REVISION
6/89

PREVALENCE OF PATENT BAYLISASCARIS PROCYONIS INFECTION IN RACCOONS (PROCYON LOTOR) IN ITHACA, NEW YORK

Jeffrey D. Kidder, Susan E. Wade[1], Milo E. Richmond[2] and Steven J. Schwager[3]

New York Cooperative Fish and Wildlife Research Unit, Department of Natural Resources, Cornell University, Ithaca, New York 14853

Received _____ 19___; accepted _____ 19___.

Send proofs to: Susan E. Wade
Diagnostic Laboratory
C-210 Schurman Hall
Cornell University
Ithaca, New York 14853
Telephone: (607) 253-3584

1. Diagnostic Laboratory, New York State College of Veterinary Medicine, Cornell University, Ithaca, New York 14853.

2. New York Cooperative Fish And Wildlife Research Unit, Fish and Wildlife Service, Cornell University, Ithaca, New York 14853

3. Biometrics Unit, Cornell University, Ithaca, New York 14853

ABSTRACT: The prevalence of patent Baylisascaris procyonis infection in raccoons was determined by examining fecal samples collected between July 1986 and May 1987 in Ithaca, New York. September, October, and November had the highest prevalence of infection (35-48%). Significant differences ($P<0.001$) were found when months were grouped by season to test the hypothesis that a fecal sample's probability of being positive does not vary from month to month. Fall was the season contributing most to the overall chi-square statistic. Host sex/age class and prevalence of patent infection were investigated. The raccoons were aged as either juveniles or adults. A significantly higher prevalence of patent infection ($P<0.001$) was found in juveniles when compared to adults. No statistically significant differences were found in other comparisons of host sex and age. Contingency analysis tested the independence of sex/age class/season and presence of eggs. The results of the test were significant ($P<0.001$).

Baylisascaris procyonis, the ascarid of the raccoon (Procyon lotor), is important in both human and veterinary medicine. Visceral larva migrans, caused by B. procyonis larvae, has been reported in many wild and domestic birds (Richardson et al., 1980; Reed et al., 1981; Kazacos et al., 1982; Kazacos and Wirtz, 1983; Myers et al., 1983; Evans and Tangredi, 1985; Kazacos et al., 1986) and mammals (Tiner, 1953; Richter and Kradel, 1964; Kelly and Innes, 1966; Fritz et al., 1968; Schueler, 1973; Nettles et al., 1975; Jacobson et al., 1976; Dade et al., 1977; Fleming and Caslick, 1978; Koch and Rapp, 1981; Kazacos et al., 1981, 1983; Roth et al, 1982; Larson and Greve, 1983; Dixon et al., 1988). Paratenic hosts, including humans, become infected by the ingestion of embryonated eggs. Larvae are found in tissues throughout the body of the paratenic host, but they cause the most damage in the central nervous system and eye (Kazacos, 1983).

The first recognized B. procyonis infection in humans occurred in 1980, when a 10-mo-old boy died as a result of eosinophilic meningoencephalitis (Huff et al., 1984). A second fatal case of eosinophilic meningoencephalitis due to B. procyonis was reported in 1984 in an 18-mo-old boy from Illinois (Fox et al., 1985).

The raccoon is a habitat generalist occurring both in rural and urban environments (Shinner and Cauley, 1974; Hoffman and Gottschang, 1977). The potential for the urban-suburban environment to support large numbers of raccoons is cause for

concern. High population density may result in significant accumulation of B. procyonis eggs in the environment (Kazacos, 1982), which could pose health risks to humans and animals.

We report the prevalence of patent B. procyonis infections in raccoons by examination of feces collected from an urban-suburban community (Ithaca, N.Y.) over an 11 mo period in 1986-87. In this respect, our study is unlike previous studies in which data were collected only for limited periods of the year.

