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Authors: Lesko, Mark J., and Smallwood, John A.

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# ECTOPARASITES OF AMERICAN KESTRELS IN NORTHWESTERN NEW JERSEY AND THEIR RELATIONSHIP TO NESTLING GROWTH AND SURVIVAL

MARK J. LESKO[1] AND JOHN A. SMALLWOOD
*Department of Biology and Molecular Biology, Montclair State University, Montclair, NJ 07043 U.S.A.*

ABSTRACT.—American Kestrel (*Falco sparverius*) populations have been declining throughout much of North America during recent decades. To determine if the ectoparasite burdens of nestlings may be a contributing factor, we examined broods of kestrels in nest boxes in northwestern New Jersey. Our objectives were to identify and quantify the arthropod ectoparasites of nestlings, and to determine if removing these parasites from nestlings would increase kestrel nesting success. Of 26 broods we examined, we randomly chose 13 and manually removed from the nestlings all visible arthropods during three visits, when nestlings were age 5–7, 10–12, and 15–17 d old; we handled the 11 control broods similarly but did not remove arthropods. Both the experimental and control broods were measured and banded at age 20–22 d, and all visible arthropods were collected from both groups. Of 1767 arthropod specimens collected, 1679 (95.0%) were *Carnus hemapterus* (Diptera: Carnidae). Our observation of the next most abundant parasite, *Ornithonyssus sylviarum* (northern fowl mite, Acari: Macronyssidae; 46 specimens), was apparently the first record of the American Kestrel as host. The remaining 42 specimens included 9 other kestrel parasites (4 species) and 33 nonparasites (19 species). *C. hemapterus* loads increased as nestlings aged, were highest at age 10–12 d, and declined thereafter. At age 20–22 d, control broods had significantly higher loads of *C. hemapterus* and other parasites. However, we detected no significant differences in nestling wing length, tail length, body mass, body mass/wing length (an index of nestling condition), or nestling survival. Thus, we found no evidence that ectoparasite removal would be an effective strategy in increasing the nesting success of American Kestrels in this study area.

KEY WORDS: *American Kestrel*; Falco sparverius; *ectoparasites*; *northern fowl mite*; Ornithonyssus sylviarum; Carnus hemapterus; *nestling growth*; *reproductive success.*

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## ECTOPARÁSITOS DE *FALCO SPARVERIUS* EN EL NOROESTE DE NUEVA JERSEY Y SU RELACIÓN CON EL CRECIMIENTO Y LA SUPERVIVENCIA DE LOS POLLUELOS

RESUMEN.—Durante las últimas décadas, las poblaciones de *Falco sparverius* han disminuido a lo largo de la mayor parte de América del Norte. Para determinar si la carga de ectoparásitos de los pichones puede ser un factor que contribuye a la disminución, examinamos las nidadas de *F. sparverius* en nidos caja en el noroeste de Nueva Jersey. Nuestros objetivos fueron identificar y cuantificar los ectoparásitos artrópodos de los polluelos y determinar si la remoción de estos parásitos de los pichones incrementa el éxito de nidificación de la especie. De las 26 nidadas que examinamos, escogimos 13 al azar y quitamos manualmente todos los artrópodos visibles de los pichones durante tres visitas, cuando las edades de los polluelos eran de 5–7, 10–12 y 15–17 días. Manipulamos las 11 nidadas de control de manera similar pero no les quitamos los artrópodos. Tanto la nidada experimental como la de control fueron medidas y anilladas a los 20–22 días de edad y todos los artrópodos visibles fueron colectados en ambos grupos. De 1767 especímenes de artrópodos colectados, 1679 (95.0%) pertenecieron a la especie *Carnus hemapterus* (Diptera: Carnidae). La observación del siguiente parásito más abundante, *Ornithonyssus sylviarum* (Acari: Macronyssidae; 46 especímenes) fue, aparentemente, el primer registro para *F. sparverius* como hospedador. Los 42 especímenes restantes incluyeron otros nueve parásitos de *F. sparverius* (4 especies) y 33 individuos no parásitos (19 especies). Las cargas de *C. hemapterus* aumentaron a medida que los pichones crecían hasta los 10–12 días de edad y a partir de entonces disminuyeron. A la edad de 20–22 días, las nidadas de control presentaron cargas significativamente mayores de *C. hemapterus* y de otros parásitos. Sin embargo, no detectamos diferencias significativas en el largo del ala de los polluelos, el largo de la cola, la masa corporal, la masa corporal/el largo del ala (un índice de la condición del polluelo) o la supervivencia de los pichones. De este modo, no encontramos evidencia de que

[1] Email address: mlesko@middlesexcc.edu



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la remoción de ectoparásitos pueda ser una estrategia efectiva para incrementar el éxito de nidificación de *F. sparverius* en el área de estudio.

