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HEMATOLOGY AND HEMATOZOA OF ADULT AND NESTLING COOPER'S HAWKS IN ARIZONA

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ABSTRACT.—We determined age- and sex-specific packed cell volume (PCV) and total blood solid (TS) levels to detect diseases in Cooper's Hawks (*Accipiter cooperii*) in southeast Arizona. We also identified hematozoa infecting Cooper's Hawks, determined age- and sex-specific infection rates, and evaluated the influence of hematozoan infections on PCV and TS. Adult male Cooper's Hawks had greater mean PCVs than adult females and nestlings ($P < 0.05$). Adult females also had a greater mean PCV than nestlings ($P < 0.05$). There was no difference in PCV between the sexes of nestlings and there was no difference in TS levels between the sexes of adults or nestlings, but TS levels were greater among adults ($P < 0.05$). Hematozoan infection rates did not differ between the sexes of adults ($P = 0.553$) but adults had a greater infection rate than nestlings ($P = 0.022$). Hematozoan infections did not appear to influence PCV or TS among adult Cooper's Hawks.

KEY WORDS: *Cooper's Hawks*; Accipiter cooperii; *Arizona*; *blood parasites*; *hematology*; *hematozoa.*

Hematologia y hematozoarios en pichones y adultos de *Accipiter cooperii* en Arizona

RESUMEN.—Determinamos el volúmen de células específicas compactadas de edad y sexo, y el total del nivel de sólidos de sangre para detectar las enfermedades de *Accipiter cooperii* en el sudeste de Arizona. También identificamos los hematozoarios que infestan a *Accipiter cooperii*, mediante la determinación de las tasas de infestación por sexo y edad. Evaluamos la influencia de los hematozoarios en las células compactadas y en el total de sólidos de sangre. El macho adulto de *Accipiter cooperii* tuvo una media mayor de células compactadas que las hembras adultas y que los pichones ($P < 0.005$). No hubo diferencias de células compactadas entre sexos de pichones como tampoco en los niveles del total de sólidos de sangre entre sexos de adultos o pichones, pero los niveles de sólidos de sangre fueron mayores entre adultos ($P < 0.05$). Las tasas de infección de hematozoarios no difirieron entre sexos de adultos ($P = 0.553$), pero los adultos tuvieron una tasa de infestación mayor que los pichones ($P = 0.022$). Las infestaciones por hematozoarios aparentemente no influenciaron las células compactadas o los sólidos de sangre en los adultos de *Accipiter cooperii.*

[Traducción de César Márquez]

Two hematological variables often measured when evaluating the health of birds are packed cell volume (PCV) and total solids (TS) or the protein concentration in the plasma (Campbell 1988). Few studies have investigated these hematological parameters for Cooper's Hawks (*Accipiter cooperii*) (Smith and Bush 1978, Hunter and Powers 1980, Gessaman et al. 1986), nor have differences between adults and nestlings or among birds with concomitant parasitic infections been investigated.

Studies of the hematozoa of North American raptors have been primarily conducted in the eastern and midwestern U.S. (Stabler and Holt 1965, Kocan et al. 1977, Kirkpatrick and Lauer 1985, Taft et al. 1994), but the occurrence of parasitic hematozoa appears to vary regionally (Greiner et al.

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1975). Evaluation of hematozoa infection rates among Cooper's Hawks has been hampered by the tendency of investigators to pool blood samples from all individuals regardless of age, season in which samples were taken, or whether they were free-ranging or captive. In a notable exception, Taft et al. (1994) evaluated infection rates of hematozoa among Cooper's Hawks on basis of sex and age during the breeding season.

We obtained blood samples from adult, subadult and nestling Cooper's Hawks while conducting a demographic study of the species in southeastern Arizona (Boal 1997). We analyzed blood samples to determine age- and sex-specific PCV and TS values for Cooper's Hawks, to identify hematozoa and hematozoan infection rates, to examine possible influences of hematozoan infections on PCV and TS, and to compare hematozoan infection rates between our study and a similar study in Wisconsin (Taft et al. 1994).

MATERIALS AND METHODS

We collected blood samples from breeding and nestling Cooper's Hawks in southeastern Arizona, primarily in the vicinity of Tucson, Arizona (32°15′N, 111°55′W) from May–June 1995 (Boal 1997). We captured breeding hawks with dho-gaza and bal-chatri traps (Bloom 1987); nestlings were captured by hand at nests. The pronounced sexual size dimorphism in Cooper's Hawks (Snyder and Wiley 1976) facilitated sexing of both adults and nestlings. We collected blood samples within 15 min of capture by drawing 0.25 ml of blood from the basilic vein with a 25-gauge nonheparinized needle and 3-ml syringe. Each sample was immediately transferred to an EDTA 0.3-ml tube and refrigerated for transport from the field.

We used the microhematocrit method to determine PCV. We centrifuged blood samples in nonheparinized mircrohematocrit tubes and determined the PCV by taking the average value of two samples from each hawk. TS values were determined by analyzing plasma samples with a No. 33077 Schuco Clinical Refractometer.

