a black bear from North Carolina (Johnson, 1975; Crum et al., 1978). Yamaguti (1941) first described *Dirofilaria ursi* from an Asiatic black bear from Japan. Subsequent reports include infections of the filarial worm in Siberian brown bears (Petrov and Krotov, 1954) and from a brown bear in south-eastern USSR (Oshmarin, 1963). The filarial worms were also reported in black bears from Ontario and Quebec (Anderson, 1952; Choquette 1952) and from black bears in Michigan (Rogers, 1975) and Minnesota (Rogers, 1975; Rogers and Seal unpublished). King et al. (1960) reported both adult filarial worms and microfilariae in black bears from

New York. Worley et al (1976) reported *Dirofilaria* in grizzly bears from Montana, and Jonkel and Cowan (1971) reported filarial worms from black bears sampled from the same state.

Rogers and Rogers 1976 reported that *Dirofilaria ursi* is common in Alaskan brown bears and were collected from Alaskan black bears by Rausch (1961). Choquette et al. (1969) reported the filarial worms in grizzly bears from north-western Canada. Yokohata et al. 1990 reported *Dirofilaria ursi* in an Asiatic black bear from Japan. Three filarial worms (*Dirofilaria ursi, Tetrapetolonema akitensis* spp. N., and *Dipetolonema japonica* sp. N.) were reported in Asiatic black bears from Japan (Uni 1983). *Dirofiliaria ursi* is primariy a subcutaneous filarial parasite of bears, but two subcutaneous cases of dirofilariasis were reported by Beaver et al. (1987) among the ten cases cited by Beaver et al. (1987).

An atypical infection of *Capillaria aerophila* reportedly proved fatal in one black bear from the southeastern US (Crum et al., 1978). *Capillaria putorii* was commonly collected from black bears in the southeastern United States (Crum et al., 1978). *Trichinella spiralis* was recovered from captive polar bears in German zoos (Bohm 1913), the Philadelphia Zoo (Canavan,1929; Brown et al., 1949) and the London Zoo (Leiper, 1938). More recently *Trichinella* infections were reported in a polar bear from the Knoxville Zoo (Sleeman et al., 1994) and from a polar bear at the Chapultepec Zoo in Mexico City. *Trichinella* spp. Infect most endothermic vertebrates (Dick 1983), including 100 species of wild mammals (Zimmerman, 1970; 1977). Trichinellosis is endemic in populations of polar bears in Alaska, Greenland, Svalbard, and the Barents and Norwegian Seas (Rausch, 1970; MacLean et al., 1989; Forbes, 2000, and Sehir et al. 2001) *Trichinella* infections in polar bears were reported from the following regions: Alaska (Rausch et al., 1956; Fay 1960; Weyerman, 1993), Canada (Cameron 1960; Brown et al., 1948); Greenland (Thorborg et al., 1948; Roth, 1950; Madsen, 1961; Born and Henriksen, 1990); Svalbard (Brown et al., 1949; Connell, 1949); Nowegian and Barents Seas (Thorshaug and Rosted, 1956); Rudolph Land (Kozemjakin, 1959); Palearctic (Brusilovskiy, 1957); N. E. Siberia (Ovsjukova, 1965). *Trichinella harma* is the species that commonly infects polar bears in the arctic (Zimmermann, 1971; Sehir, 2001). A serosurvey conducted on polar bear populations in the Beaufort and Chukchi seas indicated a 55.6 % prevalence of *Trichinella* antibodies. *Trichinella* infections in wild brown bears were reported from the following regions: Alaska (Rausch et al., 1956); Idaho, Wyoming, and Montana (Winters, 1969; Worley et al., 1969; Worley, 1974); California (Walker, 1932); N.W. Canada (Choquette et al., 1969); Finland (Oivanen et al., 2002); USSR (Lukashenko et al., 1971); N. E. Siberia (Ovsjukova, 1965); E. Siberia (Toschev, 1963); N. Siberia (Gubanov, 1964); Caucasus mountains (Rukhliadev and Rukhliadev, 1953); Azerbaijan (Sadhykov, 1962); Germany (von Bockum-Dolffs, 1888). *Trichinella* spp. Larvae were collected from grizzly bears (*Ursus arctos horribilis*) in British Columbia (Schmitt et al., 1976, Schmitt et al., 1978) and from brown bears in northwestern Alberta and grizzlies in the province east of the Rocky Mountains (Dies and Gunson, 1984). Based on serologic surveys, Zarnke et al. (1997) reported a high exposure to *Trichnella* spp. In brown bears in northern regions of Alaska and a lower serum antibody prevalence for bears in southern regions of the state. The discrepancy in serum to differences was attributed to differences in feeding ecology. A similar geographical gradient was reported for serum antibody prevalence for grizzly bears and black bears exposed to *Trichinella* in Alaska. *Trichinella* infections in wild black bears were reported from the following regions: New York (King et al., 1960); Vermont (Babbott and Day, 1968; Roselle et al., 1965); New England (Harbottle et al., 1971); Michigan, Wisconsin, Minnesotta; Colorado, New Mexico, Arizona, Wyoming, Idaho, Oregon, California, Alaska (Zimmerman, 1974); California, and Idaho (Zimmerman, 1977); California (Ruppanner et al., 1982) Montana (Worley et al., 1976); S. Alaska (Rausch et al. 1956); Quebec (Frechette and Rau, 1977); Ontario (Addison et al., 1978); Arizona (Le Count 1981); Pennsylvania (Quinn, 1981). Schad et al. (1986) reported high intensity levels of *Trichinella spiralis* in black bears from Pennsylvania. The high intensity levels in some bears evoked concern for potential single source epizootics of human trichinosis. *Trichinella* was also reported in an Asiatic black bear from Thailand (Doege, 1969). *Trichinella spiralis* was reported in one black bear from Labrador, Canada from a sample of 158 bears from Newfoundland and Labrador. The low prevalence does not implicate bears as a major component in the sylvatic life cycle of the

nematode (Butler and Khan, 1992). *Trichinella britovi* was reported in Asiatic black bears from Japan (*Ursus thibetanus japonicus*) (Pozio et al., 1996) *Trichinella* was recently reported in a black bear from New Hampshire, following a reported case of tricinellosis in a human who had consumed bear meat (Hill et al., 2005).
Trichinosis was reported in a human patient who had ingested raw meat from a black bear hunted in California. A heavy infection of Trichinella spiralis was reported in the bear meat (Jordan et al., 1975). A high seroprevalence of *Trichinella* antibodies in polar bears and human infections from the consumption of polar bear meat suggests a high potential risk to public health in arctic regions (Moorhead et al., 1999, Rah et al., 2005).

Gau et al. (1999) reported the first finding of *Nematodirus* spp. And a first stage protostrongylid in North American bears.

Among arthropods, the louse, *Trichodectes pinguis pinguis* was collected from European brown bears (Burmeister, 1838; Werneck, 1948) from wild a Asiatic black bear in Japan (Yokohata et al., 1990) and from a captive Asiatic black bear in a Parisan zoo (Neumann 1913). *Trichodectes pinguis euarctidos* was described from lice obtained from black bears in British Columbia and Ontario (Hopkins, 1954) and reported in black bears from Michigan (Rogers, 1975), New York (King et al., 1960), Montana (Jonkel & Kowan 1971), and Idaho (Binninger, 1980) and Minnesota (unpublished data). The flea *Chaetopsylla setosa* was reported from bears in the following states and provinces of North America: Black bears from British Columbia (Rothschild, 1906; Hopkins and

Rothschild, 1956), Montana (Hubbard 1947), and from black bears from Idaho; brown bears from British Columbia (Jellison and Good, 1942; Ewing and Fox, 1943; Holland 1949).

The larger flea, *Chaetopsylla hiberculaticeps ursi* was also reported in the in brown bears (Worely et al. 1976) and black bears from various provinces and states in North America: black bears: black bears from south central Alaska (Jellison and Khols, 1939); Montana (Hubbard 1947; Jonkel and Cowan, 1971); from brown bears in Southern Alberta (Rothschild, 1906, Hopkins and Rothschild, 1956); southern British Columbia (Holland, 1949); and Alaska (Rausch, 1961). *Chaetopsylla tuberculaticeps tuberculaticeps* were collected from Norweigan, Russian, and Italian populations of brown bears. *Thrassis spenceri* was collected from a brown bear from British Columbia and *Pulex irritans* were collected from black bears in California. An unidentified *Pulex* species was also collected from black bears from Montana (Worely et al., 1976). *Orchpeas caedens* were collected from a bear's den in Minnesota after it had been vacated by the bear (Rogers and Rogers, 1976).

Infestations of wood ticks (*Dermacentor andersoni*) were collected from both brown bears and black bears in Montana and from black bears in Colorado (Henshaw and Birdseye, 1911; Cooley, 1938; Hortsman, 1949). In Montana, the heaviest infestations were found on subadult black bears, a finding attributed to the poorer condition of subadults during the Spring following emergence from hibernacula (Jonkel and Cowan 1971).

Dog ticks (*Dermacentor variabilis*) were collected from black bears in Michigan and Minnesota (Rogers, 1975) and Nova Scotia (Dodds et al., 1969). Rogers (1975) also reported infestations of winter ticks (*Dermacentor albipictus*) in Minnesota black bears and King et al. (1960) found ixodid tick infestations on black bears in New York. *Dermacentor andersoni* and *Dermacentor variabilis* were recovered from black bears in Idaho (Binninger et al., 1980). *Ixodes daminii* and *Dermacentor variabilis* were collected from infested black bears from Wisconsin infected with *Borrelia burgdorferi* (Kazmierczak et al., 1988).

Couturier (1954) reported findings of *Ixodes ricinus* and *Dermacentor clvenustus* on brown bears from the Pyrenees. Although, Bromlei (1965) reported only *Ixodes persulcatus* on an Asiatic black bears in south –eastern USSR during winter, the bears are known to host *Dermacentor silvarum, Haemaphysalis japonica douglasi,* as well as *Ixodes persulcatus*. In Burma, Asiatic black bears were infested with *Dermacentor auratus* and *c,* while *Haemaphysalis formosensis* was collected from an Asiatic black bear in Taiwan. (Stiles and Baker, 1935). *Haemaphysalis megaspinosa* were collected from an Asiatic black bear from Japan (Yokohata et al., 1990). Stiles and Baker (1935) and Hoogstraal et al. (1966) also collected *Haemaphysalis histricus, Haemaphysalis leachi,* and *Haemaphysalis semermis* on sun bears in Malaya. Reports of the following tick species from unknown bear species in India were submitted by Stiles and Baker (1935): *Dermacentor compactus; Hyalomma aegvptium; Hyalloma hussaini; Hyalloma monstrossum; Rhipicephalus haemaphysaloides; Rhipicephalus sanguineau; Haemaphysalis spinigera. Haemaphysalis bispinosa* from an unknown bear and location was also reported by Stiles and Baker (1935).

A black bear in a European zoo was host to a newly described species of mite *Ursicoptes americanus* (Fain and Johnston, 1970) which was more recently reported in black bears (Yunker et al., 1981); and Neumann (1892) reported *Sarcoptes scabiei* from a brown bear in the Pyrenees. (Couterier, 1954)

More recently, Fowler et al. (1984) reported infestations of *Ursicoptes americanus* in free-ranging black bears and captive black and polar bears. Cunningham et al. (2001) reported larval trombiculid mite (*Eutrombicula splendens*) infestations in Florida black bears (*Ursus americanus floridanus*).

Among haematophagous insects, *Stomoxys calcitrans* has been reported to feed on polar bears. These biting flies serve as mechanical vectors of etiological agents (e.g. *Dermatophilus congolensis*) of dermatitis (Smith and Cordes, 1972).

Gulledge et al. (2001) cited a report of pseudohermaphroditic polar bears related to exposure to anthropogenic pollutants. Sonnie et al. (2005) reported a case of an enlarged clitoris in a polar bear which had initially been diagnosed as pseudohermaphroditism.

A report of morbidity and mortality in a population of European brown bears indicated that natural death in bears was primarily a result of intraspecific aggression, among adult and subadult bears, and starvation (Morner, 2005). Infanticide was also a common source of mortality (Swensen et al., 1997). Anthropogenic factors include euthanasia relevant to research, hunting, poaching, and kills associated with defense of life or property. Vehicular accidents were the most common source of bear mortality.

8.15 Zoonotic Pathogens of Bears

Several zoonotic pathogens are endemic in wild bear populations, although the risk of exposure and transmission is not particularly high for those who do not work with these species. Several pathogens are etiological agents of disease in both bears and humans. Among viruses, rabies is of concern if it is endemic in species of wild mammals living in sympatry with bears. Williams and Barker (2001) reported fecal shedding of Campylobacter spp. In bears Dunbar et al. (1995) isolated *Salomonella* from a bear carcass and it is presumed that ursids may frequently shed Salmonella spp., without any clinical disease. *Cryptosporidium parvum* has been isolated from bears and *giardia* is commonly reported in North American Bear species (Samuel et al., 2001). Serological surveys indicate a high seroprevalence of toxoplasma gondii in North American brown and black bears. Both *Toxoplasma gondii* and more commonly *Trichinella spiralis* have been reported in humans who have consumed bear meat. Although *Baylisascaris transfuga* is a potential zoonosis for which no treatment is available for humans afflicted with larval migrans, *B. transfuga* is less pathogenic and not as frequently contacted by humans as other *Baylisascaris* spp.

