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ABSTRACT: Members of the family Columbidae are hosts for the sarcomastigophoran, *Trichomonas gallinae*, the causative agent of trichomoniasis. Birds of prey are susceptible to the disease when they ingest infected prey. Doves are a major dietary component of urban nesting Cooper's hawks (*Accipiter cooperii*) in Tucson, Arizona (USA). During the breeding seasons of 1995 and 1996, we clinically evaluated 89 breeding age and 223 nestling Cooper's hawks from urban and exurban (i.e., undeveloped natural area) areas for infection of *T. gallinae*. There was no difference in the rate of infection between breeding age Cooper's hawks in urban and exurban locations; only one bird tested positive for *T. gallinae*. However, prevalence of *T. gallinae* was significantly greater among urban nestlings (85%) than exurban nestlings (9%). There also was a difference between the prevalence in breeding age and nestling Cooper's hawks in urban areas, but not in exurban areas. *Trichomonas gallinae* was present in at least one nestling at 98% of urban nests tested ($n = 51$), but only 13% of exurban nests tested ($n = 23$). The patterns we found probably are caused by three factors; doves are hosts for the parasite, they are present in large numbers in Tucson, and they are the primary prey of urban Cooper's hawks at that locality.

Key words: *Accipiter cooperii*, Cooper's hawk, *Trichomonas gallinae*, trichomoniasis, urban wildlife.

INTRODUCTION

Trichomoniasis is an avian disease caused by the Sarcomastigophoran (i.e., flagellated protozoan), *Trichomonas gallinae*. Primary hosts of *T. gallinae* are members of the family Columbidae (Stabler, 1951; Locke and James, 1962). Stabler (1954) speculated that *T. gallinae* was introduced to North America when rock doves (*Columba livia*) were imported from France to Nova Scotia in the early 1600's. Among North American columbids, the disease has been identified in mourning doves (*Zenaida macroura*), band-tailed pigeons (*C. fasciata*), white-winged doves (*Z. asiatica*), and Inca doves (*Columbina inca*) (Haugen, 1952; Sileo and Fitzhugh, 1969; Greiner and Baxter, 1974; Hedlund, 1998). Haugen (1952) and Stabler (1954) speculated that trichomoniasis also may have been a contributing factor in the demise of the passenger pigeon (*Ectopistes migratorius*).

Many species of predatory birds in North America (Stensrude, 1965; Stabler, 1969; Stone and Janes, 1969; Stone and Nye, 1981; Pokras et al., 1993), Europe (Cooper and Petty, 1988), Africa (Pepler and Oettle, 1993), and the Middle East (Samour et al., 1995) are known to develop trichomoniasis after ingesting infected prey. Indeed, trichomoniasis has been known as "frounce" for centuries among falconers who often fed pigeons to falconry birds (Bert, 1619). Despite an historic awareness of trichomoniasis, it is still a poorly understood disease.

Inca doves, mourning doves, rock doves, and white-winged doves regularly breed in Tucson, Arizona (USA). Of these, Inca and mourning doves are among the four most numerous avian species in Tucson (Germain, 1995). Hedlund (1998) found that 52% of Inca doves, 16% of mourning doves, and 98% of white-winged doves in Tucson carried *T. gallinae*. Columbids, especially the Inca dove and mourning dove, account for 83% of the diet of Cooper's hawks (*Accipiter cooperii*) in Tucson (Boal, 1997). Thus, Cooper's hawks in Tucson have a high probability of encountering the disease through their prey. We assessed the prevalence of trichomoniasis among Cooper's hawks in southeast Arizona on the basis of age and nesting location during the breeding seasons of 1995–1996.

MATERIALS AND METHODS

We conducted this study in two areas. The first was the greater Tucson metropolitan area, including the cities of Tucson, South Tucson, Oro Valley, and the unincorporated urbanized areas surrounding them (32°09′ to 32°22′N, 110°44′ to 111°01′W). This area was designated as the Tucson Study Area (TSA) and encompassed approximately 70,000 ha. It supported an estimated human population of about 800,000 residents. Tucson is located in the Sonoran Desert which contains Lower and Upper Sonoran vegetation types and riparian corridors. Although remnants of these vegetative communities are still found within Tucson, much of the natural vegetation has been removed or replaced with exotic species. Elevation in the TSA is approximately 730 m.