[Traducción del equipo editorial]

American Kestrel (*Falco sparverius*) populations throughout much of North America have declined significantly during recent decades (Farmer et al. 2008, Smallwood et al. 2009), prompting research into possible factors that have either increased mortality or decreased reproduction. U.S. Breeding Bird Survey and National Audubon Society Christmas Bird Count data do not support the hypothesis that Cooper's Hawk (*Accipiter cooperii*) populations are suppressing kestrel populations regionally, and kestrel populations began declining before the introduction of West Nile Virus in North America in 1999 (Smallwood et al. 2009). Local population declines have been attributed to a loss of available nesting habitat and suitable cavities (Smallwood and Collopy 1991, 1993, Wheeler 1992). Nest-box programs appear to have stimulated local increases by providing nesting opportunities for nest-site-limited populations (Bloom and Hawks 1983, Toland and Elder 1987, Wheeler 1992, Smallwood and Collopy 1993, 2009), yet over time many of these nest-box-breeding populations also are experiencing similar declines (Smallwood et al. 2009).

One area that has received little attention is the effect of ectoparasites on the growth and survival of kestrel nestlings. Many arthropod species, both arachnid (including ticks and mites) and insect (especially lice and dipteran flies), have been observed on American Kestrels. In Colorado, Williams (1947) found hematophagous nymphs of the tick *Ornithodoros aquilae* on American Kestrels; they typically attach to the head, especially near the eyes (Williams 1947, Boyd 1951), but also to other areas of the body in young nestlings prior to feather development (Williams 1947). Philips (2000) provided a review of the parasitic mites found on the Falconiformes, including American Kestrels, and the manner in which they feed on host tissues.

Numerous species of lice (Phthiraptera) have been found on American Kestrels, including several species of the genera *Degeeriella* (Roest 1957, Malcomson 1960, González-Acuña et al. 2011) and *Laemobothrion* (Malcomson 1960, Morishita et al. 2001, González-Acuña et al. 2011). Bird lice are obligatory parasites that spend their entire life cycles on the host, often have host specificity, and are found on different regions of the body depending upon their size or how fast they move about on the host's body (Peters 1930, Boyd 1951).

Dipteran species found on kestrels include both adult and larval forms. Adult black flies (*Simulium canonicolum*) were observed in large numbers at a nest in Oregon, biting nestlings through their down, and biting both the nestlings and adult female on the tarsi (Roest 1957). Hill and Work (1947) found blowfly (*Protocalliphora* sp.) larvae infesting the ears and nostrils of nestlings in California (see Sabrosky et al. 1989 for a review of avian blowfly hosts).

A parasitic fly frequently found on American Kestrel nestlings is *Carnus hemapterus*, generally regarded as a hematophagous parasite in the adult stage (Grimaldi 1997, Liker et al. 2001, Roulin et al. 2003; but see Grimaldi 1997). The larvae are thought to live in the nesting material until they pupate, after which they move onto a host (Grimaldi 1997). Most adult flies lose their wings once they infest a host (Dawson and Bortolotti 1997, Grimaldi 1997). Little is known about their mechanism for host choice or their patterns of movement (Dawson and Bortolotti 1997), but *C. hemapterus* infestations have been found only on birds in nests, nearly always in cavities (Grimaldi 1997). This species has been observed on kestrels throughout much of North America, including Colorado, Maryland, New York (Grimaldi 1997), California (Balgooyen 1976), and Saskatchewan (Dawson and Bortolotti 1997). At least 30 species of birds are known to be hosts (see Grimaldi 1997), including the European Starling (*Sturnis vulgaris*; Grimaldi 1997, Liker et al. 2001), which frequently inhabits nest boxes erected for American Kestrels (Wilmers 1987).

