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Survey of Intestinal Parasites in Zoo Populations of Two Central Illinois Zoos and Study of Current Anti-Parasitic Drugs and Prophylactic Techniques

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SURVEY OF INTESTINAL PARASITES IN ZOO POPULATIONS OF TWO CENTRAL ILLINOIS ZOOS AND STUDY OF CURRENT ANTI-PARASITIC DRUGS AND PROPHYLACTIC TECHNIQUES

by

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VITA

The author, Verona A. Barr, is the daughter of John N. Marx and Grace A. (Lewandowski) Marx. She was born November 24, 1953, in Chicago, Illinois.

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Together with Dr. Benedict J. Jaskoski and Manfred Borges, Verona Barr has published the article, "Intestinal Parasites of Well-Cared-For Dogs: an Area Revisited" in the American Journal of Tropical Medicine & Hygiene, in 1982.

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INTRODUCTION AND LITERATURE REVIEW

HISTORICAL

Since the earliest days when man and animal found it necessary to live together in close association, one of the most health hazardous and persistent problems for both, has been that of the parasite. The problem became glaringly apparent when animals of many different types were gathered together in menageries or zoos. At this point, it became obvious that individuals of many species might be afflicted with specific internal and external parasites which would cause the animal grave illness, even death. Not only dangerous for the animal collection, it has been reported over the years that man can become a host for various of these intruders.

It was for these reasons that investigators had begun to take an interest in zoo animal parasitism, that is, what parasites were involved, were they a potential hazard to the animals' lives, or to man, and how can they be eliminated, or at least be kept at a level where they will do the minimum amount of damage. The first reference to parasites of zoo animals found was that of Molin (1860) who described Spiroptera suboequalis removed from the stomach of a tiger. This was followed quickly by the work of Cobbold (1861) who described several new species of internal parasites from animals which died at the London

Zoological Society's menagerie between 1857-1860.

Following these early investigators there have been many researchers who have reported on the species of helminths and protozoa which can be found infecting exotic and domestic captive animals. Cobbold (1870, 1882) continued his work and later reported on a new genus of internal parasite from the aardwolf, as well as describing the parasites of elephants. Weidman (1913) gathered data from autopsies of animals from the Philadelphia Zoological Gardens. Vevers (1920, 1922) reported on parasitic nematodes collected from mammals which died at the Gardens of the London Zoological Society during 1919-1921. Liubimov (1927) reported filaria found in ruminants in the Moscow Zoological Park. Canavan (1929, 1931) reported occurrence of parasites of vertebrates in the Philadelphia Zoological Gardens and vicinity. Autopsies were performed on animals dying at the Calcutta Zoological Gardens by Maplestone (1931) and Meggitt (1933). In the New York Zoological Park, McClure (1932, 1933, 1934) Elek and Finkelstein (1939), Herman (1938, 1939), Olsen (1939) and Schroeder (1939) examined autopsied animals and feces from living animals for parasites. Ezzat (1945) examined helminth parasites of ungulates from the Giza Zoological Gardens in Egypt.

Shakhnazarova (1946) was one of the first investigators to experiment with prophylactic techniques to try to control a recurring parasitic infection. He

reported the control of ascariasis in the Moscow Zoological Park through use of a hot air blower with temperatures ranging from 225°F to 250°F. Ascarid ova were destroyed by this method, however the scheme proved impractical for general use since it took approximately one hour and twenty minutes to treat an area ten square meters.

Kreis (1952) reported on helminth infections at the Swiss Zoological Gardens and Porter (1953, 1954) collected parasites from animals at the London Zoological Gardens. Jaskoski and Colglazier (1956) reported Strongylus asini recovered from the liver of a Grevy zebra at Chicago Zoological Park, Brookfield, Illinois. Jaskoski and Williamson (1957, 1958) studied the prevalence of parasites at the Chicago Zoological Park, and later, Jaskoski and Krzeminski (1960) investigated the occurrence and distribution of parasites in animals at Lincoln Park Zoological Gardens and Indian Boundary Zoo in Chicago. K'Ung and Yin (1958) reported on some parasitic nematodes from wild animals in the Peking Zoological Garden, while in Holland, Swierstra, Jansen and Broek (1959) performed a survey of parasites of zoo animals in the Netherlands from 1948-1958. Davis and Anderson (1971) have compiled an informative text on the parasitic diseases of wild mammals. Levine and Ivens (1970, 1981) authored reports on the coccidian parasites of ruminants and carnivores. Howard and Gendron (1980) reported a tapeworm infection

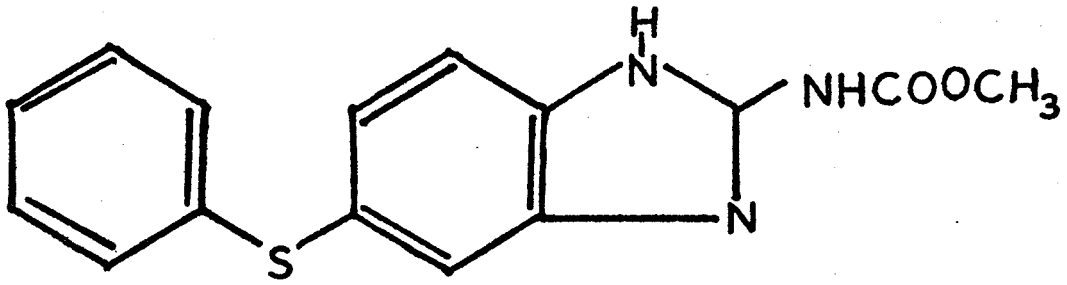
of higher primates at the Los Angeles Zoo.

A review of the literature shows that very little has been published regarding parasite surveys or individual parasite findings in zoological parks since the early 1960s. This study is intended to try to add to the early body of literature that has been published, some information on the drugs and techniques that have come into use since the sixties.

ANTI-PARASITIC DRUGS

Anti-parasitic drugs have undergone much testing and refinement over recent years. Whereas, in previous studies concerning their use, many test subjects became ill and some died as a result of treatment, today there is available a wide variety of safe and effective drugs for any parasitic infection that may be encountered. As Brander and Pugh (1977) state in their text on veterinary pharmacology and therapeutics, there are criteria for an "ideal" anthelmintic which can be met by many of the formulations currently available.

Fenbendazole, methyl 5-(phenylthio)-2-benzimidazole-carbamate, is a light brownish-gray, odorless, tasteless crystalline powder. Its empirical formula is $C_{15}H_{13}N_3O_2S$, and it has a structural formula as follows:



It has been shown to be effective against Strongylus sp. infections in equines by Duncan, McBeath and Preston (1980) studying its efficacy in multiple doses in ponys and by Drudge, Lyons and Tolliver (1978) who performed clinical trials using both the granular formulation and a suspension, in the horse.