Bears serve as sentinels for the following zoonotic agents. Serological studies suggest exposure, but clinical disease has not been reported. A seroprevalence of *Brucella* spp. has been reported in North American bears (Chomel et al., 1998), but human transmission would require exposure to reproductive tracts of the carcasses of gravid bears or reproductive tissues of aborted embryos or parturient sows (Chomel et al., 1998; Williams and Barker, 2001). Serological evidence of *Coxiella burnetii*, the etiological agent of Q fever has been reported in ursids (Ruppaner et al., 1982), but transmission to humans has not been documented. Exposure to butchered carcasses of bears harboring infections with *Francisella tularensis* the etiological agent of tularemia presents a potential health concern. Similarly exposure to butchered carcasses of bears infected with species of *Leptospira* spp. Creates a potential risk for transmission and contraction of Leptosirosis. However, the handling of live bears and exposure to urine may present a greater risk for the transmission of leptospirosis (Ruppaner et al., 1982; Wlliams and Barker, 2001).

CHAPTER 9

BAYLISASCARIS

9.1 Abstract

Baylisascaris are primarily parasitic nematodes of a limited range of terrestrial carnivore species. Infections of *Baylisascaris* roundworms may cause clinical disease in natural hosts and balisascariasis in these species is typically treatable. However, environmental contamination of their ova through fecal deposition is a source of a more insidious disease, larval migrant syndromes in incidental hosts. The lethality of larval migrans in free-ranging wildlife, non-carnivoran endangered captive wildlife, and humans presents an emerging public health concern and warrants investigation on disease transmission in captive wildlife facilities. Mortalities from larval migrans syndromes have been reported in more than ninety vertebrate species, including endangered species in zoos, where several mortalities have been reported. Although, *Baylisascaris procyonis,* the raccoon roundworm, and *Baylisascaris columnaris*, the skunk roundworm have been implicated in human deaths, and most commonly documented or suspected in the deaths of captive wildlife, zoo collections are composed of carnivores that serve as reservoirs for other *Baylisascaris* species, as well as a number of potential incidental

hosts, including endangered species. The ubiquitous bear roundworm, *Baylisascaris transfuga,* is a persistent pathogen in captive bear populations and enclosures and has been implicated in a case of larval migrans in incidental hosts and may be more significant than previously suspected. *Baylisascaris* transfuga s warrants continued investigations into public health implications associated with people working with bears, as well collection based facilities which maintain both natural hosts and potential incidental hosts.

9.2 Helminth Zoonoses Associated With Larval Migrans Syndromes

Several helminth parasites of carnivores are potential etiological agents of ocular, visceral and neural larval migrans syndromes (Beaver, 1969; Beaver et al., 1984; Kazacos, 1991; 1996; 1997; 2000; Smyth, 1995). Helminth zoonoses associated with larval migrans syndromes include ascarids, and hookworms and other helminth parasites, including gnathostomes, *Spirometra* and *Alaria,* among others (Kazacos, 2001). Among the ascarids *Baylisascaris* spp., are most often implicated as roundworm of serious zoonotic concern. Although *Baylisascaris procyonis,* the raccoon roundworm and *Baylisascaris Baylisascaris columnaris,* the skunk roundworm are most commonly implicated as zoonoses of concern other *Baylisascaris* species including *B. melis* of badgers, *B. devosi* of fisher and martens, and *B. tasmaniensis* of Tasmanian carnivores and *B. transfuga* of bears are all considered potential etiological agents of somatic larval migrans if enough ova are ingested (Kazacos, 2001).

9.3 Baylisascariasis in Natural Hosts

Definitive hosts rarely show clinical signs unless, heavy infections of adult worms block the enteric tract, a concern for zoo animals habitually exposed to parasite contaminated environments. Baylisascariasis in paratenic or incidental hosts associated with somatic larval migrans may not induce clinical signs unless an infectious dose of nematode eggs is high enough to induce hemorrhagic pneumonitis from extensive pulmonary migrations.

9.4 *Baylisascaris* spp. Pathogenicity (larval migrans syndrome)

However, migrating larva of certain species of baylisascaris (i.e., *B. Columnaris, B. melis and B. procyonis*) have characteristic tropisms for the central nervous system and share neurological disease producing capacities. In a comparison of pathogenicities among Baylisascaris species, Kazacos and Boyce (1989), found *B. procyonis* and *B. melis* to be most pathogenic, on the basis of larval migratory patterns, as well as the growth rate and overall size of their larval stages. Similarly, *B. columnaris* was ranked more pathogenic than other species of *Baylisascaris* sp, however.

9.5 Baylisascariasis Pathophysiology

Although *Baylisascaris procyonis*, the round worm of raccoons, is most commonly implicated in larval migrans disease, all *Baylisascaris* species are considered potentially zoonotic (Samuels et al., 2001; Sangster, 2004)

In laboratory studies, an index of pathogenicity has been established whereby the number of infective ingested eggs or parenterally administered egg inoculations required to induce clinical disease has been determined for *Baylisascaris* species. Furthermore, Kozacos (2001) defines central nervous system pathogenicity among different Baylisascaris species on the basis of migrations through somatic tissues, invasion of the central nervous system, aggressiveness within the central nervous system and host defense (i.e. encapsulation of larvae*).* *Baylisascaris procyonis*, *B. columnaris*, and *B. melis* produce relatively large larvae, which migrate through somatic tissues and frequently invade the CNS. Although, *Baylisascaris transfuga*, similar to *B. devosi*, and *B. tasmaniensis* are etiological agents of larval migrans disease, their slower growth rate, smaller size, and less frequent invasion of the brain, suggest that they are less pathogenic than *B. procyonis, B. columnaris*, and *B. melis.* In laboratory studies, migrating *B. transfuga* have been reported to invade the CNS producing visceral, neural, and ocular disease (Papini and Carosa, 1994; Papini et al., 1994; Papini et al., 1996; Sato, 2003).

The clinical syndrome, visceral larval migrans as described by (Beaver et al, 1992) is caused by migrating larva of certain nematode species. The most common etiological agents of ascarid larval migration syndrome in humans have been *Toxacara canis* of domestic dogs, *toxacara felis* of domestic felids, *Baylisascaris columnaris* of skunks and *Baylisascaris procyonis* of raccoons

The most susceptible human cohort to zoonotic ascarid infection are children, via exposure soil and sand substrates contaminated with embryonated ascarid ova in the excrement of domestic and wild carnivores.

Ocular larval migrans is more commonly reported in older children infected with toxocara species, but is not attributed to geophagia or pica (Duprey and Schantz, 2003). *Toxocara canis* and *Baylisascaris columnaris* do not significantly differ in diameter although they both re larger than *T. cati*. The ova of all of these species are mammilated (have pitted shells) and given the similarities in morphometric analyses it very difficult to speciate ova on the basis light microscopic examination. They can be distinguished from *Toxascaris* spp. of both domestic felids and canids.

9.6 Epizootiology and Ecopathological Patterns

Epidemiologic patterns and host ecology also influence the potential for infection and disease producing capabilities of *Baylisascaris* species. Aside from *Baylisascaris melis,* the badger roundworm, and *Baylisascaris columnaris*, the skunk roundworm, the most common etiological agent of *Baylisascaris* neural larval migrans or cerebrospinal nematodiasis is the raccoon roundworm. Although skunks are feral inhabitants of urban areas, and similar to raccoons, can be considered a peridomestic species, they are not nearly as abundant as raccoons, have characteristically different defecation habits, and their larva are not as pathogenic. Raccoons commonly aggregate in large numbers and can be found living within or near human dwellings, domestic animal facilities, and zoos. Their highly discriminate defecation habits lead to localized accumulations of heavy egg burdens which amass over time at latrine sites. On the other hand the larva of *Baylisascaris melis* are highly pathogenic, but this mustelid is not commonly found in urban areas, nor is it discriminate in its defecation habits. Hence, neither the badger nor skunk roundworms are nearly as threatening as *Bayliascaris procyonis*. As a result, *Baylisascaris* larval migrans suspected in humans and captive wildlife are presumed to be migrating larval stages of either *B. procyonis* or *B. columnaris*. However, *Baylisascaris procyonis* larva migrans is of greater concern to human and animal health, as the vast majority of cerebronematodiasis have implicated raccoons as disease threats on the basis pathogenicity of the raccoon roundworm, and certain behavioral patterns of this peri-domestic procyonid. Raccoons often establish latrines in or near human and animal dwellings. These communal fecal depositories amass extremely high numbers of eggs. Latrines also attract a host of granivorous species which feed on undigested food found in raccoon fecal deposits. Hence, granivorous small mammals often become carriers of infective L3's and transmit larva to susceptible predators or themselves succumb to *Baylisascaris* larval migrans and subsequent neurological disease. Neurological disease associated with the ingestion of raccoon roundworms is more common than disease associated with *Baylisascaris columnaris* primarily as a result of exposure. Skunks are indiscriminate in regard to fecal deposition and hence, concentrations of the skunk roundworm ova do not reach densities of ova found at raccoon latrines. Larval migrations of the skunk roundworm are also considered less aggressive and have less of a predilection for migrating to the CNS. The larva of raccoon roundworms and badgers (*Balisascaris melis*) are the most pathogenic species. Rodents, rabbits, primates, and birds are considered the most susceptible animal taxa to *Baylisascaris* neural larval migrans on the basis of epidemiological data. Other incidental or paratenic hosts are considered marginally susceptible, exhibiting larval migration limited to the intestinal wall or viscera.

9.7 Phylogenetics and Taxonomy (Order: Ascaridida)

The superfamily Ascaridoidea (Nematoda: Secernentea) is represented by four families of the order Ascaradida. Ascaridodea is characterized by large roundworms with three lips, occasionally separated by interlabia (Hartwich, 1974; Gibson, 1983). Some ascaridoid species are heteroxenous parasites of the enteric tract of vertebrates, and parasitize intermediate hosts for larval development. Two subfamilies of Ascaridae (Gibson, 1983) Ascaradinae and Toxacarinae are common helminth parasites of terrestrial mammals and of great veterinary importance. More than 50 genera are represented by these two subfamilies (Nadler, 1992). Phylogenetic study of the superfamily ascaridoidea is hindered by the paucity of well characterized morphometric documentation and the reliance on life history patterns and host specificity (Nadler, 1992). Structural characters that have been evaluated in ascaridoid phylogenetic studies include excretory systems, the esaphago-intestinal complex, lip features, and secondary sexual characteristics of males. At the intergeneric and generic levels evolutionary relationships have been proposed on the basis of a few recognized morphological and life history characteristics.

Speciation of zoonotic ascarid infections at generic (species-specific) levels for veterinary diagnostic purposes still require morphometric, serologic, and epidemiologic information (Goldberg et al., 1993). Diagnosis at the inter-generic (genus-specific) level is now possible through serological study. However, epidemiologic support and or morphological identification through histological study of infected intermediate hosts or through larval culture from embryonated ova of known definitive hosts is required for species specific diagnosis. Morphological identification requires the ability to differentiate among ascaridoid and other larval helminth parasites gained from histopathological experience. The shape and size of larva as well proportions of excretory columns, esophago-intestinal and other characteristics are used in morphometric diagnoses (Rowley, et al. 2000) Generic specific immuno assays (ELISA and IFA tests) are now available for diagnosis of *Baylisascaris* species infections ELISA and IFA tests Protein antigens of excretory-secretory products from roundworm larvae have proven useful in the development of antibody detection assays for ascarid genera.

Development of immunoassays for species-specific immunodiagnosis is precluded by excretory- secretory antigen similarities. Electrophoretic profiles of *Baylisascaris* species were prepared from 30 components of E-S antigens. *Baylisascaris procyonis, B. columnaris* and *B. melis* contained many components larger than 92 kDa. However, *B. transfuga* contained many components smaller than 70 kDa. Hence it may eventually be possible to develop a species specific immunodiagnostic assay for *Baylisascaris transfuga*. Products are useful antigens antigens.

9.8 Systematics

Baylisascaris species are ascaridoid nematodes of the subfamily Ascaridinae and exhibit both monxenous and heteroxenous life history patterns (Sprent, 1983; Adamson, 1986). The Superfamily Ascaridinae includes *Baylisascaris, Ascaris, Toxocaris, Parascaris, and Lagochilascaris.* The subfamily toxicarinae is represented by the genera *Toxocara* and *Porrocaecum.* Sprent (1968) renamed members of the genera *Ascaris* and *Toxacaris* as *Baylisascaris* species. The genus contains 10 species, two of which are recognized as provisional (Sprent, 1968; 1970). The males of *Baylisascaris* spp. Possess pericloacal roughened areas known as area rugosa. The cervical alae of adult worms posses cuticular bars which reach the surface of the cuticle (McIntosh, 1939; Sprent 1952; 1970; Hartwich, 1962). Labiae papillae (dorsal and subventral) are distinctly double. In males, spicules are stout and uniform, less than a millimeter in length. Males also possess pre-and post-cloacal groups of papillae on their tails (cited in Kazacos 2001).