The effects that arthropod ectoparasites have on host species vary widely. In addition to tissue damage caused by the ectoparasite, negative effects can also include the introduction of internal parasites or diseases, or microbial infections of the wounds ectoparasites inflict on their hosts. Some arthropod infestations may be commensal or even symbiotic. Philips (2000) noted that most mites that infest raptors are not pathogenic and do not cause harm unless the infestation is intense. He further noted that with severe feather mite infestations, much of the damage to the host is from stress and feather pulling;

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infestations of transient skin mites, such as chiggers, can cause dermatitis, and if host blood loss is extensive, the host may experience a loss of body mass and energy, become anemic, or even die. Quill mites, such as Syringophilid mites, can cause feather loss and lead to bacterial infections, and any significant effects caused by subcutaneous mites have not yet been documented.

The objectives of this study were to identify and quantify the ectoparasites found on American Kestrel nestlings in northwestern New Jersey, and to determine if removing ectoparasites from nestlings is an effective strategy to increase nesting success.

## METHODS

**Study Area.** We conducted this study in Sussex (centered at approximately 41°11′N, 78°38′W) and Warren counties (approximately 40°47′N, 75°04′W) in rural northwestern New Jersey, where we have maintained a nest-box program for kestrels since 1995. All nest boxes are located on roadside utility poles, trees, and barns or similar structures in open areas of apparently suitable habitat (Smallwood and Wargo 1997; see Neubig and Smallwood 1999 for a detailed description of the study area). We included a total of 106 nest boxes in the study, 59 in Sussex County and 47 in Warren County.

**Nest Box Monitoring.** We monitored each nest box from 19 March to 30 July, 2005. At our first visit we cleaned the box by scraping the interior surfaces, removing old nesting material, and replacing it with fresh wood chips; American Kestrels do not build nests but lay their eggs on the available substrate (Smallwood and Bird 2002). We checked each nest box at least once every 28 d to assure that kestrel eggs were discovered prior to hatching (Smallwood and Bird 2002), and then more frequently so that each nestling would be observed within a few days of hatching. Hatching date was determined by regressing body mass with age (Balgooyen 1976, J. Smallwood unpubl. data from northwestern New Jersey) and the nestling's appearance (Roest 1957, Bird and Palmer 1988). We measured and banded nestlings on our final visit when nestlings were 20–22 d old. Although the nestlings in this study area typically fledge on day 28 ( J. Smallwood unpubl. data) we did not disturb them after day 22, as they are prone to premature fledging.

**Parasite Study.** We randomly assigned each brood to one of two groups: experimental (parasites periodically removed) or control (parasites not periodically removed). This procedure resulted in approximately equal numbers of control and experimental broods throughout the season, during which parasite load and nesting success might vary. We visited each nest box four times during predetermined intervals: 5–7, 10–12, 15–17, and 20–22 d from hatching of the first nestling. Because of the proximity of siblings together in the nest box (we did observe arthropods move from one nestling to another), we considered brood as the sample unit.

During parasite removal, we removed the brood from the nest box and held each nestling over a tray containing 70% isopropyl alcohol to catch the parasites. Using a cotton alcohol swab, we dislodged parasites from nestlings by swabbing primarily in the axillary region, along the length of the underside of the wing, in the area behind the knee, and on the pits located below the nape, which were the areas of highest visible parasite density. We also gently blew on the feathers to remove any unattached parasites or those that became dislodged from the nestlings but had not yet fallen into the tray. This procedure continued until each area of the nestling had been swabbed and no more parasites were apparent. After all nestlings of a brood had been cleaned, we held the bags used for transport upside down and shook them over the tray to collect any additional specimens that may have fallen off the nestlings. We poured the alcohol in the tray into a container to store the contents for future analysis. We then cleaned experimental nest boxes by scraping the floor and sides and replacing the old bedding with fresh wood chips. We did this to lessen the chances of immediate reinfestation.

In order to control for potential effects of disturbance, we visited control broods during the same time intervals, and handled the nestlings in the same manner, except without the alcohol swabs or parasite collection. We did not clean the control nest boxes.

During the final visit at day 20–22, we recorded the wing length (length of the right seventh primary), tail length (length of the right outer rectrix), and body mass for each nestling. We also calculated body mass/wing length as an index of nestling condition because wing length is correlated primarily with nestling age (Balgooyen 1976, Smallwood and Bird 2002) whereas body mass is correlated with both age and condition. We removed the parasites from all nestlings (both control and experimental broods) during the final visit to compare the final parasite loads from nestlings where the parasites had been removed three

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times prior to those from nestlings that maintained a natural parasite load.

