

**Impacts of group selection harvest openings on the reproductive success of the Solitary Vireo (*Vireo solitarius alticola*)**

by

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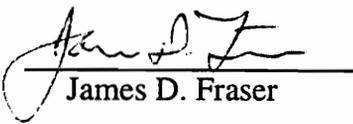
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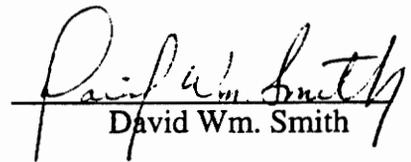
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**Key words:** edge, forestry, nesting success, pairing success, silviculture, songbirds, timber harvest, vireos

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IMPACTS OF GROUP SELECTION HARVEST OPENINGS ON THE  
REPRODUCTIVE SUCCESS OF THE SOLITARY VIREO (*VIREO SOLITARIUS  
ALTICOLA*)

by

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(ABSTRACT)

Solitary Vireos (*Vireo solitarius alticola*) were studied on an extensive mature forest landscape in 1994 and on three sites harvested using the group selection method in 1995. Pairing success was 88% on the unharvested site in 1994, however it was lower on the harvested sites in 1995 (53.8%). Low reproductive success was observed in both years (12% and 22% respectively). In 1995, the amount of opening within a 200 meter radius of the first observation point of a male was positively related to pairing success ( $p < 0.05$ ). This suggests that females may be cueing in on the increased number of shrubs in and around openings.

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# CHAPTER 1: INTRODUCTION

Forest dwelling songbirds have become the focus of much attention after several studies detected severe population declines in some species (Terborgh 1989, Askins 1993). More recent work (e.g. Robbins et al. 1989, Hill and Hagan 1991) has provided additional evidence of these population declines. The majority of declining forest species are forest interior specialists and most of these are Neotropical migrants (Askins et al. 1990, Askins 1993).

Most of the long term studies on population trends of forest dwelling songbirds have been conducted on small (< 100 ha), isolated remnant patches of forest (Askins et al. 1990, Askins 1993). Long term studies on extensive forests have not shown dramatic declines in Neotropical migrant populations (Wilcove 1988, Askins et al. 1990). Demographic parameters of Neotropical migrant landbirds, such as a restricted breeding season, one clutch per year, small clutch sizes, and the use of open cup nests, make them especially sensitive to the effects of forest fragmentation in urban and agricultural landscapes, such as a reduction of patch area and an increase in patch isolation (Whitcomb et al. 1981). Neotropical migrants are less common in small forest patches, probably resulting from minimum area breeding requirements (Blake and Karr 1982, Robbins et al. 1989), competition with forest edge species (Ambuel and Temple 1983), and changes in microhabitat characteristics in small patches (Karr 1982, Lynch and Whigham 1984). Porneluzi et al. (1993) found that Ovenbirds (*Seiurus aurocapillus*), which are forest interior specialists, produced at least 1.19 young per male in a large forest vs. 0.06 young per male in small patches, a 20-fold difference. In addition, it has been shown that forest interior species may experience lower pairing success (Villard et al. 1993) as well as increased rates of nest predation and parasitism when they nest in small forest fragments (Gates and Gysel 1978, Brittingham and Temple 1983, Wilcove 1985, Small and Hunter

1988). If birds in small forest patches experience significantly lower reproductive success, these patches may become "sinks", where within-habitat mortality exceeds production (Pulliam 1988). For example, Robinson et al. (1995) found that Brown-headed Cowbirds (*Molothrus ater*) had saturated highly fragmented agricultural landscapes in the mid-west, reducing the reproductive success of birds in forest patches to "sink" levels. However, in heavily forested landscapes, parasitism levels, as well as predation levels, were significantly lower than in the fragmented landscapes (Robinson et al. 1995). Large patches are therefore likely to play a major role as "sources" for production of new recruits and colonizers (Pulliam 1988). Consequently, it is important to consider the impacts that human-induced habitat changes may have on populations in extensive forest tracts. For example, industrial timber harvesting often creates a landscape mosaic of small, mature stands interspersed with stands in various stages of succession and/or size (i.e. sapling, pole or large tree size). Remnant mature stands may or may not become isolated from other patches of forest (Keller and Anderson 1992). As the proportion of cutover area increases, mature forest interior area decreases and forest edge increases (Franklin and Forman 1987).

