STUDIES OF THE LIFE CYCLE AND EPIDEMIOLOGY OF *PTERYGODERMATITES NYCTICEBI* (MÖNNIG, 1921) QUENTIN, 1969 FROM *LEONTOPITHECUS ROSALIA*, *PITHECIA PITHECIA*, *PITHECIA MONACHUS*, AND *CALLIMICO GOELDII* IN THE OKLAHOMA CITY ZOO

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PTERYGODERMATITES NYCTICEBI (MÖNNIG, 1921)

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PITHECIA PITHECIA, PITHECIA MONACHUS

AND CALLIMICO GOELDII IN THE

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CHAPTER I

INTRODUCTION

Efforts to guard against future extinctions of the endangered species of animals have led to the establishment of the Survival Service Commission of the International Union for Conservation of Nature and Natural Resources (IUCN's SSC) in 1949. The Commission publishes the Red Data Book which is a compilation of data on the current status of endangered animals, their survival and breeding success in captivity. Among the threatened Latin American primates, golden lion tamarins (Leontopithecus rosalia), which have often been incorrectly called golden lion marmosets, are listed as an endangered species (Anonymous, 1972; Kleiman, 1977). The census of captive golden lion tamarins as reported in 1974 was a total of 74 animals in 15 collections. The most current report of the population of golden lion tamarins in zoo and private collections as of 1977 was 75; of which 73 were maintained in the United States (Olney, 1979).

In 1980, the Oklahoma City Zoo alone has eighteen golden lion tamarins[1] which have been maintained as isolated colonies at five different locations on the zoo ground; the idea being to avoid the loss of the entire population at the outbreak of any uncontrollable disease.

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[1]In fall of 1979, on a breeding loan to the National Zoological Park, Washington, D. C., four golden lion tamarins were exchanged for another four from the said institute.

Each colony, whenever possible, consists of one male and one female tamarins. Despite cases of stillbirths, captive breeding has been successful ever since the tamarins were introduced into the Zoo in 1964 and the population is growing.

In 1974, spirurid eggs were found in the feces of white-faced sakis (Pithecia pithecia), golden lion tamarins (Leontopithecus rosalia), silver-backed sakis (Pithecia monachus) and Goeldi's marmosets (Callimico goeldii). In his study, Steurer (1975) noted the report of the recovery of Rictularia eggs in a white-faced saki. However, I could find neither worm specimens for specific identification nor records on clinical signs. Since then, more new cases of the same spirurid infection were reported. Therefore, an endemicity of the spirurid infection in these New World monkeys was suspected. In 1977, varying numbers of adult rictularids were recovered at necropsy of a white-faced saki[2] and from few tamarins that died or were administered with an anthelminthic. The spirurid eggs were confirmed to be rictularid eggs. Treatment of the infected golden lion tamarins with mebendazole had been effective in inhibiting egg shedding for three consecutive days and, at times, even stimulated the expulsion of adult worms (Yue, Jensen and Jordan, 1980).

A study of the adult worms and the descriptions of all known species has revealed that they are probably Pterygodermatites nycticebi (Mönnig, 1921). Furthermore, a literature search showed that the literature does not contain much information on the biology of this group

[2]This was the last white-faced saki of the Zoo's collection. No recruitment was made after its death.

of spirurids found in non-human primates. In order to launch an effective program for the control and the prevention of the spread of this spirurid, a better understanding of its biology is needed. Both field and experimental studies were initiated in an attempt to (1) determine the history and current status of *Pterygodermatites* infection in the golden lion tamarins, white-faced sakis, silver-backed sakis and Goeldi's marmosets of the Oklahoma City Zoo; (2) determine how *Pterygodermatites nycticebi* is being perpetuated in the Zoo; and (3) obtain leads to the life cycle of *Pterygodermatites nycticebi* for its prevention and control.

CHAPTER II

LITERATURE REVIEW

The Family Rictulariidae and Its Genera

Systematics

The taxonomy of the family Rictulariidae has been in a state of flux. According to Yamaguti (1961), the genus Rictularia (Spiruroidea: Rictulariidae) is characterized by the number of cephalic papillae, the two rows of subventral combs which diminish posteriorly into spine-like structures, the position of the vulva, the length of spicules, the number of genital papillae, and the size of the embryonated eggs.

Quentin (1969a) briefly reviewed the history of the establishment of this family, the subfamily Rictulariinae and the genera Rictularia Froelich, 1802 and Pterygodermatites Wedl, 1861. He identified some Rictularia species as actually belonging to the genus Pterygodermatites. The characteristics he used for differentiating the two genera were: (1) the orientation of the oral opening, (2) the number of esophageal teeth, and (3) the number of pairs of prevulvar combs (Table I). Quentin further divided the genus Pterygodermatites into five subgenera, each differing from the other by (1) the orientation of the oral opening, (2) the lengths of the denticles bordering the buccal cavity, (3) the position and the number of pairs of genital papillae, and (4) the number of pairs of prevulvar combs (Table II). This new classification

TABLE I

COMPARISON OF GENUS RICTULARIA FROELICH, 1802 WITH GENUS PTERYGODERMATITES WEDL, 1861

Characteristics	*Rictularia*	*Pterygodermatites*
Oral opening	totally dorsal and transverse	apical or drosal, never totally dorsal and transverse
No. esophageal teeth	1	3
No. pairs of genital papillae	1 - 4 and 8 laterally	
No. pairs of prevulvar combs	≤ 34	29 - 56
Type species	*R. cristata* Froelich, 1802	*P. plagiostoma* Wedl, 1861
Subgenus	-------	(see Table 2)
Hosts	Sciuridae; Microtidae; Muridae; Gliridae; Cheiropteras of North America and Eurasia	(see Table 2)

Source: J. C. Quentin, "Essai de classification des nématodes rictulaires," Mém. Mus. Nat. Hist. Nat., Series A (1969).

TABLE II

CHARACTERISTICS OF THE FIVE SUBGENERA OF THE GENUS PTERYGODERMATITES WEDL, 1861

	Subgenus				
Characteristics	Paucipectines	Neopaucipectines	Pterygodermatites	Mesopectines	Multipectines
Oral Opening	apical	dorsally inclined	dorsal	dorsal	dorsal
Denticles	---	---	length irregular encircle the oral opening	length regular those on ventral side replaced by 1-2 semilunar apophyses	those on ventral border of mouth replaced by a chitinous apophysis
No. of Pairs of Prevulvar Combs	29 - 39	34 - 38	40 - 46	37 - 51	47 - 58
No. of Pairs of Genital Papillae	1 - 4 and 8 laterally	1 - 4 and 8 laterally	not known	aligned in 2 subventral rows	pedunculated and regrouped
Hosts	Cricetidae; Microtidae & Sciuridae of the neartic; neotropic & north of paeleoarctic	European rodents of Middle Congo; Lemurs of Madagascar	Cheiropteras; Insectivores of Mediterranean & South Africa	Rodents (Gerbillidae, Muridae) Carnivores (Viverridae) Asiatic & African primates	Mustelidae; Felidae; Canidae; distribution worldwide
Type Species	P. Paucipectines coloradensis (Hall 1916)	P. Neopaucipectines desportesi (Chabaud & Rousselot 1956)	P. Pterygodermatites plagiostoma (Wedl 1861)	P. Mesopectines taterilli (Baylis 1928)	P. Multipectines affinis (Jagerskiold 1904)

Source: J. C. Quentin, "Essai de classification des nématodes rictulaires," Mém. Mus. Nat. Hist. Nat., Series A (1969).

scheme has been adopted in differentiating the species from North American rodents (Lichtenfels, 1970).

Host Range of Rictularids

The rictularids have a broad range of hosts; species have been reported from primates, a marsupial, carnivores, insectivores, rodents, bats and a lizard.

Three species have been found in non-human primates. Pterygodermatites (=Rictularia) alphi was reported in various species of monkeys from the Moscow Zoological Garden (Lubimov, 1933). Chabaud and Petter (1958) stated that the description of P. nycticebi which was initially called Filaria nycticebi (Mönnig, 1921) was "too ancient" and that they did not find sufficient characteristics to affirm its being a distinct species. These authors thus considered it as synonymous to P. alphi and redescribed the latter using the rictularids recovered from a Cheirogale sp. and a Lemur macaco from the Botanical Garden of Paris. Nevertheless, Quentin and Krishnasamy (1979) identified the male and two juvenile female rictularids recovered from a Nycticebus coucang as P. nycticebi. These workers redescribed this species with the male worm being described for the first time. A third species, P. lemuri from Microcebus murinus murinus in Madagascar, was described by Chabaud and Brygoo (1956). Table III shows a comparison of these species.

Pterygodermatites jägerskiöldi was the only species ever found in a marsupial; however, it was not fully described (Lent and Freitas, 1935; Quentin, 1969a).

Fifteen rictularid species have been recovered in various kinds of

TABLE III

A COMPARISON OF PTERYGODERMATITES SPECIES REPORTED FROM NON-HUMAN PRIMATES

Characteristics	Species		
	P. nycticebi	P. alphi	P. lemuri
Male			
No. of Combs & Spines	66	70	Male unknown
Spicules: left	80 µ	103 µ	
right	80 µ	90 µ	
No. of Median Fans	1	1 - 2 (mostly 2)	
No. of Genital Papillae	10 pairs	10 - 11 pairs	
Female			
No. of Combs & Spines	93	96 - 98 pairs	83 pairs
Position of Vulva	43	43rd comb	30 - 36th comb
Egg: length x width (µ)	---	37 x 29	---
Host(s)	Nycticebus tardigradus Nycticebus coucang	Cebus tatuellus Cebus hypoleucas Cebus apella Cercopithecus talopoin Cercopithecus ruber Macacus rhesus (=Macaca mulatta) Hapale jacchus (= Callithrix j. jacchus) Hapale rosalia (= Leontopithecus r. rosalia)	Microcebus murinus murinus
Habitat	Intestine	Duodenum	Digestive tract
Locality	Amsterdam Zoological Garden *	Moscow Zoological Garden	Madagascar
Reference	Mönnig 1921; Quentin & Krishnasmy, 1979	Lubimov 1933	Chabaud & Brygoo 1956

*The only male worm available for specific description was obtained from a Nycticebus coucang captured at Bukit Lagong Kepong, Malaya.

carnivores. However, the descriptions of some species are rather incomplete or fragmentary. For example, the description of P. vulpis (Galli-Valerio, 1932) was based entirely on the only male worm recovered. On the other hand, no male worms were known from P. wheeleri (Sandground, 1933) and P. dollfusi (Chabaud and Rousselot, 1956). The specific descriptions of these two species were based on the characteristics of female worms. Other species from carnivores are P. cahirensis (Jägerskiöld, 1904), P. affinis (Jägerskiöld, 1904), P. splendida (Hall, 1914), P. mjöbergi (Baylis, 1928; Chen, 1937), P. houdemeri (Hsu, 1935), P. paradoxuri (Tubangui and Marilungan, 1937), P. vitimi (Matschulsky and Makarov, 1953), P. leiperi (Ortlepp, 1961), P. myonacis (Ortlepp, 1961), P. lupi (Panine and Lavrov, 1962) and P. petrovi (Sadyknov, 1955). However, P. cahirensis, P. affinis and P. splendida had been considered to be conspecific (Gibbs, 1957).

Species that are parasites of insectivores include: P. plagiostoma (Wedl, 1861), Rictularia scalopis (Goodrich, 1932), P. aethechini (Le Roux, 1930) and P. desportesi (Chabaud and Rousselot, 1956).

Eleven species of Rictularia and 25 species of Pterygodermatites required rodent definitive hosts of families Sciuridae, Muridae, Gliridae, Cricetidae, Microtidae and Heteromyidae. These species are listed in Table IV.

Seven species (P. macdonaldi Dobson, 1880; P. lucifugus Douvres, 1956; P. nana Caballero, 1943; P. elegans Travassos, 1928; P. bovieri Blanchard, 1886; P. spinosa Willemoes-Suhn, 1869; P. shaldybini Skrjabin, Sabolev and Ivachkin, 1967) had been described in bats. Rictularia disparilis Irwin-Smith, 1922 was the only species reported to parasitize lizards. This latter species, regarded as a pseudorictularid, was

TABLE IV

LIST OF RICTULARIA AND PTERYGODERMATITES SPECIES FOUND IN RODENTS

Species	Hosts	Reference
Rictularia halli	Sciuridae	Sandground, 1935
R. citelli	Sciuridae	McLeod, 1933
R. dhanra	Sciuridae	Inglis and Ogden, 1965
R. cristata	Gliridae	Froelich, 1802
R. amurensis	Muridae, Microtidae Gliridae	
R. proni	Sciuridae, Muridae	Seurat, 1915
R. strumica	Muridae	Dimitrova Genov Karapchanski, 1963
R. oligopectinea	Muridae	Wu and Hu, 1938
R. elvirae	Sciuridae	Parona, 1889
R. muris	Muridae	Galli-Valerio, 1932
R. scalopis	Talpidae	Goodrich, 1932
Pterygodermatites coloradensis	Cricetidae, Microtidae, Sciuridae	Hall, 1916
P. quinqueflabellum	Microtidae	Sadovskaja, 1954
P. onychomis	Cricetidae, Sciuridae	Cucker, 1939
P. baicalensis	Muridae	Spassky, Ryzhikov and Sudarikov, 1952
P. sibiricensis	Microtidae	Morosov, 1959
P. kolimensis	Microtidae	Gubanov and Fedorov, 1967
P. microti	Microtidae	McPherson and Tiner, 1952
P. ondatrae	Microtidae	Chandler, 1941
P. skrjabini	Sciuridae	Matschulsky and Wosnessenskaja, 1965
P. dipodomis	Heteromyidae	Tiner, 1938
P. zygodontomis	Cricetidae	Quentin, 1967

TABLE IV (Continued)

Species	Hosts	Reference
Pterygodermatites desportesi	Muridae	Chabaud and Rousselot, 1956
P. plagiostoma	Sciuridae	Wedl, 1861
P. caucasica	Sciuridae, Gerbillidae	Schulz, 1927
P. kazachstanica	Sciuridae, Muridae, Gerbillidae	Panine, 1956
P. magna	Muridae	Kreis, 1937
P. ratti	Muridae	Khera, 1956
P. harrisi	Muridae	Baylis, 1934
P. taterilli	Gerbillidae	Baylis, 1928
P. tani	Muridae	Hoeppli, 1929
P. whartoni	Muridae, Sciuridae	Tubangui, 1931
P. fallax	Sciuridae	Jägerskiöld, 1909
P. vauceli	Sciuridae	Le Van Hoa, 1965
P. peromysci*	Muridae	Lichtenfels, 1970
P. parkeri*	Sciuridae, Muridae	Lichtenfels, 1970

Source: J. C. Quentin, "Essai de classification des nématodes rictulaires." Mém. Mus. Nat. Hist. Nat. Series A (1969).

*Species not compiled by J. C. Quentin (1969).

placed in the family of Physalopteridae by Chabaud (1965).

Life Cycle of Rictularid Species

Natural and Experimental Intermediate Hosts

Few arthropods have been incriminated to be naturally infected by species of either *Rictularia* or *Pterygodermatites*. Oswald (1958a) found that species of *Ceuthopilus* and *Parcoblatta* were naturally infected with larvae of *Pterygodermatites coloradensis*, an intestinal parasite of *Peromyscus leucopus* (Muridae). Witenbery as cited by Oswald (1958a) and Quentin (1969a) reported finding encysted larval *P. cahirensis* (Jägerskiöld, 1904) in the mesenteries of reptiles. The larvae were infective to dogs. Witenberg speculated that reptiles were the second intermediate host while the initial developments occurred in insects. Workers in India confirmed lizards to be second intermediate hosts (Srivastava, 1940; Gupta, 1970).

Experimentally, Oswald (1958a) demonstrated that various species of orthopterans (adult and nymphal *Blattella germanica*; nymphal *Supella supellectilium*; nymphal *Blatta orientalis*; nymphal *Periplaneta americana*; nymphal and adult *Parcoblatta pennsylvanica* and *P. virginia*; adult *Acheta assimilis* and adult *Ceuthopilus* sp.) and of coleopterans (larval *Tenebrio molitor*; adults of *Dicallus sculptulis* and *Chlaenius* sp.) were suitable intermediate hosts for *Pterygodermatites coloradensis*. Infective larvae (third stage) developed in the insects in 12 days.

Quentin (1969a) cited Morosov's work on *Rictularia amurensis* Schulz, 1927. The parasite was found to develop in the experimental host *Chromatoiulus projectus kochi* (Myriapoda, Diplopoda). Infective larvae were recovered between 33 and 40 days.

Quentin (1969a) described the morphology and the development of the different stages of Pterygodermatites zygodontomis Quentin, 1967 in the experimental intermediate host Doru lineare as well as in the definitive host Zygodontomys lasiurus. He found the third stage larvae at the end of 13 days in Doru lineare maintained at a temperature of 25°C.