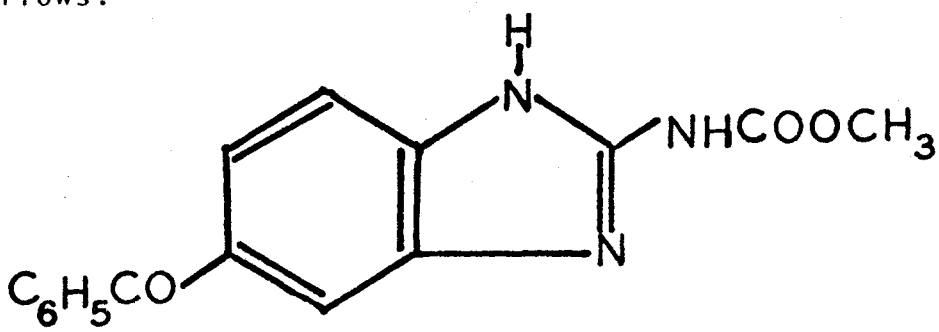
Recently, Slocombe and McCraw (1982) tested the efficacy of fenbendazole on the fourth stage larvae of Strongylus vulgaris. Sixteen pony foals were reared parasite-free and at six to fourteen weeks of age, were each innoculated with 2,500 infective larvae. It was found that fenbendazole was highly effective against the fourth stage larvae when given as a multiple dose, that is, there was an inverse relationship between number of larvae recovered at necropsy and the number of doses of the drug administered.

According to the Merck Index, fenbendazole is primarily considered to be an anthelmintic for swine. Currently, McBeath, Dean and Preston (1982) have been testing its use in pelleted form as a prophylactic, as well as a treatment, for nematode infections in sows. They found it to be effective, palatable and convenient to use, which are equally important factors when a large

number of animals are to be treated.

Fenbendazole has also been tested on reptiles. Holt and Lawrence (1982) used fenbendazole in the treatment of 82 reptiles. They found fenbendazole to be effective against single and mixed infections of ascarids, oxyurids and strongyloides in 84.1% of the reptiles treated. All of the snakes were given a single dose while the tortoises were given two doses separated by a three week interval. No deaths or side effects were observed in the test group. In general, the literature has shown that fenbendazole is apparently free of side effects.

Mebendazole, methyl 5-benzoyl-2-benzimidazole-carbamate, is an off-white granular powder. Its empirical formula is $C_{16}H_{13}N_3O_3$, and it has a structural formula as follows:



Mebendazole, according to the Veterinarians' Product and Therapeutic Reference, acts as a nematocide by inhibiting glucose uptake by the parasite, which in effect starves to death.

Mebendazole is used as an anthelmintic for humans as well as animals. Brugmans, et al (1971) conducted a study of the efficacy of mebendazole on persons with

enterobiasis. It was found that a single dose of 100 mg. was about 90% effective in both children and adults, and no side effects were reported. It was also found in this study that mebendazole is only very slightly absorbed by the host.

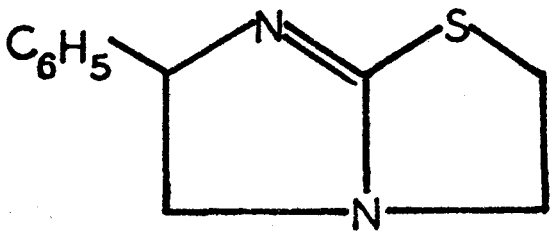
Extensive work has been done on the use of mebendazole in horses. Walker and Knight (1972) performed a field trial on the activity of mebendazole in horses; Bennett (1973), Bradley and Radhakrishman (1973), and Neave and Callear (1973) performed further clinical studies on the use of mebendazole in horses. Through these studies, and the later study of Bennett, Bickford and Lund (1974), it has been shown that mebendazole is a safe and effective anthelmintic for equines. The study of Bennet, Bickford and Lund (1974) in particular, found that, as parasites are more likely to accompany other illnesses, it is important to administer an anthelmintic which is safe for a debilitated animal. These investigators found that mebendazole caused no adverse reactions in weakened subjects, even up to doses of 40 times the recommended therapeutic dose.

Forstner, Wiesner, Jonas and Kraneburg (1976) performed a three-year study of the use of mebendazole on zoo animals. They found that a regimen of 14 days of mebendazole, given on the feed to ruminants and equines, was able to completely eliminate the passage of ova and larvae. The drug was well accepted on the feed and no

adverse reactions were noted.

The Merck Index notes that mebendazole has been found to have an LD_{50} of >80 mg/kg in sheep and >40 mg/kg in mice, rats and chickens, dosages which are about 40 times the recommended dose for these animals.

Levamisole is the L isomer of the compound tetramisole, which is DL-6-phenyl-2,3,5,6-tetrahydroimidazo [2,1-b]thiazole. The empirical formula is $C_{11}H_{12}N_2S$, and the structural formula is as follows:



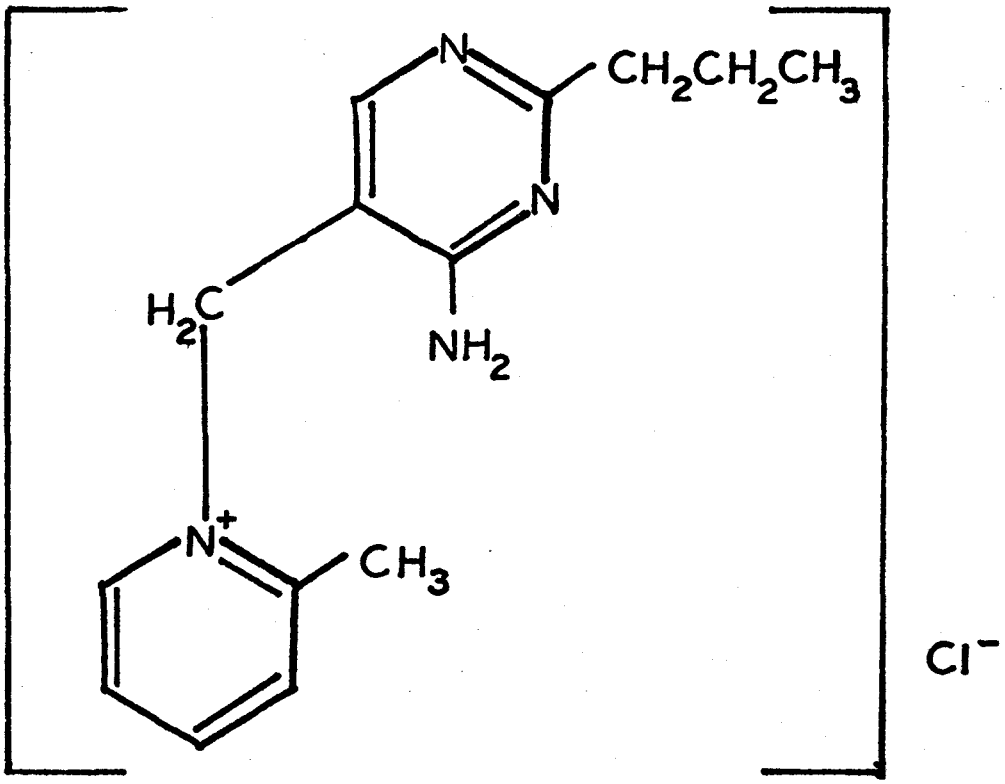
It is most often used as an anthelmintic in the hydrochloride form, $C_{11}H_{13}ClN_2S$, but for purposes of clarity it shall be referred to as simply levamisole. It is supplied, most commonly, as an injectable solution, but is also sometimes used as a drench or in a bolus.

