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SUNSHINE VAN BAEL AND STEPHEN PRUETT-JONES, *Dept. of Ecology and Evolution, Univ. of Chicago, 1101 East 57th St., Chicago, Illinois 60637* (address correspondence to SP-J). *Received 27 Sept. 1995, accepted 10 Feb. 1996.*

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Forest gap use by breeding Black-throated Green Warblers.—Habitat heterogeneity results from environmental gradients and disturbances that create spatiotemporal patchiness (White and Pickett 1985). Fine-grained patchiness resulting from forest gaps is a condition common in temperate forests (Blake and Hoppes 1986) and is typically caused by one to several tree-falls or tree death (snag) ranging in area from 0.0025 ha to about 0.1 ha (see Lorimer 1989). The resulting heterogeneity represents a habitat mosaic important to many species.

While collecting data on the foraging behavior of Black-throated Green Warblers (*Dendroica virens*) along the northern shoreline of Lake Huron in Michigan's eastern Upper Peninsula, we quantified breeding bird use of forest gaps. Data were collected from 14 June through 19 July 1994. Transects were established parallel to the Lake Huron shoreline at distances of 0.4 km (0.25 mile), 0.8 km (0.5 mile), 1.6 km (1.0 mile) and 3.2 km (2.0 mile). Observers followed these transects for a distance of 6.4 km (4.0 mile), collecting observations on males (and females if possible) at each established territory (determined by the presence of a singing male). Because birds were territorial, only one observation per sex was made at any location. A minimum distance of 100 meters between observations was established to ensure the independence of data collected (Heijl and Verner 1990).

We used Brokaw's definition of a forest gap—a hole (minimum of 5 m in diameter) in the forest canopy extending through all levels down to an average height of two meters above ground (Brokaw 1982). A bird was considered to be using a gap if it was observed foraging or singing within 1 m of the canopy edge. We did not count transients—birds flying through the gap or otherwise obviously not using the gap to obtain food or as a territorial boundary.

Forest vegetation in the study area consisted of a mixture of conifers including balsam fir (*Abies balsamea*), northern white cedar (*Thuja occidentalis*), white spruce (*Picea glauca*), eastern white pine (*Pinus strobus*) and deciduous species including paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) and red maple (*Acer rubrum*). Mature canopy was approximately 13.5 m with an understory principally of balsam fir and white spruce.

Observations within 50 m of roads, open fields or the Lake Huron shoreline were not

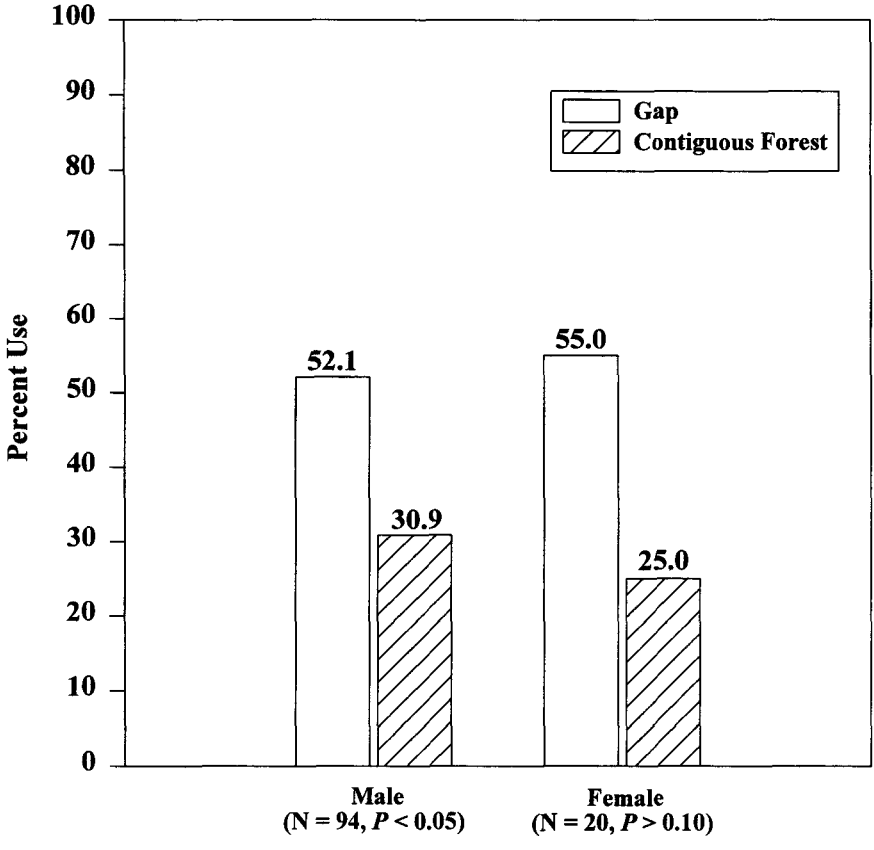

FIG. 1. Breeding Black-throated Green Warbler gap usage, 1994.

included in the statistical analysis in an effort to reduce possible bias due to edge effect. We used log-likelihood ratio G tests to analyze for differences in gap use by breeding birds (Zar 1984). As we did not measure gap area, we were unable to base our expected values on relative area of gaps versus contiguous forest. Thus, we were conservative in our calculation of expected values, assuming a 1:1 ratio of gap use to forest use.