Quentin (1969b) succeeded in identifying two dermapterans, Anisolabis annulipes and Diaperasticus erythrocephalus, as experimental intermediate hosts of P. desportesi Chabaud and Rousselot, 1956. Third stage larvae were recovered from the intestinal wall of the insect hosts.

Quentin (1970) also observed that 15 days after infection by Rictularia proni Seurat, 1915 third stage larvae developed within cysts in the wall of the proctodeum beyond the Malphigian tubules of five species of insects. These included several orthopterans (Locusta migratoria, Oedipoda germanica, Omocestus raymondi), a dermapteran (Forficula auricularia) and a coleopteran (Tenebrio molitor). No third stage larvae were ever found free in the haemocoel of the hosts.

The life cycle of Pterygodermatites hispanica Quentin, 1973 was also completed experimentally. When the intermediate host Locusta migratoria, was maintained at a temperature of 28°C, the time required for the parasite development was shortened. Instead of taking 15 days as in the known cycles of other rictularids, the larvae developed into the infective third stage in the intermediate host on the sixth day of infection. The third stage larvae were encysted in the region of the proctodeal valve (Quentin and Seureau, 1974).

Natural and Experimental Definitive Hosts

Oswald (1958b) found that male *Pterygodermatites coloradensis* matured in laboratory mice (*Mus musculus*) in about 10 days and female 21 days. The prepatent period was 33 days.

Quentin (1969b) fed third stage larvae of *P. desportesi* that developed in experimental intermediate hosts to the definitive host *Lophuromys sikapusi*. He recovered a young male and a fourth stage female four days after infection.

Male worms of *Rictularia proni* were found to mature faster than the female worms. They appeared in the host four days after infection; whereas immature female worms were observed only in six days (142 hours). Embryonated eggs were present in the uteri of females 30 days after infection (Quentin, 1970).

Third stage larvae of *Rictularia amurensis* obtained from the experimental intermediate host were infective to white mice and marmots. The fourth stage larvae were recovered from the definitive hosts in 5 - 7 days and 25 days, respectively (Quentin, 1969a).

The development of *Pterygodermatites hispanica* in its definitive host *Apodemus sylvaticus* was consistent with that of *R. proni*. Juvenile males and females were obtained a week after the infection of the host. Females became gravid in 38 days (Quentin and Seureau, 1974).

Location in Definitive Hosts

Rictularids were found to be mainly embedded in the wall of the small intestine (Le Roux, 1930; Lubimov, 1933; Cuckler, 1939). Nevertheless, those recovered from non-human primates by Lubimov (1933) were found as far down as the rectum in one monkey.

Pathology of Infected Definitive Hosts

Few workers reported the damage rictularids had done to their natural hosts and the type of host tissue response they elicited. Lubimov (1933) described severe pathologic changes in the intestines of both Old and New World monkeys infected by *Pterygodermatites alphi*. The primate hosts were very emaciated and anemic. They developed ulcerations, abscesses, degeneration of the parenchymatous organs and chronic intestinal catarrh. Practically, the whole digestive tract, from the esophagus to the duodenum (in most cases), was involved. In the monkey whose rectum was infected the affected tissue exhibited progressive edema and hyperemia. The author considered these changes to be caused by *P. alphi* and explained the generalized involvement of of the viscera as a result of the rapid penetration of the host tissues by the worms and their tendency to penetrate into the abdominal cavity.

CHAPTER III

MATERIALS AND METHODS

This research project was conducted during 1978 and 1979, and consisted of two parts: the field studies at the Oklahoma City Zoo and the experimental studies at Oklahoma State Univeristy.

Field Studies

Zoo Environment

Location of Monkeys and Description of Habitats. The population of golden lion tamarins at the Oklahoma City Zoo was maintained, in varying numbers in six different buildings (Figure 1). In 1978, the Zoo had 17 to 21 golden lion tamarins in its collection. Two groups of golden lion tamarins were maintained in the children's zoo. The first group (CZA) consisting of one male and one female was kept in a cage in the kitchen area, away from the public eye. Their cage was furnished with pieces of log and a hanging rope as vine. Their food tray and water bowl were laid on a small platform half way up the south wall. There was a big glass top window for the passage of sunlight. In July 1978, this cage was evacuated; the male was moved to the isolation area while the female was sent to the herpetarium.

The second group (CZB), a family of three, was placed in an exhibit area newly remodelled as a simulated tropical rain forest (Figure

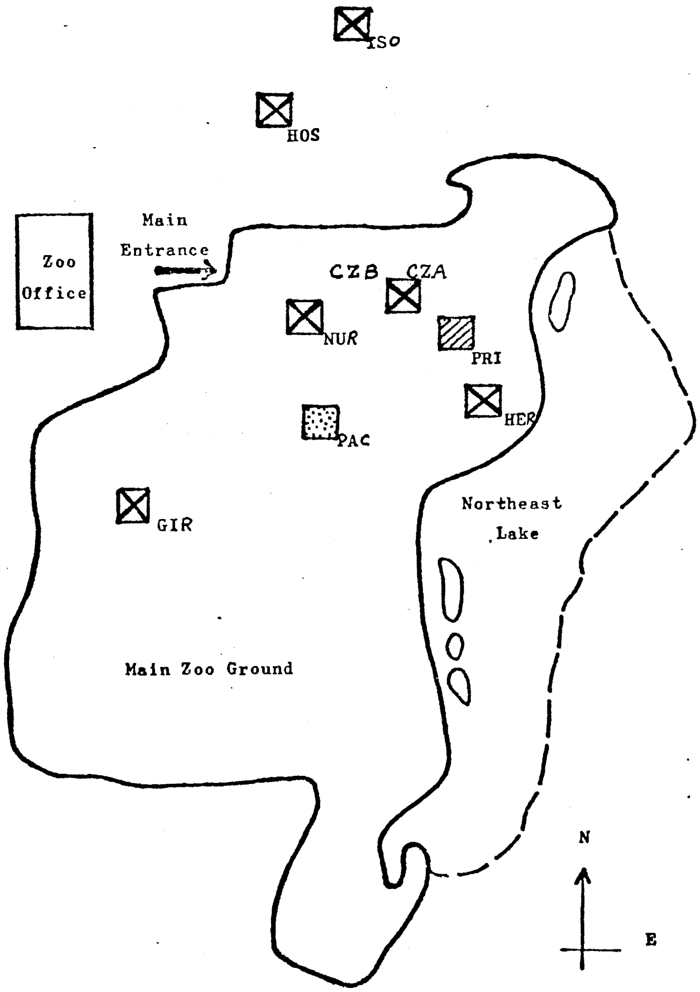

Figure 1. Map of the Oklahoma City Zoo Showing the Areas Where Golden Lion Tamarins, White-faced Sakis, Silver-backed Sakis and Goeldi's Marmosets Were Kept in 1978 and 1979. CZA and CZB = Children's Zoo; GIR = Giraffe Barn; HER = Herpetarium; ISO = Isolation Area; HOS = Animal Care Center; NUR = Nursery; PAC = Pachyderm Building; PRI = Primate House

20, Appendix). Their food bowls were held in among the branches. A communicating opening in the back wall led to the shelter box in the kitchen area. In August 1978, the adult female tamarin gave birth to twins. The juvenile female gradually became aggressive, threatened and attacked the keepers in charge during cleaning and feeding times. She was then transferred to the back cage in the animal care center in April 1979. In July, two more young were born. All appeared to be well adjusted.

Another simulated natural habitat was located at the herpetarium (Figure 21, Appendix). The cage was an old shack with access to an outside cage. In late May 1978, the two original residents were moved to stay temporarily at the isolation area and to await the completion of the renovation of their cage. The male returned to his new home with a new mate (from CZA) in mid-July 1978. A year later (July 1979), he died of an apparent bacterial infection. Another male, on a breeding loan from the National Zoological Park, Washington, D.C., was introduced in September and the new couple appeared to be compatible mates.

By 1978, the giraffe barn housed five golden lion tamarins, two of which were born in June. In May 1979, the young female was transferred to accompany the single female in the animal care center. In August, the mother tamarin delivered two newborn, one of which had an accidental but fatal fall. The cage was furnished with several dried tree branches and a nightbox. The bowls for food and water were secured in holders. The cage opened outside into an outdoor meshwired enclosure and where the tamarins could have access to natural sunlight (Figure 22, Appendix).

While the isolation area was mainly for holding animals during acclimatization, it also served at times as refuge for overflow (Figure 23, Appendix). Two isolated golden lion tamarins[4] stationed throughout 1978 and most of 1979 in meshwired enclosures. In September 1979, each of them was matched with a mate initially from the National Zoological Park. They were transferred into holding pens, each of which was furnished with a nightbox and several branches.

Occasionally, a back cage in the animal care center was used for holding tamarins either in convalescence or awaiting re-allocation (Figure 24, Appendix). In April 1979, a juvenile female from the children's zoo (CZB) occupied the cage. A month later, she was joined by another young female from the giraffe barn. They lived in harmony and were separated only after each was assigned a mate in September.

In the pachyderm building, a third simulated Latin American rain forest was occupied by the Zoo's only pair of Goeldi's marmosets (Figure 25, Appendix). Like the children's zoo area, there was a glass window in the ceiling for sunlight. In June 1978, the female died of embolism. The male remained single for almost five months before he was finally shipped out for breeding purposes. The cage remained empty until September 1979 when the aggressive juvenile female tamarin, originally from the children's zoo, was moved in with a male tamarin from the National Zoological Park.

The only pair of silver-backed sakis in the Zoo was caged in a barred menagerie at the primate house (Figure 26, Appendix); while their

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[4]A third golden lion tamarin died on July 29, 1978, and in which numerous rictularids were recovered.

baby born in November, 1978 was hand-raised in the nursery for almost a year before she was returned to occupy the cage next to her parents in October, 1979. Thus, at the end of the field studies in 1979, the Zoo had a total of three silver-backed sakis.

When this research project began, the Zoo was already depleted of its collection of white-faced sakis. Therefore, the cage for the white-faced sakis which was adjacent and similar to that of the silver-backed sakis was empty.

Management. The floors of the animal cages were routinely flushed twice a day, before the serving of the morning meal at nine and of the afternoon meal at two. Meals for all the zoo animals were prepared by the keepers of the commissaries and picked up by the keepers of the individual areas. The standard diet of the tamarins included items like slices of banana, apples and oranges, raisins, milk and commercial monkey chow. Once a week, freshly killed house crickets were served with milk. Both the Goeldi's marmosets and the silver-backed sakis were given the same diet.

In addition to a fecal examination for intestinal protozoans, helminths and/or bacteria every month, any loose stool observed was always sent to the laboratory technician for a repeated analysis. Because of a potential hazard of toxicity, the sick monkeys were treated with antibiotics or anthelminthics only upon positive laboratory findings or clinical signs. Sometimes, when only positive laboratory results were reported but overt clinical signs were not readily observable from any one monkey, the whole cage of monkeys was treated so as to provide corrective treatment for the sick and prophylaxis for those at high risk.

Epidemiology

The Parasite Status. The status of parasite infections was determined by fecal examinations. In 1978 sampling was done once a week for a period of 30 weeks (May - November); whereas, in 1979 monthly sampling was scheduled between June and October for a total of five months. In each month the fecal examination was conducted for five consecutive days. Entrance to the exhibit areas was allowed to authorized zoo personnel only. Therefore, the fecal collection was done by the zoo keepers working on the different zoo premises, and usually before or at the morning feed time. Only the moist and freshly passed feces were collected. Fresh feces were weighed and divided lengthwise into two equal halves. Standard simple fecal flotation was conducted using saturated sodium nitrate levitation solution (Sp. Gr. 1.40) with one half of the specimen; and saturated zinc sulfate levitation solution (Sp. Gr. 1.18) with the other half. All *Pterygodermatites* eggs recovered were measured and recorded.

Any golden lion tamarins, silver-backed sakis and Goeldi's marmosets that died in 1978 and 1979 were necropsied to determine the worm burden of rictularids.

Search of Zoo Records. Zoo records of both current and past residents of golden lion tamarins, white-faced sakis, silver-backed sakis and Goeldi's marmosets were examined for the reports of spirurid infection. The total number of fecal samples positive for *Pterygodermatites* eggs that occurred in each month and area was enumerated. The results of the search on the zoo records were summarized graphically.

Assuming each monkey in every cage had equal chance of being sampled, the estimate of maximum infection index as well as the average estimate of maximum infection index could be calculated as follows:

$$\text{Estimate of maximum infection index} = \frac{A}{B \times C}$$

where A = number of fecal samples positive for Pterygodermatites eggs

B = total number of fecal samples collected from the cage

C = number of monkeys in the cage at the time of collection

Average estimate of maximum infection index

$$= \frac{\sum^{n} \text{Estimate of maximum infection index}}{n}$$

where n = total number of estimates of maximum infection index of all the areas studied

Statistical Analysis of Field Studies. Chi-square test was run to test the difference in the frequency of positive fecal samples detected by the levitation solutions, sodium nitrate and zinc sulfate (Steel and Torrie, 1960). In the case when the number of positive fecal samples was small (between 8 and 50), Fisher's Exact Test was used instead (Langley, 1970). Paired-t statistics were done to test the difference in the number of Pterygodermatites eggs recovered by the two levitation solutions (Steel and Torrie, 1960).

Trapping and Examination of House Mice

Conventional live traps for small rodents were placed at strategic spots believed to be on the routes often used by house mice in the zoo buildings where the monkeys were kept. Three traps were set in each building. The bait was a scoop of peanut butter topped with oat flakes. The traps were checked every morning and reset.

Trapped house mice or young rats were killed by cervical dislocation and their bodies opened by longitudinal mid-line incision. Gross examination was performed to check for encysted larvae on the serosal surfaces of the body cavities and of the gastrointestinal tract. The gastrointestinal tract was removed, separated into parts (the stomach, the small intestine, the large intestine and the ceca), and split open. The contents and the gut wall were examined under a dissection microscope for the presence of either larval or adult Pterygodermatites. The number of positive findings was expressed as a percentage of the total number of rodents examined.

Trapping and Examination of Cockroaches

Both pint- and quart-sized jars were used as live traps. The sides of the jars were dusted with besonite clay to prevent escape of the trapped cockroaches and fresh white bread was used as bait. In July and August, the hotter months, besonite clay was removed. The mouth of each jar was coated with several centimeters wide of petrolatum and a shell vial of moist cotton ball was added to prevent excessive deaths of the cockroaches due to dryness. In 1978, the jars were checked once a week for 30 weeks; in 1979, they were emptied and reset daily throughout the weeks (from June to October) in which I stayed at the Zoo.

The cockroaches were decapitated, their entire gastrointestinal tracts removed and examined under a dissection microscope for encysted

Pterygodermatites larvae. The number of infected cockroaches was expressed as a percent of those examined.

Examination of Zoo-maintained House Crickets

A colony of house crickets (*Acheta domesticus*) had always been maintained in the basement in the kitchen area of the herpetarium. The wooden enclosure measured 5' x 2' x 2' and had a meshwired top ready for observation of the interior. Inside were stacks of egg cartons, dishes of moist sand, a plate of rabbit chow and a shallow water trough. In winter, the enclosure was kept warm with a 100-watt light bulb.

Forty or more crickets of each monthly shipment received between June and October, 1979 were examined for the presence of larval *Pterygodermatites*. The crickets were collected randomly from the wooden enclosure. They were decapitated, their gastrointestinal tracts removed and examined under a dissection microscope. Positive results were shown as a percentage of the total number of crickets examined.

Collection and Examination of Adult Worms

Pterygodermatites worms recovered from the feces and/or at necropsy of the golden lion tamarins were preserved in 10% formalin. The worm specimens and at times the entire intestinal tract of the tamarins were sent to the Department of Veterinary Parasitology, Microbiology and Public Health in Oklahoma State University for specific identification. Worms recovered from the golden hamsters, the experimental definitive host, were preserved in Beltsville solution. Some rictularids found in golden lion marmosets (tamarins) and black and red marmosets of the National Zoological Park, Washington, D.C.[5] and four female rictularids from Sanguinus oedipus and Hylobates lar lar in Topeka, Kansas Zoo[6] were also available for examination. All of these specimens were examined and included in the study.

The worm specimens were cleared in lactophenol and then studied with phase contrast microscopy. Drawings were done by means of a camera lucida.

