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INFESTATION OF NORTHERN SPOTTED OWLS BY HIPPOBOSCID (DIPTERA) FLIES IN NORTHWESTERN CALIFORNIA

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ABSTRACT: Hippoboscid flies were found on 62 (17%) of 382 northern spotted owls (*Strix occidentalis caurina*) captured between April and September, 1986 through 1990. Two species of hippoboscids were identified: *Icosta americana* and *Ornithomya anchineuria*. Male and female adult spotted owls had similar prevalences and relative densities of hippoboscid flies. Juvenile owls had lower prevalence and relative densities than adults. There were no significant differences in mean intensity of hippoboscids on adult male, adult female and juvenile spotted owls. Relative densities of flies infesting adult owls were significantly greater during years of increased fall temperatures, decreased winter precipitation, and decreased summer temperatures.

Key words: Ectoparasites, Hippoboscidae, *Icosta americana*, *Ornithomya anchineuria*, spotted owl, *Strix occidentalis caurina*, prevalence, intensity, relative density.

INTRODUCTION

The northern spotted owl is a medium-sized, non-migratory owl (Forsman et al., 1984). This species has been the center of controversy between timber producers and environmentalists, because of its apparent dependence on old growth forests and its population decline in the Pacific Northwest (Anderson et al., 1990). As a result, fundamental ecological data such as population dynamics, habitat requirements, prey base and behavior have been documented (Thomas et al., 1990). Whereas Hoberg et al. (1989) and Gutiérrez (1989), respectively, described helminth and blood parasites of spotted owls, there has been little research on their ectoparasites.

Hippoboscid flies are common on many owls, but are generally considered to be nonpathogenic (Bequaert, 1955; Maa, 1969). However, hippoboscids can cause blood loss (Jones, 1985), serve as vectors for pathogenic organisms (Bequaert, 1953; Baker, 1967; Pfadt and Roberts, 1978) and phoretically transport lice (Ischnocera) (Keirans, 1975) and mites (Acari) (Marshall, 1981). In addition, subtle negative effects on host fitness can be attributed to ectoparasitic infestation (Møller, 1991). Understanding the etiology of ectoparasites on northern spotted owls is especially important because this subspecies was recently listed as a threatened species under the Endangered Species Act (U.S. Department of Interior, 1990).

In this paper, we first compare the effectiveness of visual observation and plumage combing as indicators of hippoboscid fly presence and abundance in northern spotted owls. We then examine and describe sex-specific, age-specific and temporal differences in hippoboscid fly presence and abundance.

MATERIALS AND METHODS

Spotted owls were captured within a 10,000-km² area encompassing portions of Humboldt, Mendocino, Siskiyou and Trinity counties in northwestern California (Franklin et al., 1990). Owls were captured and banded during the breeding season (April to September) from 1986 through 1990 as part of research on spotted owl demography (Franklin et al., 1990).

The number of hippoboscid flies was noted while handling owls during banding operations. Birds were held with both hands so that the thumbs were positioned in the middle of the back and the fingers were spread along the breast. Wings and tarsi were positioned against the owl's body. Thus a large portion of the owl's body was covered by the hands of the handler, increasing the probability of forcing hippoboscids to the outer layers of the plumage. In 1986 and

1987, a systematic search for hippoboscid flies was conducted on selected birds after they had been banded and prior to their release. During these searches, a wide-toothed comb was used to lift body feathers to expose hippoboscids which may have remained hidden during handling. These searches were completed within 2 min.

Hippoboscids were captured by hand and preserved in 70% ethanol. Preserved specimens were identified following descriptions of Bequaert (1954, 1955) and Maa (1963, 1969). Representative specimens were sent to R. V. Peterson, Systematic Entomology Laboratory, Agricultural Research Institution, U.S. Department of Agriculture, Washington, D.C., USA to confirm identifications and for deposition.

Adult and subadult spotted owls have similar basic plumages while fledged juveniles have soft, down-like juvenal contour feathers over most of their body as they undergo prebasic molt (Forsman, 1981). Therefore, we categorized hosts as either adult (including subadults) or juveniles which were fledged young of the year. We determined the sex of adult hosts based on Forsman (1983) but were unable to determine the sex of juveniles.