The emergence of larval migrans syndromes and baylisascariasis associated with the raccoon roundworm (*Baylisascaris procyonis*) implicates *Baylisascaris procyonis* and their procyonid hosts as significant health threats to human health (Huff et al., 1984; Fox et al., 1985; Kuchle et al., 1993; Cunningham et al., 1994; Boschetti and Kasznica, 1995; Conrath's et al., 1996; Kazacos, 1997; 2001; Park et al., 2000; Rowley et al., 2000, Gavin et al., 2002). Aside from neural larval migrans *Baylisascaris procyonis* has been implicated in diffuse unilateral subacute neuroretinits in humans (Kazacos et al., 1985; Goldberg et al., 1993; Mets et al., 2003). *Baylisascaris procyonis* has produced choroidal granulomas, inflammation, degeneration, necrosis and disruption of the retina in primates (Kazacos, 1984).

9.9 Natural and Experimental Infections (incidental hosts)

Baylisascaris procyonis larval migrans and subsequent nematodiasis have also been reported in natural and experimental infections of more than 90 species of wild birds and mammals (Kazacos, 1997; 2001). Many natural infections have been reported in captive wildlife typically housed near captive raccoons, raccoon latrines or otherwise exposed to free-living raccoons. Cerebral or Cerebrospinal nematodiasis from migrating *Baylisascaris procyonis* have been reported in both game and non-game birds. Reports of neural larval migrans in game birds include both captive bobwhite quail (Reed et al. 1981) and wild bobwhite quail (Williams et al. 1996). Neurological disease has also been reported in columbiformes, including *Zenaida macroura* and *Columba livia* (Helfer and Dickinson, 1976; Evans and Tangredi, 1985). More recently Kazacos (2001) and Evans (2002) reported evidence of neural larval migrans in bird and mammalian hosts throughout the contiguous United States. Evans (2002) compiled a host range for California: *Baylisascaris* larval migrans were reported in house sparrow, *Passer domesticus* (Passeridae); western scrub- jay, *Aphelacoma californica,* American Crow *Corvus brachy*rhynchos (Corvidae); American robin, *Turdus migratorius* (Turdidae); loggerhead shrike, *Lanius ludovicianus* (Lannidae), common starling, *Sturnus vulgaris* (Sturnidae); greater roadrunner, *Geococcyx californianus* (Cuculidae); sanderling, *Calidris alba* (Scolopacidae), spotted towhee, *Pipilo* spp. (Emberizidae), California thrasher, *Toxostoma redivivum;* northern mockingbird, *Mimus polyglottos* (Mimidae); mallard, *Anas platyrhynchos* (Anatidae), house finch, *Carpodacus mexicanus* (Fringillidae); bushtit, *Psaltriparus minimus* (Aegithalidae); black-crowned night heron, *Nycticorax nycticorax* (Ardeidae); barn owl, *Tyto alba* (Tytonidae). Kazacos (2001) compiled a host range for clinical neural larval migrans, citing reports of natural infections of *Baylisascaris procyinis* or *B. columnaris* or undetermined *Baylisascaris* sp. The following species represent the natural host range compiled by Kazacos (2001): Australian brush-turkey, *Alectura lathami* (Megapodididae); chukar, *Alectoris chukar*, northern bobwhite, *Colinus virginianus,* California quail, *Callipepla californica,* common quail, *Phasianus colchicus*, chicken *Gallus gallus* (Phasianidae); wild turkey, *Meleagris gallopavo* (Meleagrididae); ruffed grouse, *Bonasa umbellus* (Tetraonidae); mourning dove, *Zenaida macroura,* rock dove, *Columbia livia* (Columbidae); house sparrow, *Passer domesticus* (Passeridae); bushtit, *Psaltriparus minimus* (Aegithalidae); island canary, *Serinus canaria,* house finch, *Carpodacus mexicanus* (Fringillidae); spotted towhee, *Pipilo harmacol* (Emberizidae); California thrasher, *Toxostoma redivivum,* northern mockingbird, *Mimus polyglottos* (Mimidae); American robin, *Turdus migratorius* (Turdidae); blue jay, *Cyanocitta cristata,* western scrub-jay, *Aphelocoma californica,* American crow, *Corvus brachyrhyncos* (Corvidae); common starling, *Sturnus vulgaris* (Sturnidae); sun conure, *Aratinga solstitialis,* orange-fronted conure, *Arantinga canicularis,* blue-crowned conure, *Arantinga acuticaudata,* yellow-crowned parrot, *Amazona ochrocephala oratrix,* blue-fronted amazon parrot, *Amazona aestiva aestiva,* blue and gold macaw *Ara ararauna,* Scarlet macaw, *Ara macao,* budgerigar *Melopsittacus harmacol* (Psittacidae); rose-breasted cockatoo, *Eolophus roseicapillus,* cockatiel, *Nymphicus hollandicus* (Cacatuidae); barn owl, *Tyto alba* (Tytonidae); black-crowned night-heron *Nycticorax nycticorax* (Ardeidae); Sanderling, *Calidris alba* (Scolopacidae*)*; mallard, *Anas platyrhynchos* (Anatidae); emu, *Dromaius novaehollandiae* (Dromaiidae); ostrich, *Struthio camelus* (Struthionidae).

Evans (2002) reported the following mammalian hosts to be susceptible to migrating *Baylisascaris* in a survey of California avian and mammalian species: long-tailed weasel, *Mustela frenata* (Mustelidae); American badger, *Taxidea taxus* (Mustelidae); eastern grey squirrel, *Sciurus carolinensis* (Sciuridae); dusky-footed woodrat, *Neotoma fuscipes* (Cricetidae); deer mouse, *Peromyscus maniculatus* (Cricetidae); California ground squirrel, *Spermophilus beecheyi* (Sciuridae); Bota's pocket mouse, *Thomomys bottae* (Geomyidae); Audobon's cottontail, *Sylvilagus aubudonii* (Leporidae).

The documented mammalian host range included house mouse, *Mus musculus* (Muridae); *Peromyscus leucopus,* white-footed mouse, *Peromyscus maniculatus,* deer mouse, *Peromyscus maniculatus,* brush mouse, *Peromyscus boylei,* eastern wood rat, *Neotoma magister,* dusky-footed woodrat, *Neotoma fuscipes,* muskrat, *Ondatra zibethicus* (Cricetidae); California pocket mouse *Chaetodipus californicus* (Heteromyidae); Botta's pocket gopher, *Thomomys bottae* (Geomyidae); eastern gray squirrel, *Sciurus carolinensis,* eastern fox squirrel, *Sciurus niger, Sciurus grantensis,* western gray squirrel, *Sciurus griseus, Tamiasciurus douglasii,* thirteen-lined ground squirrel, *Spermophilus tridecemlineatus,* California ground squirrel, *Spermophilus beecheyi,* black-tailed praire dog, *Cynomys ludovicianus,* woodchuck, *Marmota monax* (Sciuridae), chinchilla, *Chinchilla lanigera* (Chinchillidae); coypu, *Myocastor coypus* (Myocastoridae); North American Porcupine, *Erethizon dorsatum* (Erethizontidae);

American beaver, *Castor canidensis* (Castoridae); Patagonian cavie, *Dolichotis patagonum,* guinea pig, *Cavia porcellus* (Caviidae); Capybara, *Hydrochaeris hydrochaeris* (Hydrochaeridae); eastern cottontail, *Sylvilagus floridanus,*Audobon's cottontail, *Sylvilagus audubonii,* European rabbit, *Oryctolagus cuniculus* (Leporidae); red fox, *Vulpes vulpes,* dog, *Canis familiaris* (Canidae); American badger, *Taxidea taxus,* southern sea otter, *Enhydra lutris nereis* (Mustelidae); black and white ruffed lemur, *Varecia harmacol variegate,* red ruffed lemur, *Varecia variega rubra*; Coquerel's mouse lemur, Mirza coquereli (Lemuridae); Geoffroy's tufted-ear marmoset, *Callithrix geoffroyi,* black-mantled tamarin, *Saguinus nigricollis,* midas tamarin, *Saguinus midas,* golden lion tamarin, *Leontopithecus rosalia* (Callitrichidae); white handed gibbon, *Hylobates lar* (Hylobatidae) spider monkey, *Ateles sp*. (Cebidae); DeBraza's monkey, *Cercopithecus neglectus* (Cercopithecidae); red kangaroo, *Macropus rufus* (Macropodidae) sheep, *Ovis aries* (Bovidae).

Baylisascaris procyonis and *Baylisascaris columnaris* larva migrans and associated clinical diseases have warranted extensive investigations relevant to the pathogenicity and epidemiology of this zoonotic roundworm through experimental studies of *laboratory* animals (Papini et al., 1994). Laboratory studies on rodentia include several experimental infections of *Baylisascaris* species in the following murid species: brown rat, *Rattus norvegicus* (Tiner, 1954; Wirtz, 1982); and house mouse, *Mus musculus* (Tiner, 1949; 1952; 1953; Sprent, 1952; 1955; Clark et al., 1969; Lindquist

1978; Kazacos, 1981; Dubey, 1982; Wirtz, 1982; Boyce et al., 1988; Boyce et al., 1989; Miyashita 1983; Garrison, 1996; Sheppard and Kazacos, 1997; Boyce et al., 1988). Cerebrospinal nematodiasis was also induced via experimental infections in the following cricetid species white-footed mouse *Peromyscus leucopus* (Tiner 1949, 1953; Sheppard and Kazacos 1997; Page 1998); western harvest mouse, *Reithrodontomys megalotis* (Sheppard 1996); meadow vole, *Microtus ochragaster* (Sheppard 1996); *Microtus pennsylvanicus*, prairie vole (Berry 1985; Sheppard 1996); golden hamster, *Mesocricetus auratus* (Tiner 1949; Kazacos 1981; Wirtz 1982); and hispid cotton rat, *Sigmodon hispidus* (Tiner, 1949, 1952, 1953). Experimental infections were also reported in the following sciurids: eastern chipmunk, *Tamias striatus* (Kazacos and Boyce, 1989), eastern grey squirrel, *Sciuris carolinensis* (Tiner, 1949; 1952; 1953; Wirtz, 1982) woodchuck, *Marmota monax* (Swerczek and Helmboldt, 1970). Reports of *Baylisascaris* neural larval migans in cavids from experimental studies include the following species: guinea pig, *Cavia porcellus* (Tiner, 1949; 1953; Donelly et al., 1989). Reports of Baylisascaris neural larval migans in leporids from experimental studies include the following species: eastern cottontail, *Sylvilagus floridanus* (Tiner, 1954; Jacobson et al., 1976); and harmaco rabbit, *Oryctolagus cuniculus* (Tiner 1954; Church et al., 1975; Boyce et al., 1989). Experimental studies of *Baylisascaris* migrations in carnivores were reported in domestic dog, *Canis familiaris* (Snyder, 1983) domestic ferret, *Mustelis putorius* (Kazacos, 1981; Kazacos and Kazacos, 1988) and least weasel, *Mustelis nivalis*

(Kazacos, unpublished). Experimental infections in primates include reports of neural larva migrans in South American squirrel monkey, *Saimiri sciureus* (Kazacos et al., 1981) and long-tailed macaque, *Macaca fascicularis* (Kazacos et al., 1984; 1985). Experimental infections in birds include reports of cerebronematodiasis in chicken, *Gallus gallus* (Kazacos and Wirtz, 1983) and domestic duck, *Anas platyrhynchos* (Wirtz, 1982). Several probable cases of *Baylisascaris* neural larval migrans have been reported in zoo animals on the basis of histopathology, clinical signs and history of exposure. Campbell et al. (1997) reported cerebral nematodiasis in lemurs as cited above as well as suspect cases in emus. Armstrong et al. (1989) also suspected Baylisascaris larval migrans in peafowl as did Stringfield and Sedgwick (1997) in zoo primates, marsupial and two species of psittacines.

9.10. Zoonotic Potential (*Baylisascaris transfuga*)

The zoonotic potential of *Baylisascaris procyonis* and *Baylisascaris columnari*s have evoked an interest in the zoonotic potential of other *Baylisascaris* species. Undetermined *Baylisascaris* spp. have also been reported in a variety of vertebrate species and in captive wildlife. Among zoo animals, undetermined Baylisascaris species have been reported in at least five orders of vertebrate species (Armstrong et al. 1989, Suedmeyer et al., 1996; Stringfield and Sedgwick, 1997; Kazacos, 2001). *Baylisascaris transfuga* larval migrans has been reported in laboratory studies (Sprent, 1951; 1952, 1953; 1955; Papini, 1996). A recent account of neural larval migrans in a colony of captive macaques housed with American black bears, and in the vicinity of a raccoon enclosure was inconclusive in determining the causative agent of cerebrospinal nematodiasis. Despite the persistent infections of *B. transfuga* in the bears and the absence of *B. procyonis* in the raccoons and surrounding environment, histopathological evidence suggested *B. procyonis* as the causative agent of fatal neural larval migrans in the macaques. Hence, the potential for *Baylisascaris transfuga* neural larval migrans in zoo collections housing bears may be greater than was previously suspected. Species limitations to NLM disease as a result of *Baylisascaris* infections should warrant some skepticism, given the number of CNS diseases reported in animals in which post-mortem examinations were incomplete or limited in scope with regard to the examination of nervous tissue.