**Analysis.** Specimens collected during the study were later identified to species (where possible) by James W. Mertins of the National Veterinary Services Laboratories in Ames, Iowa. We categorized specimens into three groups: *Carnus hemapterus*, other parasites, and nonparasites. We calculated the mean number of specimens per nestling (male and female combined) for each specimen group for each brood for each visit (four visits per brood for experimental broods and one visit for each control brood). The resulting variables were mean *C. hemapterus* load per nestling, mean other parasite load per nestling, and mean nonparasite load per nestling. To control for the large differences in *C. hemapterus* loads among broods we ranked the mean *C. hemapterus* load per nestling for each brood. We then performed a two-tailed Kruskal-Wallis test on these ranks to check for any differences in parasite load per nestling as the nestlings aged.

Because most of the variables were not normally distributed, we performed the subsequent analyses using nonparametric tests. To compare the body size of males and females we performed Mann-Whitney *U*-tests on wing length, tail length, and mass. These tests were one-tailed because we expected females to be larger and heavier than males (Smallwood and Bird 2002).

We also performed Mann-Whitney *U*-tests to compare control and experimental broods in regard to wing length, tail length, body mass, body mass/wing length, mean *C. hemapterus* load per nestling at banding, mean other parasite load per nestling at banding, and mean nonparasite load per nestling at banding. The test was one-tailed for arthropod loads as these loads were expected to be lower in experimental broods, and two-tailed for size variables as no size differences were expected between the two groups. We also compared nestling survival with a one-tailed Fisher's exact test. We performed all statistical tests using IBM SPSS Statistics 19 and SAS version 9.2.

## RESULTS

A total of 27 clutches (including one replacement clutch in an experimental nest box) were initiated in 26 (24.5%) of 106 nest boxes. For control nest boxes, mean clutch size was 4.8 ± 0.4 SD (range = 4–5 eggs per clutch) eggs and mean hatching rate was 89.2% ± 27.7 SD ($n$ = 13 clutches); of the 12 clutches that hatched, all nestlings survived to fledging in eight broods, one nestling disappeared from each of three broods, and one entire brood died of unknown cause. For experimental nest boxes, mean clutch size was 4.7 ± 0.5 SD (range = 4–5 eggs per clutch) eggs and mean hatching rate was 88.6% ± 26.8 SD ($n$ = 14 clutches); of the 13 clutches that hatched, all nestlings survived to fledging in 10 broods and one nestling disappeared from each of three broods. There was no significant difference in nestling survival between control and experimental broods; all nestlings survived in 8 of 12 and 10 of 13 broods, respectively ($P$ = 0.45).

We performed parasite removals during 62 brood visits: 11 for control broods (one time for each surviving brood) and 51 for the 13 experimental broods (four times each, except only three times for one brood). We collected a total of 1767 specimens, 1679 (95.0%) of which were *Carnus hemapterus*; the remaining 88 specimens included *Ornithonyssus silviarum* (northern fowl mites; 46 specimens) and 9 other parasites (four species) and 33 nonparasites (19 species; Appendix).

We found specimens during 59 (95.2%) of 62 removal attempts during the study, including *C. hemapterus* during 55 (88.7%) visits, other parasites during 14 (22.6%) visits, and nonparasitic specimens during 20 (32.3%) visits. Broods frequently carried more than one species of arthropod. For experimental broods, *C. hemapterus* loads per nestling were highest during the second visit (10–12 d) and lowest during the final visit (20–22 d; Kruskal-Wallis $K$ = 27.0, $P < 0.001$; Fig. 1). The smallest nestling of a brood almost always had the greatest *C. hemapterus* load and occasionally was infested with more *C. hemapterus* than all other nestlings in a brood combined.

No significant difference was found between male and female nestlings at day 20–22 in regard to wing length (means of 64.4 mm ± 6.7 SD and 65.1 ± 9.2 SD, respectively; $U$ = 1199, $P$ = 0.15) or tail length (means of 42.0 mm ± 5.4 SD and 42.4 ± 7.5 SD, respectively; $U$ = 1221, $P$ = 0.18). However, female nestlings were significantly heavier than males, 116.8 g ± 12.8 SD versus 130.5 ± 16.0 SD; $U$ = 666, $P < 0.001$). Because they differed in body size, we performed the subsequent analysis for males and females separately.