We defined prevalence as the proportion of examined hosts that were infected with hippoboscids, mean intensity as the mean number of hippoboscids per infected host, and relative density as the mean number of hippoboscids per host examined (Margolis et al., 1982). We used a Wilcoxon paired-sample test (Zar, 1984, pp. 150–156) to compare the number of hippoboscids found during handling with the number found after hosts were combed. We examined how handling time affected relative density by pooling handling times into 5-min intervals and calculating relative densities for each pooled interval. Relative densities of pooled intervals were tested with Kruskal-Wallis tests (Zar, 1984, p. 176).

We used Chi-square tests of heterogeneity to compare prevalences between years and host age-classes and Kruskal-Wallis tests to compare intensities and relative densities of hippoboscids between years and host age-classes (Zar, 1984, pp. 61–70, 176). Dunn's tests (Zar, 1984, p. 200) were used for nonparametric multiple comparisons. We used Pearson product moment correlations (Zar, 1984, pp. 306–318) to compare annual relative density with seasonal mean temperatures and precipitation. Mean temperature (C) and precipitation (cm) were estimated from data collected at six weather stations distributed throughout the study area and operated by the U.S. National Weather Service. Temperature and precipitation data were grouped into four seasons: the fall (September to November) and winter (December to February) preceding the season when owls were examined for hippoboscid flies, as well as the spring (March to May) and summer (June to August) during which owls were examined for hippoboscid flies.

RESULTS

We examined 382 spotted owls from 1986 through 1990 for hippoboscid flies. We found and captured 148 hippoboscid flies on 62 (17%) of the owls examined. Of 42 hippoboscid flies identified, 41 (98%) were *Icosta americana*, and 1 (2%) was *Ornithomya anchineuria*.

We examined 27 owls which were initially handled for 13 to 25 min and then combed. Of 20 owls where no hippoboscids were found during handling, one hippoboscid was found on one (5%) individual after combing. Therefore, handling alone was 95% effective in determining prevalence of hippoboscids on spotted owls. Relative densities of hippoboscids found during handling alone ($\bar{x}$ = 0.56, SD = 1.76) and after both handling and combing ($\bar{x}$ = 0.74, SD = 1.56) were not significantly different (t = 3.0, P = 0.13). On infested hosts only, 15 (75%) hippoboscids were found during handling and an additional five (25%) were found after combing. However, for a given individual, the additional hippoboscids found during combing did not change appreciably the magnitude of the total number of flies found. In two cases, four flies were found during handling and one to two additional flies after combing; in one case two flies were found before and one additional fly after combing. Therefore, handling provided an index, but not an absolute measure, of relative density.

Owls were handled from 1 to 45 min ($\bar{x}$ = 14.6, SD = 6.8, n = 382). Relative densities for pooled handling times were not significantly different for either adults (H = 2.51, P = 0.77) or juveniles (H = 1.94, P = 0.51). However, for subsequent analyses we used only owls which had been handled for at least 5 min (n = 371).

Prevalences of hippoboscids on adult male and adult female spotted owls were

TABLE 1. Prevalence (Pc), mean intensity and relative density of hippoboscid flies on adult and juvenile northern spotted owls from 1986 through 1990 in northwest California. Sample size (n) represents number of hosts examined.

	Prevalence		Intensity			Relative density		
	Pc	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Age-class								
Adult male	0.229	131	2.53	1.72	30	0.58	1.34	131
Adult female	0.252	107	2.33	2.61	27	0.59	1.64	107
Juvenile	0.038	133	1.60	0.55	5	0.06	0.32	133
Year (adults only)								
1986	0.102	59	2.50	3.21	6	0.25	1.21	59
1987	0.160	81	2.85	3.21	13	0.46	1.63	81
1988	0.440	25	2.45	1.69	11	1.08	1.66	25
1989	0.422	45	2.32	1.63	19	0.98	1.56	45
1990	0.286	28	2.00	0.93	8	0.57	1.03	28

not significantly different ($\chi^2 = 0.18$, 1 df, $P = 0.67$; Table 1). However, prevalence on adult spotted owls (Pc = 0.239, $n = 238$) was significantly greater ($\chi^2 = 24.99$, 1 df, $P < 0.001$) than on juveniles.

Mean intensities of hippoboscids on juveniles, male adults and female adults were not significantly different ($H = 2.12$, $P = 0.35$), although infested juveniles had 58% and 46% fewer hippoboscids than adult males and females, respectively (Table 1).