MATERIALS AND METHODS

Raccoons were captured alive using box traps (Tomahawk #108, Tomahawk Live Trap Co., Tomahawk, Wisconsin) set at randomly selected sites throughout Ithaca, New York. A grid of 1-ha units was employed to randomize trap sites throughout the study area. Each animal was ear-tagged (Tag model #1005-4, National Band & Tag Co., Newport, Kentucky) for later identification.

Raccoons of both sexes were classified as juveniles or adults on the basis of tooth wear according to Grau et al. (1970). Using the criteria of Sanderson (1961), males were aged by extrusability and degree of ossification of the os penis and by testes size; females were aged by length and degree of pigmentation of the teat. Both sexes were also aged by body weight.

Fecal samples were removed from the rectum of anesthetized raccoons (Ketaset, Bristol-Myers Co., Syracuse, New York, 20-29 mg/kg) (Gregg and Olsen, 1975) using both a fecal loop and a cotton swab. Scats found in traps were also collected. All fecal material collected was fixed in 10% formalin. A sugar centrifugation flotation technique (Georgi, 1985) was used to prepare each fecal sample for microscopic examination.

The chi-square test of homogeneity was used to analyze the data.

RESULTS

Patent B. procyonis infection was found in 56 of 277 (20.2%) fecal samples collected from 243 raccoons. Eighty percent of the positive fecal samples were collected in September, October, and November (Fig. 1). Forty-five of the 106 (42.4%) samples collected in these 3 mo contained eggs.

The distribution of positive fecal samples among months was investigated to test the hypothesis that a fecal sample's probability of being positive remains fixed across months. Results indicate a significant difference in the proportion of positive fecal samples by month (X^2=47.52, d.f.=10, P<0.001).

When the months were grouped by season (Table I) and tested to determine whether positive fecal samples were equally likely in each season, the differences in the prevalence of patent B. procyonis infection were significant (X^2=42.56, d.f.=3, P<0.001). Fall contributed most to the observed chi-square statistic.

Uniformity within the fall months (September-November) was then tested. The chi-square statistic for the 3 fall months was not significant (X^2=0.64, d.f.=2, P>0.05).

Analysis of the relationship between host sex/age-class and the prevalence of patent B. procyonis infection showed a significantly higher prevalence among juveniles than adults (X^2=17.37, d.f.=1, P<0.001). However, no statistically significant difference in prevalence occurred when total males and females (X^2=0.12, d.f.=1, P>0.50), adult males and females (X^2=0.23, d.f.=1, P>0.70), and juvenile males and females

(X^2=0.79, d.f.=1, P>0.50) were compared.

A contingency table was used to determine if there was independence of sex/age-class and presence of patent B. procyonis infection when season was considered (Table II). The results of the test were significant (X^2=87.17, d.f.=7, P<0.001) indicating a relationship between these variables. The largest contributions to the chi-square statistic were made by male juveniles in the fall positive for the presence of B. procyonis eggs $(O-E)^2/E$ = 39.50, male adults in the rest of the year positive for presence $(O-E)^2/E$ = 10.34, juvenile males in the fall negative for presence $(O-E)^2/E$ = 10.01, and juvenile females in the fall positive for presence $(O-E)^2/E$ = 9.55.

DISCUSSION

Preliminary necropsy results from a previous Ithaca study suggested that fall may be the season of highest prevalence of patent B. procyonis infection. Fecal samples collected in this study substantiated this hypothesis. Most patent infections occurred in September, October, and November indicating that this was the period with the greatest potential for environmental contamination (Table I).

The strength of our study rests on the collection of a large number of fecal samples from individually ear-tagged raccoons captured at randomly selected sites throughout the study area over a period of 11 mo. The long sampling period was particularly important since patent infection was found to be seasonal in Ithaca raccoons. Sampling periods of shorter duration could give widely differing results as to the prevalence of patent infection and would have failed to detect the seasonal nature of the shedding of B. procyonis eggs (Fig. 1). This is of particular importance if the seasonality observed in Ithaca is characteristic of other regions as well.