Lyons, Drudge, Labore and Tolliver (1972) performed tests of levamisole against gastrointestinal nematodes in calves. They found no toxic effects in any of the 845 calves to receive treatment. Levamisole was found to be effective 99-100% against lungworm. It removed 96-100% of Haemonchus sp., Ostertagi osteragi, Cooperia oncophora, Cooperia punctata, Oesophagostomum radiatum and Trichuris ovis. Levamisole has been widely tested in cattle by such

investigators as Alicata and Furumoto (1969), Forsyth (1968), Hart, James and Curr (1969), Ross (1968), Rubin and Hibler (1968), and Turton (1969), whose results were all comparable with the Lyons study. The later studies of Baker and Fisk (1972) using levamisole in drinking water for cattle and as a drench for calves, both confirmed that a relatively low dosage was necessary to obtain 94-99% efficiency in ridding the host of a number of different gastrointestinal helminths.

Levamisole has also been studied most recently as a drug for parasitic prophylaxis. Fisher and MacNeill (1982) studied the responses of lactating cows and growing heifers to treatment with levamisole. The lactating cows that were treated lost less weight than the untreated cows, and the heifers treated with levamisole gained more weight than their untreated counterparts. The investigators came to the conclusion that routine anthelmintic treatment with levamisole would be beneficial in dairy herds.

Amprolium, 1-[(4-amino-2-propyl-5-pyrimidinyl) methyl]-2-picolinium chloride, is a water soluble, white odorless powder. Its empirical formula is $C_{14}H_{20}Cl_2N_4$ and has a structural formula as follows:



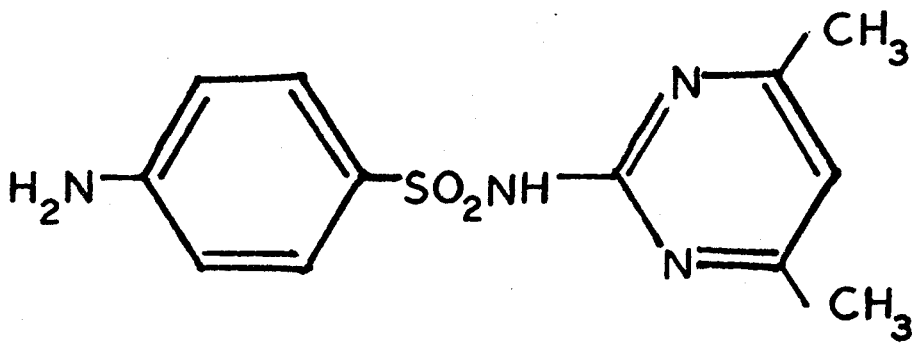
It is active as a coccidiostat by preventing the parasite from using vitamin B_1. Since its introdution in 1960, it has been used extensively as a treatment and preventative medication in poultry. Cuckler, Garzillo, Malanga and McManus (1960), Peterson and LaBorde (1962), and McLoughlin and Gardiner (1962) performed laboratory and field studies of the efficacy of amprolium against coccidia in chickens.

Stephens and Barnett (1970) performed studies to test amprolium as a coccidial prophylactic. They found it to successfully inhibit coccidiosis in all hens fed a daily ration of amprolium, and in general there were no adverse effects on egg production.

Amprolium has also been studied to determine its effectiveness against bovine coccidiosis. Peardon, Bilkovich, Todd and Hoyt (1965) tested amprolium along

with four other coccidiostats on calves which had been experimentally infected with a mixed innoculum of bovine coccidia. Norcross, Siegmund and Fraser (1974) administered amprolium in feed or water to calves also innoculated with a mixed infection. Both of these studies found that amprolium is a highly effective prophylactic or therapeutic anticoccidial agent against bovine coccidiosis. It is easy to administer and produced no observable side effects.

Sulfamethazine, 4,6-dimethyl-2-sulfanilamido-pyrimidine, has an empirical formula of $C_{12}H_{14}N_4O_2S$, and a structural formula as follows:

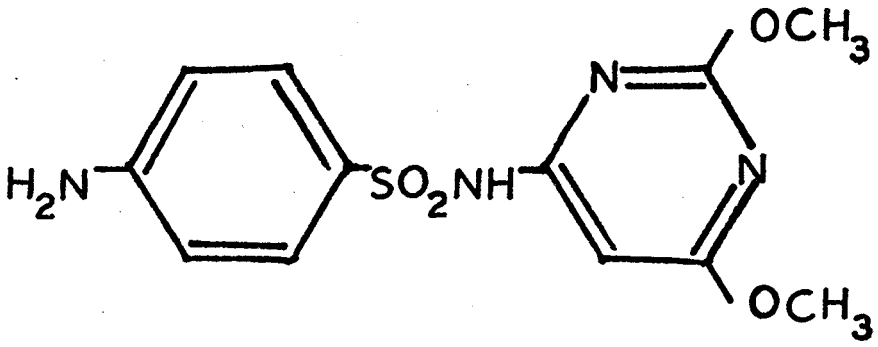


Sulfamethazine has been used for treatment and prophylaxis of coccidial infections in poultry and in cattle. Zarin (1966) and Feodorova (1966) tested the efficacy of sufamethazine against coccidia in chickens. Both studies found a recovery rate of 100%. Peardon, Bilkovich, Todd and Hoyt (1965), in their study with amprolium, also investigated the action of sulfamethazine against bovine coccidia. They found sulfamethazine to be

effective when administered intravenously.

Arakawa and Todd (1968) undertook to try to determine the effects of sulfamethazine on first generation schizonts of Eimeria bovis. They found that sulfamethazine contributes to the degeneration of first generation schizonts and that this stage of the parasite's development is particularly susceptible to treatment.

Sulfadimethoxine,2,6-dimethoxy-4-sulfanilamido-pyrimidine, is a white, almost tasteless and odorless compound. It has an empirical formula of $C_{12}H_{14}N_4O_4S$, and its structural formula is as follows:



Sulfadimethoxine, is one of a large group of long-acting sulfa compounds which have application as antibiotics as well as coccidiostats. Mitrovic and Bauernfeind (1967) performed laboratory and field studies of the chemotherapeutic value of sulfadimethoxine against a number of coccidia species, when administered in the drinking water of chickens and turkeys. They found that sulfadimethoxine had a high degree of efficacy against all pathogenic species of Eimeria in chicks, it was safe and

palatable when given over a consecutive six day period, and that chickens and turkeys previously treated proved to be immune to subsequent challenge infections.

Sulfadimethoxine has been tested in comparison to other sulfa compounds against coccidia of poultry. Mitrovic and Schildknecht (1973) found it to be either equal or superior when tested against eight other products. They further showed that sulfadimethoxine could be administered at low dosages and still maintain its effectiveness. It has shown no significant side effects.

MATERIALS AND METHODS

Fecal samples of various mammals, birds, reptiles and amphibians were collected over a fourteen month period, from April, 1983 through June, 1984 from the Miller Park Zoo in Bloomington, Illinois, and the Glen Oak Zoo in Peoria, Illinois. These are two small city operated animal collections, Miller Park Zoo having a total of 66 species, and Glen Oak Zoo housing 143 species.

The fecal samples obtained from Miller Park Zoo were collected in clean paper cups, labeled and dated, and were examined on the day of the collection. All specimens were collected in the morning, since routine zoo operation requires the animal enclosures to be cleaned daily, thus assuring the freshest possible samples. Those samples taken from Glen Oak Zoo were treated in one of two ways. A first group of samples was suspended in 10% formalin and transported back to Miller Park Zoo for examination, which took place several days later. All further samples were preserved in polyvinyl alcohol, returned to Miller Park and examined from one week to one month later.