TABLE 2. Pearson product moment correlations (r) between annual relative densities of hippoboscid flies on northern spotted owls, temperature and precipitation in northwest California from 1986 through 1990. Weather variables were estimated for the fall (September to November) and winter (December to February) preceding the season when owls were examined for hippoboscid flies and spring (March to May) and summer (June to August) when owls were examined.

Annual relative density versus:	r	P
Precipitation (cm)		
Fall	−0.113	0.832
Winter	−0.839	0.037
Spring	−0.007	0.989
Summer	0.579	0.229
Mean temperature (C)		
Fall	0.930	0.008
Winter	−0.484	0.304
Spring	−0.703	0.108
Summer	−0.914	0.010

Relative densities of hippoboscids on adult male, adult female and juvenile spotted owls were significantly different ($H = 25.05$, $P < 0.0001$; Table 1). Relative densities on adult males and females were not significantly different (Dunn's test; $Q = 3.13$, $P > 0.05$) while adult relative densities were significantly greater ($Q = 43.72$, $P < 0.01$) than for juveniles (Table 1). Relative density for adults was significantly higher ($H = 23.46$, $P < 0.001$) in 1988 and 1989 than in 1986, 1987, and 1990.

We found significant correlations between annual relative densities of hippoboscids on adult northern spotted owls and (1) mean temperature during the fall preceding sampling, (2) precipitation during the winter preceding sampling, and (3) mean temperature during the summer when sampling occurred (Table 2). Increased relative densities apparently resulted from higher fall temperatures, lower winter precipitation and lower summer temperature (Table 2, Fig. 1).

DISCUSSION

Handling of captured owls alone was a good indicator of hippoboscid presence and abundance. Bennett (1961) noted occasions where handling alone might underestimate the number of flies on birds.