The second study area was an aggregation of different exurban (i.e., undeveloped natural area) locales throughout southeast Arizona, including Aravaipa Creek (32°52′ to 32°55′N, 110°22′ to 110°25′W), Arivaca Creek (31°32′ to 31°37′N, 111°20′ to 111°25′W), the Chiricahua Mountains (31°38′ to 31°50′N, 109°08′ to 109°25′W), Cienega Creek (32°00′ to 32°02′N, 110°33′ to 110°40′W), Harshaw Creek (31°25′ to 31°30′N, 110°40′ to 110°44′W), and the San Pedro River (31°25′ to 31°45′N, 110°05′ to 110°13′W). The areas, collectively designated as the Exurban Study Area (ESA), ranged from approximately 1,046 to 1,907 m in elevation, and are representative of the environments used by Cooper's hawks outside the urban environment. Vegetation in the ESA ranged from riparian corridors of broadleaf gallery forests (e.g., *Populus* spp., *Salix* spp.) with adjacent mesquite (*Prosopis* spp.) uplands, to oak (*Quercus* spp.) savannahs and oak-pine (*Pinus* spp.) woodlands.

During the breeding seasons of 1995 and 1996, we clinically determined the prevalence of *T. gallinae* among breeding (adult and sub-adult) and nestling Cooper's hawks with In-Pouch® TF *Tritrichomonas foetus* test kits (Biomed Diagnostics, San Jose, California, USA). The test kit, originally designed to test for *Tritrichomonas foetus*, a bovine venereal disease caused by a trichomonad related to *T. gallinae*, has been demonstrated to be an effective *in vitro* method of diagnosis for *T. gallinae* (Cover et al., 1994). We collected culture specimens by swabbing the surface areas of the mouth and upper crop of each hawk for about 5 sec with a dry cotton-tipped swab (Cover et al., 1994). The specimen was immediately transferred to the InPouch® TF medium and cultured for 24 hr. We then used a light microscope at 100× magnification to examine each

TABLE 1. Prevalence of *Trichomonas gallinae* among Cooper's hawks at urban (TSA) and exurban (ESA) nests in Arizona, 1995–1996.

	TSA		ESA		
	Positive	Negative	Positive	Negative	P
Adults[a]	1	74	0	14	ns[b]
Nestlings	134	23	6	60	<0.0001
Nests	50	1	3	20	<0.0001

[a] Category includes sub-adult Cooper's hawks that were members of breeding pairs.
[b] Not significant.

sample for the presence of *T. gallinae*. During trial runs of 7 days, trichomonads were always detected within 72 hr. Thus, if trichomonads were not detected in the first examination, we made subsequent examinations every 24 hr for up to 3 days. If no trichomonads were detected by the third microscopic examination (72 hr post sample collection), we considered the sample free of *T. gallinae*.

We tested for differences in prevalence of *T. gallinae* infections between nestlings and between breeding Cooper's hawks in the TSA and ESA, and between nestlings and breeding hawks within each area. We considered each nestling tested as an independent sample. However, this assumption may be invalid because siblings may have become infected from the same prey item or from contact with each other. Thus, we also examined prevalence of *T. gallinae* infections among nests in the TSA and ESA. We used chi-square and Fishers's exact tests for all comparisons (Ramsey and Shaffer, 1997). The level of α was established at $P \leq 0.05$.