Using mean values for each variable for each sex within each brood, we thus compared the males from 13 experimental broods to the males from 11 control broods, and the females from 11 experimental broods to the females from 9 control broods. Experimental males had significantly lower

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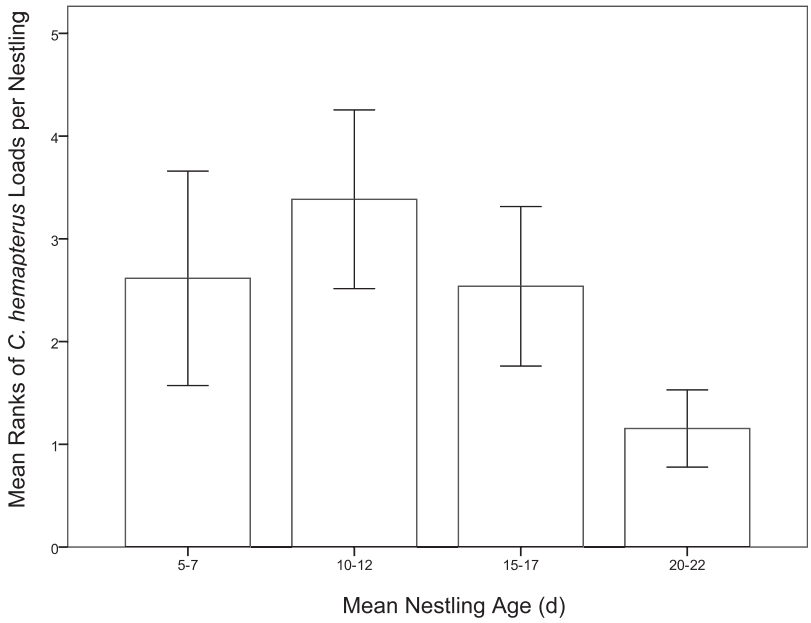



Figure 1. *Carnus hemapterus* loads of American Kestrel nestlings were highest when nestlings were 10–12 d old. Values are mean ± SD from data ranked 1 (least) to 4 (greatest) number of parasites per nestling. Data from 13 broods, northwestern New Jersey, 2005.

*C. hemapterus* loads per nestling during the final check, but did not differ significantly in wing length, tail length, mass, mass/wing length, other parasite loads per nestling, or nonparasite loads per nestling (Table 1). Experimental females also had significantly lower *C. hemapterus* loads and did not differ significantly in any of the other variables tested (Table 2).

## DISCUSSION

The mean clutch sizes we observed in this study, 4.7–4.8 eggs, were similar to those reported for American Kestrel nest-box programs and natural nests elsewhere. However, hatching rate, brood size, and overall nesting success were relatively high; see Smallwood and Bird (2002) for a comparison of reproductive measures. There was no significant

Table 1. Male American Kestrel nestlings that received three previous ectoparasite removals (13 experimental broods) had lower *Carnus hemapterus* loads at 20–22 d than males not receiving previous removals (11 control broods), but did not differ significantly in size or body condition (body mass/wing length). Data from northwestern New Jersey, 2005. Values are means ± SD.

| VARIABLE | EXPERIMENTAL[1] BROODS | CONTROL BROODS | $U$[2] | $P$ |
|---|---|---|---|---|
| Wing length[3] (mm) | 66.4 ± 6.9 | 64.4 ± 8.5 | 56.0 | 0.621 |
| Tail length[4] (mm) | 43.2 ± 5.5 | 42.0 ± 6.8 | 53.5 | 0.761 |
| Body mass (g) | 129.8 ± 13.0 | 131.4 ± 16.6 | 42.5 | 0.595 |
| Body mass/wing length (g/mm) | 2.0 ± 0.2 | 2.1 ± 0.3 | 42.0 | 0.569 |
| Number of *C. hemapterus* per nestling | 1.3 ± 3.3 | 2.3 ± 2.5 | 26.0 | 0.035 |
| Number of other parasites per nestling | 0.1 ± 0.2 | 0.1 ± 0.2 | 48.5 | 0.455 |
| Number of nonparasites | 0.1 ± 0.1 | 0.2 ± 0.2 | 33.0 | 0.077 |

[1] Ectoparasites removed 5–7, 10–12, and 15–17 d after hatching.
[2] Mann-Whitney tests: two-tailed for size variables, one-tailed for ectoparasites.
[3] Right seventh primary.
[4] Right outer rectrix.

