Population Densities of Northern Saw-whet Owls (*Aegolius acadicus*) in Degraded Boreal Forests of the Southern Appalachians

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Abstract.—A disjunct population of the Northern Saw-whet Owl (*Aegolius acadicus*) breeds in the montane spruce-fir forests of the southern Appalachian Mountains. These forests are listed as the second most endangered ecosystem in the United States, having suffered from logging and massive fir die-off from the exotic balsam woolly adelgid. We used audio playbacks to compare densities of saw-whets prior to fir die-off (1968-1969) with those now (1993-1994); numbers were almost identical, suggesting little if any impact from the adelgid. Extrapolation from our density estimates, however, show fewer than 500 pair of saw-whets in the southeastern population. Global warming, air pollution, outbreaks of new pests, and burgeoning recreational demands may further degrade these forests, leading to the possible extirpation of saw-whets from the southern Appalachians.

The Northern Saw-whet Owl (*Aegolius acadicus acadicus* Gmelin) is a widespread and common owl in the forests of southern Canada and the northern United States (Cannings 1993, Johnsgard 1988). An apparent generalist, it has been found breeding in habitats as diverse as conifer plantations, deciduous forests, and cedar bogs (Cannings 1993, Johnsgard, 1988). Two potentially isolated populations occur in the eastern United States: a mid-Atlantic disjunct on the Allegheny Plateau of eastern West Virginia and western Maryland; and a southeastern disjunct in the southern Appalachian Mountains of western North Carolina, eastern Tennessee, and southwestern Virginia (fig. 1). Both of the eastern disjuncts may represent glacial relicts (Tamashiro 1996), remnants of a more extensive boreal flora and fauna associated with the Wisconsin glacial

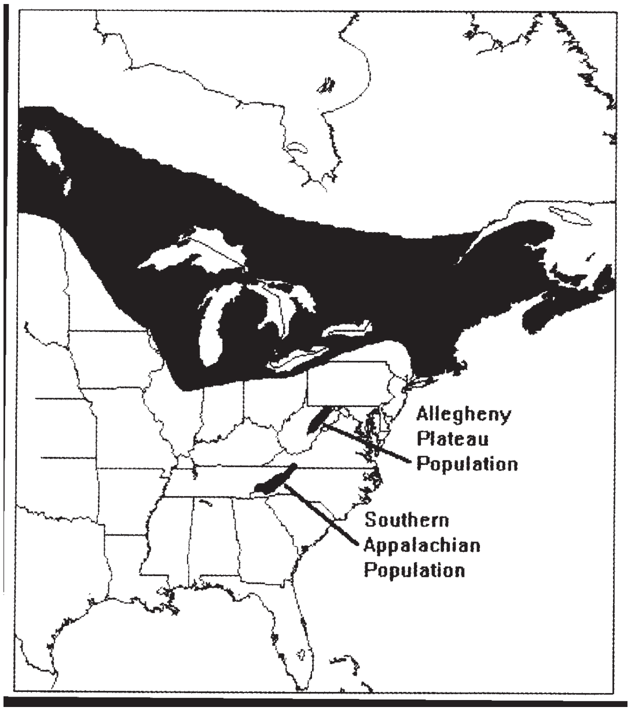

Figure 1.—*Breeding distribution of the Northern Saw-whet Owl* (Aegolius acadicus) *in the eastern United States and Canada (adapted from figure 50 in Johnsgard 1988 and figure 1 in Cannings 1993; isolation of the Allegheny Plateau population from the population in Pennsylvania/New York may be less discrete than illustrated (Gross 1992; Brinker, pers. comm.).*

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maximum of 18,000 years ago (Delcourt and Delcourt 1984, Parmalee and Klippel 1982, Wright 1981).

Unlike their northern cousins, southern Appalachian saw-whets appear to be habitat specialists, with breeding (assessed primarily by reports of territorial calling) restricted to high-elevation stands of red spruce (*Picea rubens* Sargent), Fraser fir (*Abies fraseri* (Pursh) Poiret), and associated northern hardwoods (Crutchfield 1990, Simpson 1992, Stupka 1963). The red spruce and Fraser fir are themselves glacial relicts, restricted now to elevations above 1,350 m (4,430 ft) in the southern Appalachians (Dull *et al*. 1988, White *et al*. 1993). As might be expected, the geographic isolation of southern Appalachian spruce-fir forests has produced a suite of endemic plants and animals, including at least eight endemic species and subspecies of birds (Groth 1988, Rabenold 1984). Although southern Appalachian saw-whets are not one of these eight officially-recognized avian endemics, individuals from this region are morphologically distinguishable from other populations (Tamashiro 1996), including saw-whets from the Allegheny Plateau, from the "main-range" of the northern U.S. and southern Canada, and from a distinct subspecies restricted to the Queen Charlotte Islands (*Aegolius acadicus brooksi* Fleming).

The apparent restriction of southern Appalachian saw-whets to high-elevation spruce-fir forests is worrisome, as this forest type is listed as the second-most endangered ecosystem in the U.S. (Noss and Peters 1995, White *et al*. 1993). With the retreat of the Laurentide ice sheet, spruce-fir forests became rare in the southeast, restricted to only the highest peaks in the southern Appalachians. Logging early this century decimated what little remained, with clear-cutting and slash-induced fires destroying as much as 90 percent of the virgin spruce and fir (Korstian 1937). Following logging, the forests experienced several decades of recovery, only to be threatened by the balsam woolly adelgid (*Adelges piceae* Ratzeburg), an exotic pest of fir trees brought into the United States on nursery stock from Europe. Although the adelgid was first detected on Mount Mitchell in the southern Appalachians in 1957, many of the peaks remained uninfected until the late 1960's and significant mortality of Fraser fir did not occur until the late 1970's (Dull *et al*. 1988). For example, in 1976 only 10 ha (25 acres) of fir showed heavy mortality in Great Smoky Mountains National Park, a value that had risen to 1,862 ha (4,600 acres) by 1985; 91 percent of the mature Fraser fir now stand dead in the Park (Dull *et al*. 1988). Glacial retreat, clearcutting, and the adelgid have reduced southern Appalachian spruce-fir forests to a patchy archipelago of high-elevation islands stretching from Mount Rogers in southwestern Virginia to the Great Balsam Mountains of southwestern North Carolina (fig. 2).