Experimental Studies

Artificial Infection of Laboratory-Reared German Cockroaches with Pterygodermatites Eggs

Tamarin feces that were contaminated with Pterygodermatites eggs were subject to repeated washings and centrifugations until the supernatant was clear. After the supernatant was pipetted, the sediment was mixed with ground beef (Oswald, 1958a). Twelve laboratory-reared German cockroaches (Group A) were exposed to the contaminated ground beef. Another six (Group B) were exposed to the rinsings of the container of the monkey feces positive with Pterygodermatites eggs. A control group of twelve cockroaches was provided with uncontaminated ground beef. On day 22 post-exposure, two exposed cockroaches and two controls were examined for larval Pterygodermatites. When larval Pterygodermatites were

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[5]By courtesy of Dr. J.R. Lichtenfels, leader of Parasite Classification and Distribution Unit, Animal Parasitology Institute, Agricultural Research Center, Beltsville, Maryland 20705.

[6]By courtesy of Dr. W.D. Lindquist, Department of Laboratory Medicine, College of Veterinary Medicine, Kansas State University, Manhattan, Kansas 66502.

observed, the remainder was killed and examined. The larvae recovered were fed to helminth-free golden hamsters.

Artificial Infection of Helminth-Free Golden Hamsters with *Pterygodermatites* Larvae

Live larval *Pterygodermatites* recovered from exposed German cockroaches were maintained in 0.75% physiological saline immediately after they were removed from the insect hosts. Within an hour, they were fed *per os* with a syringe and an 20 gauge canula to four laboratory-reared, helminth-free golden hamsters. A fifth hamster as the control was given only the physiological saline for equal handling. On day 10, the two golden hamsters that received a smaller inoculum were killed and examined for maturing *Pterygodermatites*. On day 28, the other exposed hamsters and the control were likewise killed and examined for juvenile or adult worms.

CHAPTER IV

RESULTS

Field Studies

Epidemiology

The Parasite Status. The two-year study on the fecal examination of the golden lion tamarins, silver-backed sakis and Goeldi's marmosets of the Oklahoma City Zoo is summarized in Table V. A total of nine fecal samples positive with eggs of Pterygodermatites nycticebi (Figure 2) was reported from only the golden lion tamarins. Six were obtained in 1978 and three in 1979 (Figure 3). These positive fecal samples were collected from the golden lion tamarins in the giraffe barn, isolation area, children's zoo (CZA) and animal care center (Figure 4). However, the silver-backed sakis and Goeldi's marmosets were always negative for this parasite egg (Table V).

Due to the low number of positive fecal samples that were observed, no Chi-square test was made (Table VI). The Fisher's Exact Test, on the other hand, showed that the difference in the results of flotation by sodium nitrate and zinc sulfate was not significant at P = 0.05 (Table VII). Analysis of the paired-t test also indicated that the difference in the number of Pterygodermatites eggs recovered by the two levitation solutions was not significant at P = 0.05 (Table VII).

TABLE V

SUMMARY OF FECAL EXAMINATIONS OF GOLDEN LION TAMARINS (GLT),
SILVER-BACKED SAKIS (SBS) AND GOELDI'S MARMOSETS (GDM)
OF THE OKLAHOMA CITY ZOO IN 1978 AND 1979

Zoo Areas	Type of Monkeys	1978					1979					Grand Total			
		No. of Monkeys	No. of Samples	I*	II**	III+	No. of Monkeys	No. of Samples	I	II	III	No. of Samples	I	II	III
CZA	GLT	2	22	4	0	4	0	–	–	–	–	22	4	0	4
CZB	GLT	3	52	0	0	0	5	30	0	0	0	82	0	0	0
GIR	GLT	4	69	1	1	1	5	30	0	0	0	99	1	1	1
HER	GLT	2	43	0	0	0	2	30	0	0	0	73	0	0	0
ISO	GLT	2	47	0	1	1	6	44	1	0	1	91	1	1	2
HOS	GLT	1	9	0	0	0	2	24	2	1	2	33	2	1	2
NUR	GLT	1	8	0	0	0	1	2	0	0	0	10	0	0	0
PAC	GDM	2	49	0	0	0	0	–	–	–	–	49	0	0	0
PAC	GLT	0	–	–	–	–	2	25	0	0	0	25	0	0	0
PRI	SBS	2	51	0	0	0	2	30	0	0	0	81	0	0	0

*I = Number of fecal samples found positive with <u>Pterygodermatites</u> eggs by using sodium nitrate solution

**II = Number of fecal samples found positive with <u>Pterygodermatites</u> eggs by using zinc sulfate solution

+III = Total Number of fecal samples positive with <u>Pterygodermatites</u> eggs

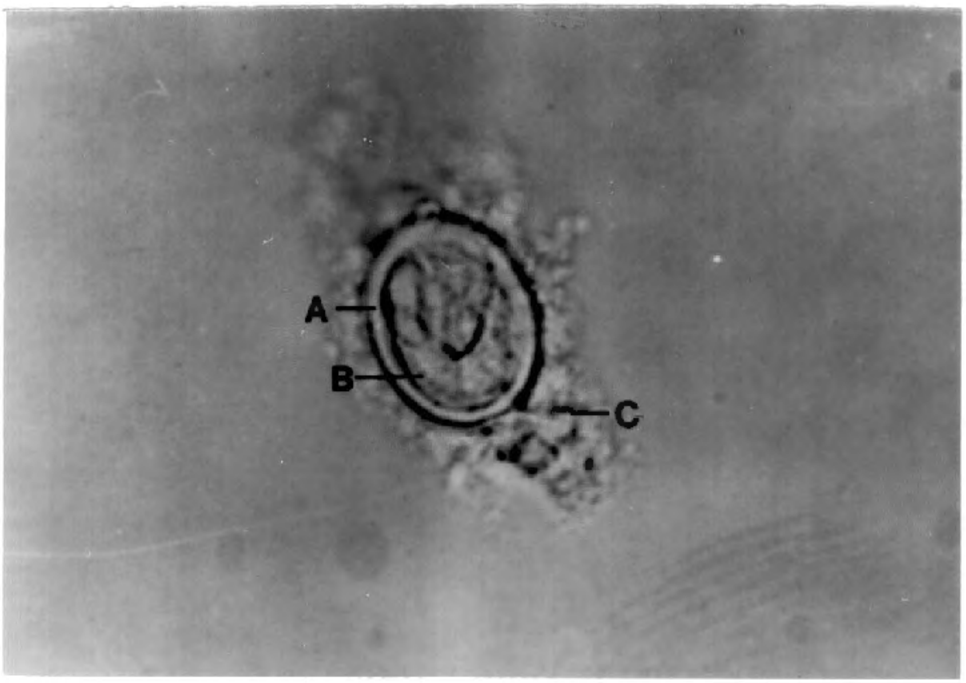


Figure 2. Egg of Pterygodermatites nycticebi. A: Egg Shell; B: Larva; C: Fecal Materials. x 400

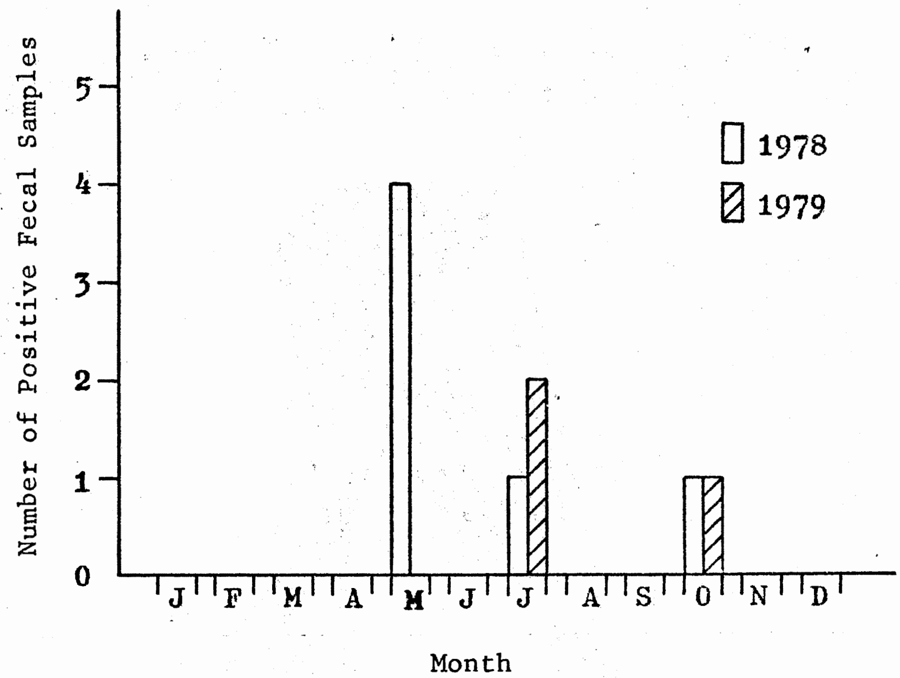


Figure 3. Number of Fecal Samples Positive with <u>Pterygodermatites</u> Eggs Reported in 1978 and 1979 in Golden Lion Tamarins, Silver-Backed Sakis and Goeldi's Marmosets in the Oklahoma City Zoo

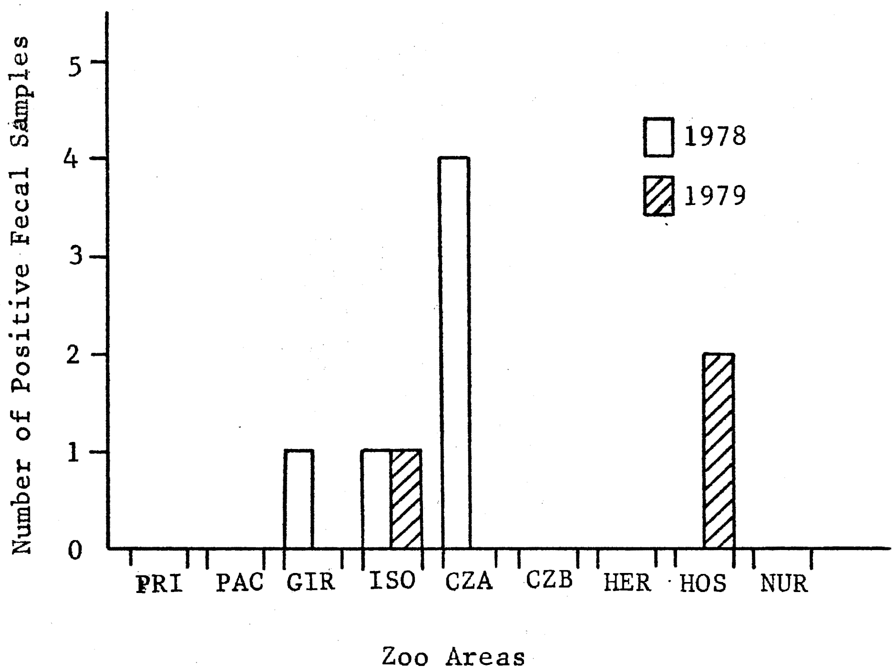


Figure 4. Number of Fecal Samples Positive with *Pterygodermatites* Eggs Reported in 1978 and 1979 from Various Areas of the Oklahoma City Zoo

TABLE VI

THE FREQUENCY OF THE PRESENCE AND ABSENCE OF PTERYGODERMATITES EGGS DETERMINED BY TWO LEVITATION SOLUTIONS, SODIUM NITRATE AND ZINC SULFATE, FROM THE FECES OF GOLDEN LION TAMARINS, SILVER-BACKED SAKIS AND GOELDI'S MARMOSETS IN THE OKLAHOMA CITY ZOO FROM 1978 TO 1979

Sodium Nitrate	Zinc Sulfate			
		Number of Negative Fecal Examination	Number of Positive Fecal Examination	Total
Number of Negative Fecal Examination	1978:	344	1	345
	1979:	210	0	210
	Total:	554	1	555
Number of Positive Fecal Examination	1978:	4	1	5
	1979:	2	1	3
	Total:	6	2	8
Total	1978:	554	1	555
	1979:	6	2	8
		560	3	563

Chi-square test: no statistical test was made due to the low egg counts for each cell of the table

TABLE VII

RESULTS OF FLOTATION* BY SODIUM NITRATE ($NaNO_3$) AND ZINC SULFATE ($ZnSO_4$) WITH FECAL SAMPLES POSITIVE WITH PTERYGODERMATITES EGGS AND THEIR STATISTICAL ANALYSES

Fecal Sample	Number of Eggs Floated $NaNO_3$	$ZnSO_4$
1	2	0
2	1	0
3	1	0
4	1	0
5	0	1
6	4	1
7	19	4
8	1	0
9	1	0

	$ZnSO_4$ Eggs Detected	$ZnSO_4$ Eggs Not Detected	Total
$NaNO_3$			
Eggs Detected	2	6	8
Eggs Not Detected	1	0	1
Total	3	6	9

*The total number of fecal samples that were examined and did not yield any *Pterygodermatites* eggs by either sodium nitrate solution or zinc sulfate solution was 554.

Fisher's Exact Test:

$$\text{Probability (P)} = \frac{8!\ 1!\ 3!\ 6!}{9!\ 2!\ 6!\ 0!}$$

$= 1/3$; not significant at $P = 0.05$

Paired-t Test:

Calculated $t = 1.69$; not significant at $P = 0.05$; $df = 8$

Pterygodermatites eggs that were recovered from the monkey feces measured 28 µ x 39 µ.

Findings from the Search of Zoo Records. Four different kinds of New World monkeys maintained in the Oklahoma City Zoo, namely, the golden lion tamarins (GLT), white-faced sakis (WFS), silver-backed sakis (SBS), and Goeldi's marmosets (GDM) were suspected to be infected by the same spirurid, Pterygodermatites nycticebi. Table VIII summarizes the six years of zoo records on these small primates. It revealed that a total of 49 fecal samples positive for Pterygodermatites eggs was recorded. They are shown chronologically as the number of fecal samples positive with Pterygodermatites eggs per month (Figure 5). The cumulative record (Figure 6) shows that more positive fecal samples were reported in January, April, July, September, October and November than in other months. The estimates of maximum infection index per month for the six years ranged from 0 in June to 0.0029 in April (Figure 7). The estimates of maximum infection index for April, July and November were higher than the average (0.0008), while those for other months were below the average.

Figure 8 shows the numbers of fecal samples positive with Pterygodermatites eggs that were reported annually from the various areas of the Zoo. The cumulative record over the six-year period is shown in Figure 9. Varying numbers of positive fecal samples were collected from all the areas studied. However, no positive fecal samples were ever reported from the herpetarium, children's zoo (CZB) and nursery. The estimate of maximum infection index for the golden lion tamarins in the pachyderm building was the highest (0.029) (Figure 10). In

TABLE VIII

SUMMARY OF THE RECORDS OF FECAL EXAMINATIONS POSITIVE WITH <u>PTERYGODERMATITES</u> EGGS REPORTED FROM GOLDEN LION TAMARINS (GLT), WHITE-FACED SAKIS (WFS), SILVER-BACKED SAKIS (SBS) AND GOELDI'S MARMOSETS (GDM) IN THE OKLAHOMA CITY ZOO FROM 1974 TO 1979

		Zoo Areas and Type of Monkeys												Total	Estimate of Maximum Infection Rate
		PAC GLT	PRI GLT	PRI WFS	PRI SBS	PAC GDM	CZA GLT	GIR GLT	ISO GLT	HER GLT	CZB GLT	NUR GLT	NUR SBS		
1974:	+ Fecal Samples	2	0	6	3	0	1	0	–	–	–	–	–	12	0.014
	No. of Samples	5	7	7	11	10	4	5	–	–	–	–	–	49	
	No. of Monkeys	2	2	3	2	2	2	5	–	–	–	–	–	18	
1975:	+ Fecal Samples	2	4	0	2	1	1	0	–	0	–	0	–	12	0.004
	No. of Samples	7	20	83	15	83	8	18	–	16	–	3	–	198	
	No. of Monkeys	2	2	3	2	3	2	3	–	1	–	1	–	18	
1976:	+ Fecal Samples	–	1	0	2	0	0	2	–	0	–	0	–	7	0.002
	No. of Samples	–	26	37	19	37	18	31	–	27	–	9	–	191	
	No. of Monkeys	–	2	2	2	2	3	3	–	2	–	2	–	18	
1977:	+ Fecal Samples	–	1	3	3	3	1	4	–	0	0	–	–	13	0.003
	No. of Samples	–	50	36	48	36	31	50	–	38	10	–	–	294	
	No. of Monkeys	–	2	2	2	2	2	3	–	2	2	–	–	17	
1978:	+ Fecal Samples	–	–	–	1	–	1	1	1	0	0	0	0	4	0.001
	No. of Samples	–	–	–	24	–	27	24	30	20	55	9	6	209	
	No. of Monkeys	–	–	–	3	–	3	5	3	2	3	1	1	22	
1979:	+ Fecal Samples	0	–	–	0	–	–	1	0	0	0	–	0	1	0
	No. of Samples	11	–	–	17	–	–	18	93	42	41	–	6	228	
	No. of Monkeys	2	–	–	3	–	–	5	5	2	4	–	1	22	
Total:	+ Fecal Samples	4	6	9	11	6	4	8	1	0	0	0	0	49	0.0004
	No. of Samples	23	103	163	134	113	88	146	123	143	106	21	6	1169	
	No. of Monkeys	6	8	10	14	10	12	24	8	9	9	4	1	115	
Estimate of Maximum Infection Rate		0.029	0.007	0.006	0.006	0.005	0.004	0.002	0.001	0	0	0	0		