The polyvinyl alcohol was prepared by first dissolving 4.5 grams of mercuric chloride in 31 ml. of 95% ethanol and adding 5 ml. glacial acetic acid to

prepare the fixative portion. Next, 5 grams of polyvinyl alcohol powder was placed in a small beaker to which 1.5 ml. glycerin was added and mixed with a glass rod. This was transfered to a 125 ml. stoppered flask, 62.5 ml. distilled water added, and left at room temperature for several hours, swirling occasionally. The flask was placed in a 70-75^{o} C. water bath for 10 minutes to dissolve most of the polyvinyl alcohol. The fixative was then added, swirling continued for 3-4 more minutes, the solution was allowed to cool, and when clear, it was stored in a tightly stoppered bottle.

Each fecal sample examined was treated using the Sheather Sugar Floatation method (1923). This method is suitable for recovery of parasite larva, ova and oocysts. The sugar solution needed was prepared by adding 500 grams of granulated sugar to 360 ml. of distilled water. The sugar and water are then stirred over a low flame until the sugar is dissolved. 6.5 ml. of dissolved phenol crystals is then added as a preservative to deter mold growth and avoid fermentation of the solution.

About one tablespoon of each sample was removed from the collection container with a clean wooden tongue blade and placed in a clean paper cup. Warm tap water was added and the sample was gently broken up to a homogenous consistency. Large particulate matter was removed by straining the mixture through two layers of cheesecloth, with the liquid portion being poured into a centrifuge

tube to within one inch of the top. The sample was then centrifuged at 1500 revolutions per minute for about 5 minutes. This will cause any parasite larva, ova, or oocysts to be concentrated at the bottom of the tube. The supernatant was then poured off and the previously prepared sugar solution was added to within one inch of the top of the tube and the sediment was stirred with a clean wooden applicator. This mixture was again centrifuged as before, causing the debris to sink, while the high specific gravity of the sugar solution allowed the larva, ova and oocysts to rise. The tubes were then carefully placed in a test tube rack and additional sugar solution was placed in the tubes to fill them completely.

A clean coverslip was placed on top of the tube in contact with the sugar solution. The tubes were allowed to stand undisturbed for 20 to 30 minutes to allow any parasites or ova to rise and adhere to the coverslip. The cover glass was then carefully placed on a slide, avoiding air bubbles if possible, and the slide was then examined under a microscope, being careful to examine every portion of the coverslip.

Any larva, ova or oocysts present were identified to genus and species, with a few notable exceptions, and the number of larva, ova or oocysts found under the 22 $mm.^2$ coverslip was noted in order to determine the relative density of infection of the animal. Samples which could not be identified readily were sent to the Miller Park Zoo

veterinarian, Dr. David G. Kruger, for identification. The samples from the Glen Oak Zoo which had been preserved either in formalin or polyvinyl alcohol (PVA) were treated in substantially the same manner as the unpreserved specimens.

All positive animals from the Miller Park Zoo were then treated with one of the various anti-parasitic drugs described earlier. It was not possible to follow up on any positive samples from the Glen Oak Zoo, mainly because those samples may have been run several days to weeks after collection and the Glen Oak Zoo routinely runs its own fecal examinations and is treated by its own veterinarian. They were informed, however, of any positive specimens that were found, and presumably followed up on these themselves.

All positive samples from Miller Park Zoo were re-run post-treatment. Due to the different handling of many of the individual cases, there was no uniform time after treatment at which every sample was re-examined. It will be necessary to discuss some of the results as individual case studies rather than as a statistical grouping.

During the course of this study, several prophylactic regimens were initiated. Fecals were done on the animals in these programs and these results will also be discussed. All fecal samples were treated as previously described, but the particulars of the

treatments will be described in a later section of this paper.

The prophylactic practices used at the Miller Park Zoo were several. All of the birds and mammals (with the exception of the rabbits which are isolated from the rest of the collection) that are housed in the Children's Petting Zoo, are on a program of coccidia prevention with the use of 9.6% amprolium solution. This is administered once per month, for the first 7 days of the month. It is given to the birds in their drinking water at a rate of 8 ounces per 100 gallons of water. The hoofstock, including donkeys, goats, sheep, a deer and a llama, are dosed at a rate of 3 ounces per quart dilution given at a rate of 1 ounce per 100 pounds body weight, administered directly into the mouth with a disposable syringe. In addition, the three donkeys are wormed once every three months with either mebendazole or fenbendazole fed directly on their grain.

In the Miller Park Zoo's Tropical Rain Forest Exhibit there are several different species of exotic birds. Some of these birds feed primarily on nectar, and as a coccidia prophylactic for this group of birds, sulfamethazine is added to the nectar at a rate of 2 ml. per one cup. The nectar is treated year round on a schedule of 10 days with medication and 7 days without.

Finally, since, as the results will illustrate, there is a problem in the Miller Park Zoo large feline

exhibits with recurring intestinal nematode infections, it was decided that some treatment of the soil of the outdoor exhibits should be tried. It was determined that the outdoor snow leopard exhibit should be heat-treated to try to stop the cycle of reinfection of the cats with the hookworm, Ancylostoma tubaeforme. To this end, the exhibit was flamed over its entire surface with a weed burner, the ground was turned with rakes and was burned a second time. The cats were kept out of the outdoor exhibit until they were found to be free of hookworm, at which time the male snow leopard was allowed back outside. No other outdoor exhibits were treated this way since no others contained hookworm, rather their inhabitants suffered from ascarids, whose ova, it was felt would not succumb to this treatment.

RESULTS

PRE-TREATMENT

During the course of this research, fecal samples were taken from animals at the Miller Park Zoo, Bloomington, Illinois, and the Glen Oak Zoo, Peoria, Illinois. This is by no means a survey of all the animals at both zoos, due to such reasons as inaccessibility to samples, movement of animals to other institutions, acquisition of new animals and deaths. It was necessary to put an end to the project at some point, and since a zoo is a dynamic rather than a static animal population, it was impossible to test all the animals at both institutions. However, this survey does represent at least one specimen of each of 88 different species housed at these zoos. A total of 202 animals were tested, of which 112 were mammals, 65 birds, 19 reptiles, and 6 amphibians. The following table, Table 1, is a listing of all animals tested by their classification.