Tim Silver

Die-off of fir trees on Mt. Mitchell, southern Appalachian Mountains.

Have logging and exotic pests affected the southeastern population of saw-whet owls? Unfortunately, the presence of a breeding population of saw-whets in the southern Appalachians was not recognized until the 1940's (Stupka 1963), decades after the spruce-fir had been logged. Impacts from the adelgid, however, might be assessed. Auditory playbacks have proven useful for determining the abundance of rare or elusive bird species (Fuller and Mosher 1981, Johnson *et al*. 1981), and have been used successfully for censusing saw-whet owls (Palmer 1987, Swengel and Swengel 1987). An early but unrecognized pioneer of this technique is Marcus Simpson, Jr. Simpson (1972) used whistled imitations of the saw-whet advertisement/territorial call (Cannings 1993) to census saw-whets in the Great Balsam Mountains of the southern Appalachians during the breeding seasons of 1968-1971, prior to adelgid-induced fir mortality in this range. The balsam woolly adelgid did not arrive in the Balsam Mountains until 1968, and death of the fir did not begin until the mid to late 1970's (Dull *et al*. 1988), as it takes 5-10

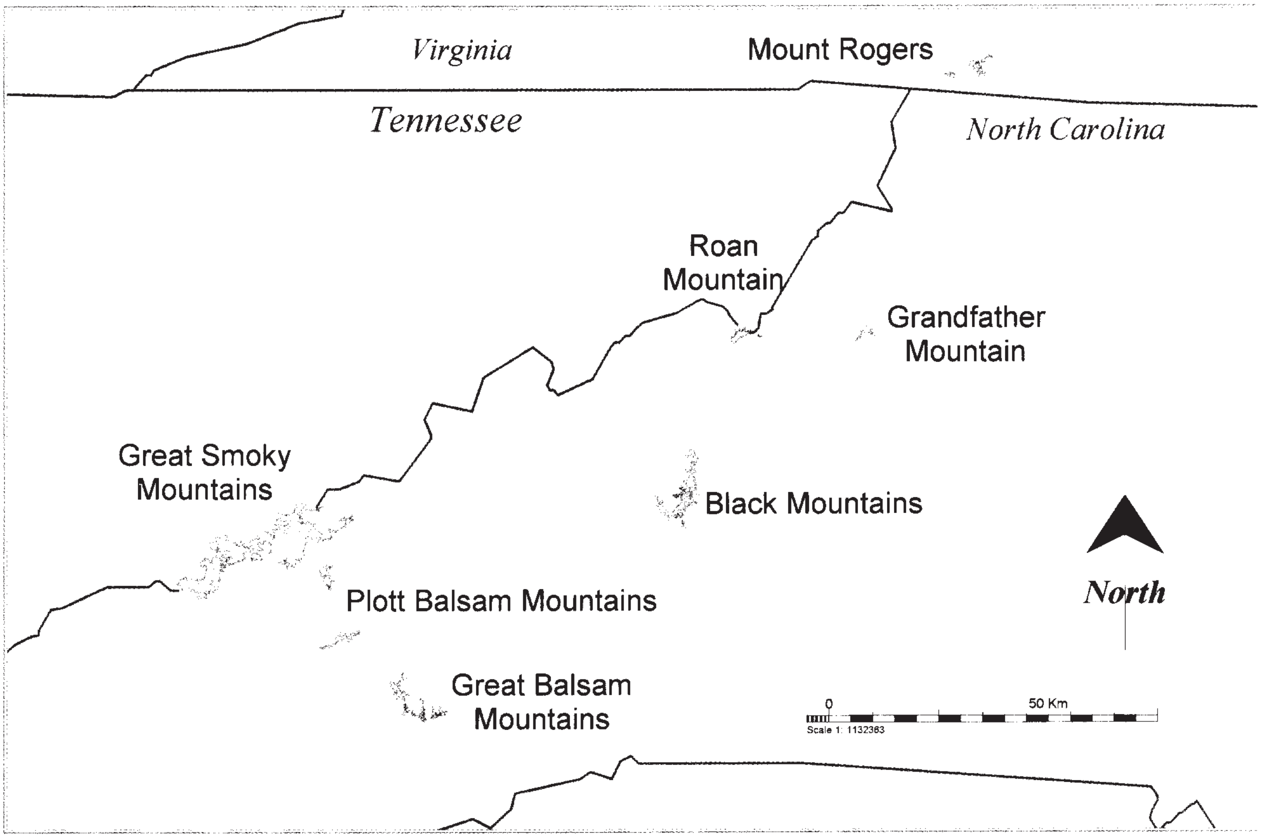

Figure 2.—*Distribution of spruce-fir forests in the southern Appalachian mountains (adapted from figure 5 in Dull* et al. *1988). Our study sites were located on Roan Mountain, the Black Mountains, and the Great Balsam Mountains.*

years before an adult fir is killed by the adelgid (Busing *et al*. 1988). A post-adelgid census of saw-whets in the Great Balsam Mountains could elucidate the impact of fir die-off on saw-whet densities in this disjunct, southeastern population.