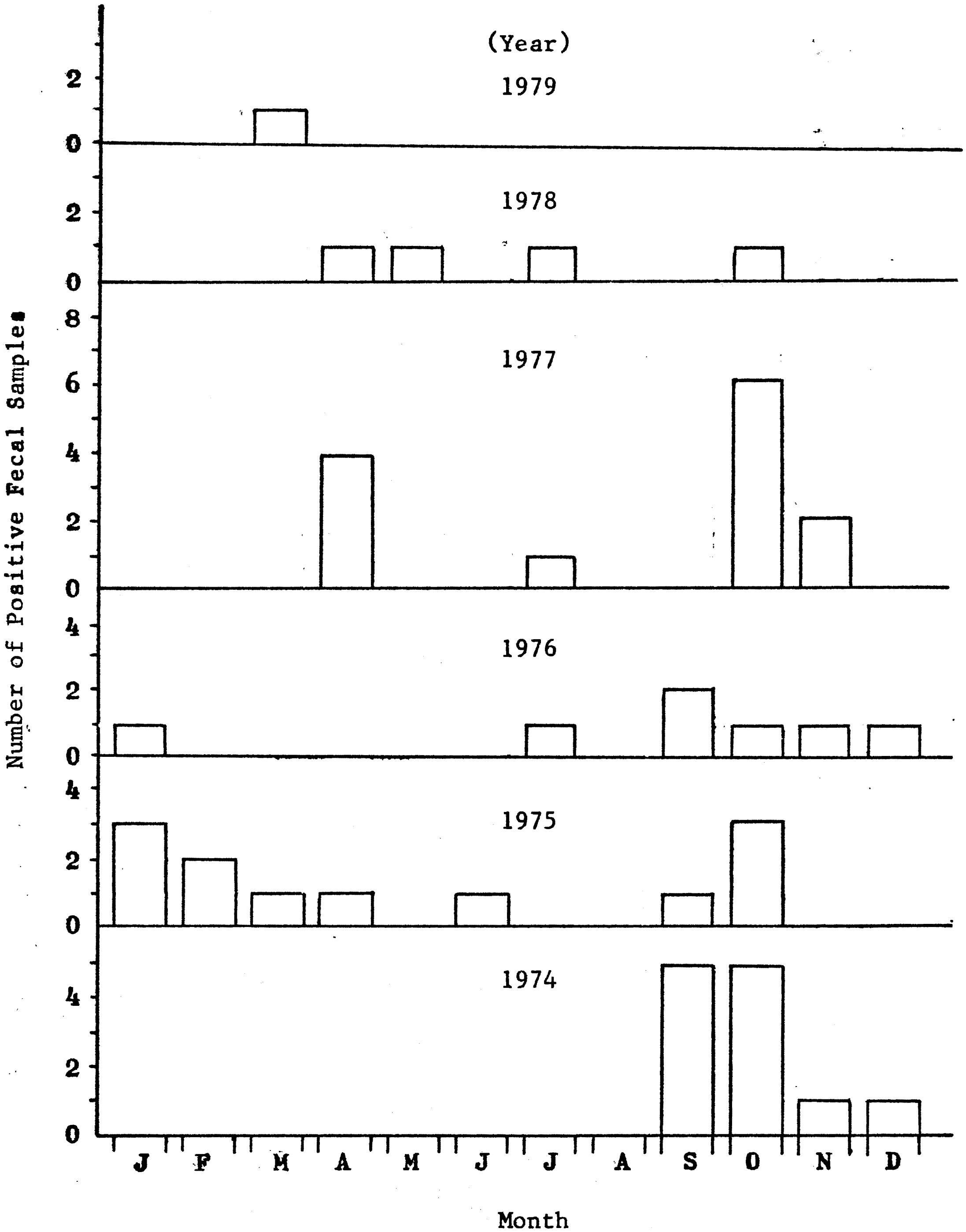


Figure 5. Number of Fecal Samples Positive with *Pterygodermatites* Eggs Reported Monthly in Golden Lion Tamarins, White-Faced Sakis, Silver-Backed Sakis and Goeldi's Marmosets in the Oklahoma City Zoo from 1974 to 1979

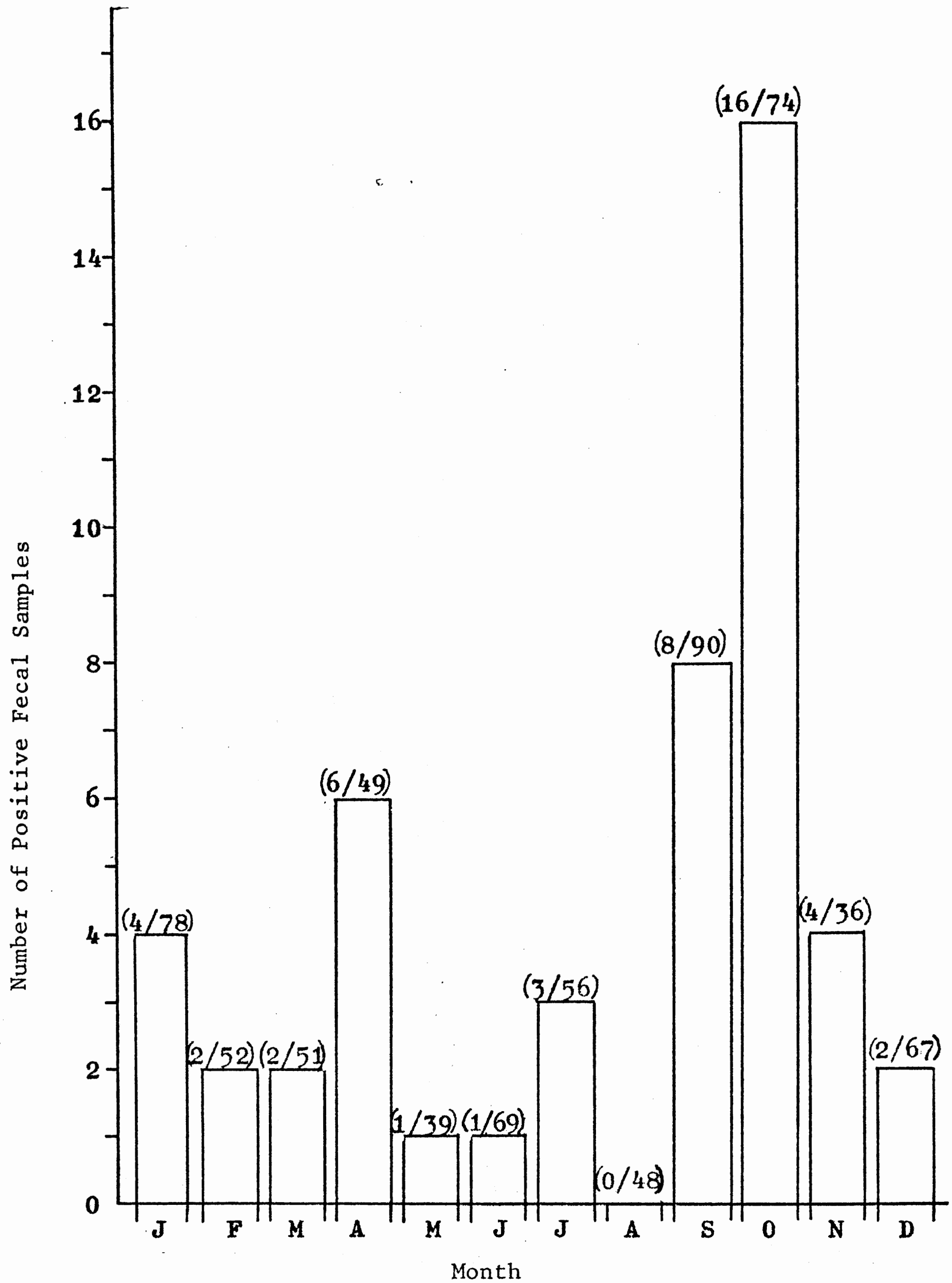


Figure 6. Cumulative Record of the Number of Fecal Samples Positive with *Pterygodermatites* Eggs Reported Monthly in Golden Lion Tamarins, White-Faced Sakis, Silver-Backed Sakis and Goeldi's Marmosets in the Oklahoma City Zoo from 1974 to 1979. Number in Parentheses = Total Number of Positive Fecal Samples Examined/Total Number of Fecal Samples Collected

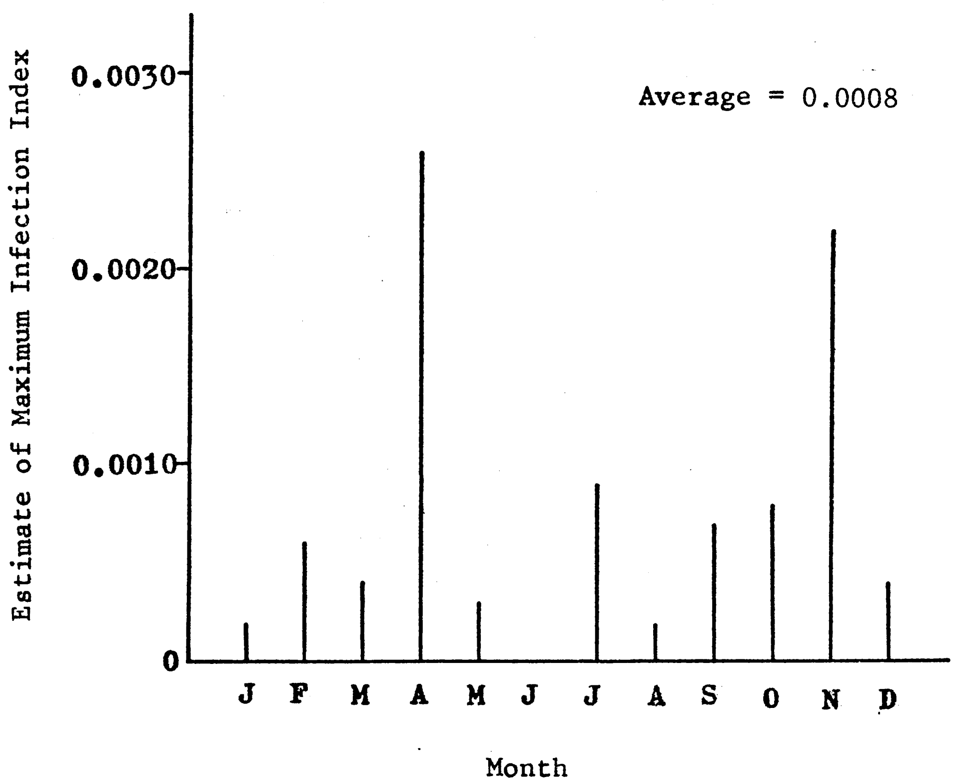


Figure 7. Estimate of Maximum Infection Index by Month of Golden Lion Tamarins, White-Faced Sakis, Silver-Backed Sakis and Goeldi's Marmosets in the Oklahoma City Zoo from 1974 to 1979

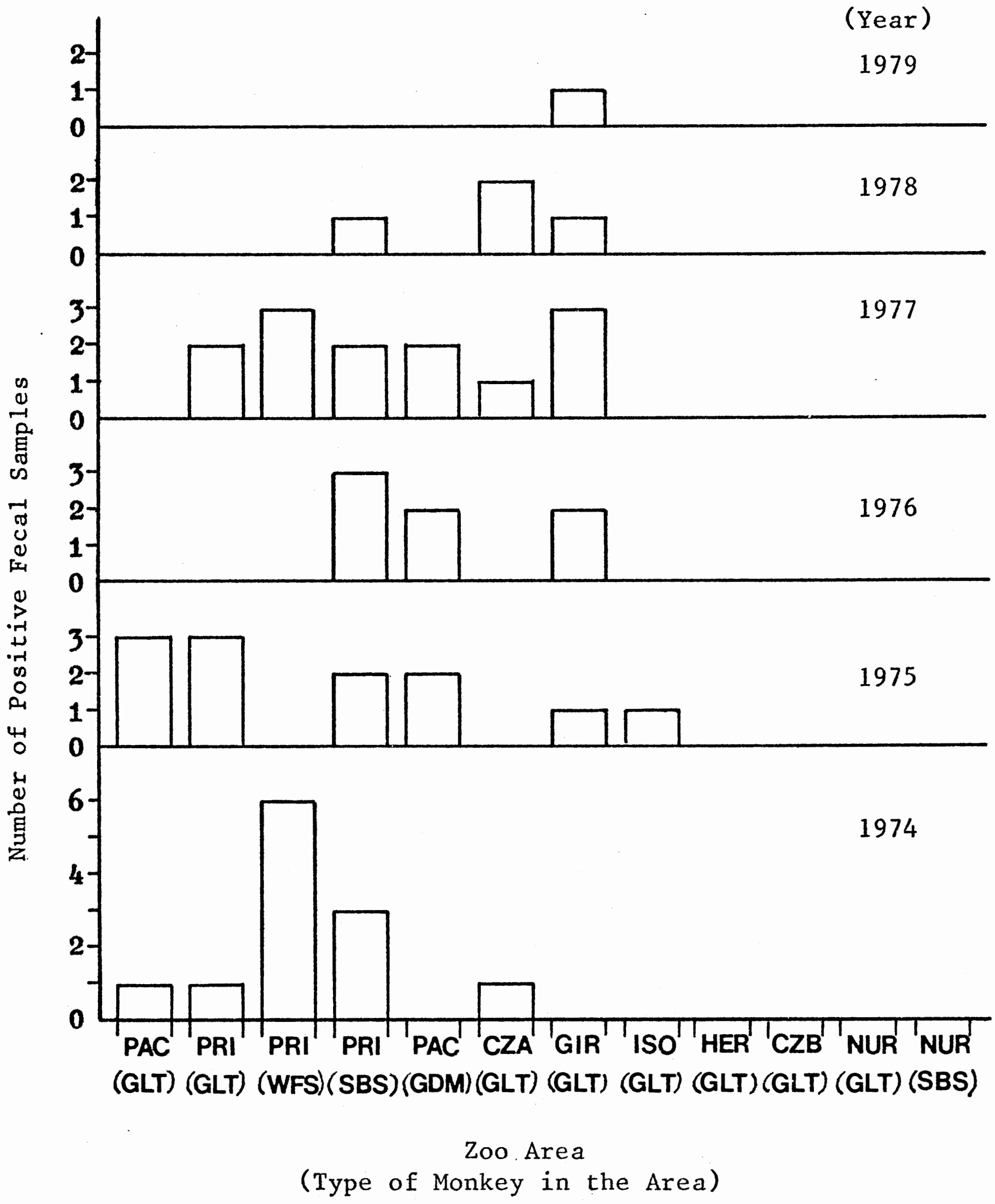


Figure 8. Number of Fecal Samples Positive with Pterygodermatites Eggs Reported in Golden Lion Tamarins, White-Faced Sakis, Silver-Backed Sakis and Goeldi's Marmosots in Various Areas of the Oklahoma City Zoo from 1974 to 1979