TABLE 1

CLASSIFICATION OF ALL ANIMALS OBSERVED

CLASSIFICATION	COMMON NAME	# TESTED
MAMMALIA		
Marsupialia		
Didelphidae		
Dedelphis marsupialis virginianus	North American opossum	6
Phalangeridae		
Trichosurus vulpecula	brush tail opossum	1
Macropodidae		
Wallabia sp.	wallaby	2
Primata		
Cebidae		
Saimiri sciureus	common squirrel monkey	1
Saimiri sciureus boliviensis	Bolivian squirrel monkey	3
Aotus trivirgatus	owl monkey (Douroucoulis)	2
Ateles geoffroyi	spider monkey	3
Lagothrix lagotricha	wooly monkey	1
Lorsidae		
Nycticebus coucang	slow loris	2

CLASSIFICATION	COMMON NAME	# TESTED
Callithricidae		
Callithrix jacchus	common marmoset	1
Leontideus rosalia	golden lion tamarin	2
Cercopithecidae		
Cynopithecus niger	Celebese crested macaque	2
Cercopithecus neglectus	DeBrazzas monkey	2
Cercopithecus aethiops aethiops	Grivet monkey	2
Colobus polykomos	Colobus monkey	5
Hylobates lar	white-handed gibbon	2
Lagomorpha		
Leporidae		
Oryctolagus cuniculus	domestic rabbit	2
Rodentia		
Chinchillidae		
Chinchilla laniger	chinchilla	2
Dasyproctidae		
Dasyprocta agouti	agouti	3
Myoprocta pratti	acouchy	3
Scuirdiae		
Sciureus niger	fox squirrel	1
Cynomys ludovicianus	prairie dog	3

CLASSIFICATION	COMMON NAME	# TESTED
Carnivora		
Felidae		
Felis concolor	mountain lion	2
Felis wiedii	margay	2
Panthera tigris sumatrae	Sumatran tiger	2
Panthera tigris	Bengal tiger	2
Panthera uncia	snow leopard	2
Panthera pardus	spotted leopard	2
Panthera onca	jaguar	4
Panthera leo	African lion	2
Panthera leo persica	Indian lion	2
Procyonidae		
Potos flavus	kinkajou	1
Procyon lotor	raccoon	1
Mustelidae		
Lontra canadensis	river otter	2
Mustela putorius furo	European ferret	7
Mephitis mephitis	striped skunk	2

CLASSIFICATION	COMMON NAME	# TESTED
Pinnipedia		
Otariidae		
Zalophus Californianus	California sea lion	3
Artiodactyla		
Bovidae		
Capra hircus	domestic goat	6
Ovis aries	sheep	7
Bas taurus	domestic cattle	1
Camelidae		
Lama peruana	llama	1
Cervidae		
Odocoileus virginianus	white-tail deer	1
Perissodactyla		
Equidae		
Equus asinus asinus	domestic donkey	6
Equus caballus	domestic horse	3
AVES		
Anseriformes		
Anatidae		
Cairina moschata	muscovy duck	3
Anser anser anser	domestic geese	2

CLASSIFICATION	COMMON NAME	# TESTED
Anas sibilatrix	Chiloe wigeon	2
Columbiformes		
Columbidae		
Geotrygon versicolor	mountain witch dove	3
Phaps sp.	common pigeon	1
Coraciiformes		
Coraciidae		
Coracias caudata	lilac-breasted roller	2
Phoeniculus purpureus marwitzi	green wood hoopoe	2
Piciformes		
Capitonidae		
Trachyphonus valliantii valliantii	Levaillant's barbet	2
Cuculiformes		
Musophagidae		
Tauraco erythrolophus	red-crested touraco	2
Falconiformes		
Accipitridae		
Buteo jamaicensis	red-tail hawk	5
Galliformes		
Meleagrididae		
Meleagris gallopavo	domestic turkey	5
Phasianidae		
Gallus gallus	domestic chicken	2

CLASSIFICATION	COMMON NAME	# TESTED
Pavo cristatus	peafowl	2
Excalfactoria chinensis	Chinese button quail	2
Chrysolophus amherstidae	Lady Amherst pheasant	2
Lophura nycthemera nycthemera	silver pheasant	2
Syrmaticus reevesi	Reeves pheasant	2
Gruiformes		
Rallidae		
Limnocorax flavirostra	black crake	1
Passeriformes		
Corvidae		
Corvus brachyrhynchos	crow	2
Rupicolidae		
Procnias nudicollis	bare-throated bellbird	1
Ploceidae		
Steganura paradisa paradisa	Paradise whydah	1
Timalidae		
Leiothrix lutea	Pekin robins	8
Psittaciformes		
Psittacidae		
Amazona viridigenalis	red-headed Amazon	2
Amazona ochrocephala ochrocephala	yellow-front Amazon	1

CLASSIFICATION	COMMON NAME	# TESTED
Aratinga leucophthalmus leucophthalmus	white-eyed conure	2
Strigiformes		
Strigidae		
Otus asio	screech owl	2
Tyto alba	barn owl	2
Nyctea scandiaca	snowy owl	1
Asio otus otus	long-eared owl	1
REPTILIA		
Crocodilia		
Crocodylidae		
Alligator mississippiensis	American alligator	2
Sauria		
Iguanidae		
Iguana iguana	common iguana	3
Serpentes		
Boidae		
Constrictor constrictor	boa constrictor	2
Pythoninae		
Python molurus	Burmese python	1
Python reticulatus	reticulated python	2

CLASSIFICATION	COMMON NAME	# TESTED
Testudinata		
Chelydridae		
Pseudemys elegans	red-eared slider	1
Kinosternon bauri	mud turtle	1
Emydidae		
Chrysemys picta	painted turtle	1
Testudinidae		
Terrapene ornata ornata	ornate box turtle	2
Terrapene carolina carolina	Eastern box turtle	2
Terrapene carolina triunguis	3-toed box turtle	1
Gopherus berlandieri	Texas tortoise	1
AMPHIBIA		
Anura		
Ranidae		
Pyxicephalus adspersus	African bullfrog	3
Urodeles		
Ambystomidae		
Ambystoma opacum	marbled salamander	1
Ambystoma mexicanum	axolotl	2
	Total Tested	202

Of the animals tested, there was a total of 29 individuals with parasitic infections, or 14.35%. Table 2 describes the prevalence of infection found in this study.

TABLE 2

PREVALENCE OF INFECTION
(TOTAL INFECTED = 29
% OF 202 = 14.35%)

PARASITE	# OF ANIMALS INFECTED	%
Toxascaris leonina	6	20.69
Toxocara canis	1	3.45
Heterakis gallinae	3	10.34
Strongylus sp.	6	20.69
Haemonchus contortus	8	27.59
Trichuris sp.	4	13.79
Eimeria arloingi	5	17.24
Capillaria sp.	1	3.45
Ancylostoma tubaeforme	2	6.89
Ophidascaris sp.	1	3.45
Isospora felis	2	6.89

As is evident from simply adding the totals in Table 2, it appears that more than 29 animals were infected. However, several of the animals harbored more than one type of parasite at the same time. Table 3 indicates the prevalence of double and triple parasitic infections.

TABLE 3

PREVALENCE OF INFECTION - MULTIPLE INFECTIONS

PARASITE	# OF ANIMALS INFECTED	%
Double Infections		
Toxascaris leonina and *Toxocara canis*	1	3.45
Trichuris sp. and *Haemonchus contortus*	1	3.45
Haemonchus contortus and *Strongylus sp.*	1	3.45
Haemonchus contortus and *Eimeria arloingi*	1	3.45
Ancylostoma tubaeforme and *Isospora felis*	1	3.45
Triple Infections		
Eimeria arloingi, *Trichuris sp.*, *Haemonchus contortus*	2	6.89

Finally, it is interesting to note the occurrence and distribution of the various types of parasites which were found in this survey. Table 4 gives the common name, genus and species of animals found to be positive, as well as the type and density of infection they were found to have. Infection density is merely the number of ova or oocysts found on the 22 $mm.^2$ coverslip.