This paper is part of a larger, ongoing investigation begun in 1991 exploring the conservation biology of southern Appalachian saw-whets. The research reported here has two main goals: first, to compare densities of saw-whet owls in the Great Balsam range of the southern Appalachians prior to and following adelgid-induced fir die-off; and second, to estimate the number of saw-whets in the disjunct southern Appalachian population.

METHODS

Study Areas

Census work was conducted from February to August in 1993 and 1994 on three mountain ranges in the southern Appalachians (fig. 2), each of which was known from published reports and our own research to harbor breeding saw-whets: Roan Mountain; the Black Mountains, including Mt. Mitchell; and the Great Balsam Mountains. A core group of high elevation forests, predominantly boreal spruce-fir forests and their lower-elevation ecotone with northern hardwoods, were identified for census during both years. We took advantage of the Blue Ridge Parkway for censusing the Black and Balsam Mountains, as this national roadway runs along the mountain ridges in both areas and provides excellent access to both the high-elevation spruce-fir forests and, in valleys and saddles between peaks, to lower-elevation hardwood and cove forests (see Simpson 1972). Surveys on Roan Mountain were conducted by driving and hiking along U.S. Forest Service access roads and hiking trails.

Census Method

We used the strip-map census technique (Emlen 1984), with a quantitative modification outlined below, to estimate the number of territorial saw-whets at each study site each year. Taped playbacks of saw-whet advertisement calls were broadcast along roads and trails to elicit vocal responses from owls. These playbacks were broadcast at intervals of 0.5 to 0.8 km (0.3 to 0.5 mi), depending on geography (e.g., closer intervals were required when playback locations were separated by a ridge line, while longer intervals could be used when surveying around a cove). At each broadcast location, census takers would listen for calling owls for 2 minutes, broadcast the playback intermittently for 5 minutes, then listen another 2 minutes for any response. Owls responding to playbacks or heard calling spontaneously (unprompted) were noted and the location mapped onto 7.5 minute USGS topographic maps. Saw-whets characteristically responded to the "tooting" advertisement call in kind, although whines (Cannings 1993, Hill 1995) were occasionally reported. We assume that most replies were from male saw-whets on, or in the process of establishing, their territories (Cannings 1993, Hill 1995, Otter 1996, Palmer 1987).

Changes of a given owl's calling site from night to night could be incorrectly designated as those of two owls and thus inflate the number of male saw-whets estimated to be holding territories near a particular playback station. Census takers therefore attempted to map the specific tree stand from which an owl responded (hereafter referred to as a "calling site"). This information was used to identify clusters of vocal activity (hereafter referred to as "calling clusters") over the course of the breeding season. Thus, our calling clusters are similar to Emlen's (1984) "point clusters" and Swengel and Swengel's (1987) "composite calling stations." We did, however, try to define our calling clusters in a more quantitative manner than has been typical of most spot-mapping and strip-mapping census techniques. Unless it could be determined that different individuals vocalized from a given calling cluster (e.g., antiphonal calling by two owls from the same cluster), calling sites mapped on different evenings less than 0.5 km (0.3 mi) from the center of a calling cluster were considered responses from the same owl. Cannings (1993) estimates that breeding densities of saw-whets in optimal habitat may reach one pair/km^2. Thus, a cluster of calling sites that fall within a half km radius are likely to be from the same male. The use of vocal "signatures" could, in future studies, further reduce the ambiguity of assigning a calling cluster to a specific owl (Hill 1995, Otter 1996).

In order to reduce the likelihood of incorrectly designating calls from transient owls as those of residents holding territory, only owls heard calling from the same calling cluster on 2 or more census nights of more than 7 days apart were assumed to be residents holding territory. Thus, our operational definition of a "territory" is the presence, during the breeding season, of a calling saw-whet in a circumscribed area (0.5 km radius) for more than 1 week. With the exception of our more quantitative method for identifying calling clusters, this definition is comparable to that employed by Simpson (1972) for his earlier census work in the Great Balsam Mountains.

Forest Classification, Mapping, and Density Analyses

We classified forests bordering the census transects into four categories: (1) high elevation boreal forests dominated by red spruce and Fraser fir; (2) high elevation boreal-ecotone forest of spruce-fir mixed with northern hardwoods, primarily yellow birch (*Betula alleghaniensis* Britt.), red maple (*Acer rubrum* L.), and American beech (*Fagus grandifolia* Ehrhart); (3) mid-elevation northern hardwood forests dominated by birch, maple, beech, and occasionally northern red oak (*Quercus rubra* L.); and (4) cove forest, typically composed of yellow buckeye (*Aesculus flava* Solander), Fraser magnolia (*Magnolia fraseri* Walt.), cucumber tree (*Magnolia acuminata* L.), basswood (*Tilia americana* L.), and red maple mixed with Eastern hemlock (*Tsuga canadensis* L.). The distributions of these four forest types along census routes were identified using 1988-1989 USGS high-altitude infrared aerial photographs, and were then plotted on USGS 7.5 minute topo maps. Forest-types along census routes were ground checked to correct inconsistencies in aerial photo interpretation.

Because proportions of each forest type were not equal at each site, and each forest type was not censused an equal number of nights or for an equal number of hours, we calculated relative occurrence by dividing the number of owls heard in each forest type by the total time that forest type was censused. The density of saw-whets in each forest type was estimated for each study site each year, with the exception of the Roan Mountain study area which was not sufficiently surveyed in 1994. Densities were calculated by dividing the total length of the censused forest type by the number of territories in that forest type that year.