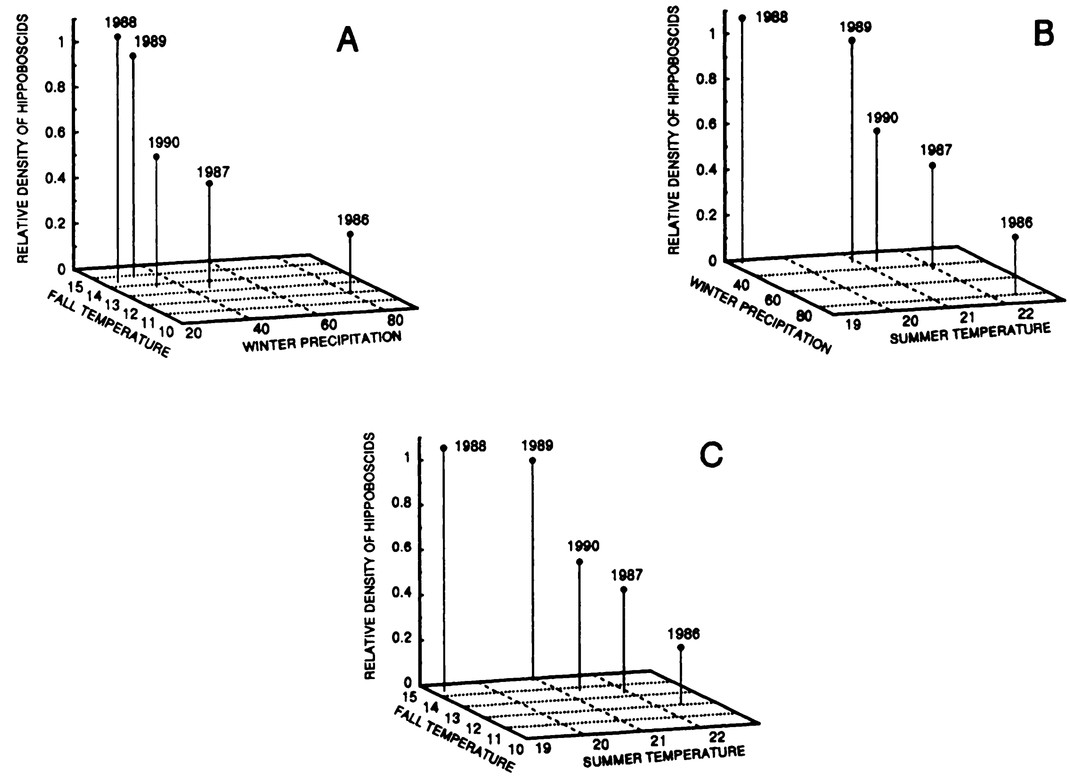

FIGURE 1. Relationship of annual relative density of hippoboscid flies on adult northern spotted owls to (A) winter precipitation (cm) and mean fall temperature (C); (B) winter precipitation and mean summer temperature; and (C) mean fall temperature and mean summer temperature in northwest California from 1986 through 1990. Winter precipitation was measured between December and February and fall temperatures were measured between September and November preceding sampling of hosts. Summer temperatures were measured between June and August during sampling of hosts.

However, our measures still provided conservative differences in relative density of hippoboscids; larger values in intensity would have increased the differences presented here.

Icosta americana has been reported on a variety of avian taxa but breeding individuals are known only from Falconiformes, Galliformes and Strigiformes (Bequaert, 1955, p. 293; Maa, 1969, p. 53; Bennett, 1961). *Icosta americana* has been reported on both the northern and the Mexican spotted owl (*S. occidentalis lucida*) (Bequaert, 1957, p. 547). Maa (1969) also reported *Ornithomya anchineuria* on other Strigiformes.

Changes in abundance of *Icosta americana* found on northern spotted owls could result from interactions with other hosts if *Icosta americana* is polyoxenous. Six other avian breeding hosts for *Icosta americana* are sympatric with the northern spotted owl in northwest California: Cooper's hawk (*Accipiter cooperi*), northern goshawk (*A. gentilis*), sharp-shinned hawk (*A. striatus*), red-tailed hawk (*Buteo jamaicensis*), ruffed grouse (*Bonasa umbellus*), and western screech owl (*Otus kennicotti*). Although these six hosts could provide a source of adult flies and puparia within spotted owl habitat, survival of hippoboscids dispersing between hosts is low (Bequaert, 1953, p. 244; Bennett, 1961).

It is more plausible that *Icosta americana* is monoxenous whose abundance is regulated by climate, acting largely in a density independent fashion (Marshall, 1981, p. 346). Changes in climate may influence hippoboscid numbers indirectly by influencing the host, or directly when the hippoboscid is away from the host. Climatic patterns which trigger physiological or behavioral changes in the host may also alter the parasite's environment (Marshall, 1981). Flies may leave the host or remain and perish if the microclimate on the owl exceeds the flies' tolerance. Flies that leave and do not return to a host within several days would likely perish (Bennett, 1961). Puparia affixed to owls or distributed in the owls' habitat would also be vulnerable to the influences of climate. Bennett (1961) demonstrated that puparia of this species was more resistant to cool rather than warm temperature extremes ($T_a > 24$ C).

Our results suggested that relative density of hippoboscid flies increased following higher fall temperatures, lower winter precipitation, and lower summer temperatures. Increased fall temperatures likely represented extended growing seasons which promoted female longevity, and permitted additional production and metamorphosis of puparia. Likewise, reduced summer temperatures would promote optimal conditions for puparia development and survival. Lastly, increased winter precipitation may decrease the number of reproductive adults, reduce the longevity of reproductive females, or reduce the development time and survival of puparia by triggering behavioral or physiological adjustments in the host. However, these relationships may be spurious due to limited temporal sample size and should be examined over a longer time frame.

Populations of hippoboscids are normally higher on nestlings and juveniles than on adult birds (Marshall, 1981, p. 299). However, we found that juvenile spotted owls had significantly lower relative densities of flies than adult owls. Juvenile spotted owls leave the nest before hippoboscid populations peak in July (Bennett, 1961; Marshall, 1981, p. 296). Juvenile spotted owls do not finish growing contour feathers until September or October (Forsman, 1981). We suspect that their juvenal plumage does not provide protection from preening for the flies (Bennett, 1961; Hutson, 1981). Avoidance of parasites may be one reason why young owls, in general, leave the nest before attaining basic plumage (Johnsgard, 1988, p. 69).

Parasites that are normally nonpathogenic may assume greater importance when individuals become malnourished or stressed. Hippoboscids are vectors of several hematozoans which Gutiérrez (1989) found prevalent in spotted owls (Baker, 1967). As a result, there is a need for research on the effects of parasites on spotted owl populations, especially as those populations become impacted from other environmental influences.

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