9.11 Immunity to Ascarids

Ascaris lumbricoides is the most prevalent helminth parasite known to infect humans. Goldschmidt (1910) first reported *Ascaris* induced allergens in humans, but very little research on immunity to ascarids in human and animal populations have been documented. Early investigations of ascaris immunity in humans were based on epidemiological studies and reported that prevalence and intensity levels of *Ascaris lumbricoides* were higher in younger age cohorts where ascariasis is endemic. In treated individuals, a recurrence of infection occurred at pre-treatment levels if preventive medicine, sanitation and disinfection protocols are not adhered to (Grove, 1982).

This would suggest that humans to not develop any resistance to ascariasis. However, Spillman (1975) suggested that repetitive infections may permit the development of a desensitization or acquired tolerance of worms by the host. Resistance to ascarids has been examined in both canine companions, domestic livestock and equids. Age resistance to *Toxocara canis* has been reported by (Greve, 1971; and Oshima, 1976) Foals require an innate resistance to roundworms which they develop through exposure to eggs and migrating larvae (Murray, 2003).

CHAPTER 10

FACTORS INFLUENCING *BAYLISASCARIS* PERSISTENCE AND SURVIVAL IN CAPTIVE BEARS

10.1 Abstract

Various environmental parameters associated with captive animal enclosures, influence the survival and persistence of certain pathogenic agents. In many instances environmental factors in modern day facilities exacerbate the problem of pathogen contamination within an enclosure and surrounding areas. The ubiquitous bear roundworm, *Baylisascaris transfuga* is particularly difficult, if not impossible to eliminate from the captive environment. Without continual intervention with antihelminthic therapy, baylisacariasis poses a health threat to bears. Furthermore, perpetual environmental contamination of *Baylisascaris* ova may also lead to the exposure of other zoo animals and handlers to infectious concentrations of ascarid eggs, the casusitive agents of visceral, ocular, and neural larva migans. Although *Baylisascaris procyonis* larval migrans has produced lethal cerebrospinal nematodiasis in zoo animals, in some cases the species of *Baylisascaris* was not determined. In this study a questionnaire was submitted to bear holding institutions to survey environmental factors which may

contribute to pathogen persistence in bear enclosures, determine current prevalence of *Baylisascaris* in zoo bears, and assess risk factors for *Baylisascaris* parasite exposure in other collection animals.

10.2 Introduction

Although modern, biofunctional, naturalistic exhibits may enrich the lives of captive animals, contribute to their psychological well being (Carlstead et al., 1991; Kohn, 1994; Mench, 1994, Mellen and Macphee, 2001; Gareth, 2006) and enhance conservation educational initiatives for zoo patrons, sophisticated animal displays and movements of animals between sub-populations expose animals to more health hazards than ever before in the history of captive animal management (Kirkwood, 1996; McAloose, 2004). Of greatest concern to animal health are trauma, infectious diseases, and dietary regiments. Trauma resulting from intra and interspecific aggression, and injuries associated with biotic and abiotic exhibit and enclosure artifacts have been most commonly reported. Dietary concerns relevant to mixed species exhibits are particularly complex and challenging. Among infectious diseases, metazoan parasites continue to be problematic as are some bacterial pathogens and emerging viral diseases. Viral (Richman et al. 2000; Converse et al. 2001), bacterial (Kik et al., 1997; Ward et al., 2000) and parasitic (Nichols et al., 1986; Chakaborty, 1994; Juan –Salles, 1997; Craig et al., 1998; Lukesova and Literak, 1998; Sato et al., 1999; Epiphanio et al., 2000; McAloose

2001; Schrenzel, 2001) disease transmission has been reported in naturalistic enclosures. Preventive Medicine protocols have been implemented by zoo health and husbandry departments to reduce the incidence of parasitic pathogens, particularly metazoan parasites (Wiliams and Thorne, 1996). Many continue to persistent in the environment and remain problematic (McAloose, 2004). Endoparasites have been reported to be the major cause of morbidity in zoo mammals. (Kanneene et al., 1985; McAloose, 2004).

Persistent endoparasites, such as roundworms can reach high levels of contamination in captive enclosures, and continually re-infect zoo populations of zoo carnivores, as well as develop susceptibilities to antihelminthic resistance. The development of Drug resistance in many antihelminthic agents is particularly noteworthy in livestock and has elicited much concern for the continued reliance on drug therapy for the control of endoparasites (Murray, 2003).

As with other infectious and potentially zoonotic pathogens, migrating species of roundworms may also represent a health threat to humans and other susceptible captive animals selected as candidates for conservation programs (Dasak et al., 2000). These disease agents are difficult, if not impossible to eradicate with appropriate sanitation and disinfection protocols and can survive for years in zoo enclosures. The design of the enclosures often precludes adequate decontamination because of the purpose of display animal exhibits (Kalter, 2006). Among carnivores, bears commonly suffer from ascariasis and require routine treatment with ascaricidal agents (Abdelrsoul and Fowler, 1979). The following study, attempts to elucidate environmental factors that may promote the persistence of bear roundworms (*Baylisascaris transfuga*) in captive enclosures, a perpetual problem that may exacerbate the environmental stressors that also perhaps, influence host susceptibility to parasitic diseases.

Despite advances in animal husbandry and exhibit design it is virtually impossible to maintain captive bears in sterile enclosures (Partridge, 1992). To strengthen parasite control programs and improve animal welfare, it is necessary to obtain data on parasite prevalence, transmission, and epizootiology (Epe et al., 2001) to help reduce husbandry factors which contribute to pathogen contamination and persistence (Fowler, 1996; Porter 1996). Aside from disease monitoring for the detection of agents of disease in a population, and continual surveillance of disease status (Fowler, 1996), it is imperative to understand the dynamics of disease transmission and parasite ecology. Investigations of disease lifecycles and transmission dynamics provide information that is most useful for controlling diseases among and within populations (Munson and Cook 1993). Environmental stress factors associated with captivity or degraded wild habitat can induce stress in animals (Lyles and Dobson 1993) and subsequently depress immune function, rendering animals particularly susceptible to disease (Fowler 1986).

10.3 Parasite Control & Treatment

Proposed guidelines for parasite control in zoological parks and aquariums (AAZV Veterinary Standards Committee, 1998) include special consideration for susceptible species known to harbor persistent parasites as well as aberrant parasites known to cause fatalities in collection animals. The guidelines specifically caution the movement of animals or "cage furniture" among exhibits known to be contaminated or potentially contaminated with aberrant parasites such as "*Baylisascaris*." AAZV guidelines recommend that fecal samples be conducted annually on individual animals or composite samples be examined on a group of animals. For susceptible species such as bears, more frequent exams may be needed for detection and as well as routine treatment with antihelminthic agents. Ivermectin has been used to treat a host of ecto- and endoparasites in a number of zoo animals. Its high potency permits efficient administration via several formulations (e.g., oral drench, paste, sub-cutaneous injection, topical transdermal delivery). Carnivores are typically administered subcutaneous injections upon sedation for routine examinations or when sedated for movement or procedures requiring anesthesia.

10.4 Coprodiagnostic Assays in Zoological Parks

Although zoos may employ direct fecal smears, passive (stationary) fecal floatation, fecal centrifugation flotation, and or fecal sedimentation procedures for microscopic fecal examination, the most common technique employed by zoo veterinarians and zoo veterinary technicians is the passive floatation. The disadvantage of the direct smear is that the diagnostician is limited in the amount of feces that can be examined. Typically a small amount of sample is placed on a slide with an equal amount of saline solution or flotation media. The mixture is smeared across the slide until a thin layer of sample can be examined with light microscopy. This technique requires only a short procedure time and requires minimal equipment.

The use of concentrated salts and sugars for flotation solutions allow diagnosticians to modify techniques that target the recovery of parasite eggs, oocysts, larva and fecal debris. Fecal floatation procedures allow diagnosticians to utilize the disparities in specific gravities of flotation media relative to the specific gravities of parasite eggs and oocysts and adjust flotation media for the recovery over targeted parasite ova. The majority of parasite ova have specific gravities between 1.1 and 1.2 (g/ml) and the selected salt and sugar flotation solutions consist of concentrations that have specific gravities between 1.2 and 1.25 (g/ml). Thus, concentrated solutions of salts and sugar have been widely used in coprodiagnostic studies, whereby ova, suspended in a mixture of fecal samples and flotation media are permitted to ascend to the top of a floatation container. A coverslip affixed to the top the meniscus of the solution allows for the eggs to adhere to the transparent slip. After 10 to 15 minutes recovered eggs that have adhered to the surface of a coverslip are than examined via light micrscopy once the coverslip has been placed on a microscope slide.

These “simple,” “passive,” or “stationary” floatation techniques have been enhanced by additional concentration techniques which employ centrifugal force. In some cases centrifugation may even reduce procedure time, but more importantly studies indicate that centrifugal flotation procedures greatly enhance ova recovery ( ). For these procedures a centrifuge capable of holding 15 ml or 50 ml centrifuge tubes is required. The fecal and floatation media suspension are centrifuged at a force of 400 x to 650 x prior to concentrate the eggs and expedite there ascension. Again, a coverslip is place atop the meniscus for egg adherence. A variety of fecal washes are also employed for both passive and centrifugal flotation techniques to aid in the concentration of ova and elimination of debris from submitted fecal samples.

Sodium Nitrate solutions are considered the most efficient flotation media for passive floatation procedures and are available in both commercial formulations and in commercial fecal diagnostic kits. Sodium Nitrate solutions will crystallize in a short period of time and eventually distort eggs. Hence, this solution is not typically useful for centrifugation flotation. Likewise Sodium Chloride requires immediate examination of samples due to crystallization, but due to its caustic properties, it is a poor candidate among available flotation media. Zinc Sulfate solution is often used for centrifugal flotation procedures and is recommended for recovering oocysts of protozoa and hence, is an ideal candidate for recovering common protozoa such as giardia species. Epsom salt or Magnesium Sulfate. Sheather's sugar solution is less efficient in recovering helminth eggs as it is known to float fewer eggs, relative to sodium nitrate. Hence, it is not a useful medium for passive flotation. It does not, however, require that suspensions and recovered eggs be examined immediately as sugar does not crystallize. Sugar does not distort the shape of roundworm eggs and is therefore a preferred medium for examining ascarids. Although fecal sedimentation techniques concentrate larvae and eggs, it is not as effective as flotation procedures, in that it retains debris which obscures microscopic examination. It is not effective for recovering a high percentage of helminthes eggs. Sedimentation is selected for recovering ova with higher specific gravities than typical flotation solutions and instances where parasite eggs might be greatly distorted by flotation media.

10.5 Materials and Methods

Questionnaires were submitted to 123 captive bear holding facilities to determine the prevalence of roundworm infections in captive bears. Information was also solicited on current antihelminthic therapies, abiotic factors associated with husbandry practices and enclosure parameters that might influence parasite contamination in captive facilities. Along with requests for abiotic and biotic parameters associated with enclosures and other holding facilities designated for the confinement of bear collections in captivity, data on demographic information was requested for individual bears (see tables 1-3). Health and behavioral histories and profiles along with attempts to mitigate any health concerns or aberrant behavior were requested. To assess decontamination and exposure of parasite ova to bears and other collection animals, data was collected on any additional species sharing enclosures with bears, additional collection animals serviced by keepers working with bears, and disinfection and cleaning protocols for bear holding and exhibit areas. Data on prophylactic and post-infection treatment with parasiticidal pharmacologics, use of single and combined agents along with frequency of treatments, alternation regimes, method of administration, and administration rates. Information was also requested regarding temporal and environmental access to enclosures. These holding management protocols included the following management regimes: indoor & outdoor access during the day (locked inside at night); indoor & outdoor access at night (locked outside during the day); indoor access during the day (locked inside at night); dual access day at all times to determine relationships with aberrant behavior. Data was collected on specific substrates and vegetation. Soil and sand were classified as “Ground Substrates,” woodchips, fallenbark, and mulch was classified as “Soft Substrates” and rock and cement were classified as “Hard Substrates”. The questionnaire also solicited enrichment items from special food offerings to exhibit furniture, toys, enrichment devices, and other exhibit features used in captive environments as well as water quality and management issues. Water quality and related parameters regarding chemistry, filtration and water treatment were also requested. Because quality of space, and environmental enrichment devices have also been correlated with aberrant behavior, neuropathies are commonly found in captive bears and a source of much concern with regard to bear welfare. Relationships between the presence of roundworms and substrates were analyzed by regression analyses.