Detailed maps of the boreal forest present on each mountain range in the southern Appalachians are presented in Dull *et al*. (1988). These maps were digitized for each of our three study areas. The roads and trails we used for our playbacks were overlaid on these maps. The distribution of spruce-fir forests in the southern Appalachians is not only fragmented across ranges, but also is quite narrow in any given range; i.e., in the southern Appalachians, spruce and fir are limited to elevations above 1,350 m (4,430 ft), and thus their distribution usually follows the contours of high-elevation ridge lines. Indeed, the major forest types exhibit a noticeable "zonation" in the southern Appalachians (Simpson 1992, White *et al*. 1993): fir grows in relatively pure stands only on the highest peaks (> 1,800 m, or 5,900 ft); mixed fir and spruce occur below 1,800 m, with fir giving way to spruce at lower elevations; the transition between spruce-fir and northern hardwoods occurs at elevations between 1,400 -1,680 m (4,593-5,249 ft); northern hardwoods themselves give way to southern oak-hickory forests below 1,300 m (4,265 ft); cove forests occur in the moist drainages along the mid to lower slopes at elevations up to 1,372 m (4,500 ft). Thus, in areas where our census route (e.g., the Blue Ridge Parkway) traversed a mountain below the ridge line, playbacks carried all the way from the fir-dominated ridge above us down into the oak-hickory carpeted valleys below (pers. observ.). When a survey route followed a ridge line, playbacks were audible down both slopes. We could neither hear a playback, nor did playbacks generate an audible response from owls, from over a ridge line.

Owl densities were therefore calculated by first identifying the area effectively censused on each side of our roughly linear transects. This area was delimited using the detection-threshold distance technique (Emlen 1984), which we determined to be a strip approximately 1.2 km (0.75 mi) in width. Where a strip of this width extended beyond terrain barriers that would interfere with hearing an owl's response (e.g., over ridge lines), the area beyond those barriers was eliminated from our estimates of total area censused. Relative densities of saw-whets in each of the three surveyed mountain ranges were computed by dividing the number of identified territories by the area censused. Because saw-whets are restricted almost exclusively to boreal and ecotone forests (Simpson 1972, 1992; and see Results below), and the extent of this forest type is known (Saunders 1979, cited in White *et al*. 1993; Dull *et al*. 1988) the absolute size of the saw-whet population in the southern Appalachians was estimated by extrapolating from relative densities.

RESULTS

Seasonality

A total of 227 census hours generated 159 saw-whet responses. Of the 227 census hours, 143.25 were from 1993 and 83.75 from 1994.

The peak calling period for saw-whets in the southern Appalachians has been reported to be between late March and mid-June (Alsop 1991, Simpson 1992). Our data support this observation. Although we have heard spontaneous, unprompted calling during calm nights at all times of the year, the earliest responses during our playback work occurred on 11 March 1993 and 18 February 1994. Both of these records are from the Great Balsam Mountains, the southernmost of our three study sites and, indeed, the southern limit of spruce-fir forest in the Appalachians. The number of owls heard calling per census increased to a maximum between mid-April and late May. The latest seasonal record of spontaneous calling was 25 June 1994, although owls continued to respond to playbacks throughout the census period. There appears to be a second bout of calling, and concomitantly an increased responsiveness to playbacks, in September and October (unpubl. data; see also Cannings 1993), perhaps due to dispersal of the young in the fall.

Spontaneous calling of saw-whets made playbacks virtually unnecessary during the peak period from mid-April to late May. Males would commonly call for hours from locations within their territories. Peak nights of vocal activity were on 16 and 27 May 1993, and 20 and 24 April 1994. During these periods, owls in adjacent territories would almost invariably be calling, such that a string of owls could be heard for 4.8 to 6.4 km (3 to 4 miles) along the transect route. On 27 May 1993, for example, 7 owls were heard simultaneously calling along a 6 km (3.7 mi) section of the Blue Ridge Parkway in the Great Balsam Mountains.

The earliest dates and the period of peak calling differed between years, with 1993 lagging behind 1994 by approximately 1 month. March 1993 was severe, with the so-called “storm of the century” bringing record snows and record low temperatures during the middle of the month (e.g., -23°C on 15 March 1993; National Weather Service data from Banner Elk, NC). Deep snow and cold temperatures may have delayed nesting and interrupted territorial establishment.

Density Per Forest Type

A total length of 86.7 km (53.9 mi) of forest transects was repeatedly censused in 1993 and 96.2 km (59.8 mi) in 1994. The boreal and boreal-ecotone forests comprised 70 percent of the length censused in 1993 and 61 percent in 1994. Northern hardwood forests comprised 22 and 39 percent of the census length for the 2 years respectively. Cove forest comprised only 8 percent of the length censused in 1993 and was not censused in 1994.

Saw-whet owls called almost exclusively from high elevation boreal and boreal-ecotone forests. Indeed, over 90 percent of the 159 responses were from sites higher than 1,524 m (5,000 ft) in elevation (table 1). Broken down by mountain range and year, the proportions of calling sites located in boreal or boreal-ecotone forests were: Black Mountains, 1993 - 95 percent, 1994 - 100 percent; Great Balsam Mountains, 1993 - 100 percent, 1994 - 84 percent; Roan Mountain, 100 percent both years. The remainder of calling sites were located in northern hardwood forests; owls were never heard responding from cove forests. The relative occurrence of saw-whets per forest type (i.e., responses per habitat type per census hour) are shown in table 2. Two points are obvious from this table. First, owls called from more sites than there were territories, an expected result if calls are given from transient owls or if territorial establishment requires some adjustment. And second, both the number of calling sites and the eventual number of established territories were greater than expected in spruce-fir and spruce-fir/ecotone forests, and lower than expected in northern hardwoods or forests. These differences are highly significant for calling sites ($\chi^2 = 24.03$, df = 3, $p < 0.0005$; Feldman *et al*. 1987), and