The only previously published report (Jacobson et al., 1982) of the prevalence of patent B. procyonis infections based on examination of fecal samples was conducted in an urban and a rural area of Indiana. Raccoon scats were collected from three sites in each area during October and November 1980. Rectal fecal samples were also collected from raccoons livetrapped during 1979 and 1980. Twenty-seven percent of the scats from the urban area

and 31% of the scats from the rural area contained B. procyonis eggs. No significant difference in the prevalence of eggs was found between scats and rectal fecal samples suggesting that the prevalence of B. procyonis in a raccoon population could be monitored by analyzing scats. However, it is uncertain whether each fecal sample came from a different raccoon since no indication was given that identification of individual animals was attempted and since scat collections were made from only three sites in each study area. Thus, the estimates of B. procyonis prevalence are potentially biased. The results of the Ithaca study indicated that the presence of eggs in a scat depended upon the sex and age of the raccoon and the season of scat deposition. This coupled with the uncertainty that scats are collected from different animals calls into question the feasibility of using scats to determine B. procyonis prevalence in a raccoon population.

Regional surveys based on necropsy results have been reported by Snyder and Fitzgerald (1985a, 1985b), Dubey (1982), and Jacobson et. al. (1982). In all these surveys, the animals were obtained during limited time periods.

Contingency table analysis of host sex and age revealed a significantly higher prevalence of patent B. procyonis infections in juveniles than in adults. Other sex and age comparisons (i.e. total males and females, adult males and females, and juvenile males and females) showed no significant difference in prevalence.

However, analysis of host sex and age without taking season into account may be too inclusive; it treats 2 very different seasonal patterns, e.g. male juveniles in the fall and the rest of the year, as a single category. This can result in a completely misleading analysis. If the level of prevalence in a particular sex/age-class is high in one part of the year and low in another part of the year, the combining of these seasons will mask important patterns in the data. For this reason, contingency table analysis was used to test independence of the presence of patent B. procyonis infection from sex, age, and season when considered together (Fig. 2). Significant results indicated a relationship between presence and the combination of sex, age, and season. Juvenile males and females in the fall had a much higher prevalence of patent infection than expected, and contributed most to the significant chi-square statistic. The juvenile males had an prevalence 4 times greater than the females. Adult males from the rest of the year had far fewer patent infections than expected. These 3 groups together contributed most to the large chi-square value.

Previous evaluation of the effect of host sex and age on prevalence of B. procyonis has been reported by Ermer and Fodge (1986) and Snyder and Fitzgerald (1985b). These studies report a higher prevalence of B. procyonis in juveniles than in adults. Because these studies are based on necropsy results and report the prevalence of worms and not the prevalence of patent infection, comparison with the Ithaca study is difficult. It is

likely, however, that peak prevalence of worms may be correlated with peak prevalence of patent worms.

The results of our study point out the need for further investigation of the details of the parasite life cycle. Further knowledge of parasite-host interactions throughout the year may shed light on the observed seasonality of B. procyonis patency. The seasonal variability in parasite patency may be due to the prepatent period of B. procyonis or to the mode of infection of the raccoon. Another possible explanation is the period of winter inactivity of the host resulting in lowered body temperature and reduced food intake that may affect the survival of adult worms.

Further study is also needed to ascertain the relationship between host sex/age and season. The high prevalence of patent infection in male juveniles in the fall and the lower than expected infection of adult males during the rest of the year may be related to hormonal influences or the immunological status of the host.

LITERATURE CITED

Dade, A. W., J. F. Williams, A. L. Trapp, and W. H. Ball. 1977. Cerebral nematodiasis in captive nutria. Journal of the American Veterinary Medical Association **171:** 885-886.

Dixon, D., G. R. Reinhard, K. R. Kazacos, and C. Arriaga. 1988. Cerebrospinal nematodiasis in prairie dogs from a research facility. Journal of the American Veterinary Medical Association **193:** 251-253.

Dubey, J. P. 1982. Baylisascaris procyonis and eimerian infections in raccoons. Journal of the American Veterinary Medical Association **181:** 1292-1294.