10.6 Results

Individual profiles were obtained for 493 bears, representing all eight species. Information on roundworm infections was provided in health histories for 260 of the bears for which profiles were submitted (see table 2). Five (2.2.1) giant panda, *Ailuropoda melanoleuca* (2 males; 2 females); 14 (5.7.2) sloth bears *Melursus ursinus* (5 males; 7 females); 21 (3.9.9) Asiatic black bears, *Ursus thibetanus* (3.9.9); 25 (16.9.0) Andean bears, *Tremarctos ornatus* (16 males; 9 females); 51 (20.26.5) polar bears, *Ursus maratimus* (20 males; 26 females); 54 American black bears, *Ursus americanus* (21.18.15) 59 brown bear, *Ursus arctos* (21 males; 18 females); 31 (8.16.7) Malayan sun bears, *Helarctos malayanus*, (8 males; 16 females). Gender was not provided for fifty of the 260 bears. Among the remaining individuals 111 were female and 99 were male. Ninety –one were wild born and 1 58 were captive born animals. The birth history was not documented for 11 of the 260 bears. One hundred and twenty –five bears had histories of roundworm infections and 135 bears were reported to have no history of roundworm infection.

A logistic regression was performed on data for 182 of 260 bears to determine the predictive value of parasite prevalence from 20 explanatory categorical variables relevant to individual health and demographic parameters to environmental parameters associated with enclosure and husbandry parameters. The binary dependent variable, presence or absence of roundworms (from retrospective data) was regressed with twenty explanatory categorical variables for the demographic and enclosure parameters that were presumed to have the most influence among the parameters queried in the original questionnaire. Hence, the following explanatory covariates were used in a binary logistic regression to determine if any such variables associated with bear health and husbandry were significantly associated with a history of roundworm presence or absence in 182 bears: (gender; birth status (wild or captive born); age; weight; species (polar; brown; American black; Asiatic black; sloth; Malayan sun; Andean; brown; and giant panda); the number of bears in the categories of substrates used in the enclosures(“ground”; “soft” and hard”); enrichment; and filtration of pools.

The birth history was associated with infections of ascarids. Wild birth was a significant predictor of roundworm prevalence (P=.000). There was a strong correlation between wild birth and the prevalence of roundworms while in captivity. Captive birth was not a significant predictor of roundworm prevalence. There was also a species specific predilection for roundworm prevalence. Categorically, polar bears were significant indicators roundworm prevalence (P=.004), as were sloth bears (P=.013). The six other species were not independently associated with a higher prevalence of ascarid worms

The number of bears in the collection was also a predictor of infection with roundworms for individual bears (P=.000). More specifically, Wild born individuals had 11.7 times (=exp[2.45951]) the risk of harboring roundworms as those which were captive born. There was also a species specific predilection for roundworm prevalence (see table 5). Polar bears were independently associated with roundworm infections (P=.004), as were sloth bears (P=.013). Among the bears surveyed polar bears had 37.57 times (=exp[3.62620]) the risk of being infected with roundworms and sloth bears had 82.68 times (=exp[4.41502]) the risk of being infected with roundworms. The number of bears in the collection was also a predictor of infection with roundworms for individual bears (P=.000). Bears that were housed in collections with more than one individual had 2.43 times (=exp[.887845]) the risk of being infected with roundworms than bears housed alone. The risk of being infected with roundworms is significantly correlated with three of the four substrate categories (see table 6). Bears displayed on soil or sand were more likely to harbor roundworm infections (P=.001) as were bears displayed on soft substrate (woodchips; fallenbark and vegetation) (P=.001). The use of straw as bedding for bears was correlated with a lower prevalence of roundworms (P=.000) (see table 9) Filtration of pools was correlated with a lower prevalence of roundworms (P=.000) (see table 10.)

10.7 Discussion

The comprehensive survey provided a selection of explanatory covariates which could be used in a binary logistic regression to determine if any such variables associated with bear health and husbandry were significantly associated with a history of roundworm presence or absence in 182 bears. Among those that were suspected to be strong predictors of roundworm prevalence, neither, gender or weight were significant predictors. Age was also not a significant predictor. This may have been due to the data analyses. Regression analyses were not performed independently for species, but rather for the total population. Hence, gender and age, which both correlate with weight for each species (some are more sexually dimorphic than others) as reported by Garshelis, (2001), may have been strong predictors of parasite prevalence. Although captive bears live much longer than their wild counterparts, and may show much less pronounced dimorphism due to management regimes (feeding; restriction from torpor), the age of bears might be a strong predictor of parasite prevalence because of acquired immunity to ascarid infections. It is therefore, not surprising that wild born animals were at a significantly greater risk of harboring parasites because they likely acquired infections from their parents. Such vertical transmission was not likely prenatal via larval migrations, but rather through exposure to excrement of the sows (dams). Hence, regardless of age, wild born animals may have developed a tolerance, whereas captive born animals were either hand reared or their mothers were administered non-teratogenic ascaradicidal agents and were not exposed to high levels ascarid infections. These animals may have developed a lower tolerance for infections, but were also subjected to routine deworming protocols and hence their susceptibility to clinical or sub-clinical disease is largely unapparent. It would be interesting to evalauate post-mortem records to perhaps elucidate patterns of morbidity and mortality associated with *Baylisascariasis.* Captive born bears may not tolerate worm burdens with out routine treatment for parasite control and may be more vulnerable or susceptible to Baylisascariasis. This would be of great concern for bear species and captive populations which are currently being considered for reintroduction and /or other translocation programs. Weight was not a predictor of parasite prevalence. Again, bears maintained in captivity are often overfed such that they are obese, are fed a much higher protein diet relative to their conspecifics, and do not share the physiological ecology of wild conspecifics subjected to seasonal factors which determine food availability and variability. Hence, infracommunities of parasites, and ascarids in particular, may not exhibit similar survival and reproductive tactics that they exhibit as enteric macrofauna of wild bears.

Alternatively, wild bears may be more susceptible to helminth infections or ascarid infections, in particular. Once introduced to captive enclosures and cagemates, they are exposed to ascarid genomes which have coevolved to withstand unnatural host feeding, behavior, and physiological ecologies as well as antihelminthic treatment. Hence, wild born bear immune systems may be naïve to generations of ascarid genomes which have evolved to adapt as symbionts or persistent commensal organisms. These naïve bears, particularly those of the subfamily Ursinae are known to expel roundworms in cyclical patterns associated with seasons and the pre-induction of torpor. Hence, the ascaridoid fauna of captive born bears in zoological parks may have adapted to conditions which place constraints on normal metabolic and energetic ecologies of bears. If captivity feeding and metabolic activities proceed, largely uninterrupted by normal changes in gut physiology, the parasite fauna may have adapted, whereby roundworm intensities reach a threshold or upper level capacity. Wild born bears, many of which are now maintained in captivity for various reasons, and were previously exposed to natural infections and populations of roundworms, may be susceptible or immunocompromised with regard to tolerating population of roundworms which have evolved and adapted to enteric conditions found in captive bears. Although drug treatment kills worms and may mimic natural expulsion of worms, many are administered with greater frequency (i.e. avermecticns and other macrolides) as broad spectrum nematocidal prophylactic agents for the prevention of *Dirofilaria ursi* as well as for the control of persistent helminth infections. Induction of the expulsion of worms on monthly or quarterly basis as opposed to natural elimination prior to entering torpor on an annual basis, required because worm burdens can reach levels such that they obstruct the intestinal tract, however this means of controlling parasites, and the influence it has on parasite ecology and host health may exacerbate problems with drug resistance and host susceptibility and immunity. Gender was not strongly associated with a risk for roundworm infections.

Zoos typically exhibit bears in small groups or pairs although they are known to be solitary in the wild, with the exception of a sow and cubs. Collective housing minimizes constraints of limited space for zoo collections and provides social contact, a behavioral enrichment provision for megavertebrates prone to boredom. Hence, castrated males are often displayed along with females and occasionally two boars or two sows are displayed together. Although, intensity levels may increase across gender, prevalence is not likely to change because saprophytic pathogens contaminate surfaces in holding areas, exhibits, and most likely fomites in keeper areas. It is difficult to sterilize zoo facilities for either animals or people. It might perhaps be better to evaluate factors associated with sociobiology. Subordinate animals may not gain exposure to mulch pits or enriched substrates where embryonated eggs persist. However, ascarid eggs cling to under fur and guard hair and so transmission is quite probable. Bears use much of their exhibit space, even if they are subordinate animals, and they are moved back and forth from holding to display areas on a regular basis. Opportunities for exposure to infective ova are great, and despite cleaning and sanitation efforts, few if any zoos use appropriate or adequate disinfectants.

There was also a species specific predilection for harboring roundworm infections. Roundworm prevalence was strongly associated with polar bears and sloth bears. Although wild polar bears harbor *Baylisascaris*, the high prevalence in captivity may be explained by factors associated with their activity patterns in the wild and the aquatic environments provided for them in captivity. In the wild polar bears migrate farther than other ursids. Many populations live on ice year round and feed on a narrow spectrum of prey (pinnipeds). Some polar bear populations rarely, if ever, encounter the diversity of susceptible intermediate hosts of ascarids (primarily rodents and birds) as other bears. Even giant pandas occasionally hunt small mammals. Polar bears of the high arctic may be exposed to toxicants that bioaccumulate in their prey, but pathogens are diluted and contamination of organic debris is limited, relative to the habitats of temperate and tropical ursid species, which are also more sedentary. Hence, polar bears may not have coevolved as definitive hosts for roundworms that persist in both monoxenous (direct) and heteroxenous (indirect) life cycles.

Furthermore, polar bears defecate on land as well as in the water. On land their feces often freeze (in colder seasons) and are less likely to be dispersed by mechanical vectors or biological vectors (i.e. coprophasic birds and mammals) that may forage on their scat. Even is their scat is dispersed by mechanical vectors, conditions may not be conducive for larval development. Eggs are precluded from reaching viable embryonated stages in harsh climates. In the water, their scat is diluted or consumed by non-viable ectotherm hosts. Given these dilution factors and the constraints imposed on larval development in polar climates, polar bears may have relatively naïve immune responses to roundworm infections. Hence, in temperate climates where most captive polar bears are maintained, conditions are much more conducive to ascarid survival, persistence, and monoxenous life cycles. Water filtration in bear exhibits was associated with reduced prevalence of roundworm infections. Many polar bear pools are drained and cleaned manually. The effect filtration has on egg exposure may warrant the implementation or installation of sand filters or other filtration units used in aquaria or marine parks to complement aquatic life support systems. The incorporation of closed system filtration may also explain why the prevalence of ascarids is lower in polar bears than in sloth bears. Sloth bears are myrmeciphagous. Although they are not typically fed termites in captivity they do investigate substrates and organic debris with more fervor than other bears. Hence, they may be inadvertently exposed to saprophytic pathogens than other ursids. They also have long shaggy coats which may provide extra surface area for ascarid eggs to adhere to.

Zoos typically house bears on natural substrates, in naturalistic enclosures, whereby synthetic materials are used to construct displays which simulate natural habitats. Other zoos continue to house bears on artificial substrates, which have not been modified to mimic natural habitat. These traditional bear grottos and naturalistic exhibits may both be constructed out of artificial materials and some naturalistic exhibits incorporate organic materials in an attempt to simulate natural habitats. Natural exhibits are more commonly found among sanctuaries, where by animals are placed in natural environments, but confined by perimeter walls or fencing.

Many conventional zoos continue to display bears on hard surfaces. Concrete or gunite rock is the two most commonly used hard substrates (AZFA). The benefit to displaying bears in grottos include security, ease of sanitation or disinfection, and durability. These enclosures can safely contain these very powerful and destructive animals and have allowed zoos to display bears in open quarters separated by dry moats as opposed to behind cages. Bear pits are considered antiquated enclosures which predate the bear grottos. These were constructed out of brick or rock, and although they displayed the animals in what has been perceived as a negative context, they contained the animals. Hard substrates are easy to clean and endure inclement weather and destructive activities of bears. They were not designed for natural substrates and have drawn much criticism in recent years because they fail to provide environmentally enriched materials for animals that dig and uproot vegetation as a natural habit. There has also been concern that a lack of soft substrates may be detrimental to the physical health of bears (Forthama and Bakeman, 1992). Walking and running on hard surfaces may damage joints and put undue pressure on skeletal tissues. To mitigate these issues many zoos have made modifications to the surface and have and installed beds designated for placement of soft substrates. Others have packed soft-substrates on top of grotto surfaces to allow natural flora to grow and take root. Some may use a combination of both substrate beds and areas where hard surfaces have been removed and replaced with soft substrates or substrate has been added to the surface. There were very strong correlations between parasite prevalence for bears offered “ground substrates” and soft substrates, but not “hard substrates,” the category represented by rock, gunite or cement. Hence, this would suggest that parasite ova do not survive for long on hard substrates or do not develop to infective stages. However, the microenvironments provided by soft substrates with regard to temperature and moisture are likely conducive to the development and embryonation of ova. It is also much more difficult to clean, sanitize and disinfect enclosures with organic substrates. Hard surfaces are much easier to clean.

The used of straw which is primarily used for bedding down holding areas was correlated with a lower prevalence of roundworms in bears. This may be due to husbandry protocols associated with the use of bedding. Unless the bedding is contaminated with feces or urine, keepers will usually leave it undisturbed. Perhaps this leads to less frequent hosing of holding areas which both leads to the aerosolitazion of pathogenic agents and adds additional moisture to the area.