To examine the prevalence of hematozoa in Cooper's Hawks, we made two thin smears of each blood sample on glass slides. The slides were air-dried, fixed in methanol, stained in Giemsa, and microscopically examined at 1000× for hematazoa. The entire blood smear was examined for all samples. We also compared our results to data from Wisconsin (Taft et al. 1994) to examine age- and sex-specific hematozoa infection rates of Cooper's Hawks from northern and southern parts of their breeding range.

We used *t*-tests and one-way analysis of variance tests (Ramsey and Schafer 1997) to examine differences in PCV and TS between adult and nestling Cooper's Hawks, between males and females in each age class, and to examine the influence of hematozoa on PCV and TS. We report means and standard errors for PCV and TS levels. Subadult Cooper's Hawks that were members of breeding pairs were pooled with adults for our analyses. When necessary, we logarithmically transformed data to meet assumptions of normality and equal variance. If transformations failed, we used Mann-Whitney rank sum tests and Kruskal-Wallis one-way analysis of variance on ranks (Ramsey and Schafer 1997). We used chi-square contingency tables with Yates correction for continuity (Ramsey and Schafer 1997) to compare hematozoa infection rates between sexes of adults, between adults and nestlings, and between regions. We used Fisher's exact test (Ramsey and Schafer 1997) when small cell counts violated assumptions of a contingency table. Statistical analyses were conducted with the SigmaStat statistical package version 1.0.

Table 1. Packed cell volume (PCV) and total solids (TS) for free-ranging adult and nestling Cooper's Hawks in southeastern Arizona in 1995.

AGE/SEX	*N*	PCV	SE	TS	SE
Adult ♀♀	35	50.7	0.64	4.13	0.10
Adult ♂♂	26	53.7	0.51	4.02	0.06
Nestling ♀♀	8	42.2	1.16	3.15	1.70
Nestling ♂♂	5	38.7	1.04	3.12	0.16

RESULTS

We collected blood samples from 61 adult and 28 nestling Cooper's Hawks. Data for PCV and TS of 15 of these nestlings were excluded due to *Trichomonas gallinae* infections (Boal et al. 1998) that could have biased results. We found that PCV levels varied significantly among the ages and sexes of Cooper's Hawks ($F_{3,70} = 46.7$, $P < 0.001$; Table 1). A pairwise multiple comparison procedure indicated adult males ($\bar{x} = 53.7 \pm 0.51$) and adult females ($\bar{x} = 50.7 \pm 0.64$) had greater mean PCVs than nestling males ($\bar{x} = 42.2 \pm 1.16$) or nestling females ($\bar{x} = 38.7 \pm 1.04$, $P < 0.05$; Table 1). Adult males also had a greater mean PCV than adult females ($P < 0.05$) but there was no difference in mean PCV between nestling males and nestling females (Table 1). We found that TS levels also varied among the age and sex categories of Cooper's Hawks ($H_3 = 24$, $P < 0.001$; Table 1). A pairwise multiple comparison showed that age was the source of variability in TS levels. There was no difference between adult males ($\bar{x} = 4.02 \pm 0.06$) and females ($\bar{x} = 4.13 \pm 0.10$) or between nestling males ($\bar{x} = 3.12 \pm 0.16$) and females ($\bar{x} = 3.15 \pm 1.70$), but adults had greater mean TS levels than nestlings ($P < 0.05$; Table 1).

We examined blood smears of 44 breeding and 18 nestling Cooper's Hawks for the presence of parasitic avian hematozoa. Infection rates were not different between the sexes of adult hawks ($\chi^2_1 = 0.351$, $P = 0.553$) but rates were greater among

Table 2. Hematozoa infection rates of Cooper's Hawks in southeastern Arizona in 1995 in relation to age and sex.

AGE/SEX	N	N_I (%)	N_L (%)	N_H (%)	N_P (%)
Adult ♂♂	17	8 (47)	1 (6)	8 (47)	1 (6)
Adult ♀♀	27	9 (33)	3 (11)	8 (30)	4 (15)
Nestling ♂♂	6	0 (0)	0 (0)	0 (0)	0 (0)
Nestling ♀♀	12	1 (8)	1 (8)	0 (0)	0 (0)
Total	62	18 (29)	5 (8)	16 (26)	5 (8)

N_I = number infected; N_L = *Leukocytozoan*; N_H = *Haemoproteus*; N_P = *Plasmodium*.

adults (39%) than nestlings (5%) ($\chi^2_1 = 5.27$, $P = 0.022$; Table 2). We identified *Leucocytozoan toddi* (as per Greiner and Kocan 1977), *Haemoproteus* spp., and *Plasmodium* spp. among the samples. All three hematozoa were found in two (4%) of the breeding Cooper's Hawks (Table 2).

There was no relationship between PCV and presence of hematozoa among adult females ($t_{25} = 0.862$, $P = 0.417$) or males ($t_{15} = 0.227$, $P = 0.823$), nor was there a relationship between TS and presence of hematozoa among adult females ($U = 114.0$, $P = 0.554$) or males ($t_{15} = 0.434$, $P = 0.671$). A low infection rate prevented us from evaluating the influences of hematozoa on PCV and TS of nestlings.