Ermer, E. M., and J. Fodge. 1986. Occurrence of the raccoon roundworm in raccoons in western New York. New York Fish and Game Journal. **33:** 58-61.

Evans, R. H., and B. Tangredi. 1985. Cerebrospinal nematodiasis in free-ranging birds. Journal of the American Veterinary Medical Association **187:** 1213-1214.

Fleming, W. J., and J. W. Caslick. 1978. Rabies and cerebrospinal nematodiasis in woodchucks (Marmota monax) from New York. Cornell Veterinarian **68:** 391-395.

Fox, A. S., K. R. Kazacos, N. S. Gould, P. T. Heydemann, C. Thomas, and K. M. Boyer. 1985. Fatal Eosinophilic meningoencephalitis and visceral larva migrans caused by the raccoon ascarid Baylisascaris procyonis. New England Journal of Medicine **312:** 1619-1623.

Fritz, T. E., D. E. Smith, and R. J. Flynn. 1968. A central nervous system disorder in ground squirrels (Citellus tridecemlineatus) associated with visceral larva migrans. Journal of the American Veterinary Medical Association **153**: 841-844.

Georgi, J. R. 1985. Parasitology for veterinarians. 4th ed. W.B. Saunders Co., Philadelphia, Pennsylvania, pp. 228-229.

Grau, G. A., G. C. Sanderson, and J. P. Rogers. 1970. Age determination of raccoons. Journal of Wildlife Management **34**: 364-372.

Gregg, D. A., and L. D. Olsen. 1975. The use of ketamine hydrochloride as an anesthetic for raccoons. Journal of Wildlife Diseases **11**: 335-337.

Hoffman, C. O., and J. L. Gottschang. 1977. Numbers, distribution, and movements of a raccoon population in a suburban residential community. Journal of Mammalogy **58**: 623-636.

Huff, D. S., R. C. Neafie, M. J. Binder, G. A. DeLeon, L. W. Brown, K. R. Kazacos. 1984. Case 4 The first fatal Baylisascaris infection in humans: An infant with eosinophilic meningoencephalitis. Pediatric Pathology **2**: 345-352.

Jacobson, H. A.; P. F. Scanlon, V. F. Nettles, and W. R. Davidson. 1976. Epizootiology of an outbreak of cerebrospinal nematodiasis in cottontail rabbits and woodchucks. Journal of Wildlife Diseases **12**: 357-360.

Jacobson, J. E., K. R. Kazacos, and F. H. Montague, Jr. 1982. Prevalence of eggs of Baylisascaris procyonis (Nematoda: Ascaroidea) in raccoon scats from an Urban and a Rural Community. Journal of Wildlife Diseases **18:** 461-464.

Kazacos, K. R. 1982. Contaminative ability of Baylisascaris procyonis infected raccoons in an outbreak of cerebrospinal nematodiasis. Proceedings of the Helminthological Society of Washington **49:** 155-157.

———. 1983. Raccoon roundworms (Baylisascaris procyonis). A cause of animal and human disease. Bulletin 422, Purdue Agricultural Experiment Station, West Lafayette, Indiana. pp. 1-25.

———, G. O. Appel, and H. L. Thacker. 1981. Cerebrospinal nematodiasis in a woodchuck suspected of having rabies. Journal of the American Veterinary Medical Association **179:** 1102-1104.

———, E. A. Kazacos, J. A. Render, and H. L. Thacker. 1982. Cerebrospinal nematodiasis and visceral larva migrans in an Australian (Latham's) Brush Turkey. Journal of the American Veterinary Medical Association **181:** 1295-1298.

———, W. M. Reed, E. A. Kazacos, and H. L. Thacker. 1983. Fatal cerebrospinal disease caused by Baylisascaris procyonis in domestic rabbits. Journal of the American Veterinary Medical Association **183:** 967-971.

———, ———, and H. L. Thacker. 1986. Cerebrospinal nematodiasis in pheasants. Journal of the American Veterinary Medical Association **189:** 1353-1354.