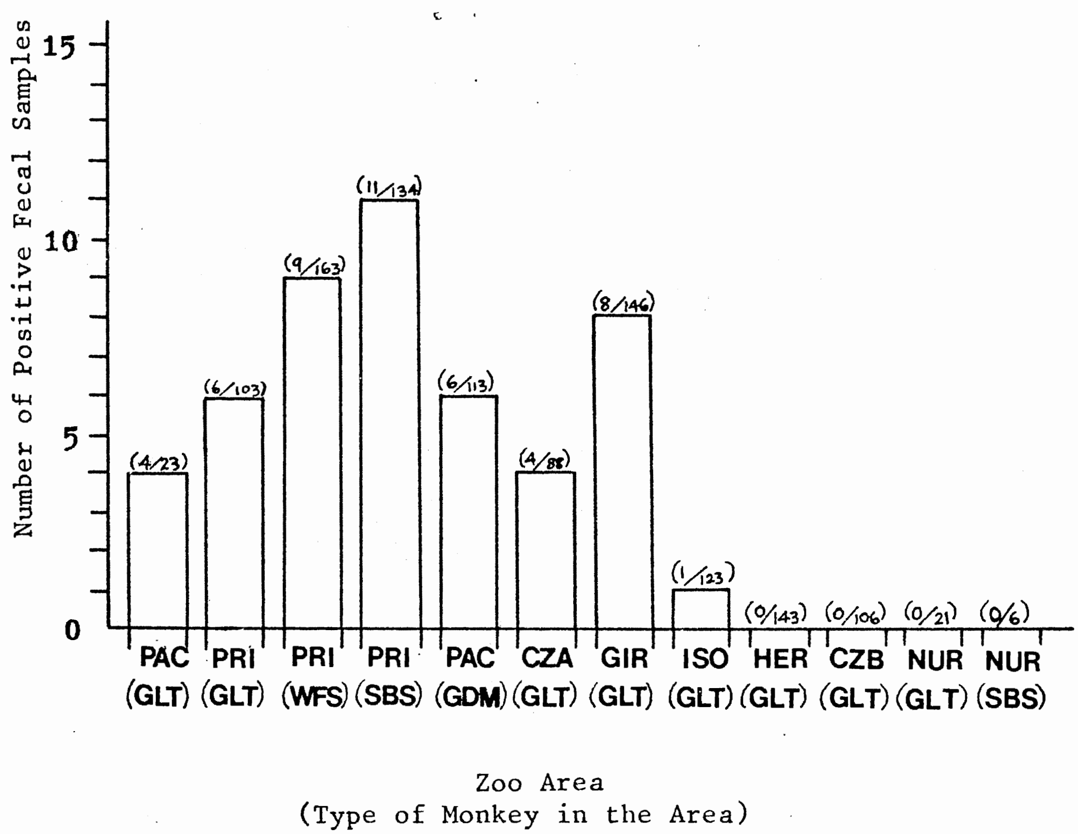


Figure 9. Cumulative Record of the Number of Fecal Samples Positive with Pterygodermatites Eggs Reported from Various Areas of the Oklahoma City Zoo from 1974 to 1979. Number in Parentheses = Total Number of Positive Fecal Samples Examined/Total Number of Fecal Samples Collected

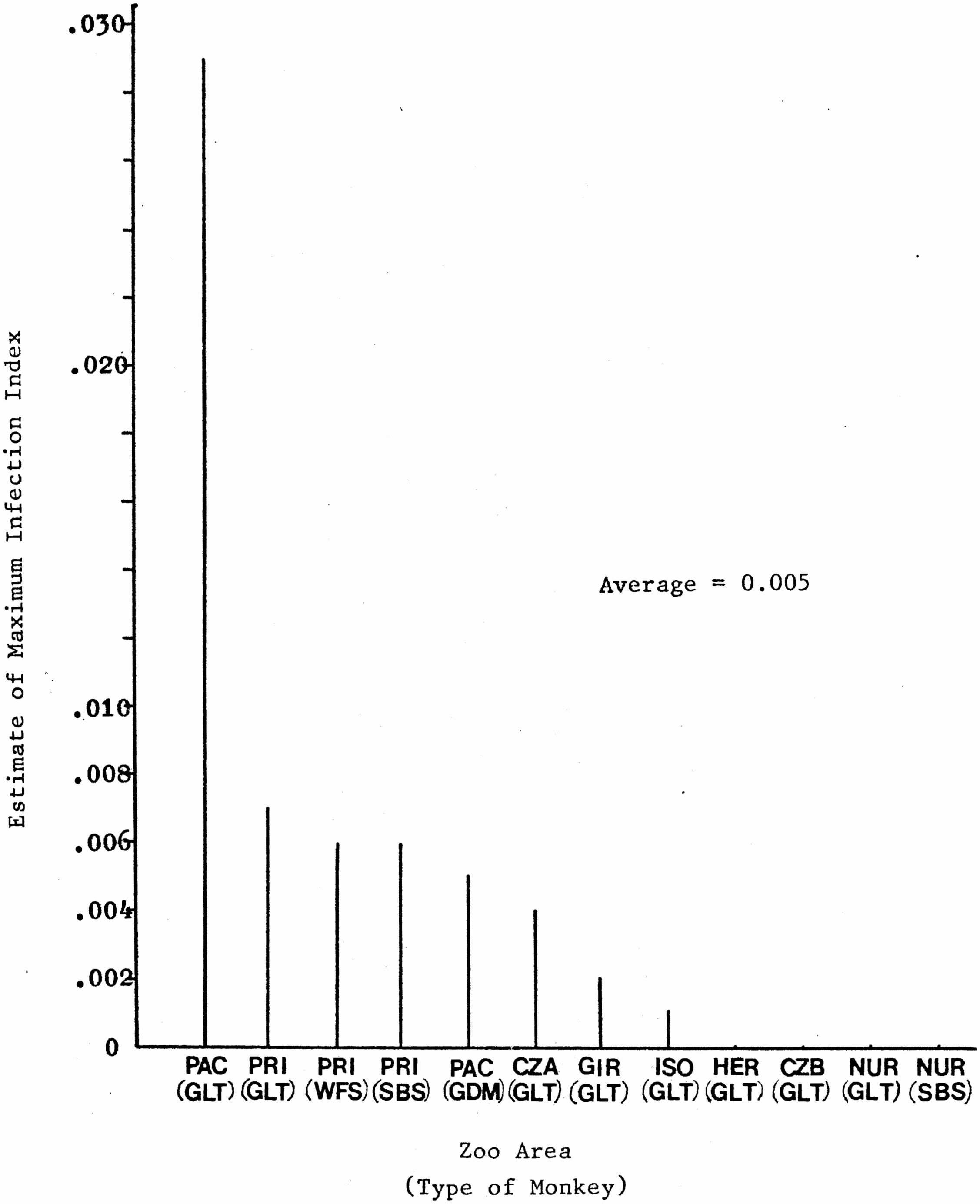


Figure 10. Estimate of Maximum Infection Index by Zoo Area Where Golden Lion Tamarins, White-Faced Sakis, Silver-Backed Sakis and Goeldi's Marmosets Were Maintained in the Oklahoma City Zoo from 1974 to 1979

contrast, the estimates of maximum infection index for the monkeys in other areas were relatively low. The average was 0.005.

The total number of positive fecal samples reported annually declined over the six-year period (Figure 11). The record for 1977 was exceptional in that it was the highest among the six years. The estimate of maximum infection index by year was the highest in 1974 and it declined drastically in the following years (Figure 12). Though the index in 1977 rose slightly, it was below the average (0.004).

The zoo records showed that the Zoo bought 33 white-faced sakis between 1972 and 1973. Within one to three months of their arrival at the Zoo, 26 of the 33 died of shipping stress, or bacterial, or viral, or hookworm infections. One female white-faced saki had repeatedly passed spirurid eggs in her second week of quarantine in the isolation area. When she died two months afterwards, no worms were found in her gut at necropsy (Table IX). The last white-faced saki in the Zoo's collection was housed in the primate house. She died shortly before this research project was initiated. At necropsy, more than 50 mature spirurids were recovered from her small intestine (Table IX). They were identified to be of the genus Pterygodermatites.

The Zoo also purchased eight silver-backed sakis in 1972 and four succumbed to shipping stress. After quarantine the remaining four were maintained in the primate house, adjacent to the white-faced sakis. A female silver-backed saki which was never found to pass any parasite eggs died of a heavy intestinal parasitic infection. The parasites found in her gut were ascarids, hookworms, rhabditoids (Strongyloides sp.) and unidentified spirurids. The worm specimens were not preserved.

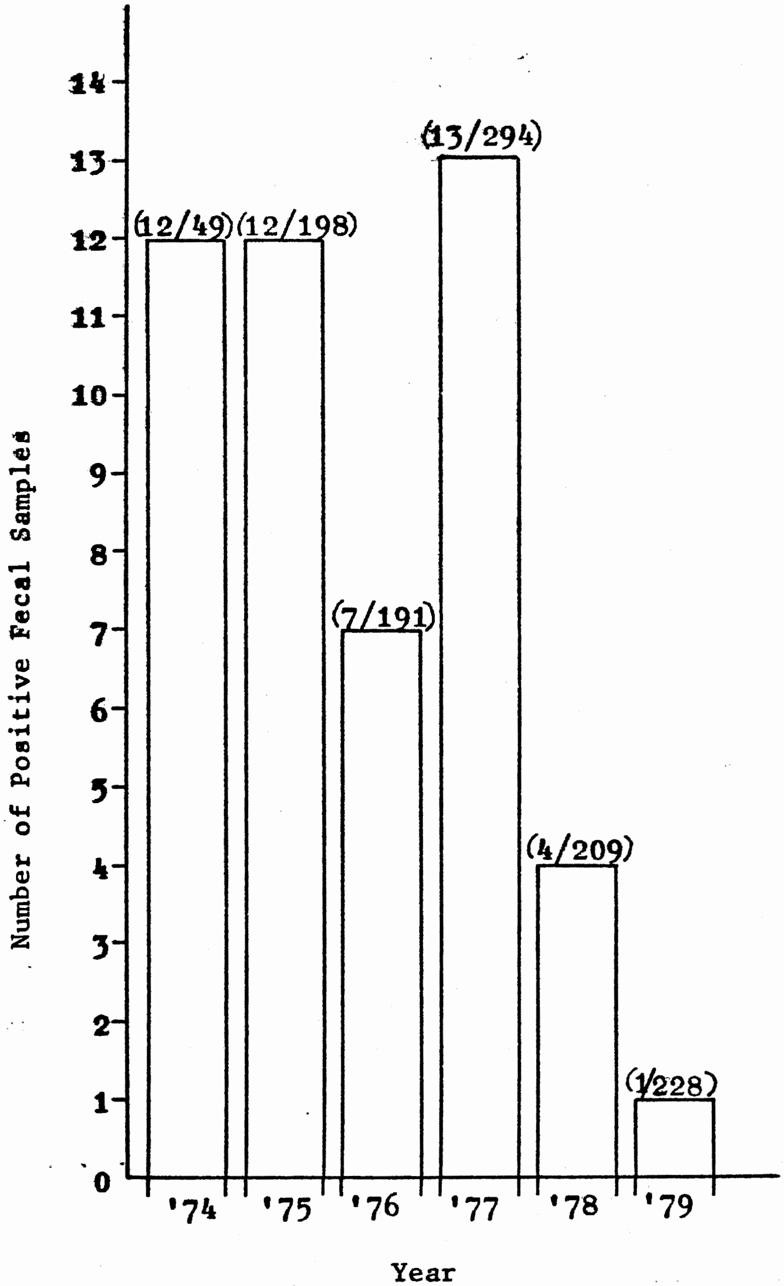


Figure 11. Annual Total Number of Fecal Samples Positive with Pterygodermatites Eggs Reported in Golden Lion Tamarins, White-Faced Sakis, Silver-Backed Sakis and Goeldi's Marmosets in the Oklahoma City Zoo from 1974 to 1979. Number in Parentheses = Total Number of Positive Fecal Samples Examined/Total Number of Fecal Samples Collected

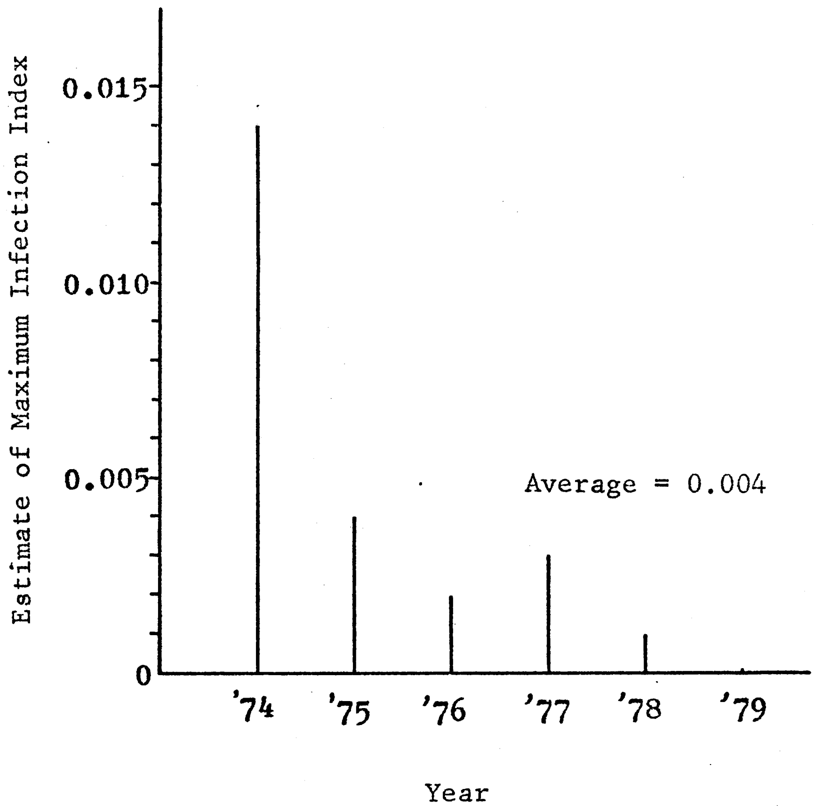


Figure 12. Annual Estimate of Maximum Infection Index of Golden Lion Tamarins, White-Faced Sakis, Silver-Backed Sakis and Goeldi's Marmosets in the Oklahoma City Zoo from 1974 to 1979

TABLE IX

SUMMARY OF RECORDS OF THE RECOVERY OF RICTULARID WORMS FROM THE FECES OR AT NECROPSY OF GOLDEN LION TAMARINS (GLT), WHITE-FACED SAKIS (WFS), SILVER-BACKED SAKIS (SBS) AND GOELDI'S MARMOSETS (GDM) IN THE OKLAHOMA CITY ZOO (OKC) FROM 1974 TO 1979

Type of Monkeys	Area*	Sex	Birth Place	Number of Positive Fecal Examinations	Number of Worms Recovered From Feces	At Necropsy
GLT	PRI	M	OKC	0	?**	0
GLT	PAC	M	OKC	4	0	0
GLT	GIR	F	OKC	3	0	0
GLT	GIR	M	OKC	2	0	0
GLT	GIR	F	OKC	0	0	50 mature worms
GLT	PRI	M	OKC	2	0	0
GLT	PRI	M	OKC	3	2	0
WFS	PRI	F	in the wild	1	0	50+ mature worms
WFS	ISO	F	in the wild	2	0	0
SBS	PRI	F	in the wild	0	0	?
SBS	PRI	M	in the wild	8	?+	
GDM	PAC	F	in the wild	5	0	0

*Areas represented: PRI = primate house; PAC = pachyderm building; GIR = giraffe barn; ISO = isolation area.

**Number of worms recovered not recorded.

+Monkey still active.

On September 17, 1974, spirurid eggs were detected for the first time in the feces of the last pair of silver-backed sakis in the Zoo. The eggs were identified as those of Pterygodermatites. This pair of sakis delivered a baby in November, 1978. She was hand-raised in the nursery. Spirurid eggs had never been observed in her feces.

The Zoo bought a couple of Goeldi's marmosets in 1971. On April 11, 1975, spirurid eggs similar to those found in the sakis and golden lion tamarins were recovered from the marmoset feces. Fecal samples positive for the same spirurid eggs were collected several times before the female marmoset died of embolism in July, 1978. Yet, no worms were recovered from her intestinal tract. The male marmoset passed neither worms nor eggs in the feces since the death of his mate and even up to the time he was sent away on a breeding loan.

The first two pairs of golden lion tamarins were introduced into the Zoo in 1964. All were born in the wild. Three pairs of captive-born golden lion tamarins were added to the Zoo's collection between 1968 and 1972 to establish individual colonies. These breeder tamarins had scored a total of 40 offspring. The breeding success and infantile survival were high with the groups in the herpetarium and the giraffe barn. Consequently, yearlings from either groups were often transferred to other areas in the Zoo for mating.

Spirurid eggs were first observed in the feces of a male golden lion tamarin on September 12, 1974. This three-year-old tamarin was born at the herpetarium and was transferred to the pachyderm building as a yearling. Subsequently, positive fecal samples were reported from the tamarins at the giraffe barn, the primate house and the isolation area. Adult worms were also found in the feces of two male tamarins (from the primate house) and at necropsy of a female tamarin housed in the giraffe barn (Table IX). Although some worm specimens were misplaced, those available for examination were confirmed to be conspecific with those recovered in the white-faced saki. The spirurids were identified as *Pterygodermatites nycticebi* (Mönnig, 1921).

Examination of House Mice

During the two-year study, 114 feral house mice and three rats were trapped, killed and examined for larval and adult *Pterygodermatites*. None was found to be infected (Table X). The average number of small rodents trapped per night was 2.28 (114/50).

Examination of Wild Cockroaches

Three kinds of cockroaches were collected: American cockroach (*Periplaneta americana*), German cockroach (*Blattella germanica*), and Oriental cockroach (*Blatta orientalis*). A total of 190 gastrointestinal tracts was examined for encysted larvae of *Pterygodermatites*; but all were uninfected (Table X). The number of cockroaches per trap night was 3.8 (190/50).

Two grasshoppers that accidentally jumped into the roach traps were also negative for *Pterygodermatites* larvae (Table X).