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Table 2. Female American Kestrel nestlings that received three previous ectoparasite removals (11 experimental broods) had lower *Carnus hemapterus* loads at 20–22 d than females not receiving previous removals (9 control broods), but did not differ significantly in size or body condition (body mass/wing length). Data from northwestern New Jersey, 2005. Values are means ± SD.

| VARIABLE | EXPERIMENTAL[1] BROODS | CONTROL BROODS | $U$[2] | $P$ |
|---|---|---|---|---|
| Wing length[3] (mm) | 65.5 ± 7.8 | 64.0 ± 3.9 | 77.5 | 0.728 |
| Tail length[4] (mm) | 42.8 ± 5.4 | 42.7 ± 4.0 | 71.5 | 1.000 |
| Body mass (g) | 119.7 ± 13.0 | 120.6 ± 12.2 | 69.0 | 0.885 |
| Body mass/wing length (g/mm) | 1.8 ± 0.2 | 1.9 ± 0.2 | 60.0 | 0.505 |
| Number of *C. hemapterus* per nestling | 1.2 ± 3.0 | 2.3 ± 2.3 | 34.0 | 0.014 |
| Number of other parasites per nestling | 0.6 ± 1.5 | 0.1 ± 0.2 | 78.0 | 0.320 |
| Number of nonparasites | 0.1 ± 0.2 | 0.2 ± 0.2 | 53.5 | 0.120 |

[1] Ectoparasites removed 5–7, 10–12, and 15–17 d after hatching.
[2] Mann-Whitney tests: two-tailed for size variables, one-tailed for ectoparasites.
[3] Right seventh primary.
[4] Right outer rectrix.

difference in nestling survival between control and experimental broods.

*C. hemapterus* was the most prevalent ectoparasite we found in this study. This hematophagous dipteran parasite occurred in all active nest boxes and some infestation levels were severe. *C. hemapterus* infestations also were found in all nests during a study of American Kestrels in California and some also were severe (Balgooyen 1976). The mean *C. hemapterus* load per brood during the second visit for experimental broods (54.7 ± 67.3, range = 0–245) were comparable to those found on European Starlings (*Sturnus vulgaris*) near Budapest (Liker et al. 2001), where a median of 54 flies per brood (range = 0–284), but far greater than the mean of 3.0 ± 2.6 flies per nestling (range = 1–17) found in kestrel broods in Saskatchewan (Dawson and Bortolotti 1997). The substantial differences in *C. hemapterus* loads between these studies may be due to differences in host species available, climate, densities of other host species, or overall population sizes of *C. hemapterus* between years, or to the spatial distribution of nests and nest boxes. Further study would be necessary to determine if any of these factors are responsible.

Following removal, *C. hemapterus* quickly recolonized nest boxes, typically within 4 to 8 d, and in many cases the infestations increased to much higher than they had been during the previous visit. The rapid reinfestation of experimental nest boxes suggests that *C. hemapterus* may be able to colonize a new host quickly. However, the mode of transmission and method of host selection for *C. hemapterus* has been little studied (Dawson and Bortolotti 1997). *C. hemapterus* has not been reported to infest adult birds (Grimaldi 1997); thus, it was likely that reinfestation of nestlings was not due to contact with adults. The larvae of these parasites apparently are attracted to carrion-laden nesting material (Grimaldi 1997). As we frequently removed the nesting material from experimental nest boxes, the individual parasites that reinfested the nest boxes most likely came from external sources, although it was possible that some larvae remained in cracks in the nest boxes (Dawson and Bortolotti 1997).

*C. hemapterus* appears to prefer younger nestlings. Dawson and Bortolotti (1997) found that nestlings younger than 12 d old were more heavily parasitized than older nestlings. In this study most of the highest infestation levels for experimental nest boxes occurred during the second visit (10–12 d) and the lowest during the final visit (20–22 d). Dawson and Bortolotti (1997) noted that as nestlings mature they spend more time preening, so an increase in the physical removal of ectoparasites may explain the decreasing loads as nestlings grow older. Also, because *C. hemapterus* appears to feed mostly in featherless areas, as nestlings age the increase in coverage by feathers may reduce the preferred feeding areas.