Table 1.—*Distribution by elevation for 159 Northern Saw-whet Owl (*Aegolius acadicus*) responses recorded during our surveys (1993-1994) in North Carolina. Elevations listed by 500 ft (152 m) increments; thus, we heard only a single saw-whet response in the Black Mountains at an elevation between 4,000-4,499 ft, five responses between 4,500-4,999 ft, etc. Cells lacking entries indicate elevations that were not censused.*

Mountain range	**Elevation (ft)**						
	3,500	**4,000**	**4,500**	**5,000**	**5,500**	**6,000**	**6,500**
Blacks[1]	0	1	5	18	12	22	5
Balsams	0	0	6	21	39	6	NA[3]
Roan[2]					24	0	NA[3]

[1] Surveys in the Black Mountains actually extended down to 3,177 ft (968 m), but no responses were heard below 4,460 ft (1,359 m).

[2] Systematic, altitudinal surveys of Roan Mountain were not part of the census design during 1993 or 1994; however, a low-elevation (2,840 ft; 866 m) hemlock forest was repeatedly surveyed and no saw-whets were discovered. Moreover, altitudinal surveys conducted during 1995 and 1996 found no saw-whets below 5,200 ft (1,585 m) .

[3] Maximum elevation in the Great Balsam Mountains is 6,410 ft (1,954 m) and on Roan Mountain it is 6,285 ft (1,916 m).

Table 2.—*Relative occurrence of Northern Saw-whet Owls (*Aegolius acadicus*) by forest type (i.e., the number of calling sites and the number of territories per habitat type per hour of census) (1993-1994), North Carolina.*

Forest type	**Calling sites per hour**	**Territories per hour**
Spruce-fir	1.4	0.36
Spruce-fir/northern hardwood ecotone	1.1	0.27
Northern hardwood	0.3	0.03
Cove forest	0.0	0.00

approach significance for territories ($\chi^2 = 6.31$, df = 3, $p < 0.10$; Feldman *et al*. 1987). Thus, our census results support Simpson's suggestions (1972, 1992) that southern Appalachian saw-whets are essentially birds of boreal and boreal-ecotone forests.

Saw-whets have, however, been reported from atypical sites in the southern Appalachians, including several observations meeting our operational definition of "territorial." Repeated observations of a singing male have been reported from a red-oak forest at 1,463 m (4,800 ft) near Pickens Nose in the Nantahala Mountains (Boynton, pers. comm.), and another has been reported from a northern hardwood forest at 1,524 m (5,000 ft) at Hooper Bald in the Unicoi Mountains (Hughes, pers. comm.). Two radio-harnassed saw-whets were monitored during the spring and summer of 1996[4] in a cool but low-elevation (1,036 m, 3,400 ft) drainage dominated by old-growth hemlock near the NPS Price Lake campground. None of these sites contained either spruce or fir. Moreover, 9 of the 159 responses to our census playbacks, representing owls on two territories, were from northern hardwood forests. Although one of these territories was in a mountain gap immediately surrounded by boreal forests, the other was in pure hardwood forest in the Great Balsam Mountains, a site at least 8 km (5 mi) from any appreciable stands of spruce or fir. Reproductive data would be needed to determine whether these atypical sites represent population "sources" or "sinks" (Bart and Forsman 1992, Pulliam 1988). These sites may, for example, represent sub-optimal habitat occupied by juvenile or subordinate birds that have been excluded from boreal habitats.

Whether saw-whets in these atypical sites are reproducing or not, two additional pieces of evidence suggest that such sites are rare. First, the data summarized in table 2 represent surveys by forest type immediately bordering our census routes. Because of the altitudinal zonation of forest types along our transects, however, we were in truth sampling multiple forest types even when our playback location was in spruce-fir. For example, we often heard responses from Barred Owls (*Strix varia* Barton) and Eastern Screech-owls (*Otus asio* Linnaeus) from the cove and oak-hickory forests in the valleys below, while saw-whets were never heard responding from below the mid-elevation northern hardwood zone. This is not, we believe, an artifact of species differences in song amplitude; the tooting call of saw-whets appears to carry at least as far as the bounce and whinny calls of screech owls. Moreover, our detection-threshold distance (Emlen 1984) for saw-whets was up to 1.2 km (0.75 mi), a distance sufficient for us to have noted the presence of saw-whets if they had responded from low-elevation forests.

Second, approximately one-dozen breeding-season surveys were conducted at two additional, high-elevation spruce-fir sites in 1991 and 1992: Mt. Rogers in southwestern Virginia and Grandfather Mountain in western North

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[4] Cooper, P.C. in prep. Winter ecology of southern Appalachian saw-whet owls. M.S. thesis in Biology, Appalachian State University, expected November 1998.

Carolina (fig. 2, unpubl. data from Tomlinson and Rowe). Surveys were conducted on foot, with playbacks approximately every 0.3 km (0.18 mi), alternately starting and finishing in high elevation spruce-fir stands (1,676 m or 5,500 ft on Mt. Rogers, 1,707 m or 5,600 ft on Grandfather Mountain) and low-elevation northern hardwood/oak-hickory forests (1,329 m or 4,360 ft on Mt. Rogers, 1,219 m or 4,000 ft on Grandfather Mountain). Territorial saw-whets were found on both mountains, always in either boreal or boreal-ecotone forests.