CHAPTER 11

MANAGEMENT REGIMES

11.1 Introduction

In the last century zoological parks have emerged as conservation centers (Moriarty, 1998). Archaic exhibitions of exotic animal menageries have evolved into captive wildlife sanctuaries and propagation facilities, whereby collections have been significantly reduced in size. Enclosures have been greatly enlarged and constructed as naturalistic exhibits. None-the-less, the exhibition of captive bears and other wildlife species has evoked increasing concern regarding the welfare of confined animals (Rietschel, 2002) which must adapt to artificial enclosures designed by man (Altmann-Langwald, 1996). In the past two decades, zoo animal welfare has been scrutinized to nearly the same degree as biomedical and agricultural livestock populations. Criticism has largely developed as a result of new legislation, societal pressures, and from psychological issues elucidated by the emerging field of applied ethology (Kreger, 1997). The mission of zoos is to maintain wildlife in captivity for conservation, research, education, and recreation (Tudge, 1991). These objectives are typically justifiable from ethical perspectives, if animal welfare standards are adhered to (Wickins-Dražilová, 2006). Primary criticisms, both justifiable and unwarranted include critiques of holding conditions, space, feeding and health status (Rietschel, 2002). More general criteria for meeting welfare standards include reproductive success, longevity, and physical health (Wickins-Dražilová, 2006). In terms of physical health, evaluations of both preclinical and clinical conditions must be considered (Dawkins, 2003). Fowler (1996) asserts that both housing and feeding programs are suboptimal and species specific concerns are often overlooked or misunderstood. Zoo managers must consider not only the natural history of the species, but the individual history of each animal and enclosure constraints in offering species specific provisions for environmental enrichment as a means of enhancing psychological welfare (Mellen and MacPhee, 2001).

Enclosure design catering to species-specific behaviors for Andean bears was considered the primary factory influencing animal welfare, aside from health care practices and has become the most influential factor contributing to captive carnivore welfare (Mallapur et al., 2002). For instance the enclosure design, for the Zurich zoo Andean bear collection, along with appropriate environmental enrichment and stimuli were standardized by Swiss animal welfare law and animal welfare regulations to optimize the physical and psychological well-being of captive carnivores (Rubel, 1996). Forthman and Baker (1992) reported that social factors including rearing history and conspecific composition, as well as environmental factors influenced social activity patterns among captive sloth bears. The authors recommended that social and enclosure variables be considered with regard to improving health management and propagation management programs. They also encourage that such biotic and abiotic factors be considered for the purposes of increasing the educational value of captive bear exhibition (Forthman and Baker, 1992; Reade and Waran, 1996). In a behavorial assessment of mother –reared polar bear at the Roger Williams Zoo, Greenwald & Dabek (2003) observed significant changes in behavior following exposure to environmental enrichment and husbandry training. Most recently, aberrant behaviors in bears and other wide ranging carnivores has been attributed to enclosure size. Animals with larger home ranges were reported to exhibit more stereotopies than species with smaller home ranges (Clubb and Mason, 2003). Commonly reported aberrant behavior in captive bears include excessive inactivity as well as stereotypic behaviors which include, but are not limited to pacing, head-swinging, and patterned swimming in polar bears. Polar bears may be the species most commonly reported to exhibit stereotypic behaviors (Meyer- Holzapfel, 1968; van keulen Kromhout, 1978; Jakobi, 1990; Ames, 1991; Carlstead et al., 1991; Weschler, 1991). All of these reports indicate that various factors induce these manifestations of aberrant behavior and the episodes vary in length and severity among individuals. Extrinsic factors include seasonality, photoperiods and climactic factors, feeding time, keeper interaction and other stimuli (e.g., loud noises). The reproductive status or management of oestrous has been implicated as an inductor of male stereotypic behaviors. Although feeding enrichment programs reduce stereotypic behaviors, they do not extinguish them. Stereotypic behaviors often resume when the animal has ceased feeding (Altman, 1999). Altman

(1999) reported species specific responses to environmental enrichment. Access to inedible objects and enrichment devices reduced stereotypic behaviors in Andean bears, increased stereotypic behaviors in captive bears, and elicited no response from sloth bears. Andean bears displayed a limited range of their species typical behavioral repertoire with respect to ethograms developed for behavioral evaluations of captive bears. Along with exhibiting a restricted subset of behaviors, they utilized a limited amount of space within the enclosure. The introduction of climbing structure for these arboreal ursids increased the diversity of behavioral activity as well as the uses of the enclosure (Renner and Lussier, 2002). A recent multi-institutional study of stereotopies in European brown bears showed that stereotopies were most common in medium aged animals that were housed in small exhibits. Stereotypic pacing was most frequently observed in animals, where keepers inadvertently reinforced pacing with food rewards. Older animals spent more time resting (Montaudouin and Pape, 2004). Vickery and Mason (2004) reported age and species specific differences in stereotypic behaviors as well as potential motivating factors for appetitive stereotopies in two different species of Asian bears. Hence, the authors recommend that evaluations of aberrant behaviors be evaluated in greater detail to determine factors influencing behaviors in specific age, gender and species cohorts.

For US zoos, the need to follow regulations set forth by the 1999 Animal Welfare Act (USDA-Aphis) has served prompted captive wildlife managers to reevaluate the psychological welfare of exotic collections. Some aspects of psychological behavioral welfare have been re-evaluated in the context of behavioral training and enrichment, and enclosure design (Tresz, 2006). Swaisgood and Shepherdson (2005) report that studies on stereotypic behaviors in zoo animals indicate that environmental enrichment reduces captivity- induced aberrant behavior, but more rigorous studies on larger samples sizes are warranted to predict the effects of enrichment as a husbandry tool to reduce and or eradicate stereotypic behaviors.

Mother reared and peer reared studies in captive pandas suggest that non-mother reared individuals lag behind in development in comparison to mother reared individuals. As a consequence, conspecific rearing programs should be tailored to provide social stimulation from sows (Snyder et al., 2003). More recently, a prevalence study of bone fracture disease in polar bears suggested nutritional deficiencies in the captive population and elicited concern regarding enclosure design in terms the physical well-being of polar bears maintained in captivity (Lin et al., 2005).

11.2 Materials & Methods

The data compiled for 260 bears included information on husbandry, enclosure parameters, as well as individual health profiles with specific data on roundworm infection histories. Captive managers were also asked to provide data on management with particular reference to animal access to exhibit and holding areas for a 24 hour period. Five discreet management tactics were reported. In order to access exhibits for daily cleaning, bears which are neither tractable nor managed in free-contact programs are brought inside or moved into adjacent holding areas for brief periods. Different management programs are dictated by a variety of factors. For security factors or husbandry training and conditioning regimens some managers bring bears in for the evening and lock them inside overnight. Others institutions may bring bears in during the day for extended periods and then permit them access to the enclosure. Access may or may not be restricted in these various management regimens have been reported and most institutions follow one or more of the following protocols depending on the individual or group of animals. Some bears are offered indoor or holding area access only. Others lock animals out on enclosure for much of the 24 hour cycle. Some institutions provide dual access to holding and exhibit areas. Others lock animals inside or in holding areas overnight, while others lock animals inside or in holding areas for part of the day, typically in the morning. This area access data is deemed relevant to the manifestation of stereotypic behaviors. Aberrant behaviors, particularly stereotypic pacing or swimming (i.e. polar bears) has been attributed to a variety of stressors, including access to living space. A Chi Square test was performed across management regimens and across species to determine if any of these variables influenced the prevalence of stereotypic behaviors.

11.3 Results

In analyzing the effects of different management regime categories, restricted access to space, either to exhibit or to holding areas, was a predictor of aberrant behavior. Stereotypies were also found to be species specific on the basis of the data provided from the surveys. There was a strong correlation between animals that were locked either outside ($P=0.000$) and prevalence of stereotypic behavior. There was also a slightly significant relationship between animals that were locked inside ($P=0.045$) and the prevalence of stereotypies. This supports earlier work on stereotypies which suggest that impeding control or access to food or mates induces stress responses. These manifestations of obsessive compulsive behavior may be a coping mechanism for dealing with appetitive behaviors. However, the prevalence of stereotopies ($P=.005$) was strongly associated with brown bears and slightly less profound in polar bears ($P=.023$). This contradicts the findings from the recent study on stereotypies in zoo carnivores (Mason 2005) and the most recent explanation for stereotypic behavior found in polar bears. The study found that animals with the largest home range were most likely to exhibit stereotopies. The data compiled from the survey submitted to zoos in this study indicate that brown bears were more likely to exhibit stereotopies than polar bears, but polar bears have longer home ranges. However, these species are closely related, the largest members of Ursidae and have the largest home ranges among the bear family.

Other bears may hunt small mammals with greater frequency and have evolved as definitive hosts for heteroxenous life cycles. Polar bears were significant indicators of roundworm prevalence (P=.004), as were sloth bears (P=.013). The six other species were not independently associated with a higher prevalence of ascarid infections.

CHAPTER 12

COMPARISON OF TWO COPRODIAGNOSTIC TECHNIQUES FOR THE SURVEILLANCE OF *BAYLISASCARIS* INFECTIONS IN CAPTIVE BEARS

12.1 Abstract

Several coprological assays have been developed for diagnostic study of endoparasites. Passive or stationary flotation techniques are most commonly used in zoological parks, followed by centrifugation floatation procedures for parasite ova detection. Recovery rates for parasite ova are typically greater when samples for floatation procedures incorporate centrifugation. The integrity of ascarid egg shell morphology is preserved with sugar floatation media. In this study the prevalence and intensity levels of *Baylisascaris transfuga* ova from captive bears were determined using both passive flotation and flotation centrifugation techniques to compare recovery rates.

12.2 Introduction

Coprological assays for the detection of parasite ova, larva, cysts, and oocysts encompass the most widely practiced diagnostic procedures used in both human and veterinary clinical parasitology (Cringoli, 2004). Modifications to copromicroscopic techniques continue to be developed to enhance the diagnostic study of disease and increase the sensitivity of the fecal parasite assays. The emergence of parasitic zoonoses and public health concerns regarding parasitic diseases of domestic species and wildlife, warrants the development of more sensitive diagnostic techniques for veterinary medicine, as does the growing concern for parasite resistance to anti-helminthic drugs. More adequate detection of parasitic pathogens can lead to the diagnoses of illnesses and promote more efficacious control strategies and preventive medicine protocols.

Several studies report higher recoveries of parasite ova in feces when flotation procedures are combined with centrifugation techniques (Zajac et al., 2002; Cringoli 2004; Dryden et al., 2005). Although zoo surveillance programs for helminth parasites include routine fecal submissions for parasite ova detection, the coprological assays employed are not always sensitive enough to detect the prevalence of parasite eggs. The majority of zoos continue to utilize passive or stationary floatation, whereby fecal specimens are suspended in a fluid medium with a specific gravity that is higher than that of the parasite ova. Hence, the parasite ova can be recovered, as they ascend to the surface of the selected media. Several studies indicate that ova recovery is enhanced by centrifugation of the suspension. The selection of floatation media also influences the recovery of parasite ova. Although Sheathers effectively recovers parasite ova when used as flotation media for centrifugation procedures, the sugar solution is not as effective as sodium nitrate in recovering parasite ova in passive flotation procedures. In the case of ascarids, adult females produce 200,000 eggs per day which are eliminated in the hosts’ excrement (Dryden et al. 2005). Routine testing is recommended because eggs are not shed consistently in the feces. Hence, a series of fecal samples should be submitted for coprodiagnostic study following an administration of antihelminthics to ensure that the worms have been eliminated or rendered reproductively unviable.

In captive ungulates, nematode infection levels were influenced primarily by husbandry conditions, and to a lesser degree, by species specific or individual susceptibility to parasite infections (Goosens et al., 2004). Elucidating patterns of helminth infections in zoo animals permits the development of more efficacious enclosure specific or species specific helminth control programs.

12.3 Materials & Methods

Ten grams of bear feces were requested from all species of individual bears maintained at (Zoos). Bear feces were collected by animal care staff from feces of individual bears Samples were collected fresh or within 24 hours from holding cages and/or from fecal deposits on exhibit and placed in plastic whiplock bags. Institutions which could not isolate animals utilized food markers or provided composite samples from no more than two animals. The samples, contained in bags, were returned in coolers to the Laboratory for Wildlife & Environmental Health at the Department of Veterinary Preventive Medicine at The Ohio State University. The samples were shipped overnight and stored in their respective coolers in a walk-in Forma Scientific Laboratory Environmental Chambers. Two Five gram samples of feces were placed in separate 15 ml or 50 ml polypropylene centrifuge tubes. The samples were prepared and submitted for coprodiagnostic analyses using two fecal floatation methods. A passive floatation was conducted using a commercial formula of solution of Sodium Nitrate (Fecasol ™) with a specific gravity between (1.18-1.20 sg). Fecal specimens were suspended in Fecosol and a cover-slide was placed atop the meniscus formed at the surface of the suspension/solution. The 24 X 40 (960 sq. mm) coverslip was removed after 15 minutes and placed on a glass slide (25 X 75 X 1.0 mm) for microscopic examination. Roundworm ova were subsequently examined under light microscopy using a Nikon Eclipse E400 Light Microscope lens (40 X 100). All contents under the coverslip were examined for the prevalence and intensity levels of *Baylisascaris* ova. The remaining 5 grams of fecal specimen contained in centrifugation tubes were submitted to personnel at the University Laboratory Animal Resources (ULAR) diagnostic lab at The Ohio State University's College of Veterinary Medicine for coprodiagnostic parasite ova assays using a centrifugation flotation technique. A Sheather's sugar solution (SG 1.27) was prepared at Ular 454 grams granulated sugar, dissolved in 355ml water, with stir bar over low heat and stored in a refrigerator by ULAR personnel. Upon reception or within 5 days of receipt of the samples, the centrifuge tubes were placed in a Marathon 3200 rotating head centrifuge for 5 minutes at a speed of 1100 RPM for five minutes and a 22 X 22 (484 sq. mm)cover-slip was placed atop the positive meniscus formed at the surface of the suspension/solution. The coverslip was removed after 10 minutes and placed on a glass slide (25 X 75 X 1.0 mm) for microscopic examination. The coverslips were not of equivalent surface area and hence the egg counts for the centrifuge data which were counted under a 484 sq mm coverslip was multiplied by a factor of 1.9835 to standardize the counts and remove the random effect of disparate coverslip slides from the following results. Prevalence and intensity levels were recorded for individual bears. Fecal specimens submitted to ULAR were labeled with a code to prevent any subjective biases on a part of the examiner, with regard to species, gender, age, or home institution. Each centrifuge was labeled with a code. Both prevalence and intensity levels of *Baylisascaris* eggs were determined for each sample submitted form bears.