RESULTS

We tested 312 breeding and nestling Cooper's hawks from 51 nests in the TSA and 23 nests in the ESA for infection of *T. gallinae* (Table 1). There were no between-year differences in prevalence for nestlings in the TSA ($\chi^2 = 1.97$, df = 1, $P = 0.160$) or ESA (Fisher's exact test, $P = 0.217$), so data from both years were combined for analysis and comparisons between areas. The prevalence of *T. gallinae* was significantly greater among nestlings in the TSA (85%) than in the ESA (9%) ($\chi^2 = 112.4$, df = 1, $P < 0.0001$) (Table 1). There also was a significant difference between the areas in terms of nests con-

taining ≥ 1 nestling that tested positive for *T. gallinae* ($\chi^2 = 52.2$, df $= 1$, $P < 0.0001$) (Table 1). There was no difference in the prevalence of *T. gallinae* between breeding Cooper's hawks in the TSA and ESA (Fisher's exact test, $P = 1.000$) (Table 1). Only one of 89 breeding Cooper's hawks, a second year female in the TSA, tested positive *T. gallinae*. Thus, it was not surprising that there was a significant difference in the prevalence of infection between breeding hawks and nestlings in the TSA ($\chi^2 = 143.8$, df $= 1$, $P < 0.0001$) (Table 1). However, there was no difference between breeding age and nestling hawks in the ESA (Fisher's exact test, $P = 0.584$) (Table 1). The high prevalence of *T. gallinae* among urban nestlings prompted us to investigate a possible difference in prevalence between the sexes; there was none ($\chi^2 = 0.246$, df $= 1$, $P = 0.62$).

DISCUSSION

Although the abundance of columbid prey in Tucson may be attractive to Cooper's hawks, it has a profoundly negative effect on nesting success and nestling survival. Cooper's hawk nestlings in Tucson suffered a 41% mortality rate due to trichomoniasis (Boal, 1997). Based on exposure rates to *T. gallinae* and actual mortalities due to the disease, trichomoniasis among Cooper's hawks in this study is clearly associated with the urban environment. This is most likely due to the presence of high numbers of doves consumed by Cooper's hawks in Tucson (Boal, 1997). Cooper's hawks probably encounter the disease at a lower rate in the ESA because mourning doves nest in lower numbers and Inca doves are absent. The prevalence of *T. gallinae* in mourning doves in exurban areas is unknown. If the prevalence is lower than that found in Tucson, the probability of exurban Cooper's hawks encountering *T. gallinae* is further decreased.

The epidemiological patterns of infection of Cooper's hawks with trichomoniasis we found are not easy to explain, and the lack of information on raptor physiology and immunology further complicates the issue. Almost 85% of the nestling Cooper's hawks in the TSA tested positive for the *T. gallinae*, yet only one breeding bird tested positive. All the Cooper's hawks, regardless of age, were eating the same prey, so exposure should have been equal among them. Nestlings of many species of birds are immunocompromised (Hoffman-Fezer and Lade, 1972). If Cooper's hawks follow this pattern, it may partially explain why *T. gallinae* could persist in the crops of nestlings but not adults. Other environmental stressors, such as sibling competition, also may promote the onset of the disease.

Adult hawks in Tucson undoubtedly ingest trichomonads when consuming their prey, yet something prevents *T. gallinae* from persisting in their crops even for short periods. The absence of *T. gallinae* in adult Cooper's hawks may be related to a pH level in the crops of adult birds that trichomonads cannot tolerate. Likewise, once a Cooper's hawk has been exposed to, and survived, *T. gallinae*, it may acquire an immunity that prevents the protozoans from becoming established. Also, nestlings exposed to *T. gallinae* after they have attained immunocompetence may be better able to resist infection.

The Cooper's hawks' reliance on doves as primary prey and the subsequent nestling mortality due to trichomoniasis may have a negative influence on the species at the population level in Tucson (Boal, 1997). Activities that decrease or prevent doves from aggregating may minimize the spread of the parasite, but the reproductive and social interactions of doves will likely maintain *T. gallinae* within their populations. However, we suspect the prevalence of *T. gallinae* among doves in Tucson cannot be easily affected. As long as doves and Cooper's hawks are sympatric in Tucson, the nestling hawks are likely to experience high prevalence of trichomoniasis.

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