Examination of Zoo-Maintained House Crickets

Every shipment of commerically raised crickets received by the Zoo between June and October, 1979 was examined for *Pterygodermatites* larvae. Not a single cricket of the 246 house crickets (*Acheta domesticus*)

TABLE X

RESULTS OF EXAMINATION OF WILD RODENTS AND INSECTS TRAPPED IN THE NEIGHBORHOOD OF THE CAGES OF GOLDEN LION TAMARINS, SILVER-BACKED SAKIS AND GOELDI'S MARMOSETS IN THE OKLAHOMA CITY ZOO FOR THE PRESENCE OF ADULT AND LARVAL PTERYGODERMATITES

Organism	Number Killed and Examined			Number Infected
	1978	1979	Total	
Rodents				
Mice	73	41	114	0
Rats	1	2	3	0
Insects				
Cockroaches	72	118	190	0
Crickets*	10	246	256	0
Grasshoppers	2	0	2	0

*Crickets were sampled from a colony maintained in the herpetarium and they are a food item for small primates and other zoo animals.

examined was found to harbor any larvae, encysted or otherwise. Ten house crickets, possible escapees from the kitchen area, were found in the roach traps in the herpetarium. They were checked for the parasite and were not infected either (Table X).

Examination of Adult Worms

Pterygodermatites worms were recovered at necropsy of a white-faced saki and several golden lion tamarins. Some were collected from feces of golden lion tamarin after the administration of an anthelminthic. Two juvenile females were recovered from the experimental host, the golden hamster.

General Characteristics. Live worms collected in the golden hamsters were whitish pink. Preserved worms were white to light brown. The head of adult worms of both sexes was tapering and bent ventrally after fixation. The mouth was dorsal, subterminal and transverse. There were three esophageal teeth. Two were located ventro-laterally. In most specimens, they appeared to be sharp-pointed; in others they were serrated. A third tooth on the dorsal wall of the buccal cavity was semilunar and rugged. Bordering the dorsal edge of the buccal cavity were ten or more denticles of irregular length (Figure 13). The ventral (anterior) border was also finely serrated. The conspicuous structures around the mouth were: chitinous apophyses on the ventral side and four bulbous lateral papillae, two dorsal and two ventral. Latero-ventrally, there were two rows of combs and spines which were paired and extended along the entire length of the body. Combs were located in the anterior half of the worm and they lied close together.

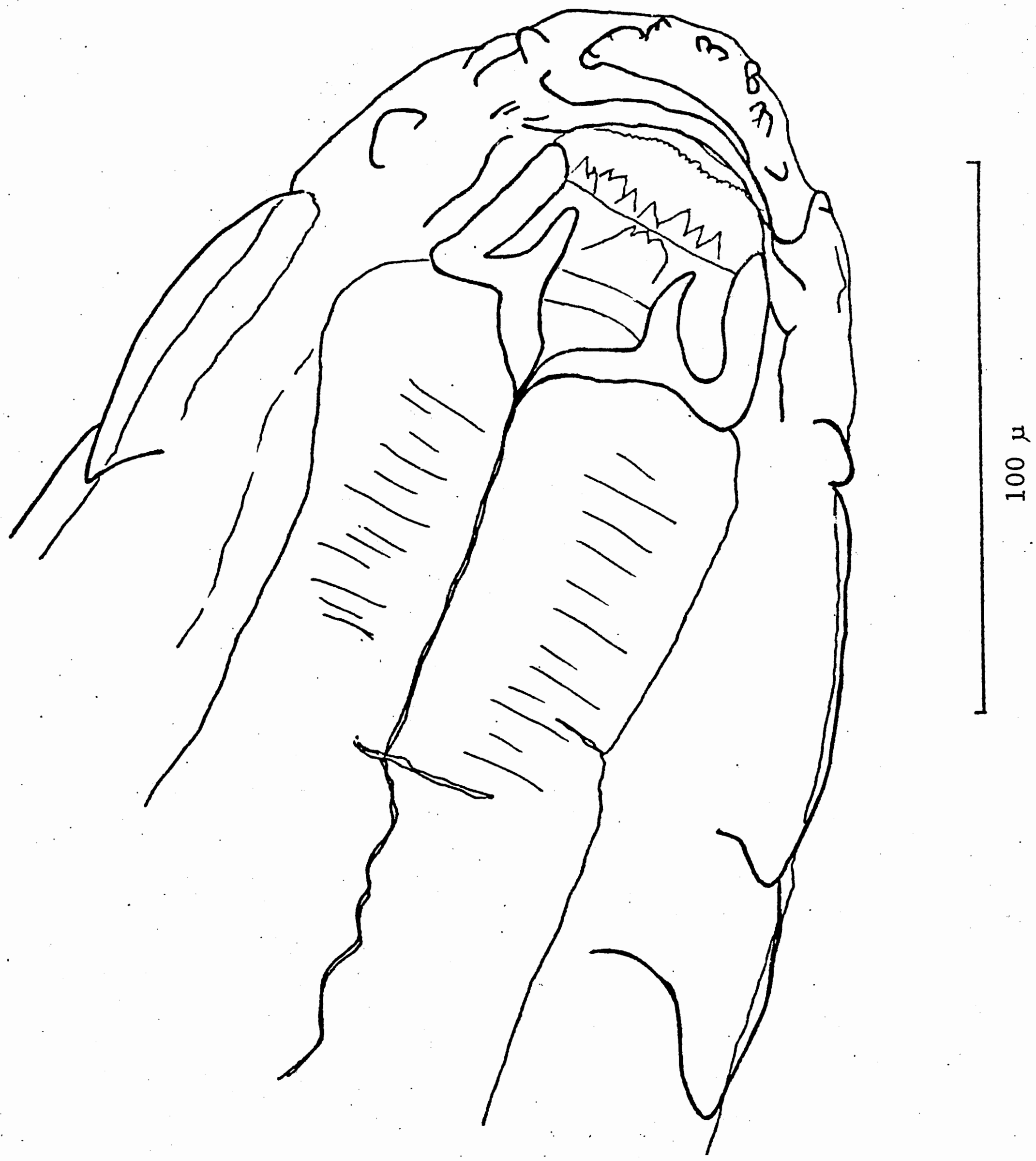


Figure 13. Mouth Parts of Female Pterygodermatites nycticebi. x 400

The combs gradually became further apart and reduced to spiny structures on the posterior half of the body (Figure 14). The transition from combs to spines was gradual. A pair of spiny cervical papillae was located between the 9th and the 10th combs.

Male Worms. Male worms measured from 5.0 mm to 9.5 mm. There were 37 - 43 pairs of combs and 25 - 28 pairs of spines. The total number of pairs of combs and spines varied between 66 and 68. The last pair usually appeared to be under-developed and thus vestigial (Figure 14). Spicules were similar and about equal. The left spicule was 78.0 - 96.2 μ long; and the right spicule 62.4 - 88.4 μ. One to four fan-like cuticular expansions were located on the mid-ventral line of the body just in front of the cloaca. They were of different sizes, being progressively larger posteriorly. The tail was often curled over itself and difficult to flatten dorsoventrally. It appeared that genital papillae were paired. There were two pairs of precloacal papillae, one pair at cloaca and 6 - 7 pairs post cloaca (Figure 15).

Female Worms. Females, varying from 17 mm to 32 mm, were longer than males. The body was more stout and straight. The vulva was located on the anterior third of the body and between the 42nd and 43rd pairs of combs. There were, altogether, 92 pairs of subventral combs and spines, with the distinct spines being posterior to the vulva. The posterior end of the esophagus was 6 - 8 combs behind the vulva. The tip of the conical tail was ended in a spike (Figure 16). In gravid females the uterus was packed with eggs. Those near the

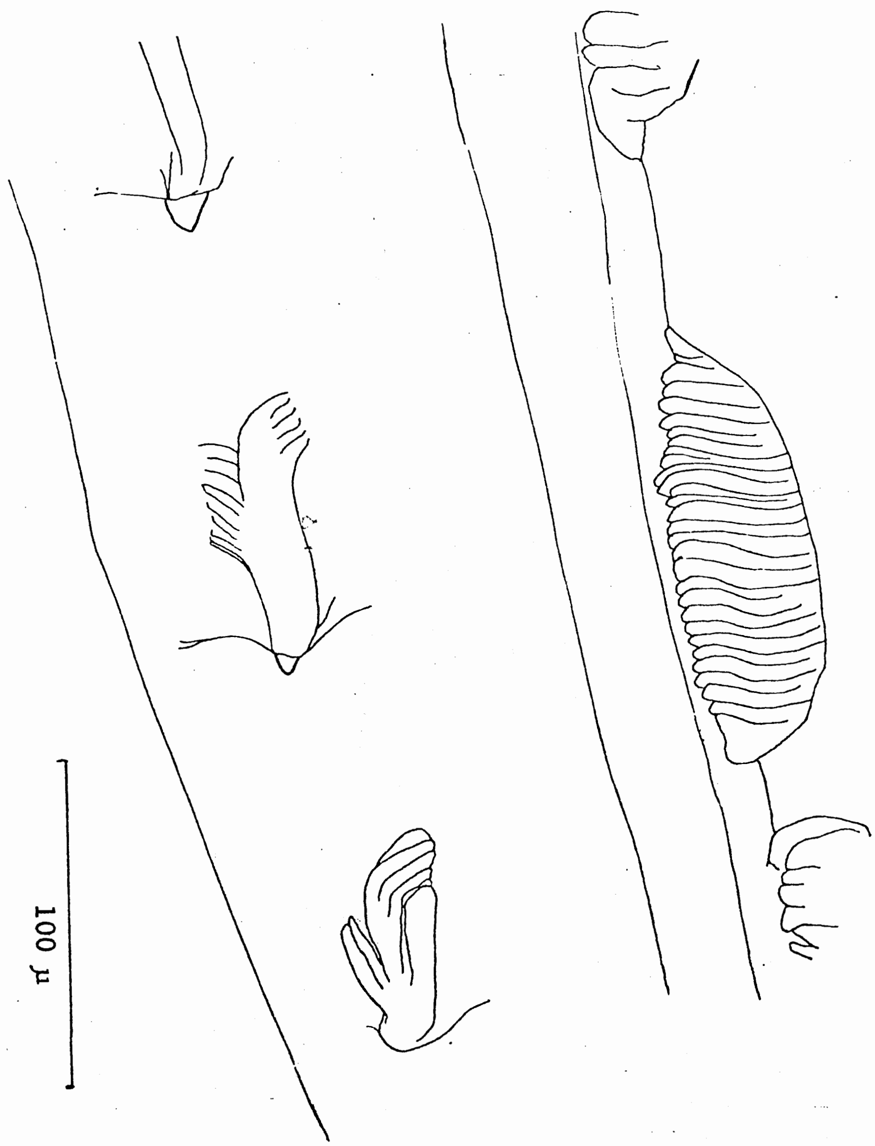


Figure 14. Posterior End of Male Pterygodermatites nycticebi Showing Last Three Spines and Fans. x 400

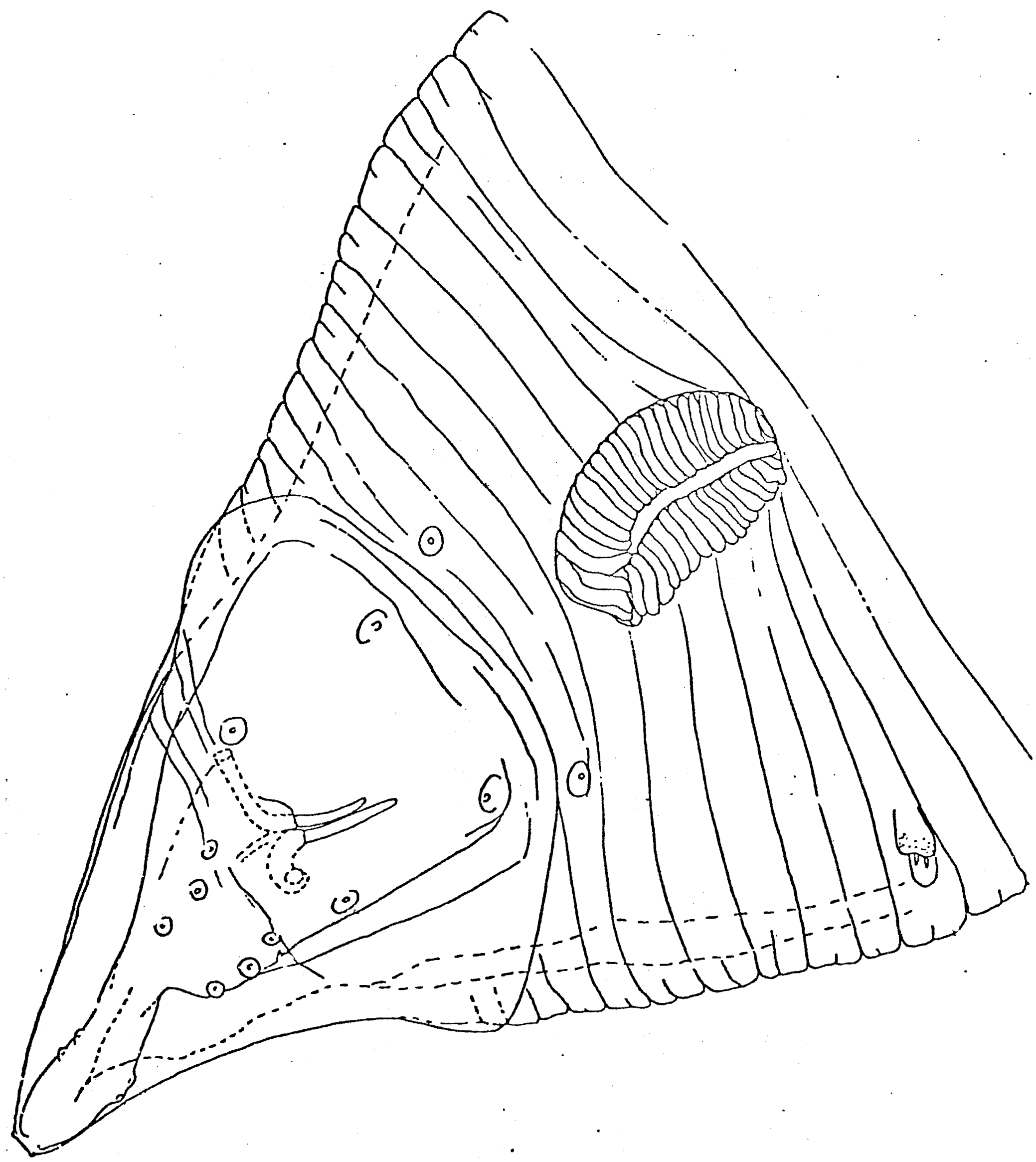


Figure 15. Tail of Male *Pterygodermatites nycticebi* Showing Genital Papillae. x 200

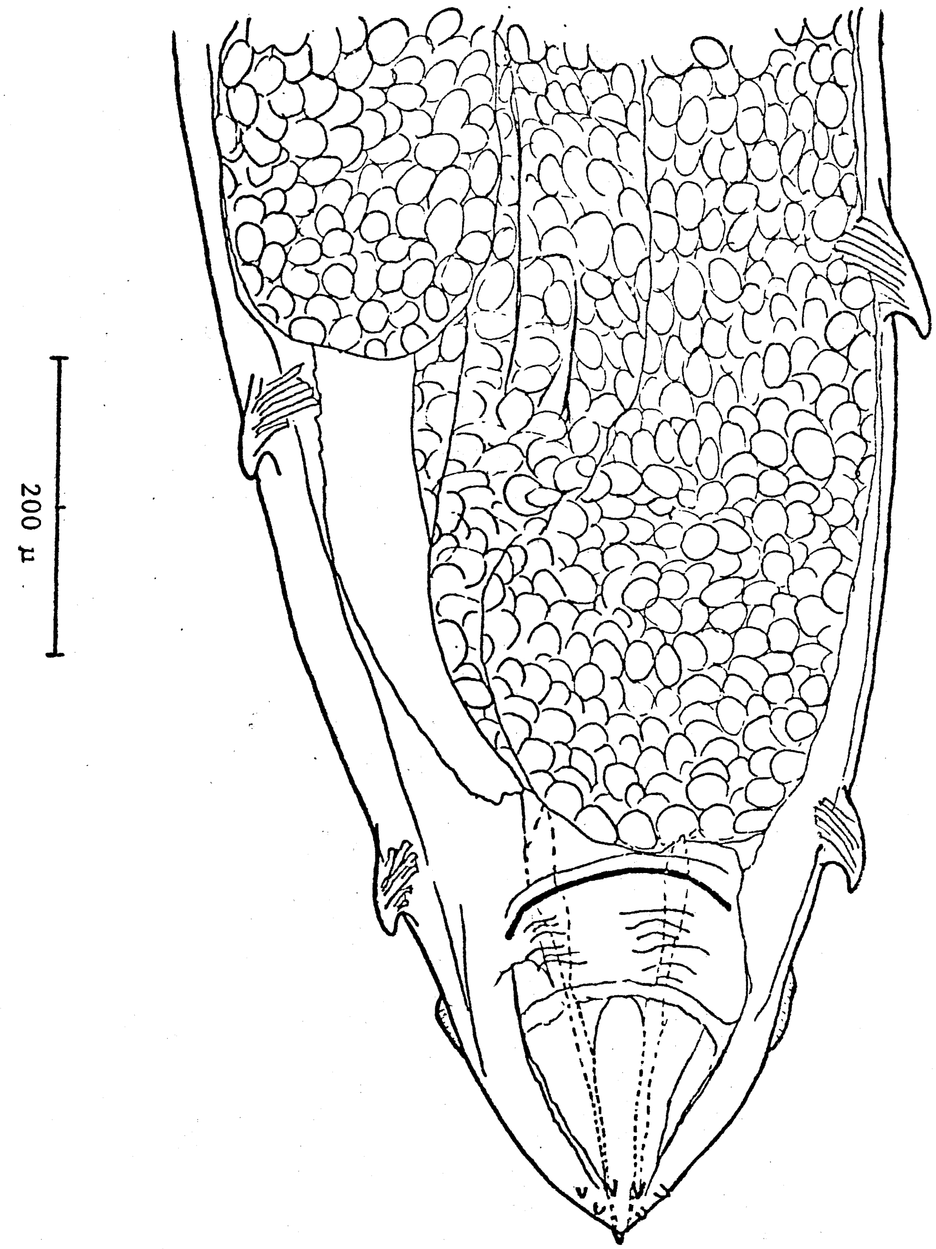


Figure 16. Tail of Female <u>Pterygodermatites nycticebi</u>. x 100

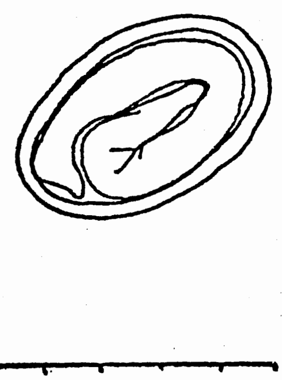
vulvar opening carried a tightly coiled larva in them, and measured 26 - 28 µ x 38 - 39 µ (Figure 17). Where adult Pterygodermatites worms were found, females always outnumbered males.