TABLE 4

OCCURRENCE AND DISTRIBUTION OF PARASITES

ANIMAL	INFECTION	INFECTION DENSITY (# Ova/22 mm.^{2} coverslip)
Felis concolor		
female mountain lion	*Toxascaris leonina*	33
male mountain lion	*Toxascaris leonina*	91
Panthera pardus		
male spotted leopard	*Toxascaris leonina*	1
female spotted leopard	*Toxaxcaris leonina*	65
	and *Toxocara canis*	33
	Isospora felis	28
Panthera uncia		
female snow leopard	*Ancylostoma tubaeforme*	7
male snow leopard	*Ancylostoma tubaeforme*	158
	and *Isopora felis*	21
Panthera leo persica		
male Indian lion	*Toxascaris leonina*	500+
female Indian lion	*Toxascaris leonina*	500+
Equus asinus asinus		
male Sicilian donkey	*Strogylus sp.*	500+
female Sicilian donkey	*Strogylus sp.*	500+

ANIMAL	INFECTION	INFECTION DENSITY
male juvenile Sicilian donkey	*Strogylus sp.*	145
female domestic donkey	*Strogylus sp.*	8
Equus caballus domestic pony	*Strogylus sp.*	297
Capra hircus female domestic goat	*Haemonchus contortus*	150
male domestic goat	*Haemonchus contortus*	150
male domestic goat	*Haemonchus contortus*	88
	and *Eimeria arloingi*	132
male domestic goat	*Haemonchus contortus*	130
	and *Eimeria arloingi*	304
	and *Trichuris sp.*	4
male domestic goat	*Haemonchus contortus*	30
	and *Eimeria arloingi*	33
	and *Trichuris sp.*	6
male domestic goat	*Eimeria arloingi*	10
Ovis aries female domestic sheep	*Haemonchus contortus*	2
male domestic sheep	*Eimeria arloingi*	500+

ANIMAL	INFECTION	INFECTION DENSITY
Lama peruana llama	*Haemonchus contortus* *Trichuris sp.*	7 4
Odocoileus virginianus white-tail deer	*Haemonchus contortus* *Strongylus sp.*	52 12
Colobus polykomos Colobus monkey	*Trichuris sp.*	39
Geotrygon versicolor mountain witch dove	*Heterakis gallinae*	2
Meleagris gallopavo domestic turkey	*Heterakis gallinae*	42
Gallus gallus domestic chicken	*Heterakis gallinae*	21
Python reticulatus reticulated python	*Capillaria sp.*	42
Gopherus berlandieri Texas tortoise	*Ophidascaris sp.*	1000+

From Table 4 it is possible to go into detail of the treatments used and their efficacy against the various parasites found. Although presentation of this material would be possible in table format, it would not present a total picture of the treatment and follow-up regimen undertaken, which included some of the prophylactic techniques mentioned earlier. For this reason results obtained after treatment with the various drugs will be presented in table form up to and including the first follow-up fecal examination. Any further work done with these individuals after that point will be presented in case study format.

POST-TREATMENT

All of the subjects that were found to have positive fecal samples, with the exception of the Colobus monkey and the mountain witch dove, were treated with one or more of the anthelmintics described earlier. The following tables describe the drugs administered to the various animals, their dosages and methods of administration, and the results of the first fecal examination performed post-treatment.

Table 5-A lists those animals treated with fenbendazole suspension. The liquid contains fenbendazole at the rate of 100 mg. per ml.. The dosage given to these subjects was 1 ml. per 5 pounds of body weight.

TABLE 5-A

FENBENDAZOLE SUSPENSION

ANIMAL	METHOD OF ADMINISTRATION	FECAL RESULTS
mountain lion-f	in horsemeat, 3 days	Negative
mountain lion-m	in horsemeat, 3 days	Negative
spotted leopard-m	in horsemeat, 3 days	Negative
spotted leopard-f	in horsemeat, 3 days	Negative
Texas tortoise	shot into mouth, 5 days	Positive

Table 5-B lists those animals treated with the powder form of fenbendazole. The powder contains 222 mg. of fenbendazole per gram and is administered at a rate of 2.3 mg. per pound of body weight.

TABLE 5-B

FENBENDAZOLE POWDER

ANIMAL	METHOD OF ADMINISTRATION	FECAL RESULTS
Sicilian donkey-m	on grain, one dose	Negative
Sicilian donkey-m	on grain, one dose	Negative
Sicilian donkey-f	on grain, one dose	Negative
domestic donkey-f	on grain, one dose	Negative
llama	on grain, one dose	Negative
domestic pony	on grain, one dose	Negative
white-tail deer	on grain, one dose	Negative

Table 6 contains the information on those subjects treated with mebendazole. Mebendazole was supplied as a powder containing 40 mg. of active ingredient per gram of powder. The dosage used was 10 mg. per pound of body weight.

TABLE 6

MEBENDAZOLE POWDER

ANIMAL	METHOD OF ADMINISTRATION	FECAL RESULTS
domestic turkey	suspended in water, shot into mouth, 3 days	Negative
domestic chicken	suspended in water, shot into mouth, 3 days	Negative
reticulated python	suspended in water, intubated to stomach, 3 days	Negative
snow leopard-m	in horsemeat, 2 days	Positive
snow leopard-f	in horsemeat, 2 days	Positive
Indian lion-f	in horsemeat, 3 days	Negative
Indian lion-m	in horsemeat, 3 days	Negative

The next table contains information regarding the administration of levamisole. Levamisole was supplied as an injectable liquid, containing 136.5 mg. per ml. of the drug, and was administered at a dosage of 2 ml. per 100 pounds of body weight.

TABLE 7

LEVAMISOLE

ANIMAL	METHOD OF ADMINISTRATION	FECAL RESULTS
domestic goat-m	IM injection, once	Negative
domestic goat-f	IM injection, once	Negative
domestic goat-m	IM injection, once	Negative
domestic goat-m	IM injection, once	Negative
domestic sheep-f	IM injection, once	Negative
domestic goat-m	IM injection, once	Negative

Table 8 concerns the use of the anti-coccidial, amprolium, which is supplied as a 9.6% solution, and was administered at a rate of 10 mg. per kg. of body weight.

TABLE 8

AMPROLIUM

ANIMAL	METHOD OF ADMINISTRATION	FECAL RESULTS
domestic goat-m	suspended in water, 5 days	Negative
domestic sheep-m	suspended in water, 5 days	Positive
domestic goat-m	suspended in water, 5 days	Negative
domestic goat-m	suspended in water, 5 days	Negative
llama	suspended in water, 5 days	Negative
domestic goat-m	suspended in water, 5 days	Negative

The coccidiostat sulfamethazine was not used in this study as a drug for treatment of any active infections. As was stated before, the sulfamethazine was placed into a nectar mixture which was offered free-choice to the nectar feeding birds in the Miller Park Zoo aviary. The drug was supplied as a 12.5% solution, of which 2 ml. was added to each cup of nectar prepared. Of the thirteen different species of birds housed in the tropical rain forest exhibit during the period of this study, four species are known to take the nectar. None of the fecal examinations done on birds housed in the aviary were found to be positive for coccidia.

As the preceding tables illustrate, amprolium was used in this study as a treatment for coccidia. Amprolium was also used for the control of coccidial infections in the Miller Park Zoo Petting Zoo. The regimen described in the Materials and Methods section was followed, once per month for one year and a final fecal examination was taken at the end of that period to assess the effectiveness of the program. In addition, the donkeys were treated once every 3 months with either fenbendazole or mebendazole powder, at the dosages previously given, and a fecal examination taken at the end of the year to judge their efficacy as prophylactics. The results of these final fecals are contained in Table 9, along with the infection densities observed at the start of this research, before any regular prophylactic treatments had been initiated.