Densities Across Mountain Ranges

Of the 227 census hours, 66.25 were conducted in the Black Mountains in 1993 and 35.25 hours in 1994; 25.75 census hours were conducted in the Great Balsams in 1993, 32.25 in 1994; 51.0 hours were spent at Roan Mountain in 1993, with only 16.25 in 1994. None of the census hours from Roan in 1994 overlapped the peak calling season for saw-whets, and thus are dropped from further analyses.

Ten territories were mapped in the Great Balsams in 1993, eight in 1994 (fig. 3); seven were mapped in the Black Mountains in 1993, while five were found the following year; and finally, five territories were discovered on Roan in 1993. Reassuringly, Barb (1995), working independently of our project, also mapped five saw-whet territories on Roan in 1993.

The densities of territorial saw-whets differed across mountain ranges. Roan Mountain and the Great Balsam Mountains had similar densities in 1993, averaging one territory every 2.1 and 2.3 km (1.3 and 1.4 mi), respectively. Territories were slightly less dense in the Balsams in 1994, with one male per 3.1 km (1.9 mi). Densities in the Black Mountains were considerably lower than those in the other two study areas, with territories spaced every 3.9 and 4.5 km (2.4 and 2.8 mi) for 1993 and 1994, respectively.

DISCUSSION

Adelgid Impact on Saw-whet Density

Have saw-whet densities in the Great Balsam Mountains changed since Simpson's (1972) pioneering study of the late 1960's? Before answering, we should note the differences between our and Simpson's methodologies. Simpson whistled an imitation of the saw-whet's advertisement call; we broadcast taped calls at above-normal amplitudes. Simpson's surveys were conducted almost exclusively during the peak of saw-whet calling; our surveys started before, continued through, and ended after the peak season. And although Simpson's definition of what constitutes a saw-whet territory is basically the same employed here (i.e., an owl heard calling at the same site at least twice), Simpson pooled records over his 4 years of surveys while we required that an owl be heard twice during the same year. Nonetheless, densities reported by both studies are remarkably similar. We found 10 and eight territories in the Balsams in 1993 and 1994, respectively, while Simpson reported eight territories in both 1968 and 1969, with nine territories pooling over all 4 years of his study. The majority of Simpson's surveys were conducted in 1968 and 1969, and he reports an average density of one territory every 2.6 km (1.6 mi) for both years. By comparison, we found average densities in 1993-1994 of one territory per 2.7 km (1.7 mi). Similarities are also reported for calling sites (i.e., a location from which a saw-whet was heard at least once); 12 of the 15 calling sites reported by Simpson in the 1960's were occupied by saw-whets during our study in the 1990's.

Even though the Great Balsam Mountain range was the last range in the southern Appalachians to become infected with the woolly adelgid, the impact of these insects on the forests has been severe. Indeed, 84 percent of the fir have died, and mortality as a proportion of total fir volume is higher in the Balsams than in any other range (Dull *et al.* 1988). Comparisons of our results with Simpson's (1972) therefore suggest that adelgid-induced fir die-off has had little impact on the saw-whet population in the Great Balsam Mountains, and perhaps in the entire southern Appalachians. Telemetry data[5] do show that saw-whets avoid fir stands that have suffered heavy mortality. Apparently, the relatively healthy stands of red spruce just downslope of the degraded fir provide sufficient resources for the owls, as densities in the Great Balsams are

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[5] Milling, T.C. in prep. Habitat requirements and population densities of saw-whets in the southern Appalachians. M.S. thesis in Biology, Appalachian State University, expected June 1998.