Experimental Studies

Experimental Infection of Laboratory-Reared German Cockroaches with Pterygodermatites Eggs

A dozen of laboratory-reared German cockroaches was exposed to ground beef contaminated with larvated Pterygodermatites nycticebi eggs. Three cockroaches died three days after the exposure (Table XI). They were discarded without examination. Twenty-two days lapsed before the cockroaches were checked for the presence of Pterygodermatites larvae. Eight of the nine cockroaches in group A were found to carry larvae which were encysted in the epithelial wall of the hindgut (Table XI). No cysts were found free in the body cavity of the insect hosts. The number of cysts in the infected cockroaches varied from one to nine (Table XI). Four of the six cockroaches in group B became infected and the number of cysts found was low (Table XI). These two trials yielded 80% (12/15) of the exposed German cockroaches to be susceptible and infected (Table XII).

The cysts appeared to be thin-walled and fragile. Most of the cysts contained single larvae but one appeared to contain two (Figure 18). Compound cysts as observed in crickets infected with P. coloradensis (Oswald, 1958a) were not encountered. Even a slight pressure on the coverslip could easily help the loosely coiled larva to excyst. The cuticle of the larva was transversely striated (Figure 19). The tail



50 µ

Figure 17. Embryonated Egg of Pterygodermatites nycticebi. x 400

TABLE XI

RESULTS OF EXPERIMENTAL INFECTION OF LABORATORY-REARED GERMAN COCKROACHES (*BLATTELLA GERMANICA*) WITH *PTERYGODERMATITES* EGGS

Developmental Stage and Sex of Cockroach	Number of Encysted Larvae
Experimental Group A	
Adult male	4
male	2
male	3
male	more than 9
male	1
male	0
Adult female	2
female	3
female	8
3 adults (dead)	Discarded without examination
Experimental Group B	
Adult male	0
male	1
male	1, with brown pigment deposits in cyst
Adult female	2
female	1
Nymph	0
Control Group	
6 adult males	0
4 adult females	0
2 nymphs	0

TABLE XII

SUMMARY OF RESULTS OF EXPERIMENTAL INFECTION OF BLATTELLA GERMANICA WITH PTERYGODERMATITES EGGS

Group	Number Infected / Number Examined	% Infected	Number of Cysts Per Cockroach
A	8/9	88.9	1 - 9
B	4/6	66.7	1 - 2
Total	12/15	80.0	1 - 9

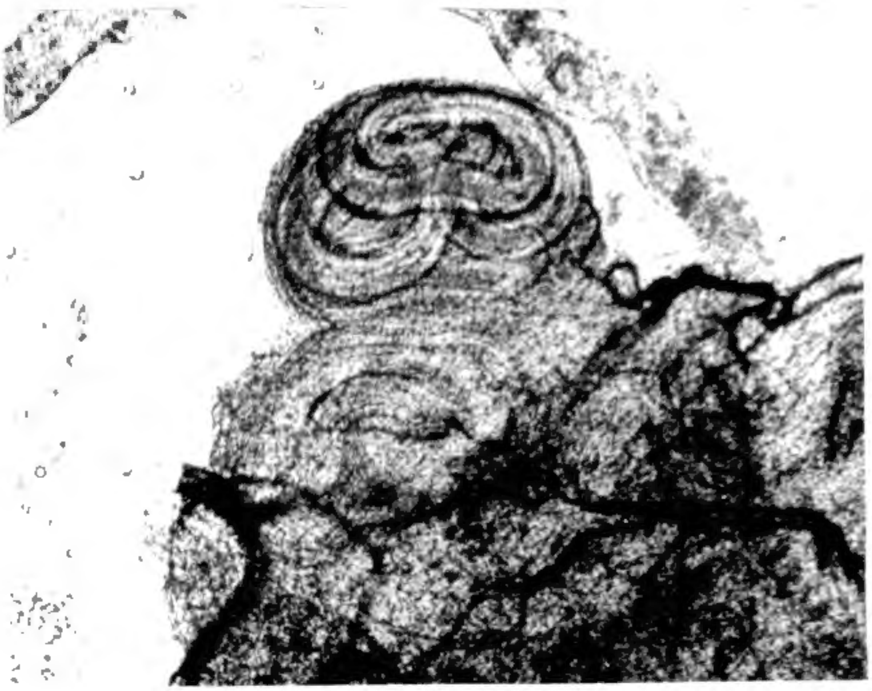


Figure 18. Encysted Larvae of Pterygodermatites nycticebi in the Epithelial Wall of the Hindgut of Blattella germanica. x 200

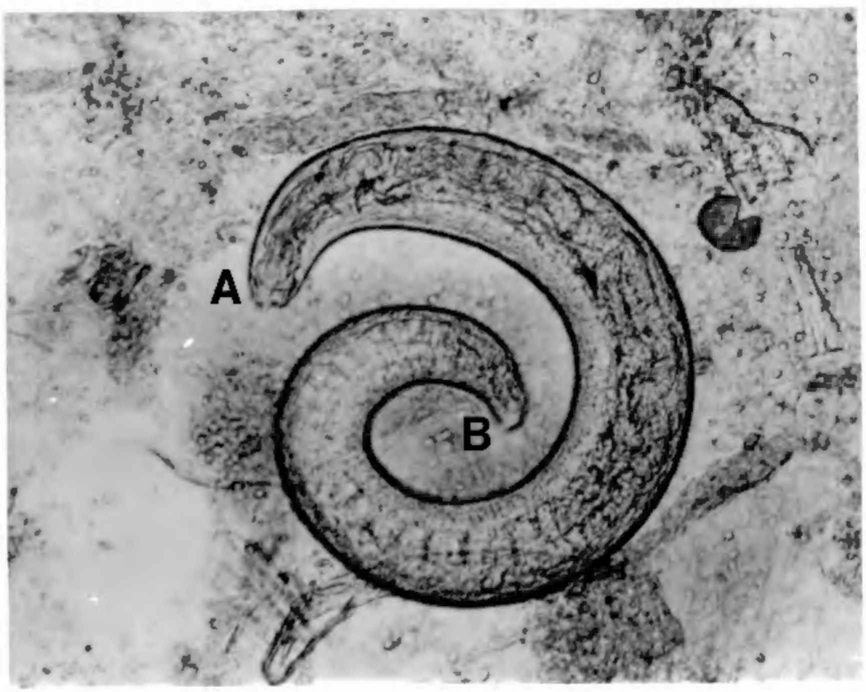


Figure 19. Larva of Pterygodermatites nycticebi Mechanically Released from Cyst. A: Head; B: Tail. x 200

of the larva was pointed and the genital primordia were not obvious.

One male cockroach carried a tightly coiled larva inside a cyst which was heavily and almost entirely coated and obliterated with coarse grains of a reddish brown pigment. The cyst was immersed in warm 0.75% physiological saline under a coverslip and then pressed to release the larva. It remained coiled and immobilized and was apparently dead. The possibility that the thick, granular cyst was host tissue response was not determined in this study.

Experimental Infection of Helminth-Free Golden Hamsters with *Pterygodermatites* Larvae

Ten days after the four female hamsters were inoculated, two hamsters that were fed three and five *Pterygodermatites* larvae were examined. Larvae were not recovered. The two remaining hamsters were examined 18 days (28 days post exposure) after the first two. The one that was fed with more than nine larvae was found to harbor two young sexually mature female *Pterygodermatites nycticebi* (Table XIII). Eggs were beginning to form in their uteri.

TABLE XIII

RESULTS OF EXPERIMENTAL INFECTION OF *MESOCRICETUS AURATUS* WITH *PTERYGODERMATITES* LARVAE

Number of Larvae Fed	Number of Hamsters Exposed	Number of Hamsters Infected	Number of Worms Recovered
3 - 5	2	0	0
8 - 9	2	1	2

CHAPTER V

DISCUSSION

Field Studies

The results of the fecal examination done by me and those recorded by the medical technician of the Oklahoma City Zoo showed that only a few fecal samples positive with *Pterygodermatites* eggs were collected in 1978 and 1979 (Tables V, VII and VIII). The number of positive fecal samples recorded in the past six years was low and it appeared to decrease over the years (Figure 11). This decrease was possibly due to the fact that (1) this spirurid has a low egg production; (2) the fecundity of female worms was lowered by the resistance in immune monkeys which were exposed repeatedly to infective *Pterygodermatites* larvae; (3) a self-cure reaction had occurred in the infected monkeys before the project was started; (4) some of the monkeys had never been infected; (5) some of the monkeys simply passed eggs presumably ingested from contaminated food and/or water; (6) mebendazole, the drug currently used in the Zoo to treat monkeys infected by *Pterygodermatites*, is an effective anthelminthic or it suppresses the egg production of female *Pterygodermatites*; (7) the levitation solutions, sodium nitrate and zinc sulfate, are not desirable to readily recover *Pterygodermatites* eggs from monkey feces; and (8) a combination of two or more of the above factors prevails.

It is teleologic to assume that the fecundity of known Pterygodermatites species is low, because studies on this aspect of the biology of this group of spirurids have never been documented.

Circadian rhythm in the egg release by female parasitic nematodes has been observed in human pinworm Enterobius vermicularis (Cram, 1943), rat pinworm Syphacia muris (Van de Gulden, 1967) and mouse pinworm Aspiculuris tetraptera (Phillipson, 1974). Both the human pinworm and the rat pinworm displayed a diurnal rhythm. Most eggs could be collected early in the morning. The mouse pinworms, on the hand, shed eggs intermittently and the highest egg count peaked with production of feces at dawn.

Chandler (1935) demonstrated that egg production of Nippostrongylus braziliensis in rats declined in immune hosts. Once the worms were transferred to fresh or non-immune rats, their maximum fecundity was resumed. A fall in fecal egg count which likens the "self-cure" reaction was observed in sheep infected by Haemonchus contortus and inoculated intravenously with Salmonella typhimurium vaccine (Stewart, 1953). The same mechanism might be operative in the monkeys upon repeated exposure to Pterygodermatites larvae and a superimposing bacterial infection.

The low yield of Pterygodermatites eggs on flotation might be accounted for by (1) a low egg production of Pterygodermatites species; (2) the presence of only few gravid females; (3) a periodicity in the shedding of eggs by gravid female Pterygodermatites; (4) an uneven distribution of Pterygodermatites eggs in the host feces; (5) a low wormburden in the infected hosts; (6) the establishment of immunity in the monkeys with a previous Pterygodermatites infection; (7) the problem of sampling groups of monkeys instead of individuals; and (8) the effectiveness of the levitation solutions, sodium nitrate and zinc sulfate, to recover Pterygodermatites eggs in feces. All these factors can work, either singly or in combination, to affect the success of finding Pterygodermatites eggs in the monkey feces.

Due to the small number of positive fecal samples and Pterygodermatites eggs obtained in this study, the effectiveness of sodium nitrate and zinc sulfate solutions to float Pterygodermatites eggs could not be determined. An alternative method is to do reciprocal flotation with monkey feces spiked with known numbers of this spirurid egg. A ratio of the numbers of eggs recovered by either levitation solution will in-indicate their relative effectiveness. Parasite eggs for this study can possibly be obtained from an infected definitive host maintained under a controlled environment, or from an experimental definitive host.

The estimates of maximum infection index per group of monkeys for the years of 1974 to 1979 (Figure 10) indicated that possibly the golden lion tamarins in all areas (except those in the herpetarium, the CZB group at the children's zoo and the nursery), the white-faced sakis, the silver-backed sakis and the Goeldi's marmosets in the Zoo's collection were infected. The annual estimates of maximum infection index of 1974 and 1975 were higher than those of the subsequent years (Figure 12). Analysis of the indices suggested a decrease in the number of infected monkeys over the years, possibly attributable to an awareness of the presence of the spirurid parasite and control with an effective anthelminthic or of the self-cure reaction upon repeated exposure. This decrease was not readily detectable in Figure 11 and it became obvious when the total number of fecal samples and the number of monkeys sampled were taken into consideration (Figure 12). The more frequent the fecal examinations were performed, the more accurate the estimate of maximum infection index became.

The zoo records showed a curious finding in that no parasites were found at necropsy of some of the monkeys that known to pass Pterygodermatites eggs (Table IX). Perhaps, those monkeys were never infected, they simply passed eggs that were ingested accidentally, or the worms were removed by drug. The policy of the zoo veterinarian was that whenever a positive fecal examination was reported from any individual monkey or group of monkeys, anthelminthic was administered as a remedial treatment. The monkeys that were treated stopped passing Pterygodermatites eggs and some also passed worms in the feces (Yue, Jensen and Jordan 1980). However, it is possible that the monkeys have, upon repeated ingestion of infective larvae, developed immunity from the initial infection to expel worms acquired in subsequent infections. The passage of worms could also be due to the senility of the worms. Nevertheless, the expulsion of some worms would reduce the worm burden of the host and make it become more tolerant to a parasite that was of low pathogenicity.

Yue, Jensen and Jordan (1980) reported occasional lethargy and/or diarrhea as the only clinical signs of infected golden lion tamarins. In this study, the monkeys in all areas appeared to be very active and were apparently in good health. Most of the fecal samples collected were well-formed and of normal color. Though diarrheic fecal samples were obtained in five occasions, only one was found to carry a few Pterygodermatites eggs. The mild course of infection might be due to the low pathogenicity of Pterygodermatites and a low worm burden.

Oswald (1958b) reported that natural Pterygodermatites infection in Peromyscus leucopus was characterized by a small worm burden. The zoo veterinarian of the Oklahoma City Zoo reported finding 50 and more adult Pterygodermatites in a golden lion tamarin that was born captive in the Zoo and a wild-born white-faced saki (Table IX). These findings suggested that a build-up of the worm burden was possible. Another implication was that infective larvae were available to the monkeys in the Zoo. Oswald (1958b) also noted that in natural infection by P. coloradensis more females than males were usually present, but the female worms varied considerably in their growth rates. A similar situation might prevail in the Pterygodermatites infection in the lower primates and, thus, explained in part the low number of parasite eggs observed in the monkey feces.