TABLE 9

RESULTS OF AMPROLIUM, FENBENDAZOLE AND MEBENDAZOLE PROPHYLACTIC USE

ANIMAL	FORMER INFECTION DENSITY	CURRENT INFECTION DENSITY
	AMPROLIUM	
domestic goat-f	Negative	Negative
domestic goat-m	Negative	Negative
domestic goat-m	132	51
domestic goat-m	304	35
domestic goat-m	33	50
domestic sheep-f	Negative	Negative

ANIMAL	FORMER INFECTION DENSITY	CURRENT INFECTION DENSITY
domestic sheep-m	500+	132
Sicilian donkey-m	Negative	Negative
Sicilian donkey-f	Negative	Negative
domestic donkey-f	Negative	Negative
llama	Negative	Negative
white-tail deer	Negative	Negative
domestic turkey	Negative	Negative
domestic chicken	Negative	Negative
Peafowl-m	Negative	Negative
Peafowl-f	Negative	Negative
	MEBENDAZOLE/FENBENDAZOLE	
Sicilian donkey-m	500+	143
Sicilian donkey-f	500+	85
Domestic donkey-f	8	8

The coccidiostat sulfadimethoxine was not used until after the first repeat fecal examination was performed. In order to examine its use and efficacy, it will be necessary to detail the further observation and treatment of several of the subjects. This will also facilitate the presentation of the results obtained when the outdoor snow leopard exhibit was burned in order to try to eliminate the ova and larva of the hookworm Ancylostoma tubaeforme from the soil.

Case 1: This subject was a male mountain lion. The initial fecal examination revealed the presence of Toxascaris leonina. Treatment was with fenbendazole

suspension, at previously described dosage, for three days. Another fecal sample taken approximately 2 weeks post-treatment was negative. Approximately 6 months later, a total of about 75 to 100 adult worms were observed in the vomitus from this animal. A small sample of the discharge was examined under the compound microscope and Toxascaris leonina ova were identified. Treatment was initiated with mebendazole powder, at the previously stated dosage, for three days. A fecal examination two weeks later was negative. This cat had other pre-existing medical problems, which were exacerbated by a chronic parasitic infection. For this reason the zoo veterinarian recommended that this mountain lion have regular monthly fecal examinations performed. Thus, about one month after the last negative sample was obtained, another sample was taken. This sample again contained Toxascaris leonina ova at a density of 157 on the 22 $mm.^2$ coverslip. The cat was again treated with mebendazole for 3 days. Routine fecal examinations since then have all been negative.

Case 2: This subject was a female spotted leopard. The initial fecal examination revealed the presence of a double infection of Toxascaris leonina and Toxocara canis. The post-treatment fecal sample, done approximately two weeks after treatment with fenbendazole suspension for three days was negative. The routine fecal examination performed about eight months later was still negative for

the roundworm, but was found to contain Isospora felis at an infection density of 28 oocysts. Treatment with sulfadimethoxine was initiated. The drug was supplied in tablet form and administered at a dosage of 25 mg. per pound of body weight daily for 10 days. A fecal sample taken about two weeks post-treatment was negative.

Cases 3 & 4: This is a pair of snow leopards, male and female. These two individuals had been housed together before their arrival at Miller Park Zoo, and continued to be together until May, 1984, when they were separated due to the expectation of the birth of cubs. These cats had been chronically infected with the hookworm Ancylostoma tubaeforme prior to their arrival at the Miller Park Zoo. An initial fecal examination performed when they arrived was negative. Because there had been a problem in the past, another sample was examined one month later. Despite the fact that they were quartered together, it was possible for the zoo keeper that regularly worked the area to be reasonably certain which fecal sample came from which cat. Thus, these results reflect that two samples, one from each subject, were examined while the snow leopards were together. However, since they were in such close proximity to each other, when a positive sample was found, both individuals were treated, even though one of the two samples may have been negative.

When this second fecal examination was performed,

the female snow leopard was found to have A. tubaeforme at a density of 7 ova. Treatment was initiated on both snow leopards with mebendazole powder for two days. One month post-treatment, the fecal examination was repeated and the male snow leopard was found to have A. tubaeforme at a density of 158 ova. Again, both subjects were treated, this time with fenbendazole suspension, regular dosage, for three days. Fecal examinations were performed every two weeks post-treatment for six weeks, with all three of these being negative. One month after the last of these successive negative fecal examinations, another fecal sample was obtained. This time the male snow leopard was positive for A. tubaeforme, with a density of 2 ova, and Isospora felis, with a density of 21 oocysts. Both cats were again treated with mebendazole powder for 3 days and sulfadimethoxine tablets at 25 mg. per pound of body weight for 10 days. At this point the snow leopards were separated, with the female snow leopard being kept in the indoor exhibit and the male going to the outdoor exhibit. Before the male snow leopard was let outside, the entire ground surface of the outdoor exhibit, which consisted of sandy soil, was flamed with a weed burner. The soil was turned with rakes and hoes, and the surface was flamed again. The male snow leopard had been outside about a week after the treatment of the soil when another fecal sample was taken. Again the male snow leopard was found to be infected with A. tubaeforme, infection density

of 34 ova. This time only he was treated, with levamisole injectable administered by mouth in a horsemeat meatball. A one ml. dose of 136.5 mg. per ml. was given and another 1 ml. dose was administered two weeks later. Two weeks post-treatment, another fecal sample was taken, which proved negative. Two more negative samples, at monthly intervals, have been obtained.

Case 5: This is a male domestic lamb which was acquired by Miller Park Zoo by donation. His initial fecal sample was positive for Eimeria arloingi, with an infection density too high to count. The animal was treated with amprolium at the previously mentioned dosage for 5 days, at which time a repeat fecal was taken. The lamb was still positive for coccidia, but with an infection density of 406 oocysts. He was treated again with the same regimen and the fecal sample showed an infection density of 310 oocysts. Treatment was repeated a third time, a negative fecal was obtained and the lamb was started on the prophylactic amprolium regimen. After about two months on this program, another fecal examination was done, which showed an infection density of coccidia of 132 oocysts.

Case 6: This is a land turtle, commonly known as a Texas tortoise, which was a wild-caught specimen acquired by donation. The initial fecal examination showed Ophidascaris sp. at an infection density too high to count. The animal was treated with fenbendazole

suspension at the previously ennumerated dosage for 5 days. The fenbendazole was delivered directly into the tortoise's mouth with the use of a disposable syringe. The post-treatment fecal which was examined two weeks later showed an infection density of the roundworm ova of 620. Treatment was repeated for another 5 days and a fecal sample was again taken in two weeks. The infection density of this positive sample was 25 ova. A third time the treatment was repeated, and the post-treatment fecal this time was negative.

DISCUSSION

Unfortunately for the wild animal populations in the world, the world is indeed getting smaller all the time. Thanks to the foresight and concern of many nations' governments, thousands of acres of land have already been set aside as wildlife refuges. Despite these good efforts, new species appear on the U.S. Federal Endangered Species list every month, and even as this paper is being written, species are becoming extinct. As long as civilization continues to flourish and grow, there will be a need for zoological gardens and parks to serve as a haven and a repository for the world's wild animal resources. The function of the zoo is four fold: education, conservation, recreation, and research. Without the captive management and breeding programs followed by the many parks and zoological gardens, the extinction rate which is already alarming would be staggering.