During the breeding season, males were observed utilizing forest gaps significantly more and contiguous forest significantly less than expected ($G = 5.19$, $P < 0.05$; Fig. 1). Males were observed in, or immediately adjacent to, tree-fall forest gaps in 52.1% of our observations and in contiguous forest in 30.9% of our observations (N = 94). Females demonstrated an even greater difference in use, utilizing gaps 55.0% of the time and contiguous forest 25.0%, however, this was not significant ($G = 2.31$, $P > 0.10$) (Fig. 1). This lack of significance may be the result of low statistical power due to small female sample size (N = 20).

These observations, though potentially limited in that data were from only one breeding season, indicate the potential importance of gaps to breeding birds. Gaps may be important to breeding birds for a variety of reasons. For instance, foliage insectivores such as the

Black-throated Green Warbler may select preferentially gaps in response to differential prey abundance. There may be more insects in gaps due to greater primary productivity associated with higher light levels (Fogden 1972, Blake and Hoppes 1986). Previous work has demonstrated differences in assemblages of birds captured in gaps and the surrounding understory (Blake and Hoppes 1986, Martin and Karr 1986, McGowan-Stinski, pers. comm.). These differences have been correlated to an increased insect, fruit, and total foliage abundance in forest gaps (Blake and Hoppes 1986, Martin and Karr 1986).

The increased light penetration in forest gaps (Fogden 1972, Blake and Hoppes 1986), may result in warmer microclimates in gaps as compared to contiguous forest. Warmer microhabitats could benefit the thermoregulatory physiology of insects, increasing insect activity and abundance. Birds may thus be attracted to this activity and/or abundance as they attempt to increase foraging opportunities. Additionally, warmer temperatures within a gap may benefit a bird as it attempts to budget energy and deal with exigencies faced during the early breeding season such as cold mornings. Thus, gap foraging may be energetically advantageous through providing a bird with a concentrated source of prey, as well as a reducing an individual's thermoregulatory costs, allowing birds to shunt more energy into the breeding effort and less into individual maintenance.

The vegetation structure of forest gaps may help birds maximize their foraging profitability. Because gaps typically have a lower vegetation profile as well as a higher density of foliage (see Martin and Karr 1986), gaps may present birds with a more compact area to visually search and move about in. Increases in foliage density may yield more insect prey per unit of search time and reduce an individual's energetic expense in movement. High foliage density in gaps may also reduce a foraging bird's vulnerability to predators.

Finally, anecdotal evidence suggests forest gaps may aid males in establishment and maintenance of territorial boundaries. Black-throated Green males typically spend much of their time defending territory through visible and acoustical advertisement (Morse 1993). Utilization of a forest gap, especially a younger gap, as a territorial boundary may benefit males through increased visibility and song projection. We observed numerous aggressive male interactions occurring over or immediately adjacent to forest gaps by territorial males. Singing males were also observed responding to each other across gaps. This evidence suggests that at least some males at our study site may have been using forest gaps as territorial boundaries.

Our data suggest the importance of forest gaps to breeding Black-throated Green Warblers along the northern Lake Huron shoreline. This use suggests that structural heterogeneity in mature forest provides Black-throated Green Warblers with higher quality habitat than is found in less heterogeneous, more even-aged forest stands. A better understanding of the importance small scale disturbances play is critical if forest managers are to maintain high quality habitat for breeding resident and neotropical migrant birds.

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ROBERT SMITH AND MATTHEW DALLMAN, *Dept. of Biology, Central Michigan Univ., Mt. Pleasant, Michigan 48858.* (Present address RS: *Dept. of Biological Sciences, Univ. of Southern Mississippi, Hattiesburg, Mississippi 39406.* Present address MD: *The Nature Conservancy, 618 Main Street West, Ashland, Wisconsin 54806*). *Received 3 Nov. 1995, accepted 1 March 1996.*

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Courtship behavior of Golden-cheeked Warblers.—The Golden-cheeked Warbler (*Dendroica chrysoparia*) is an endangered species with a known breeding range mostly confined to the Edwards Plateau of Texas. These warblers inhabit oak-juniper woodlands and are dependant on *Juniperus ashei* bark for nesting material (Sexton, Birding 24:373–376).

Pulich (1967, The Golden-cheeked Warbler, a Bioecological Study, Texas Parks and Wildlife) described courtship displays in Golden-cheeked Warblers in which males attentively followed females and briefly displayed before copulation. There are no other published accounts of this type of behavior in this species. Courtship behavior in Golden-cheeked Warblers was observed on two occasions during spring 1995. The following observations were made at Pedernales Falls State Park, Blanco Co., Texas on 27 March 1995 and at Colorado Bend State Park, San Saba Co., Texas on 4 April 1995. In both cases, a female Golden-cheeked Warbler was discovered constructing the base platform of a nest prior to the observations of courtship behavior. The female warbler would make short forays into neighboring *Juniperus ashei* to collect strips of bark. All of the nesting material gathered during these observations was from trees within 15 m of the nest tree. The nest at Pedernales Falls was 5.3 m high in *J. ashei*, and the nest at Colorado Bend was 4.7 m high in *Ulmus crassifolia*. While observing the female's activities, a quiet, warbler-like song was heard that was unlike either of the primary songs of the Golden-cheeked Warbler (Pulich 1976). This song was muted, but more rapidly paced, than the typical songs of the species. This combination gave the song a more twittery quality than the primary songs. However, despite these differences, the song had tonal qualities similar to the other songs of the species. The