The clinical signs of the Pterygodermatites infection are often mild. Fecal examination of the infected monkey or group of monkeys may not have been made frequent enough to recover the parasite eggs. Additionally, necropsies of infected monkeys may have been performed with less care and thus Pterygodermatites worms from these monkeys might have been missed. However, the potential threat of Pterygodermatites nycticebi to the health of the smaller primates in the Oklahoma City Zoo should not be taken lightly. Live worms recovered in the golden hamster, the experimental definitive host, were pink; therefore, they possibly sucked blood. I speculate that in time, a heavy worm burden might build up in those monkeys which had access to a large number of infected arthropod hosts (intermediate hosts). Overt clinical signs might be manifested by heavily infected hosts when they, especially females, were under severe physiological (e.g. pregnancy) and environmental (e.g.

shipping) stresses.

The low animal-trap night ratio and that fewer rats than mice were trapped in the Oklahoma City Zoo was possibly due to the limitation of areas where the traps could be placed. For esthetic reasons and precaution against dislocation of the traps by curious zoo visitors, the traps had to be kept away from the public eye. Another limitation was that the traps could not be hidden inside or too close to the animal cages, lest the monkeys might manage to reach the traps and pick them up as play things, or hurt themselves with the traps, or devour the trapped rodents. Thus, every danger was considered before the traps were placed at strategic spots as close to the cages as possible.

However, the fact that different kinds of mice and rats are naturally and experimentally infected with Pterygodermatites species suggests that house mice and rats are possibly suitable definitive hosts. Once exposed and infected, they are able to spread the parasites by seeding the zoo environment. The compromise imposed on this aspect of the study may have resulted in not trapping infected mice that frequented the monkey cages. Therefore, the potential for house mice in the Oklahoma City Zoo to be suitable definitive hosts cannot be ruled out.

The operation of trapping cockroaches suffered the same limitations as those for trapping the house mice. The cockroaches trapped may not have been those that previously visited the monkey cages. Additionally, some cockroaches were lost due to desiccation partially from the baysonite clay used to prevent escape of the trapped cockroaches from the live traps. More trapped cockroaches remained alive when the baysonite clay was replaced by petrolatum.

Lindquist et al. (1980) speculated that Pterygodermatites species in small primates could cycle locally in zoos. They implied that the intermediate hosts were commonly found in zoos. Experimentally, cockroaches had been incriminated as suitable intermediate hosts for *Pterygodermatites coloradensis* (Oswald, 1958a). There is a high possibility for cockroaches to be suitable intermediate hosts for *Pterygodermatites nycticebi*. Cockroaches, being common house pests in the Oklahoma City Zoo, were singled out for the field studies. That none of the cockroaches examined was found to be infected did not disprove their suitability to be intermediate hosts. The "negative" findings of the examination might be due to the limited places where the traps were set.

The results of the examination of the colony of house crickets maintained by the Oklahoma City Zoo as feed for its animals suggested that the house crickets were probably not infected by *Pterygodermatites* larvae. However, live house crickets should never be introduced into the cages as feed for the small primates so as to avoid their coming into contact with monkey feces that possibly carry infective *Pterygodermatites* eggs.

The examination of the adult *Pterygodermatites* recovered from few golden lion tamarins and a white-faced saki revealed that they were probably *Pterygodermatites nycticebi*. A review of the literature indicated that the present paper was the first record of *Pterygodermatites nycticebi* ever recovered in the white-faced sakis (*Pithecia pithecia*), golden lion tamarins (*Leontopithecus rosalia*), silver-backed sakis (*Pithecia monachus*) and Goeldi's marmosets (*Callimico goeldii*), either in the wild or in captivity.

Chabaud and Petter (1958) considered *Pterygodermatites alphi* and *P. nycticebi* to be synonymous. Without stating any justification, they redescribed P. alphi. The materials they used for study were not obtained from any one of the type hosts previously reported by Lubimov. Their description was similar to the present one but very different from the original description by Lubimov. The variations among their specimens were so wide that I suspect they might be dealing with a case of mixed infections, or a species other than P. alphi. In fact, some of their specimens were likely to be P. nycticebi.

Quentin (1969a) in his "Essai de classification des Nématodes Rictulaires" did not synonymize P. alphi and P. nycticebi. Yet, instead of giving the measurements by Lubimov, he cited those given by Chabaud and Petter as the characteristics of P. alphi. Quentin and Krishnasamy (1979) obtained one male and two females from Nycticebus coucang in Malaya. They compared the measurements of their female specimens with the general drawings of those from Nycticebus tardigradus by Mönnig and concluded that they were one and the same species. They redescribed P. nycticebi with the male worm being described for the first time. I found that the measurements of the Pterygodermatites adults recovered from the golden lion tamarins and the white-faced saki were close to those published by Quentin and Krishnasamy, and considered them to be conspecific. Specimens of Pteyygodermatites nycticebi recovered from the golden lion tamarins and the white-faced saki have been deposited with the National Parasite Collection at Beltsville, Maryland. Their respecitve USNM. Hel. Coll. No. are 76158 and 76159.

The rictularids found in golden lion marmosets (tamarins) and black and red marmosets of the National Zoological Park and from Sanguinus oedipus and Hylobates lar lar in Topeka, Kansas Zoo were also examined. Their measurements suggest to me that they possibly are

Pterygodermatites nycticebi. The finding of P. nycticebi in different kinds of primate hosts has indicated that this spirurid is not host specific, and that it might be prevalent among the New World monkeys, both in captivity and in nature.

Experimental Studies

Results of the present experimental studies of the life cycle of Pterygodermatites in small primates were consistent with those of Pterygodermatites in rodents reported in the literature. The percent infection was high in German cockroaches but the number of cysts in each cockroach was low (Oswald, 1958a). Both the percent infection and the number of cysts found in the cockroaches of group A were higher than those in the cockroaches of group B. The difference was dose dependent.

The time required for rictularid larvae to develop into infective third stage was reported to be between 12 and 15 days; an exception was found in Rictularia amurensis which took between 33 and 40 days (Oswald, 1958a; Quentin, 1969a; Quentin and Seureau, 1974). Due to the small number of parasite eggs available for infection and in order to allow the parasite larvae enough time to grow into infective third stage in the cockroaches, examination was delayed till 22 days after infection. The larvae recovered were still viable and infective to golden hamster, the experimental definitive host. Pigmentation of cysts was found in one German cockroach. The same observation was reported in the American cockroaches, Oriental cockroaches and ground beetles infected with Pterygodermatites coloradensis (Oswald, 1958a).

The encysted larvae of Pterygodermatites nycticebi were, like those of Pterygodermatites hispanica and Rictularia proni, never found free in the haemocoel of the insect hosts (Quentin, 1970). However, the encysted larvae of Pterygodermatites coloradensis were all free in the body cavities of the infected camel crickets (Oswald, 1958a).

Females of other rictularids matured between 30 and 38 days (Quentin, 1970; Quentin and Seureau, 1974). That the females of Pterygodermatites nycticebi were found to begin to mature on 28 days indicated that the time taken for adult development was consistent among the known species. Due to the small number of eggs of Pterygodermatites nycticebi recovered from the feces of infected monkeys and the low number of infective larvae available, the prepatent period of the female worms of this species was not determined.

CHAPTER VI

SUMMARY

Adult worms of Pterygodermatites nycticebi (Mönnig, 1921) were recovered in the golden lion tamarins (Leontopithecus rosalia) and the white-faced sakis (Pithecia pithecia) of the Oklahoma City Zoo. It was also suspected to infect other captive monkeys on exhibition; namely, the silver-backed sakis (Pithecia monachus) and the Goeldi's marmosets (Callimico goeldii). This research project was an attempt to reveal a possible weak link of the biological cycle of P. nycticebi.

The project comprised of two parts. Part I (Field studies) involved a search of the zoo records and fecal examinations of the four kinds of New World monkeys to determine the history of the Pterygodermatites infection and its present status in these monkeys. Some wild-born golden lion tamarins, white-faced sakis, silver-backed sakis and Goeldi's marmosets were found infected as evidenced by the passage of parasite eggs and/or adult worms. Captive golden lion tamarins, born in the Oklahoma City Zoo, were also infected. Pterygodermatites nycticebi was, therefore, believed to have been established and perpetuated in the Zoo. Domesticated crickets, wild cockroaches and feral house mice trapped in the zoo buildings were examined for natural infection with immature P. nycticebi. None was found to be infected. This finding showed that the natural infection rate might be very low, but it did not disprove

the suitability of cockroaches and crickets to be intermediate hosts or of house mice to be paratenic or definitive host. Another aspect of the studies was to compare the effectiveness of sodium nitrate solution and zinc sulfate solution to determine which of these two solutions was a better levitation solution to float Pterygodermatites eggs. Conclusive statements could not be made regarding the relative effectiveness of the two solutions because only small numbers of Pterygodermatites eggs were recovered throughout this study.

In part II (Experimental studies), the life cycle of Pterygodermatites nycticebi was completed using experimental animals of the same types naturally occurring in the Zoo. In 22 days Pterygodermatites larvae developed in the epithelial wall of the hindgut of laboratory-raised German cockroaches that were exposed to Pterygodermatites eggs. The larvae grew into mature worms in the small intestine of golden hamsters (Mesocricetus auratus), the experimental definitive host, 28 days after infection.

Results of the experimental infections of Pterygodermatites nycticebi in German cockroaches and golden hamsters are supportive evidences of the speculation that this parasite cycles in the Oklahoma City Zoo. Infections of the New World monkeys probably occurred after their ingestion of cockroaches infected by larval Pterygodermatites nycticebi.

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APPENDIX

Figure 20. Simulated Rain Forest Habitat of Golden Lion Tamarins in the Children's Zoo (CZB)

Figure 21. Simulated Natural Habitat of Golden Lion Tamarins in the Herpetarium

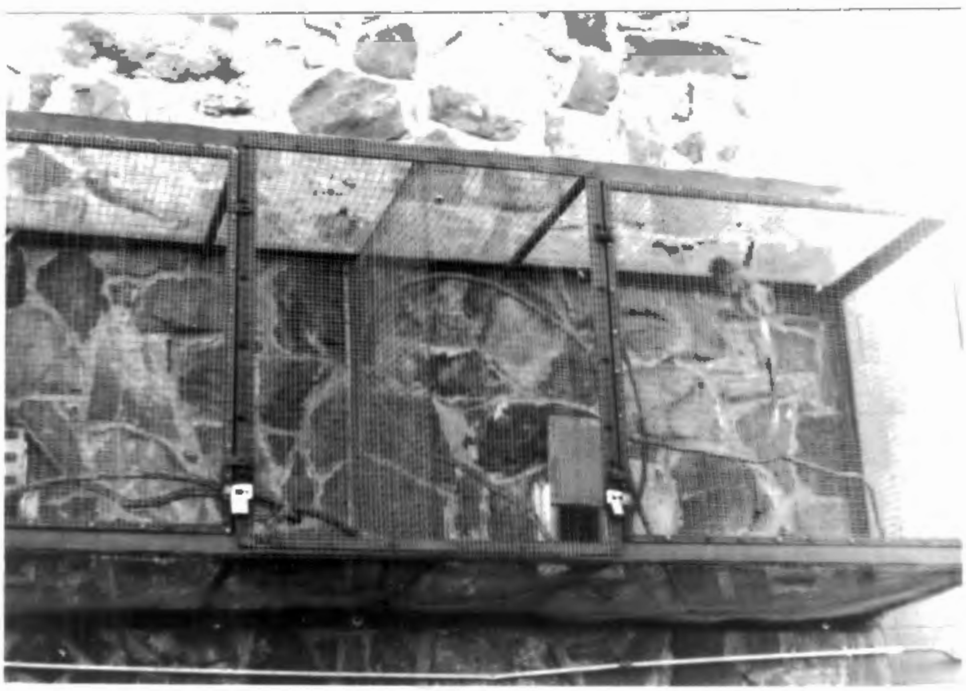

Figure 22. Outdoor Cage of Golden Lion Tamarins in the Giraffe Barn

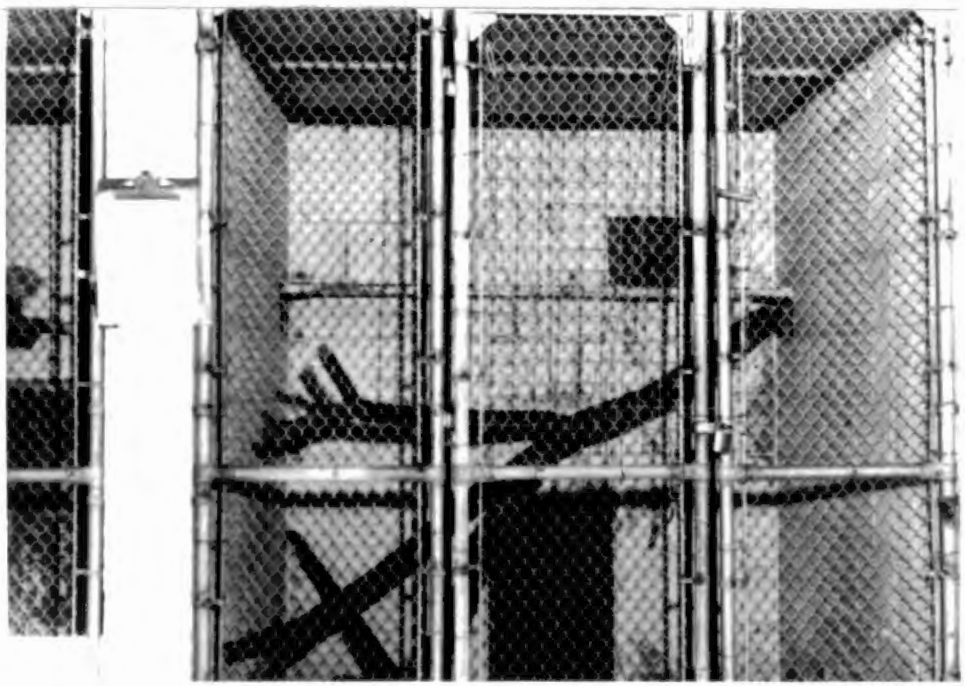

Figure 23. Holding Pen of Golden Lion Tamarins in the Isolation Area

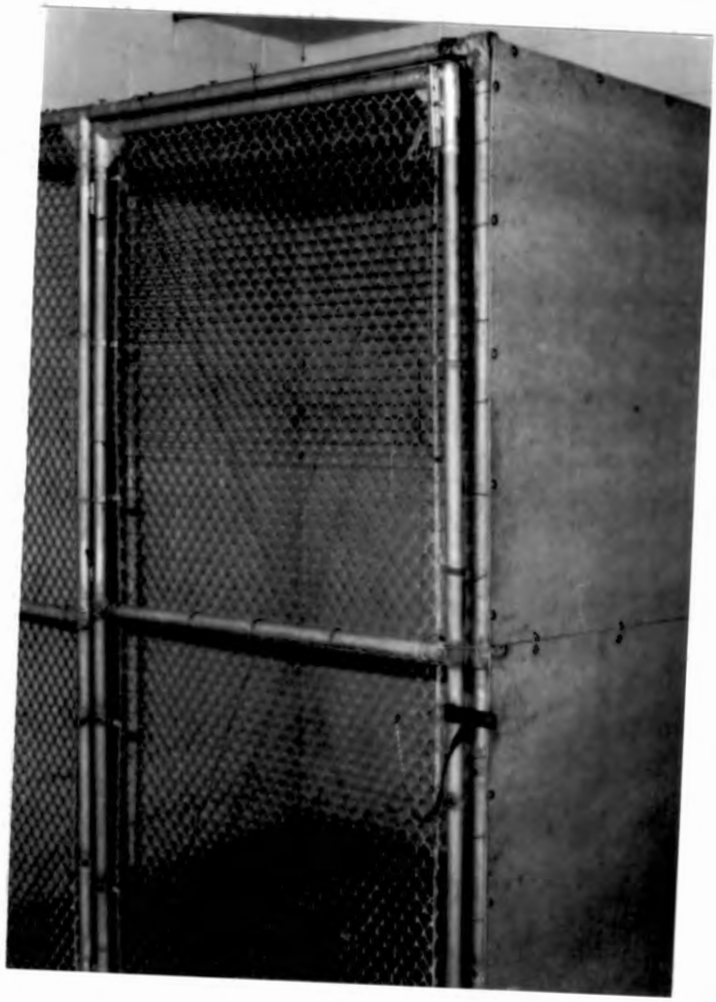

Figure 24. Holding Pen in the Animal Care Center (Hospital)

Figure 25. Simulated Tropical Rain Forest in the
Pachyderm Building

Figure 26. Barred Menagerie in the Primate House

2

VITA

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Doctor of Philosophy

Thesis: STUDIES OF THE LIFE CYCLE AND EPIDEMIOLOGY OF *PTERYGODERMATITES NYCTICEBI* (MÖNNIG, 1921) QUENTIN, 1969 FROM *LEONTOPITHECUS ROSALIA*, *PITHECIA PITHECIA*, *PITHECIA MONACHUS*, AND *CALLIMICO GOELDII* IN THE OKLAHOMA CITY ZOO

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