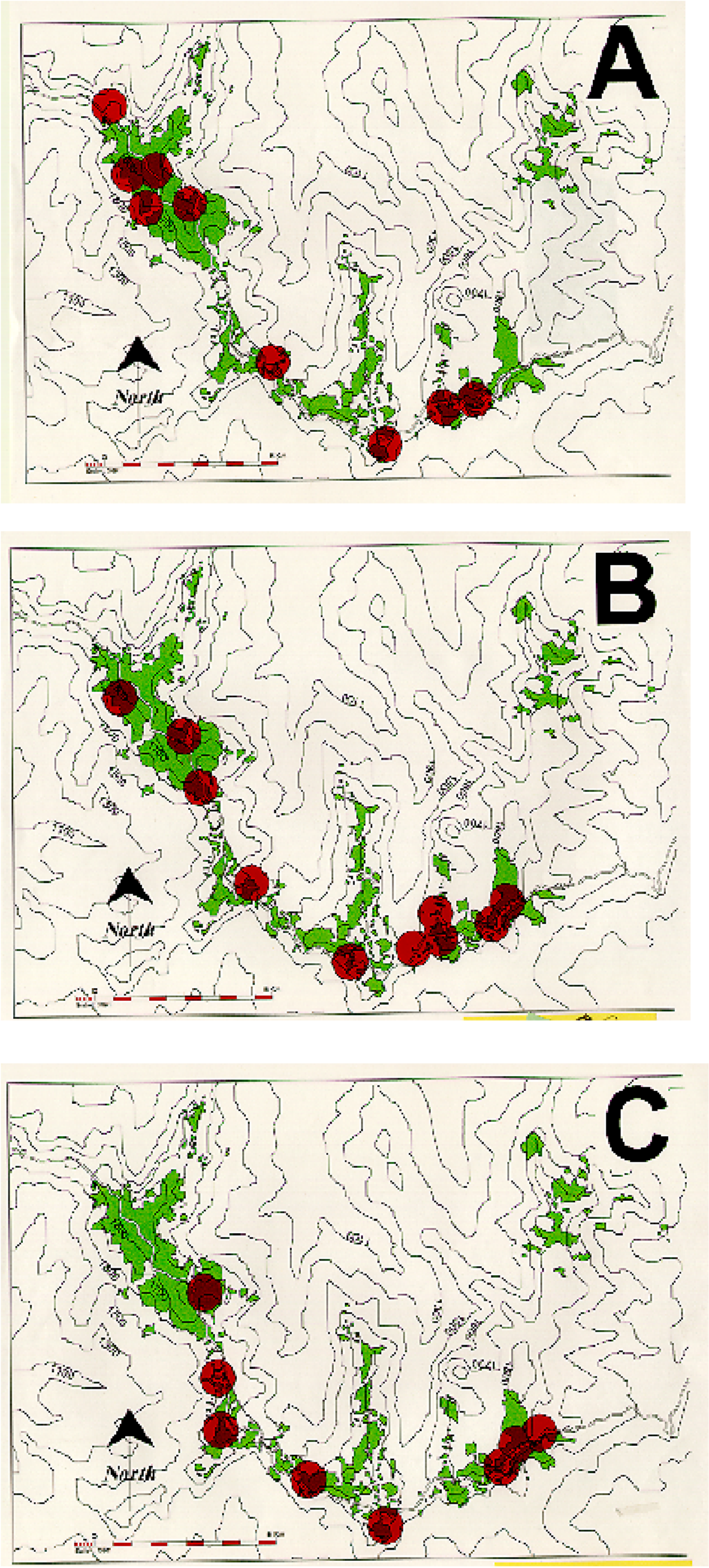

Figure 3.—*Locations of Northern Saw-whet Owl (*Aegolius acadicus*) calling clusters (territories) in the Great Balsam Mountains, North Carolina, during: (A) 1968-1971 (adapted from figure 1 in Simpson 1972); (B) 1993; and (C) 1994.*

essentially identical to those reported almost 30 years ago (Simpson 1972), prior to death of the fir. That the adelgid has had little impact on saw-whets is further supported by comparisons across mountain ranges. In our surveys, saw-whet densities were nearly identical on both Roan Mountain and in the Great Balsams, although adelgid-induced fir mortality is quite different on these peaks (44 vs. 84 percent, respectively; Dull *et al*. 1988). By contrast, saw-whet densities in the Black Mountains were twice as low, even though fir mortality (49 percent) is comparable to that on Roan (Dull *et al*. 1988). Explanations for differences in saw-whet densities across ranges are, at this point, speculative. Perhaps forests in the Black Mountains were damaged more severely by clearcutting earlier this century. Alternatively, prey abundance may have been higher during our survey years in the Great Balsams and on Roan than in the Blacks. Or perhaps the Black Mountains, being the highest range in the southern Appalachians, intercept more atmospheric pollutants and have reduced forest health. It may be noteworthy that the Black Mountains have the highest mortality of red spruce reported from any range in the southern Appalachians (Dull *et al*. 1988).

In the Great Balsam Mountains, at least, the population of Northern Saw-whet Owls appears relatively stable. Territorial densities and even calling sites look comparable from year-to-year and even decade-to-decade. We see little hint of the order-of-magnitude cycles reported for other populations of saw-whets (Palmer 1987, Swengel and Swengel 1995), although we caution that 2 consecutive years of surveys in the late 1960's and 2 in the mid-1990's may be insufficient for detecting such cycles. If confirmed, the stability of the southern Appalachian saw-whet population relative to other populations may be explained by dietary differences. Rodents comprise over 90 percent of the prey consumed by saw-whets at most sites (see review in Cannings 1993), and saw-whet populations may be tracking rodent cycles (Palmer 1987, Swengel and Swengel 1995).

Almost 60 percent of the prey consumed by saw-whets at our study sites, however, are shrews (Cockerel 1997). In North America, at least, shrew populations appear less cyclic than rodents (Getz 1989). Additionally, Korpimäki (1986) has demonstrated a significant, inverse relationship between owl-population cycles and dietary niche breadth in Tengmalm's Owls (*Aegolius funereus* Linnaeus); a broad diet presumably buffers certain Tengmalm's populations from the cycles of any single prey. Saw-whets in the southern Appalachians have a significantly higher dietary niche breadth than values reported for any other saw-whet population (Cockerel 1997), higher even than the most stable populations of Tengmalm's Owls. Two other trends reported by Korpimäki (1986) for Tengmalm's Owls also seem relevant: northern populations are more cyclic than southern populations; and nomadic/migatory populations are more cyclic than residents. Southern Appalachian saw-whets are, obviously, southern (fig. 1), and preliminary data suggest that these owls are year-round residents, exhibiting at most a moderate downslope movement only during harsh winter weather (Milling in prep., Cooper in prep.).

Southern Appalachian Saw-whet Owls: Current Status and Future Prospects

What is the size of the saw-whet population in the southern Appalachians? Based upon digital quantification of maps provided in Dull *et al*. (1988), we surveyed 734.4 ha (1,814.7 acres) of boreal and boreal-ecotone forest in the Great Balsam Mountains in 1993 and again in 1994. We found 10 saw-whets on territories in the surveyed area in 1993, suggesting a density of one pair per 73.4 ha (181.4 acres) of these forest types**.** This is the highest density of saw-whets we found at any site in either year. Similarly, we surveyed 1,252.5 ha (3,095 acres) of boreal and boreal-ecotone forest both years in the Black Mountains. We found only five territories in the Black Mountains in 1994, suggesting a density of one pair per 250.5 ha (619 acres) of spruce-fir and mixed spruce-fir-hardwood forest; this represents the lowest density of saw-whets in our study. Thus, saw-whets in the southern Appalachians utilize somewhere between 73.4 to 250.5 ha of boreal and boreal-ecotone forest in their territories.

