Possible Insect Repellent Function of Green Leaves Placed on Nests by Hawks

The study shows that leaves used by hawks in nests have an insect repellent function. Tree species used by hawks were identified and used in laboratory experiments employing house flies to test repellent qualities.

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Many accipitrids have been observed to place sprigs of green leaves on the edges of their nests. These raptors seem to select leaves of only certain tree species, and they replace the old leaves with fresh ones daily or every few days (Sprunt 1955, Brown and Amadon 1968, Wimberger 1984; our pers. obs.). The Northern Goshawk (*Accipiter gentilis*) has been reported to use the leaves of white pine (*Pinus strobus*); Zone-tailed Hawk (*Buteo albonotatus*) to use cottonwood (*Populus deltoides*); Short-tailed Hawk (*Buteo brachyurus*) to use bald cypress (*Taxodium distichum*); Red-tailed Hawk (*Buteo jamaicensis*), quaking aspen (*Populus tremuloides*) and cottonwood; Red-shouldered Hawk (*Buteo lineatus*), silver maple (*Acer saccharinum*), sugar maple (*A. saccharum*), bigtooth aspen (*Populus grandidentata*), red pine (*Pinus resinosa*), white pine, balsam fir (*Abies balsamea*), northern white cedar (*Thuja occidentalis*), and eastern hemlock (*Tsuga canadensis*); Broad-winged Hawk (*Buteo platypterus*), black cherry (*Prunus serotina*) and quaking aspen; and Bald Eagle (*Haliaetus leucocephalus*), an aromatic sedge (*Carex* sp.) and white pine (Sprunt 1955; J.P. Jacobs, pers. comm.; our pers. obs.).

Several hypotheses for this behavior in raptors have been advanced: (1) camouflages the nest; (2) raises humidity in the nest; (3) shades the nest; (4) insulates the nest; (5) serves as a means of nest sanitation (excrement coverage or removal); (6) advertises nest occupancy; and (7) aids in ectoparasite reduction (Newton 1979, Wimberger 1984, Clark and Mason 1985, Clark and Mason 1988, Clark 1990). Both Wimberger (1984) and Clark (1990) discussed the implausibility of the first six. Wimberger believed that in hawks the best hypothesis was that of ectoparasite

reduction. Clark and Mason (1988) demonstrated experimentally the validity of the ectoparasite reduction hypothesis for the European Starling (*Sturnus vulgaris*).

We propose an eighth hypothesis, that of simple insect repellency. Many volatile compounds isolated from tree leaves have been shown to be toxic and/or repellent to insects. Cyanide (HCN) from fresh black cherry leaves was demonstrated to have a knockdown time of 1 sec for flying insects (Hall et al. 1969). Cedar and pine chips are known to be toxic to the house fly, *Musca domestica* (Dethier 1976). Volatiles found in the chips are the same as in the leaves of these trees (Kuznetsov et al. 1968). *Beta*-pinene, limonene, delta-3-carene, bornyl acetate, *alpha*-terpineol, and terpinyl acetate all have been isolated from pine needles and shown to be toxic to larval and adult dipterans (Kuznetsov et al. 1968) as well as other insects (Vasechko et al. 1970). Terpenoid and phenolic compounds from *Populus* leaves have been isolated and some have been shown to be toxic to insects and certain other organisms; e.g., the phenolic, catechol, has antibacterial properties (Pearl and Darling 1967).

Adult hawks leave freshly killed prey on the nest to feed their young. The carcasses or young themselves may attract insects, especially dipterans, to the nest. This is potentially dangerous to the young, particularly because many hematophagous dipterans (e.g. black flies: Simuliidae; mosquitoes: Culicidae) not only sap their strength but also are known vectors of disease. A few (e.g. louse flies: Hippoboscidae) actually parasitize them. Several dipterans (e.g. house flies: Muscidae; blow flies: Calliphoridae; flesh flies: Sarcophidae) may introduce bacteria and/or reduce the food value of dead prey items by feeding upon the carcasses themselves.

This study was conducted to support the hypothesis that hawks select certain plant species because of their insect repellent effect. We tested repellent properties of extracts from leaves of several tree species on the very common and available house fly. We expected leaves used by hawks to show repellent properties and those not used by hawks to have little or no repellent effect.