———, and W. L. Wirtz. 1983. Experimental cerebrospinal nematodiasis due to Baylisascaris procyonis in chickens. Avian Disease **27:** 55-65.

Kelly, W. R., and J. R. M. Innes. 1966. Cerebrospinal nematodiasis with focal encephalomalacia as a cause of paralysis of beavers (Castor canadensis) in the Dublin Zoological Gardens. British Veterinary Journal **122:** 285-287.

Koch, F., and J. Rapp. 1981. Zerebrale Nematodiasis bei Sumpfbibern (Myocastor coypus) - verursacht durch Larven von Baylisascaris (Nematoda). Berliner und Munchener Tierarztliche Wochenschrift **94:** 111-114.

Larson, D. J., and J. H. Greve. 1983. Encephalitis caused by Baylisascaris migration in a silver fox. Journal of the American Veterinary Medical Association **183:** 1274-1275.

Myers, R. K., W. E. Monroe, and J. H. Greve. 1983. Cerebrospinal nematodiasis in a Cockatiel. Journal of the American Veterinary Medical Association **183:** 1089-1090.

Nettles, V. F., W. R. Davidson, S. K. Fish, and H. A. Jacobson. 1975. An epizootic of cerebrospinal nematodiasis in cottontail rabbits. Journal of the American Veterinary Medical Association **167**: 600-602.

Reed, W. M., K. R. Kazacos, A. S. Dhillon, R. W. Winterfield, and H. L. Thacker. 1981. Cerebrospinal nematodiasis in bobwhite quail. Avian Disease **25**: 1039-1046.

Richardson, J. A., K. R. Kazacos, H. L. Thacker, A. S. Dhillon, and R. W. Winterfield. 1980. Verminous encephalitis in commercial chickens. Avian Disease **24**: 498-503.

Richter, C. B., and D. C. Kradel. 1964. Cerebrospinal nematodosis in Pennsylvania groundhogs (Marmota monax). American Journal of Veterinary Research **25**: 1230-1235.

Roth, L., M. E. Georgi, J. M. King, and B. C. Tennant. 1982. Parasitic encephalitis due to Baylisascaris sp. in wild and captive woodchucks (Marmota monax). Veterinary Pathology **19**: 658-662.

Sanderson, G. C. 1961. Techniques for determining the age of raccoons. Illinois Natural History Survey, Biological Notes **45**: 1-16.

Schueler, R. L. 1973. Cerebral nematodiasis in a red squirrel. Journal of Wildlife Diseases **9**: 58-60.

Shinner, J. R., and D. L. Cauley. 1974. The ecology of urban raccoons in Cincinnati, Ohio. In Wildlife in an Urbanizing Environment. Cooperative Extension Service, University of Massachusetts, Series 28: 125-130.

Snyder, D. E., and P. R. Fitzgerald. 1985a. Helminth parasites from Illinois raccoons (Procyon lotor). Journal of Parasitology **71**: 274-278.

———, and ———. 1985b. The relationship of Baylisascaris procyonis to Illinois raccoons (Procyon lotor). Journal of Parasitology **71**: 596-598.