The "edge effect", or the increase in numbers of species and population density in an ecotone, is a well known concept in wildlife management. This transition zone between plant communities usually contains not only species present in both communities, but also species present only in the ecotone (Odum 1971). The study of edge effects is easily applied to avian communities (Odum 1971). In addition to greater density and species richness along an edge, several studies have found that edges may be serving as an "ecological trap", where density dependent effects, such as nest predation and parasitism rates, are amplified (Gates and Gysel 1978, Wilcove 1985). Because timber harvest associated with even-aged regeneration methods may often result in increased amounts of

edge as compared to forests subjected to natural disturbance regimes, this concept becomes especially relevant to the debate over the causes of Neotropical migrant landbird declines.

Most studies examining the effects of increased edge on avian communities have been conducted in urban or agricultural landscapes (Galli et al. 1976, Ambuel and Temple 1983, Lynch and Whigham 1984, Andren and Angelstam 1988 ). Patches, as well as edges, in these landscapes may be functionally different from patches and edges created by timber harvesting associated with regeneration methods in a primarily forested landscape, because the matrix around mature forest has been permanently converted to non-forest. Agricultural and urban landscapes tend to have elevated populations of predators because they provide food sources for edge predators such as American Crows (*Corvus brachyrhynchos*), Blue Jays (*Cyanocitta cristata*), raccoons (*Procyon lotor*), and squirrels (*Sciurus sp.*). In addition, urban landscapes have high populations of domestic cats, which prey on adult songbirds. Agricultural landscapes with grazed pasture provide feeding sites for the Brown-headed Cowbird (*Molothrus ater*). Studies on the impacts of timber harvesting of extensively forested landscapes have primarily focused on changes in bird community composition (Titterington et al. 1979, Horn 1984, Thompson et al. 1992). Whereas the dynamic landscape created by timber harvesting associated with stand regeneration results in increased bird species diversity and species richness (Strelke and Dickson 1980, Horn 1984, Derleth et al. 1989), it may also result in the loss of some forest interior species because of reduced patch area of mature forest ( Thompson et al. 1992).

Few studies on extensively forested landscapes have examined the effects of forest-clearcut edges on the population parameters of birds. Rudnický and Hunter (1993) suggest that these abrupt edges have a less abundant avifauna than field-forest edges, and

therefore are less likely to attract nest predators. However, both Yahner et al. (1989) and Rudnický and Hunter (1993), in Pennsylvania and Maine respectively, found higher rates of nest predation on artificial nests along forest-clearcut edges than in the forest interior. Rates of predation along the edge were also greater on artificial shrub nests than on artificial ground nests, suggesting that in forest dominated landscapes, nest height is the primary determinant of predation rates. The major predators on shrub nests in both studies were determined to be avian predators, who are better able to locate nests and observe nesting behavior along an edge. A study by Martin (1993) on real nests supports the findings of Yahner et al. (1989) and Rudnický and Hunter (1993). Shrub nests in his study had the highest rates of predation in forested habitats. Artificial nests cannot be used to assess rates of Brown-headed Cowbird parasitism and little is known about cowbird use of these edges.

Gates and Gysel (1978) and Brittingham and Temple (1983) found increasing rates of cowbird parasitism with decreasing distance to field-forest edge. Brittingham and Temple (1983) also examined the effects of forest openings on rates of parasitism. With openings greater than or equal to 0.2 ha, the frequency of parasitism declined as distance to the opening increased. With openings between 0.01 and 0.2 ha in size, parasitism was more frequent within 35 meters of the openings, but the difference was not significant. They also found no significant relationship between the distance from the nest to any particular type of opening, suggesting that the proximity of open habitat is more important than the type of opening in determining rates of parasitism.