Methods

Extracts of leaves of eight tree species were tested for insect repellent capability: quaking aspen, bigtooth aspen, black cherry, silver maple, sugar maple, black oak (*Quercus velutina*), red pine, and white pine. Of these, all except black oak are reported to be used by hawks. Leaves were collected from trees in Grantsburg, Montello, and Ripon, Wisconsin, were double-bagged in plastic and frozen until use. To make an extract, about 0.5 kg of each type of leaf was placed in a high-speed blender filled with distilled water for 10 min. The aqueous slurry was strained through window screening to remove larger leaf particles, then was mixed well with about 400 ml petroleum ether and allowed to stand for 12 h. The petroleum ether fraction was washed with distilled water, concentrated to a thick paste on a rotary evaporator, sealed in a 50-ml round-bottom flask, and frozen until use.

House fly pupae were obtained from Carolina Biological Supply, Inc. After emergence they were given a food solution made of 100 g dextrose, 100 g dehydrated buttermilk, and 1 g cholesterol in 500 ml distilled water. Extract test plates were prepared by placing 10 g bacto-agar in 800 ml distilled water and spinning on a hotplate for 5 min at 100°C. The agar was cooled to 60°C and divided into 100-ml portions. With each of these portions 200 mg of a leaf extract and 20 ml food solution were mixed (we had found that leaf extract concentrations >200–250 mg often were lethal to adult house flies). This mixture was poured thinly into petri dishes. Control plates were similar but were made without leaf extract.

To check leaf extracts for repellent qualities, a test plate and a control plate were placed approximately 10 cm apart in each of two screen-covered 5-gal plastic pails used as test chambers. About 25 houseflies that had been deprived of food for a day so that they would seek out food were introduced into each chamber. Every 3 min, for a total of 30 min, the number of flies present on each plate was recorded. All leaf extract treatments were tested in similar fashion, each with its own control.

Table 1. Mean number of flies present on test (leaf extract) vs. control plates.

Species	Mean ± SD
Red pine	1.9 ± 2.0
Control	15.2 ± 5.8
White pine	2.1 ± 1.7
Control	13.5 ± 4.5
Bigtooth aspen	2.3 ± 2.2
Control	12.0 ± 4.6
Silver maple	1.8 ± 1.2
Control	8.9 ± 5.5
Quaking aspen	3.0 ± 2.5
Control	14.3 ± 7.8
Sugar maple	2.1 ± 2.0
Control	10.0 ± 5.4
Black cherry	2.7 ± 2.8
Control	11.3 ± 4.2
Black oak	7.5 ± 4.6
Control	8.6 ± 6.2

Results and Discussion

Statistical analysis of the data (paired t-test; n 20 for each extract) showed that all tree species except black oak exhibited a statistically significant ($P < 0.001$) repellent effect (Table 1). These results fit our hypothesis, as all these tree species except for the oak are reported to be used by hawks.

Fresh leaves placed on nests by adults soon dry out and lose their volatile compounds. In addition, many of these volatiles have been shown to be very sensitive to air and photooxidation (Wiemer et al. 1984, Wiemer and Hubbell 1986), and have a limited half-life. Hence, the effectiveness of these leaves as insect repellents would be lessened over a relatively short period of time unless replaced. The exposure of leaves to drying and to oxidizing agents at the nest edge could explain the adaptive advantage of their routine replacement by adults daily or every few days.

Clark and Mason's (1985, 1988) work involved nest ectoparasites of European Starlings. Starlings are cavity-nesters, and by using green leaves of certain plants in their nest lining,

they significantly reduce nest mites (*Ornithonyssus sylviarum*) in the enclosed space. Although Clark and Mason's hypothesis of nest mite reduction appears valid for these starlings, it may not hold for hawks, whose nesting ecology is quite different. Hawks place leaves near the edges of their nests, and nest out in the open, where there is good air circulation. Unless young hawks rest upon or among the green leaves, or rub them on their bodies (neither of which has been reported), nest mite control does not seem to be the major function of green foliage for hawks.

Instead, we tend to agree with Wimberger (1984), regarding hawks. In suggesting that placing fresh foliage on nest edges functioned to reduce the parasite load on nestlings, he employed a broader definition of parasite that included larger, flying insects we do not consider parasites in the same sense as Clark and Mason's nest mites. Without arguing the definition of a parasite, we postulate that the repellent activity of leaf extracts demonstrated in our study against house flies also exists against other insects. Our results lend indirect support to a general insect repellent function of green leaves placed on nest edges by hawks, but certainly do not preclude some effect on non-insect parasites such as nest mites and bacteria.

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