It is therefore essential that the animals that are entrusted to the care of the zoological parks be housed in quarters that are clean and healthy, but that also simulate as closely as possible their natural habitats in order to encourage breeding and rearing of the young, as

well as the other normal behavior patterns of the species.

In earlier studies of this type Jaskoski and Williamson (1957) found a prevalence of nematode infection of 53.7% at the Chicago Zoological Park; Jaskoski (1958) found a prevalence of 20.8% at the Lincoln Park Zoological Gardens; and Jaskoski and Krzeminski (1960) found a prevalence of 12.85% parasite infection at the Lincoln Park Zoological Gardens and the Indian Boundary Zoo in Chicago, Illinois. In the current study done at the Miller Park Zoo in Bloomington, Illinois and the Glen Oak Zoo in Peoria, Illinois, a prevalence of infection of 14.35% was found. Of the 202 animals examined, 29 were found to be infected with intestinal parasites. Of the 29 infected animals, 5 were found to harbor double infections and 2 had triple infections. In the current study the infection density was found by counting all the ova or oocysts present under the 22mm.^{2} coverslip. This was done in order to get a general idea as to whether a particular animal was lightly, moderately or heavily infected. Most of the positive samples found could be catagorized as light to moderate infections.

A comparison of the results of the three previous studies mentioned with those of this study would seem to indicate a slight upswing in the prevalence of parasitism. There may be several reasons why these results are misleading. At the time the previous studies were done, a zoo was essentially a place for members of the general

public to go, perhaps on a Sunday afternoon, to view exotic animals that were inaccessible to them in any other way. The majority of these animals were wild-caught, with many zoo directors, curators and keepers actually going on collection expeditions into the bush to obtain specimens. These animals were quite often heavily infected with parasites when received at the zoo, and indeed many died in transit from their infections. Upon arrival at the park, fecal examinations were often performed and an anthelmintic administered. These early drugs often caused harmful side effects and had to be discontinued before they had done the job, and sometimes they even killed the animal they were intended to cure.

Then the animal was placed into an exhibit. As in the case of the study done at the Chicago Zoological Park, the animals continued to have a high prevalence of parasite infection because they were placed in large outdoor exhibits where there was ample opportunity for re-infection, and because anthelmintics were only administered when random fecal sampling indicated the presence of ova or when obvious physical symptoms, such as bloat, edema, lethargy or diarrhea, were noticed. It was probably for these reasons, among others, that the infection rate found at the Chicago Zoological Park in 1957 was 53.7%.

On the other side of the animal management coin, the study done in 1958 at the Lincoln Park Zoological Gardens

shows an infection rate of only 20.8%, and only two years later, in 1960, the rate found for that zoo combined with the values for the Indian Boundary Zoo were only 12.85%. Three factors probably contributed to this dramatic reduction in the rate of parasitism. First, the Lincoln Park Zoo, being an inner-city institution, had fewer large outdoor exhibits and more smaller, easily disinfected indoor exhibits, with good drainage and concrete floors. Sanitary conditions were easier to maintain and once an animal was treated, there was less chance of re-infection. Second, as the animal populations in the wild began to shrink, fewer collection expeditions were organized and energies were focused on captive breeding programs. Thus, a much larger portion of the zoo's collection was now born right at the zoo, or was acquired from other zoos either by purchase or trade, and therefore fewer heavily parasitized wild animals had to be dealt with. And third, as the 1960 study notes, the Lincoln Park Zoological Gardens began to try a regular prophylactic anthelmintic program with some of its animals, but as Krzeminski points out, the drug that was tried proved to be nephrotoxic with extended use and had to be discontinued.

Both of these early approaches to animal management have proven over the years to have their individual disadvantages. The wild-caught animal in a completely open enclosure is subject to grave illness and an early death from heavy parasitic infection. A more insidious

but equally life-threatening problem occurs with the easily disinfected, small, animal enclosure. The animals are not given the natural stimulation that they would get in the wild and this leads to aberrant behaviors, refusal to eat or mate, self-mutilation, and an early death due to ill health precipitated by boredom or despondency.

Currently most zoos, such as the Miller Park Zoo and Glen Oak Zoo are struggling with these problems and trying to find a balance which will afford the animals in their care the best possible environment in a captive situation. The use of large, outdoor natural enclosures, multi-species exhibits to create a small, closed ecosystem, and the creation of man-made environments with many forms of stimulation for the animal, are all serving to enhance the quality of life, and thus the longevity, of the many diverse captive species.

However, with this increased emphasis on the natural environment, a potential increase in parasitism occurs, both from re-infection by the animals themselves and from cross-infection from other species either housed with them or able to enter their enclosures from the outside. It is for this reason that the Miller Park Zoo and the Glen Oak Zoo have programs of regular fecal examination. Miller Park Zoo also, as has been stated earlier, uses drugs as parasite prophylactics, as well as physical means, such as the flaming of the outdoor snow leopard exhibit, which have proved quite effective.

According to Veterinary Applied Pharmacology and Therapeutics, an ideal anthelmintic should have certain characteristics. It should: 1. Have a wide therapeutic index. This is the ratio of effective dose to toxic dose. If for example, the ratio is 1:2, this means that a dosage twice that normally given would be toxic. A drug with a ratio below 1:4 would not be considered a safe drug. 2. Have a wide spectrum of activity. 3. Be active against both the mature and immature stages of the parasite. 4. Not cause any changes in the normal life of the animal, nor have adverse effects upon its development. 5. Be palatable, so that it is easy to administer. 6. Be reasonably priced so that it can be readily used in a control regimen.

The results obtained in this study show an infection rate of 14.35% pre-treatment and there were some cases that proved intractable to treatment. However, the animals at these zoos have been on control programs which the results show have reduced the infection densities, if not totally eliminated the parasites in question. Using the above ennumerated criteria, the anthelmintics and anti-coccidials used in this study meet or exceed these guidelines. Their toxic ratios are safe, they are active against a number of different species and stages of these species, none of the animals to whom the drugs were administered became ill from them, the medications were readily acceptable to the animal, and the cost of a

control program is nominal compared to the costs of replacing valuable exotics.

SUMMARY AND CONCLUSIONS

Of 202 animals of 88 different species examined at the Miller Park Zoo, Bloomington, Illinois, and the Glen Oak Zoo, Peoria, Illinois, a total of 29, or 14.35% were found to be infected with parasites. All of the anthelmintics used to treat the infected animals proved to be effective against most of the various parasites found, with some of the infections being highly resistant to any treatment tried. There were no cases of illness due to the use of any of the anthelmintics, nor were there any deaths in the collections during the time of the study which were attributable to parasite infection.

The prophylactic drug regimens employed at the Miller Park Zoo were of limited efficacy given the difficulty of prevention of re-infection when animals are housed together in outdoor enclosures. The procedure of burning the ground in the outdoor snow leopard exhibit appears to have been effective, since no further infection has been found in the male snow leopard who currently inhabits that area. Possible reasons for the differences in parasite incidence rates between the earlier studies of Lincoln Park Zoological Gardens, Indian Boundary Zoo, and the Chicago Zoological Park, and the current study are cited.

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The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

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