In contrast to our findings, Dawson and Bortolotti (1997) observed the highest *C. hemapterus* loads on the heaviest nestlings within a brood. The *C. hemapterus* loads in our study almost always were highest on the smallest nestling within a brood, consistent with Roulin et al. (2003), who found that *C. hemapterus* loads within a brood were higher for the younger (smaller) nestlings (mean = 21 ± 4 parasites

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per nestling) than for older (larger) nestlings (mean = 14 ± 2 parasites per nestling) in Eurasian Kestrels (*Falco tinnunculus*), and for Barn Owls (*Tyto alba*) where the mean for younger nestlings was 62 ± 6 and for older nestlings was 33 ± 4. *C. hemapterus* appears to be opportunistic not only in finding a suitable host species (see Grimaldi 1997) but also in parasitizing whichever nestlings within a brood best fit its needs.

A total of 46 northern fowl mites (*Ornithonyssus sylviarum*) were found on kestrel nestlings. This temperate-region skin parasite has a global distribution, and within North America it is known to infest 72 species of birds, including the Merlin (*Falco columbarius*; Knee and Proctor 2007). However, our observation apparently represents the first report of the American Kestrel as a host.

Ectoparasites and other insects and arachnids have numerous possible ways of entering the nest. They may enter on their own by flying or crawling in, or be transported into the nest on adult birds or in their feces as eggs or larvae. Nest box locations, nest conditions, types of prey brought into the nest, and parental activity all may play roles in determining what types of ectoparasites enter the nest.

Lice, mites, and ticks would most likely come in contact with nestlings only if they were brought into the nest on prey or on adult kestrels. American Kestrel diets include small birds, mammals, rodents, and a variety of insects (Balgooyen 1976, Smallwood and Bird 2002). Two of the mite species (*Laelaps alaskensis* and *Androlaelaps fahrenholzi*) found in this study were rodent mites, and most likely encountered the kestrel nestlings when rodent prey was brought into the nest, which we observed infrequently in this study. Also, as adult kestrels do not spend much time in the nests once the nestlings become larger, vertical transmission (from adult to nestling) of mites and lice may have been limited during this time due to minimal contact between adults and nestlings. Darolova et al. (2001) found that three species of chewing lice were transmitted horizontally (between adults) much more than vertically in the colonial-nesting European Bee-eater (*Merops apiaster*). In their study, only 10.8% of the nestlings were infested, whereas 98.3% of adults were infested.

Because many lice and mites feed on feathers, nestlings with a few downy feathers may not be as attractive as adults to these parasites, and many parasites may not infest nestlings until they are older. It also is possible that heavy *C. hemapterus* loads may deter other parasites from colonizing a host, although further study would be required to determine this.

Nest sanitation also may have played a role in keeping other parasite levels low. At the start of the breeding season we cleaned all nest boxes. The removal of old nesting material may have substantially reduced infestation levels by removing adult parasites, eggs, or larva that were in the old bedding from the previous season. Also, kestrels eliminate waste in a projectile motion, often onto the walls of the nest box, where it dries quickly, rather than onto the nesting substrate or other nestlings (Balgooyen 1976; M. Lesko and J. Smallwood unpubl. data). The scent of ammonia, commonly observed at nests with older kestrel nestlings, may deter some parasitic species from colonizing (Balgooyen 1976).

In addition to parasites, other nonparasitic insects and arachnids have been found in kestrel nest boxes (Philips and Dindal 1990). Balgooyen (1976) noted that carrion-eating arthropods may help to keep nests sanitized as well as hinder infestations by other parasite species. Neubig and Smallwood (1999) found several arthropod species inhabiting kestrel nest boxes in this study area, including carrion beetles (*Silpha inaequalis*), hister beetles (*Atholus americanus* and *Phelister subrotundus*), dermestid beetles (*Dermestes caninus*), and skin beetles (*Trox foveicollis*). The actions of dermestid beetles reduce the volume of prey remains and thus may reduce the loads of nest parasites (Balgooyen 1976). Although we did not collect them unless they were found directly on a nestling, we did observe beetles in many nest boxes in this study, and their presence may help explain the low abundance of ectoparasitic larvae, such dipteran species that lay eggs in animal remains.