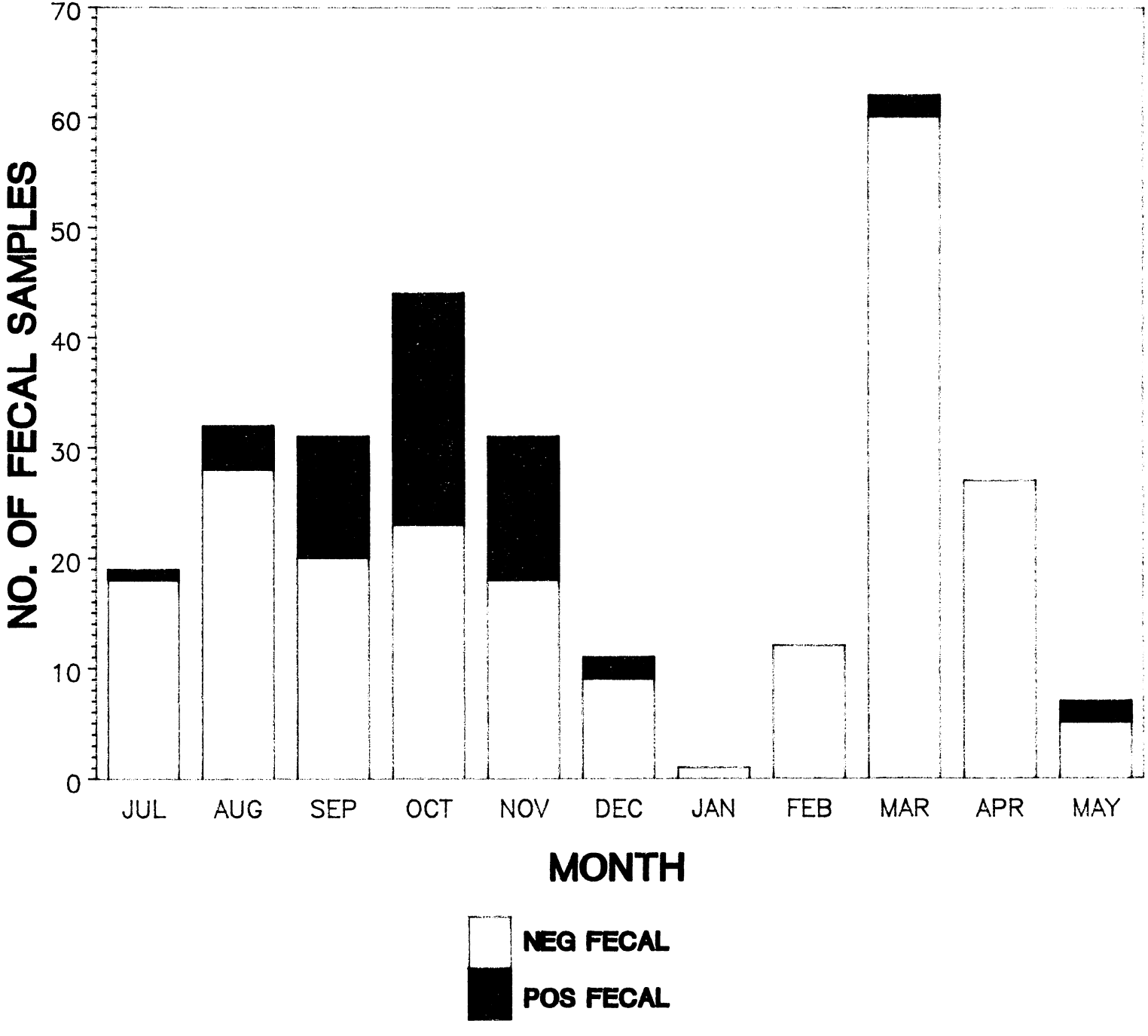
Tiner, J. D. 1953. Fatalities in rodents caused by larval Ascaris in the central nervous system. Journal of Mammalogy **34**: 153-167.

Table I. Number of Procyon lotor fecal samples positive for Baylisascaris procyonis eggs compared to the expected number throughout the year.

Season	Number of samples	Observed number positive	Expected number positive
July-August	51	5	10.31
September-November	106	45	21.43
December-February	24	2	4.85
March-May	96	4	19.41
Total	277	56	56.00

Figure 1. Frequency distribution of Procyon lotor fecal samples examined for patent Baylisascaris procyonis infection.

Figure 2. Contingency table testing for the independence of sex/age-class/season and presence of *Baylisascaris procyonis* eggs in feces of *Procyon lotor*.


NO. OF FECAL SAMPLES
70
60
50
40
30
20
10
0
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
MONTH
NEG FECAL
POS FECAL

Season	Fecal	Male		Female	
		Juv.	Adult	Juv.	Adult
Fall	Pos.	22	8	12	3
	Neg.	9	16	13	21
Rest of Year	Pos.	2	3	5	1
	Neg.	32	75	31	24