In addition to increased nest predation and parasitism in fragmented landscapes, male birds may experience a lower rate of pairing success in marginal habitats, such as isolated forest "islands" (Gibbs and Faaborg 1990, Villard et al. 1993). Villard et al. (1993) found lower pairing success in Ovenbirds in small forest patches than in extensive

forest. Probst and Hayes (1987), Gibbs and Faaborg (1990) and Villard et al. (1993), suggest that pairing success may be affected by female assessment of territory quality, and therefore males in marginal habitats experience lower pairing success than males in higher quality habitats, such as extensive forest. In addition, Van Horn et al. (1995) suggest that female Ovenbirds in Missouri may be avoiding males who defend territories near edges. Since small patches have greater edge to area ratios than large patches, fewer males have territories sufficiently far from an edge. Pairing success estimates are important because they have implications for estimates of reproduction and other aspects of bird population dynamics, and can provide information on the relative quality of breeding habitats (Probst and Hayes 1987). In addition, trends in pairing success have implications for the methods used to assess habitat quality and the size or health of breeding bird populations. Most estimates of breeding populations, such as point counts, spot maps or line transect counts, rely on counts of singing males. However studies have shown that unpaired males are more likely to sing more frequently than paired males ( James 1981, Gibbs and Faaborg 1990, Ziehmer 1993). Therefore high counts of singing males may reflect failure to breed rather than a healthy breeding population.

As public opinion continues to oppose clearcutting, foresters and wildlife managers have begun to examine alternative regeneration harvesting methods, such as group selection cutting (USFS policy letter of June 4, 1992 to regional foresters and station directors). Group selection is one of a suite of silvicultural practices designed to create and maintain an uneven-aged stand structure. Small openings, usually twice the width of the tallest tree or smaller (averaging between 0.2 to 0.4 ha), are used to create regeneration within these stands (Smith 1986). Little work has been conducted on the effect of group selection harvest openings on either the pairing success or nesting success of Neotropical migrant birds. However, Ziehmer (1993) found a considerably higher rate

of pairing success in Ovenbirds and Red-eyed Vireos (*Vireo olivaceus*) in an untreated stands than in a stands regenerated by a group selection harvest in Missouri. In addition, Brittingham and Temple (1983) have shown these openings may be large enough to attract edge predators and nest parasites such as the Brown-headed Cowbird. Using computer simulations to model the effects of timber harvests on the reproductive success of birds, both Thompson (1992) and Gustafson and Crow (1994), found that small openings had greater effects than larger clearcuts. For example, Gustafson and Crow (1994) found that the area of forest interior was dramatically reduced and the amount of edge increased, using a mean clearcut size of 1 hectare, as compared to larger clearcut sizes, even with low amounts of total harvest. Thompson (1992) found that the simulated population size of a forest interior bird was greater with clearcutting than with group selection harvests, because under the group selection regeneration method, the forest contained a greater amount of edge. Approximately 77.8% of the simulated nests were within 100 meters of an edge with the group selection option, whereas under the clearcutting option only 7.4% of the simulated nests were within 100 meters of an edge. In both these studies, the negative effects of edge incorporated into the models were based on data derived from studies of agricultural or suburban edges.

In this study, I examined whether internal edges negatively affect a forest interior species by impacting parameters such as pairing success and rates of nest predation and parasitism, by focusing on the breeding biology of the Solitary Vireo (*Vireo solitarius alticola*). By examining these impacts, if any, I was able to address basic questions regarding the effects of landscape structure on avian breeding ecology, and describe bird population changes likely to occur as a consequence of certain silvicultural practices.

The following hypotheses were tested, 1) distance from edge does not affect pairing or nesting success, 2) size of the nearest opening does not affect pairing or nesting

success, 3) amount of opening and edge within a 50, 100, or 200 m radius does not affect pairing or nesting success.

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## CHAPTER 2: SOLITARY VIREO LIFE HISTORY

The Solitary Vireo (*Vireo solitarius*) is a polytypic species whose range encompasses most of forested North America, the highlands of Mexico and northern central America to central Honduras (Barlow 1980, A.O.U. 1983). Recent evidence suggests that two subspecies of the solitary vireo should be considered distinct species. These include *Vireo solitarius cassinii*, whose range includes the mountains of western North America from southern British Columbia, northern Idaho and California to northern Baja California; and *Vireo solitarius plumbeus* whose range includes the mountains from southern Idaho, Wyoming, southeastern Montana and southwestern South Dakota south through the southwestern United States (Sibley and Monroe 1990, Barlow *pers. comm.*). Several other subspecies of *Vireo solitarius* are also recognized. These include *Vireo solitarius solitarius* (northeastern United States and Canada), *Vireo solitarius alticola* (southern Appalachians), *Vireo solitarius leucasanus* (Baja California), *Vireo solitarius pinicolus* (northwestern Mexico), *Vireo solitarius repetens* (central Mexico), *Vireo solitarius montanus* (Guatemala), and *Vireo solitarius notius* (British Honduras) (Hamilton 1958, Barlow, *pers. comm.*).