12.4 Results

Fecal samples were obtained from 76 bears housed at 16 US zoos (see table 11) (Erie Zoo, Erie Pennsylvania; Houston Zoo, Inc., Houston Texas, Cheyenne Mountain Zoo, Cheyenne Colorado; Fresno Zoo, Fresno, California; Buffalo Zoo, Buffalo, New York, Cleveland Metroparks Zoo, Cleveland, Ohio, Columbus Zoo & Aquarium, Columbus, Ohio; Seneca Park Zoo, Rochester, New York; Washington Park Zoo, Michigan; Alaska Zoo, Anchorage Alaska; Silver Springs bear park, Silver Springs Florida; San Francisco Zoo, San Francisco, California; Jacksonville Zoo, Jacksonville, Florida; Pittsburgh Zoo & Aquarium, Pittsburgh, Pennsylvania; Zoo Atlanta, Atlanta, Georgia; Toledo Zoo, Toledo, Ohio). Fecal samples were obtained from all eight species of bears (2 giant pandas; 2 Asiatic black bears; 4 sloth bears; 4 sun bears;13 American black bears; 15 polar bears; 17 Andean bears; 19 brown bears) . Both passive floatation and centrifugation floatation Diagnostic techniques were performed on 120 samples, representing 76 bears paired T-Test was performed on the egg counts for 76 bears for data obtained from passive floatation techniques and centrifugation flotation techniques. A significant difference was found in the recovery of eggs between the two coprodiagnostic assays employed for the evaluation of ascarid ova intensities (P=.001). The mean intensity level for the samples that were centrifuged was 105.762 eggs per cover-slip and the mean intensity level for the samples submitted for passive floatation was 1.237 eggs per cover slip. For the 76 samples from individual bears, 10 of the samples were positive when subjected to centrifugation, but no eggs were detected when the same samples were submitted for passive flotation coprodiagnostic assays.

12.5 Discussion

Evidence from the comparative study of coprodiagnostic tests suggests that the dynamic procedure of centrifugation floatation will detect substantially more ascarid ova than the passive floatation method. Our data supports earlier studies by Zajac et al. (2002), Cringoli (2004) and Dryden et al. (2005) which indicated the higher sensitivity or enhanced recovery of eggs when centrifugation techiniques were incorporated with floatations. As hypothesized, the ability of two coprodiagnostic flotation methods to recover *Baylisascaris transfuga* eggs was significantly different. The selection of floatation media also influences the recovery of parasite ova. Although Sheathers effectively recovers parasite ova when used as flotation media for centrifugation procedures, the sugar solution is not as effective as sodium nitrate in recoving parasite ova in passive flotation procedures. In the case of ascarids Sheather's solution is the preferred medium for recovering ascarids and may particularly efficacious because Sheathers is inexpensive and commonly used for centrifugation floatations. In zoos centrifugation may also be more practical than for general practices, because centrifugation reduces procedure time. Sugar solution can also be easily prepared, and although it is a sticky medium to work with, it does not distort the ova, as do the salt solutions which crystallize after a short period. Hence, sugar also allows clinicians to maintain ova on slides indefinitely. In a follow-up request for information on coprodiagnostic parasite procedures used in zoos, ten institutions responded: Columbus Zoo & Aquarium; Pittsburgh Zoo & Aquarium; Brookfield Zoo; Zoo Atlanta, Houston Zoo, Inc, Living Desert Zoo and Gardens State Park; Philadelphia Zoo, Erie Zoo Minnesota Zoo, Hershey Park's Zoo America, Topeka Zoo, Sedwick County Zoo, Montgomery Zoo. One of 13 zoos (7.6%) used centrifugation floatation along with passive floatation, and one institution use fecal smears along with passive floatation. If this sample is representative of most institutions, most are significantly underestimating the prevalence of roundworms in their bear collections. This leads to several problems. First, they may be placing quarantined animals on exhibit because their diagnostic tests provided evidence for negative results which were indeed positive. Hence, the diagnostic procedures are not sensitive enough and animals are inadvertently released into enclosures where they contaminate or recontaminate holding areas and exhibit and subsequently infect other bears. Secondly, they may continue to use the same antihleminthic because there would be little concern for inducing parasite resistance as the parasites are perceived to have been eliminated, and the drug perceived to have been most effective in eliminating worms. Hence, these institutions may be less inclined to try new drugs or develop and alternation regiment for the purposes of preventing parasite resistance. Finally, many sanctuaries and rehabilitation centres which may hold bears from multiple sources and participate in release and perhaps repatriation programs, may inadvertently release animals suspected to be cleared of infectious agents. Conservation based reintroduction programs have decimated wild populations because of disease agents that were transmitted to wild conspecifics or naïve and aberrant host species. Because adult worms shed intermittently and bears are dewormed routinely or as needed, the results, in some cases may inflate or greatly underestimate roundworm infections. The samples may have been submitted at a time when eggs were not shed, but worm infections were profound. Alternatively, samples may have been provided follow antihelminthic administration. Future diagnostic studies are warranted which evaluate repeated submissions with great frequency throughout a year or more. This would eliminate confounding variables associated with the intermittent shedding of eggs and the chance that samples were provided post treatment. This would allow for more intensive and comprehensive analyses of drug efficacies and permit repeated sampling measures both pre and post treatment.

CHAPTER 13

FIELD RESEARCH

13.1 Introduction

The emerging field of interactive or integrated conservation (Conway) involves a holistic or collaborative approach to propagation, reintroduction, and repatriation programs. Hence, epizootiological studies of both captive and free-ranging wildlife are warranted to effectively execute combined *Ex Situ & In situ* conservation initiatives for threatened and endangered wildlife species. Although wild bears are host to a number of helminthes with both monoxenous (nematodes) and heteroxenous (cestodes, nematodes and trematodes) protozoans and ectoparasites, they rarely harbor intensity levels or high incidences of ascarid infections as have been reported in captive bears. Hence, it is important to routinely survey captive bear infection levels and free-ranging bear infection levels to remove disease threats which may unknowingly sabotage conservation initiatives via the transmission or inadvertent contamination of pathogens in and between wild and captive populations. The purpose of this study was to obtain baseline parameters of parasite prevalence and intensities among and bear populations over two collecting seasons.

13.2 Materials & Methods

Scat was collected from Coastal brown bears from two isolated populations in Alaska during the August of 2004 & August of 2005 in pristine preserves accessibly only by float plane. Visible deposits of fresh and (old) scat were collected in the remote tundra of Katmai National Park (gps coordinates) where brown bears aggregated along (riparian habitat) riverine habitat during late seasonal spawning runs of red and silver salmon. The fecal samples from some known and unknown individuals (as advised by C. Day) were returned to the Laboratory for Wildlife & Environmental Health. Samples were also shipped from C. Day following opportunistic collections during the preceding months for the respective and aforementioned collection periods while guiding visitors through the park. Twenty –three viable samples were collected over a period of two summer seasons (2004-2005) from Katmai National Park and five brown bear scat samples were collected along riverine habitat on Admiralty Island (Coordinates) during August of 2005.

13.3 Results

All 28 samples were negative for roundworms and tapeworm ova despite the likely predation on small mammals and fish scales and ototliths and other skeletal remains found in the Scat.

13.4 Discussion

It is unclear from a review of the literature on helminth surveys from nearby collection sites in Alaska, as to whether or not ascarids have been previously reported in these remote and relatively pristine coastal regions of AK where brown bears are known to aggregate. If an absence of parasites are indicators of health or lack of exposure to fomites, introduced host reservoirs (e.g. via paratenic host predation) or cross species transmission /contamination from wild, feral or domestic canids or other carnivores, than these bear populations which habitually aggregate at seasonal salmon runs are healthy. Alternatively, wild brown bears in less remote regions with reported infections of *Baylisascaris* spp. (i.e. grizzly bear populations) and captive brown bears are thus hosts to parasites which are not necessarily normal enteric pathogens in bears. Further study on remote wild populations of bears from habitats where paratenic mammalian hosts are more commonly consumed may further support or refute this assertion. If these results are indeed representative of infection levels in a multitude of populations of free ranging brown bears, the high prevalence of roundworms in bears may warrant more aggressive efforts to eradicate round worms from captive bear populations and decontaminate bear enclosures. This investigation would be particularly worth investigating, given concern for emerging *Baylisascariasis* in aberrant hosts maintained in zoo collections, the zoonotic potentential for the pathogen with regard to clinicians and animal care takers, and the renewed interest in brown bear repatriation programs in Europe.

CHAPTER 14

PROPHYLACTIC AND POST- INFECTION TREATMENT

14.1 Introduction

Several chemotherapeutic agents have long been recognized as effective in the prophylactic and post infection treatment of ascariasis in definitive hosts (Katz, 1977). Treating larval migrans in definitive or aberrant hosts has been much less successful, and depends greatly on the location, number and pathogenic index of the species of migrating larva. Laser surgery can reverse ocular damage produced by larvae which have migrated through the retina. Much more documentation exists for the treatment and elimination of raccoons with *Baylisascaris*. The most effective parasiticidal agents used in the treatment and control of raccoon roundworms include piperazine, fenbendazole, pyrantel pamoate, levamisole and the organophosphate dichlorovos. Kazacos (2001) successfully cleared raccoons of adult worms with single administrations of piperazine citrate (120–240 mg/kg), pyrantel pamoate = embonate (6–10 mg/kg) and fenbendazole given at 50–100 mg/kg for 3–5 days. Bauer and Gey (1995) demonstrated the efficacy of six ant-helminthics (pyrantel embonate = pamoate; 20 mg base/kg; ivermectin (1 mg/kg); moxidectin (1 mg/kg); albendazole (50 mg/kg daily for 3 days); fenbendazole (50 mg/kg daily for 3 days); and flubendazole (22 mg/kg daily for 3 days)) at necropsy seven days post treatment. Ivermectin delivered to raccoons at 2 mg/kg was also highly effective in treating adult worms as determined by subsequent coprodiagnostic study (Hill et al., 1991). Veracruse et al., (1976) successfully treated 5 polar bears with Menbendazole. Mechanisms of action for anti-helminthics used in the treatment of *Balisascaris* and other helminthic infections in natural hosts include a variety of biostatic and biocidal modalitities which do not effect biochemical pathways of hosts, but successfully target and interrupt biological function of adult worms, larvae and their eggs. The mechanisms of action of these drugs include the inhibition of microtubules which induces an irreversible blockage of glucose uptake, rendering the parasite metabolically impaired. The inhibition of tubulin polerimization precludes microtubule formation. Fenbendazole (Panacur), a member of the benzimidazole class of antihelminthics is commonly administered to raccoons and bears in captive collections to eliminate nematodes, cestodes, trematodes and protozoa. Fenbendazole is not readily absorped in the gut. The drug is largely passed in feces and some of the drug which is metabolized to oxfendazole in the liver, is returned to gut in bile. The drug is totallyeliminated in 48 hours. Another commonly used benzimidazole is mebendazole (Telmintic powder) Febantel (Drontal Plus also contains pyrantel pamoate and praziquantel).

Pyrantel embonate and Pyrantel pamoate belong to the chemical class of agents known as Imidazothiazole. As an acetylcholine agonist and hence, depolarizing neuromuscular blocking agent, this class of drugs induce rigid muscle contractions of the muscles. Imidazothiazole derivatives like target nerve ganglia and impair nematode muscle cell membranes. These salts effectively treat ascarids and other nematodes. Vacuolization of the schistosome tegument, increased cell membrane permeability, resulting in intracellular calcium loss and increased cell membrane permeability to chloride ions via chloride channels precludes physiological processes required to sustain life.