Overall hematozoan infection rates were lower among breeding Cooper's Hawks in Arizona (38.6%) than in Wisconsin (98.6%, Taft et al. 1994) ($\chi^2_1 = 5.55$, $P = 0.018$). Cooper's Hawks in Arizona had lower infection rates of *Haemoproteus* spp. ($\chi^2_1 = 4.87$, $P = 0.027$) and *L. toddi* ($\chi^2_1 = 58.5$, $P < 0.001$) than in Wisconsin. *Plasmodium* spp. was not encountered in Wisconsin, but was detected in 11.3% of the Cooper's Hawks sampled in Arizona (Table 2). Hematozoan infection rates were low among nestling Cooper's Hawks in both Arizona (5%) (Table 2) and Wisconsin (12%) (Taft et al. 1994) (Fisher's exact test, $P = 0.65$).

DISCUSSION

Smith and Bush (1978) suggested PCVs are consistent among raptors, but other studies indicate the parameter is highly variable (Balasch et al. 1976, Hunter and Powers 1980, Rehder et al. 1982, Rehder and Bird 1983, Redig 1993). This may be due in part to differences in hematology between free-ranging and captive raptors (Gessaman et al. 1986, Powers et al. 1994). Among free-ranging *Accipiter* hawks, we found PCV levels for breeding Cooper's Hawks were slightly higher than those for migrating Cooper's Hawks and Sharp-shinned Hawks (*A. striatus*) (Gessaman et al. 1986, Powers et al. 1994) and similar to wintering Northern Goshawks (*A. gentilis*) (Hunter and Powers 1980).

Breeding male Cooper's Hawks had consistently higher PCVs than adult females. In contrast, there were no differences between the sexes of migrating Cooper's Hawks and Sharp-shinned Hawks (Gessaman et al. 1986, Powers et al. 1994). This may be due to breeding males having higher androgen levels (Domm 1964, Rehder et al. 1982) which cause an increase in red blood cell production and thus PCV. Estrogen levels in female birds caring for young can be quite variable depending on the species. Estrogen causes bone marrow suppression in some animals and, if elevated in female Cooper's Hawks during the nesting cycle, could cause a decrease in their PCV. An elevated PCV and/or TS may be indicative of dehydration (Smith and Bush 1978) but all adult hawks in our study had an apparently unlimited access to water at riparian streams, ponds, bird baths, and other anthropogenic sources of water (Boal 1997).

Cooper's Hawk nestlings had PCV levels 17% (females) and 28% (males) lower than adults. Similarly, the PCV of nestling Red-tailed Hawks (*Buteo jamaicensis*) is 26% lower than the PCV of adults (Redig 1993). The lower PCV values of the nestling Cooper's Hawks may represent a normal preadult hematological status as is documented in many animals (Jacobson and Kollias 1988). Lower preadult PCV levels may result when young hawks are under stress (e.g., sibling competition for food or nest crowding). Stress stimulates production of adrenocorticotropic hormone, which in turn stimulates the adrenal gland to produce steroids such as corticosterone and cortisol (Harvey et al. 1986) which may reduce PCV. Another possible explanation is that nestling Cooper's Hawks may have smaller RBCs than adults, as is seen in some other avian species (Jacobson and Kollias 1988). Thus, nestlings and adults may have similar RBC counts, but the smaller cell size in nestlings results in lower PCV. We did not determine red blood cell numbers of either age group in our study.

Age-specific levels of thyroid activity could also explain PCV differences among Cooper's Hawks. Ronald and George (1988) demonstrated that increased thyroid activity in four races of Canada Geese (*Branta canadensis*) was correlated with higher red blood cell counts and PCV. McNabb et al.

(1984) found thyroid activity in quail and doves did not reach adult levels until postfledging. Nestling Cooper's Hawks may likewise have lower thyroid hormone levels and, thus, lower PCV levels.

Haemoproteus spp. has been identified as the most commonly detected avian hematozoan in infected wild birds (67%), with *Plasmodium* spp. (41.5%) and *L. toddi* (39%) occurring in similar frequencies (Bennett et al. 1982). We found all three of these hematozoan parasites in Cooper's Hawks in southern Arizona, but they did not appear to affect PCV or TS. Prevalence of *Haemoproteus* spp. and *L. toddi* were lower in Arizona than in Wisconsin. This difference may have been due to the life cycle of vectors. For example, black flies (*Simuliidae*), the vector of *L. toddi,* require running water to complete their life cycle. Running water is rare in the desert southwest, possibly decreasing the potential for spread of *L. toddi.*

We did not quantify the severity of infections (i.e., percentage of infected red blood cells) but, subjectively, they appeared mild. The single exception was a nestling that was heavily parasitized by *L. toddi.* Our data are from only one breeding season, but it appears hematozoa infections among Cooper's Hawks in southern Arizona are less prevalent than in more northern parts of their range.

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