How much boreal forest remains in the southern Appalachians? Using a restrictive definition of what constitutes "spruce-fir," Saunders (1979, cited in White *et al*. 1993) suggests that all that is left of this forest type is 69 km^2 (26.6

mi^2). Dull *et al*. (1988), using a broader definition that includes spruce-fir and ecotone forests, and perhaps pockets of northern hardwood (White *et al*. 1993), suggests there is 266 km^2 (102.7 mi^2) of boreal forest in the southern Appalachians.

Pessimistically, if saw-whets use 250.5 ha of boreal forest per pair and only 69 km^2 of this forest type remains, then there are only 27 pairs of saw-whets in the entire southern Appalachian population. More optimistically, if saw-whets use only 73.4 ha of boreal forest per territory, and 266 km^2 remains, then there are 362 pairs of saw-whets in the southern Appalachians. There are two reasons we feel the latter estimate is more reasonable. First, our survey work identified 22 territories (in 1993) at just three sites: Roan Mountain, the Great Balsam Mountains, and the Black Mountains. These three sites contain only 22 percent of the spruce-fir and ecotone forests in the entire southern Appalachian region (Dull *et al*. 1988), and we did not census all of the boreal forest found on just these three sites. Second, the operational definition employed by Dull *et al*. (1988) for what constitutes "spruce-fir" (including not just pure spruce-fir but mixed spruce-fir-northern hardwood ecotones and some inclusions of pure hardwood) is similar to what southern saw-whets appear to be choosing. Telemetry data (Milling in prep.) indicate that southern saw-whets typically include all of these forest types in their territories.

In 1994, however, a little over 12 percent of the territories we identified were in stands of almost pure northern hardwood (by contrast, no territories in 1993 were restricted to hardwoods). And as reviewed earlier, several saw-whets have been reported from other high-elevation hardwood forests and from cool, moist, lower-elevation sites dominated by mature hemlock. To account for birds that may be breeding in atypical habitat outside of the spruce and fir, it might be conservative to add an additional 20 percent to our estimate of 362 territories, producing a value of less than 450 pair. Using a correction factor of 40 percent, which we believe extravagant, still generates an estimate of only 500 pair of saw-whets in the southeastern U.S.

What will be the fate of this small, disjunct, and distinct population of saw-whets? Our data suggest that fir die-off has had little impact on southern saw-whets. Equally encouraging, allozyme analyses indicate that southern saw-whets still maintain relatively high levels of genetic heterozygosity (Tamashiro 1996). The future of this population, however, is far from secure. The small size and fragmented distribution of the population makes southern Appalachian saw-whets extremely vulnerable to stochastic environmental and demographic events (Lande 1988). Continued degradation of high-elevation forests could easily lead to the extirpation of saw-whets in the southeastern U.S., and the prognosis for these montane forests is disheartening (Boyce and Martin 1993, SAMAB 1996). A second exotic pest, the hemlock woolly adelgid (*Adelges tsugae* Annand), threatens to decimate eastern hemlocks (SAMAB 1996, Young *et al*. 1995), and acid deposition appears to be causing growth decline among red spruce (Thornton *et al*. 1994). Global warming may lead to the elimination of not only spruce and the remaining fir, but also northern hardwoods (Roberts 1989). Even if remnants of boreal forest do survive, increased ambient temperatures could push southern saw-whets beyond their own thermal tolerance limits (Brinker *et al*. 1997), leading to their eventual extirpation.

Surprisingly, outdoor recreation may also threaten the owls. Over 90 percent of the boreal forests of the southern Appalachians are held in public ownership (Boyce and Martin 1993), primarily as national forests or national parks, including Great Smoky Mountains National Park and the Blue Ridge Parkway. Two radio-harnessed saw-whets, one each at two different campgrounds along the Parkway, abandoned their territories when these seasonal campgrounds opened in the spring (Milling in prep., Cooper in prep.). Additionally, heavily used hiking trails (e.g., the Appalachian Trail and the Cloudland Trail on Roan Mountain), appear to have below-normal densities of saw-whets (Milling in prep.). Between 1960 and 1990, the human population of the states of North Carolina, Tennessee, and Virginia increased by over 46 percent (Boyce and Martin 1993). Recreational use of the high-elevation forests appears to be growing even faster; trail use by day hikers in Great Smoky Mountains National Park increased by 57 percent between 1979 and 1993 alone (Anonymous 1995), and visits to the area's national forests almost doubled during this period (figure 4.21 in SAMAB 1996 vol. 4). The demand for additional campgrounds, picnic areas, and scenic roadways will continue to grow (SAMAB 1996), with potentially adverse effects on the saw-whet population.

What then can be done? First, we call on state wildlife agencies in North Carolina, Tennessee, and Virginia to add southern Appalachian saw-whets to their respective state's endangered species lists; currently, saw-whets are listed only as a "species of special concern" in each of these three states. Second, long-term monitoring should be initiated to assess trends in the southern Appalachian saw-whet population; such monitoring could employ a combination of systematic playback surveys and the use of nest boxes (Hayward *et al*. 1992). Lastly and most importantly, greater attention needs to be directed at protecting the high-elevation boreal forests of the southern Appalachians, recently recognized as the second-most endangered ecosystem in the U.S. (Noss and Peters 1995). Closing on a brighter note, we mention that at least two different public opinion polls demonstrate overwhelming support by people in the southern Appalachians for protecting the region's biological diversity (SAMAB 1996, Williams and Gaskill 1996). We hope that southern Appalachian saw-whets receive this protection.

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