Macrocyclic lactones are a broadspectrum, relatively non-toxic class of anti-helminthics which have emerged as perhaps the most effective parasiticides for treatments of human and animal parasites. The macrolides are antibiotics derived from streptomycete microorganisms. They bind to glutamate gated chloride channels, and trigger an influx of chloride ions (Arena et al 1991, Martin 1993; Shoop et al. 1995). This mechanism of action hyperpolarizes the neuron of parasites and precludes the normal conductance of action potentials. Subsequently, the macrolides paralyze and kill the parasites. Ivermectin is marketed under several trade names. Heartgard Plus which also contains Pyrantel Pamoate was developed for canids and effectively treats *Toxocara canis*. It is less effective in the treatment of *Toxascaris harmac* and *Toxascaris vulpis*. The combination of ivermectin and pyrantel pamoate has been marketed under the proprietary name HeartGard 30- Plus and has been reported to effectively treat and control *Toxocara canis* and *Toxascaris*.

Selemectin was formulated as a semi-synthetic derivative of Doramectin (Dectomax), an avermectin labeled for use in the treatment and control of bovine and swine parasites. Hence, Selemectin is a modified form of a mutant strain of the fermentation product *Streptomyces avermitilis* (Bishop et al. 2000). In cats, it has shown to be effective in the treatment and control of *Toxocara cati* and McTier et al. (2000) reported its efficacy in the control and treatment of *Toxocara canis* and *Toxocara leonine* in dogs.

Milbemycin oxime is derived from the fermentation of *Streptomyces hygroscopicus aureolacrimosis* and has both a similar structure and mechanism of action as Avermectins. It has shown efficacy against Toxocara canis in experimentally infected dogs (Bowman et al., 1988; Bowman, 1992).

Benzimidazoles are another group of broadspectrum class of antihelminthics that have been used in the control and treatment of human and animal helminthiasis (Cambell, 1990; Lacey, 1990; McKellar and Scott, 1990). However, reports of helminth resistance to benzimidazoles have been reported in many species and albendazole, mebendazole, and oxfendazoles are known teratogens, precluding their uses in pregnant animals (Lynn, 2003). Benzimidazoles selectively bind to Tubulin molecules of nematodes, exhibiting a much lower affinity for binding to Tubulin of mammals. Tubulin binding precludes microtubule formation and subsequently disrupts cell division (Frayha et al. 1997;

Reinemeyer and Courtney, 2001). Through its inhibition of fumarate reductase, benzimidazoles deplete parasites of energy, through the blockage of mitochondrial function (Lynn, 2003). Febantel, a nonbenzimidazole is metabolized to fenbendazole, which is approved for use in zoo animals and oxfendazole, a benzimidazole which is used to treat helminths in bovids and equids. Fenbantel, praziquantel, a cestocidal agent, and pyrantel have been formulated as a broad-spectrum antihelminthic under the trade name Drontal Plus. As an ascaracidal agent it effectively treats *Toxocara canis, Toxascaris leonine,* and *Toxocara vulpis* (Bowman and Arthur, 1993; Cruthers et al., 1993).

Several salts of Pyrantel, morantel, and oxantel represent the class of Tetrahydropyrimidines. Tetrahydropyrimidines are very potent nicotinic agonists. They induce tonic paralysis through the disruption of neuromuscular function in nematodes (Aubrey et al. 1970; Eyre, 1970, Martin 1993). Pyrantel is the most commonly used tetrahydropyrimidine. Pyrantel pamoate, marketed under the trade name Nemex is labeled for use in dogs for the treatment of *Toxocara canis* and *Toxascaris leonine.*

14.2 Heterrocyclics

Piperazine and its analogue diethylcarbazine have central heterocyclic rings. They disrupt GABA neurotransmission through the production of a neuromuscular blockade. Piperazine has shown to be effective against *Toxocara canis*, *Toxocara cati* and *Toxascaris*. (English and Sprent, 1965; Sharp et al., 1973, Jacobs, 1987; Jacobs

1987). Diethylcarbamazine is marketed under the trade names Filaribits and Nemacide and shows some efficacy in the treatment of *Toxocara canis*, *Toxocara cati* and *Toxascaris leonine* (Arundel et al., 1985).

Several broad-spectrum combinations are now available for treatment of nematodes and other helminth parasites. Trivermicide worm capsules contain both a cestocidal and nematocidal agent. Trivermicide contains the nematocidal agent methylbenzene and dichlorphene as the cestocidal agent. This compound successfully treats *T. canis*.

Iverheart Plus, Ivomec), Moxidectin (PROHEART, Proheart 6),) Selamectin (Revolution, Milbemycin oxime (Interceptor, Sentinel also contains Lufenuron) are commonly administered Macrocyclic lactones. Selamectin the newest of the Macocyclic Lactones and is marketed under the trade name Revolution. It is labeled for use in domestic canids and effectively treats *Toxocara cati* (McTier et al., 2000*)*. In carnivores the half life of the drug is 24-36 hours. With the exception of adult heartworms, Ivermectin is used to treat adult nematodes and mites. It is not effective against cestodes. Dichlorvous, marketed under the trade name Task, is an organophosphate which inhibits acetycholinesterase. Normally acetycholinesterase removes acetycholine from post synaptic junctions. The accumulation of acetycholine in gap junctions induces continued depolarization of neurons and subsequently results in paralysis of the parasite (Fest and

Schmidt, 1982). Piperazine is marketed under the following proprietary names: Pipa-tabs, Tasty Paste, WRM Rid. It is a GABA agonist. Hence, like the neurotransmitter GABA, piperazine effectively induces the hyperpolarization of nerve membranea and subsequently causes flaccid paralysis of nematodes. As with the induction of paralysis by other antihelminthic agents the worms are removed by normal peristalsis of host gut musculature.

Diethylcarbamazine citrate is commonly used in dogs as a heartworm prophylactic and is also used to treat *Toxocara* spp. and *Toxascaris*. It is marketed under the following proprietary names: Filaribits Plus w/ oxibendizole; Filaribits; Nemacide. This herterocyclic compound is closely related to piperazine citrate.

Although fenbendazole, the only benzimidazole labeled for use in zoo carnivores for the treatment of ascarids, it is not the only anti-helminthic selected by zoo animal health managers and clinicians for use in the prevention, control and treatment for zoo parasites, although it does have cestocidal and trematocidal properties, in addition to its high level of efficacy in the treatment of nematodes. Milbemycin and avermectins are another class of broad spectrum antihelminthics that are often administered with greater frequency for prophylactic measures, and specifically to prevent heartworm infections in carnivores. *Dirofilaria* spp. Are known to infect a great number of carnivore hosts and thus macrolides are commonly used because of their efficacy in both the treatment and control of of blood or vector-borne nematodal parasites other nematodes, including roundworms and ectoparasites. Pyrantel, a tetrahydropyrimidine is also commonly used in the treatment of roundworm infections.

14.3 Materials and Methods

The prophylactic and post-infection treatment regimens for the prevention and control of bear roundworms were surveyed at 123 international captive wildlife facilities. Information on drug selection, dosage, administration rates and frequencies, formulas, and delivery of parasiticides were requested.

14.4 Results

Five classes of drugs were used in parasite control regimens in captive facilities, although not all parasiticides were antihelminthics (Figure 33). The sulfa drugs (sulfonimides) were used presumably used for the treatment of coccidiosis. Aside from antiprotozoals, and cestocidal Isoquinolones (praziquantel & epsiprantel, etc.) all other classes of drugs (Macrolides (milbemycin & avermectins); Benzimidazoles; Tetrahydropyrimidines (pyrantel)) were used in parasite control programs for helminth infections. Heterocyclics (piperazine) were reported from incomplete data set for certain zoos and used in treatment for parasites in the 492 bears for which some or all data was provided. Although some institutions have implemented species specific or individual parastite control protocols, the majority of institutions use the same prophylactic treatments for all species of bears and all individuals. Thirty-six of the 290 bears for which completed data was provided, received commercial pharmacotherapeutics composed of multiple agents or received different drugs (within a drug class) or agents from different drug classes in rotation. Six drug class combinations or alternation regimens were reported. The most commonly administered drug classes were macrolides, followed by benzimidazoles, tetrahydropyrimidines, isoquinolones (cestocides) and sulfonimides (anti-protozoals).

14.5 Discussion

Many drugs reported to be used in this study are for prophylactic treatment. Hence, concern for heart worm infection dictates much of the implemented protocols for parasite control. Unfortunately, those institutions which do not report non vector mediated helminth prevalence, or undereport prevalences, as a result of insufficient or insensitive coprodiagnostic studies, may be inadvertently promoting drug resistance. Only 12% percent of the reported drug regimens for individual bears suggest concern for drug resistance. Those zoos which administer compounds or alternate drugs may be protecting their own collections, but can make little contribution to the collective populations of captive bears. Most facilities implement routine administrations of single drug or drug classes in their preventive medicine protocols and inadvertently promote drug resistance. As more genomes of drug resistant helminths permitted to persist in captive host reservoirs evolve, the more difficult it will be to manage parasite control, particularly given the continued practice of moving animals between zoos and the growing practice of integrated conservation which involve exchange of animals among zoos, sanctuaries, and rehabilitation facilities. The renewed interest in translocation and repatriation programs for bears will further exacerbate the issue.

APPENDIX

Common Name	Species	Number of Individuals
Asiatic black	(*Ursus thibetanus*)	21
Brown	(Ursus arctos)	58
Giant panda	(Ailuropoda melanoleuca)	5
American black bear	(Ursus americanus)	54
Polar bear	(Ursus maritimus)	51
Sloth bear	(Melursus ursinus)	14
Spectacled bear	(Tremarctos ornatus)	25
Sun	(Helarctos malaynus)	29

Table 1 Number of bears (classified by species) for which parasite data was provided

Common Name	Species	male	female	unknown
Asiatic black	(*Ursus thibetanus*)	3	9	9
Brown bear	(Ursus arctos)	24	24	11
Giant panda	(Ailuropoda melanoleuca)	2	2	1
American black bear	(Ursus americanus)	21	18	15
Polar bear	(Ursus maritimus)	20	26	5
Sloth bear	(Melursus ursinus)	5	7	2
Spectacled bear	(Tremarctos ornatus)	16	9	0
Sun bear	(Helarctos malaynus)	8	16	7

Table 2 Gender ratio for bears

Common Name	Species	Mean Age	Range
Asiatic black	(*Ursus thibetanus*)	14.79	2.5-28
Brown	(*Ursus arctos*)	13.42	67-38
Giant panda	(*Ailuropoda melanoleuca*)	5.15	.75-7
American black bear	(*Ursus americanus*)	10.83	2.5-25
Polar bear	(*Ursus maritimus*0	14.27	1-33
Sloth bear	(*Melursus ursinus*)	11.21	2-23
Spectacled bear	(*Tremarctos ornatus*)	14.53	.6-28
Sun	(*Helarctos malaynus*)	17.93	5-33

Table 3 Mean age and age range of bears (classified by species) for which parasite data was provided

Captive born	Wild Born	Unconfirmed
158	91	11

Female	Male	Unconfirmed
111	99	50

Table 4 Rearing History and Gender for 260 bears for which parasite data was provided

		Roundworm Prevalence	
Common Name	Species	Not Reported	Positive
Asiatic black	(*Ursus thibetanus*)	17	4
Brown bear	(*Ursus arctos*)	19	40
Giant panda	(*Ailuropoda melanoleuca*)	4	1
American black bear	(*Ursus americanus*)	39	15
Polar bear	(*Ursus maritimus*)	17	34
Sloth bear	(*Melursus ursinus*)	2	12
Spectacled bear	(*Tremarctos ornatus*)	16	9
Sun bear	(*Helarctos malaynus*)	21	10

Table 5 Prevalence of roundworms reported and/ or confirmed for 260 bears

Hard Substrates (Cement; Gunite; Rock)

Substrate Present
117 bears positive
23 bears negative

Substrate Absent
8 bears positive
112 bears negative

Table 6 Prevalence of roundworms for bears maintained with or without “hard,” substrates.

Soft Substrates (Sand; Soil)
Substrate Present
79 bears positive
41 bears negative

Substrate Absent
46 bears positive
91 bears negative

Table 7 Prevalence of roundworms for bears maintained with or without “soft” substrates.

Loose Substrates (Woodchips; Fallen bark; Vegetation)
Substrate Present
80 bears positive
40 bears negative

Substrate Absent
45 bears positive
95 bears negative

Table 8 Prevalence of roundworms for bears maintained with or without “loose” substrates.

Bedding Substrate (Straw)
Substrate Present
53 bears positive
41 bears negative

Substrate Absent
72 bears positive
94 bears negative

Table 9 Prevalence of roundworms for bears maintained with or without straw
Filtration (Automatic)

Automatic
23 bears positive
61 bears negative

Manual/No filtration
102 bears positive
74 bears negative

Table 10 Prevalence of roundworms for bears maintained with or without water filtration

Passive Float Test		**Centrifugation Results**	
Fecal Results	**# Tests**	**Fecal Results**	**# Tests**
Negative	69	**Negative**	59
Positive	7	**Positive**	17

Passive Float Test		**Centrifugation Results**	
Fecal Results	**# Tests**	**Fecal Results**	**# Tests**
Negative	120	**Negative**	110
Positive	7	**Positive**	17

Table 11 Prevalence of roundworm for passive and centrifuged floatation techniques

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