It also is possible that some ectoparasites were present but not observed. Many species of lice and mites burrow into the nasal cavities or other openings of the bird, feed subcutaneously, or burrow into the lumen of quills (Boyd 1951). Very small parasites, such as lice and mites, may have been present in larger numbers but not detected due to their size and ability to move quickly to concealed areas of the body. Philips (2000) noted that mites can be as small as 0.3 mm long, and large raptors infested by 15 000 feather mites or 4000 quill mites may appear parasite-free to the unaided eye. Because the relatively large size of *C. hemapterus* makes them easy to detect visually, we believe our sampling method did not substantially underestimate the abundance of this parasite.

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We found no evidence that the ectoparasites observed in this study had a significant effect on the growth or survival of kestrel nestlings. Dawson and Bortolotti (1997) also found no significant relationship between *C. hemapterus* loads and nestling survival, hematocrit, or plasma proteins, although *C. hemapterus* loads in their study were considerably lower than those in our study. Both the similarity of control and experimental nestlings and the rapid reinfestation of *C. hemapterus* indicate that parasite removal is not an effective strategy for increasing the nesting success of American Kestrels in this study area.

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Appendix. Arthropods collected from American Kestrel nestlings in 24 nest boxes in northwestern New Jersey, 19 March to 30 July, 2005.

| TAXA | | | | | SPECIMENS |
|---|---|---|---|---|---|
| **Kestrel Parasites** | | | | | |
| | Arachnids | | | | |
| | | Acari | | | |
| | | | Ixodidae | | |
| | | | | Deer tick, *Ixodes scapularis* | 1 |
| | | | Macronyssidae | | |
| | | | | Northern fowl mites, *Ornithonyssus sylviarum* | 46 |
| | Insects | | | | |
| | | Phthiraptera | | | |
| | | | Menoponidae | | |
| | | | | Falcon chewing lice, *Colpocephalum subzerafae* | 6 |
| | | | Philopteridae | | |
| | | | | American Kestrel chewing louse, *Degeeriella carruthi* | 1 |
| | | Diptera | | | |
| | | | Carnidae | | |
| | | | | *Carnus hemapterus* | 1679 |
| | | | Calliphoridae | | |
| | | | | Bird blowfly larvae, *Protocalliphora* sp. | 1 |
| **Other Species**[a] | | | | | |
| | Arachnids | | | | |
| | | Acari | | | |
| | | | Laelapidae | | |
| | | | | Rodent nest mites, *Laelaps alaskensis* | 2 |
| | | | | Common rodent mites, *Androlaelaps fahrenholzi* | 2 |
| | | | Oribatidae | | |
| | | | | Soil mite | 1 |

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Appendix. Continued.

| TAXA | | | | SPECIMENS |
|---|---|---|---|---|
| Insects | | | | |
| | Collembola | | | |
| | | Entomobryidae | | |
| | | | Slender springtail* | 1 |
| | | Sminthuridae | | |
| | | | Springtails* | 2 |
| | Psocoptera | | | |
| | | Undetermined family | | |
| | | | Psocids* | 3 |
| | Thysanoptera | | | |
| | | Thripidae | | |
| | | | Thrips | 4 |
| | Homoptera | | | |
| | | Derbidae | | |
| | | | Derbid planthopper | 1 |
| | | Aphididae | | |
| | | | Aphid | 1 |
| | Coleoptera | | | |
| | | Curculionidae | | |
| | | | Weevil | 1 |
| | | Staphylinidae | | |
| | | | Rove beetle* | 1 |
| | | Undetermined family | | |
| | | | Beetle larva | 1 |
| | Diptera | | | |
| | | Sciaridae | | |
| | | | Dark-winged fungus gnats* | 5 |
| | | Scatopsidae | | |
| | | | Black dung midge* | 1 |
| | | Cecidomyiidae | | |
| | | | Gall midge | 1 |
| | | Piophilidae | | |
| | | | Skipper fly | 1 |
| | | Chloropidae | | |
| | | | Grass flies | 3 |
| | | Undetermined family | | |
| | | | Undetermined fly | 1 |
| | Hymenoptera | | | |
| | | Pteromalidae | | |
| | | | Parasitoid wasp | 1 |

[a] Includes incidental and commensal species. Likely commensals are marked with asterisks.

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