### *Wintering grounds*

The wintering grounds of the western species of *Vireo solitarius* (*V. s. cassinii* and *V. s. plumbeus*) greatly overlap with the ranges of resident races in southern Mexico (*V. s. repetens*) and Central America (*V. s. montanus*) (Barlow 1980). Of the eastern races, *V. s. alticola* winters mostly in the southern United States in Florida and along the gulf coast whereas *V. s. solitarius* winters in Mexico and parts of Guatemala, Honduras, Belize, Nicaragua and El Salvador (Hamilton 1958, Barlow 1980). It is sympatric with *Vireo*

*flavifrons* from the Yucatan peninsula south to El Salvador and Nicaragua, however *V. s. solitarius* usually occurs at higher elevations whereas *V. flavifrons* is found at lower elevations (Barlow 1980).

### ***Plumage***

Solitary Vireos (*V. s. solitarius* and *V. s. alticola*) have an olive-green back, with a slate gray head. They have a white belly and bold white spectacles, two white or yellowish wing bars, and yellow flank feathers. There is no sexual dimorphism in plumage. A partial prebasic molt occurs in hatching year birds in July through September. After-hatch-year birds show a complete prebasic molt in July through August. The prebasic molts occur on the summer grounds. The pre-alternate molt is absent or limited (Pyle et al. 1987). Solitary vireos have 10 primaries and wing length ranges from 70-85 mm, with little sexual dimorphism. Male wing lengths range from 71-85 mm, females from 70-84 mm (Pyle et al. 1987). Godfrey (1986) gives wing measurements of 69.6-74.8 mm for males and 72.2-74.6 mm for females in Canada (*V. s. solitarius*). In this study, average wing length (males and females) was 78 mm (n = 7, *V. s. alticola*).

### ***Geographic variation***

As indicated above, *Vireo solitarius* has a wide distribution, and in addition, demonstrates pronounced geographic variation, not only in wing, bill, and tail length, but also in plumage and song characteristics (Hamilton 1958, Martindale 1977). Solitary vireos are considered to have an allohiemic migration pattern, with the northern populations wintering farther south than the southern populations. Thus, northern populations are long distance migrants and southern populations are short distance migrants (Hamilton 1958). Hamilton (1958) found that in eastern U.S. populations of

*Vireo solitarius* (*V. s. solitarius* and *V. s. alticola*) *V. s. alticola* has a greater wing length than that of *V. s. solitarius*. Similar patterns for bill and tail length were also noted. The greatest wing lengths were found in northwestern and central Mexico (*V. s. pinicolus* and *V. s. repetens* segments). Hamilton (1958) in addition, found wide ranging species of the genus *Vireo* to have pigment depositions in accordance with Gloger's rule (individuals living in dry climates tend to be of lighter color than those living in humid climates). Melanin deposition in populations of *Vireo solitarius* are most intense in *V. s. cassinii*, *V. s. solitarius*, *V. s. alticola* and *V. s. montanus*. *V. s. solitarius* and *V. s. alticola* have "bluish" crown feathers which are darker than those in *V. s. cassinii* or *V. s. montanus*. In addition to these plumage variations, *Vireo solitarius plumbeus* exhibits a gray instead of olive-green back, and a grayish wash on the flank feathers rather than yellow.

William Brewster described and named the subspecies *alticola*, often called the mountain vireo, in 1886 (Bent 1965). He said "This new form may be easily distinguished from *solitarius* by its larger size, heavier bill, and different color of the upper parts. In *solitarius* the crown and sides of the head are clear, pure ash, in strong contrast with the olive green of the back and rump, whereas in *alticola* the entire upper parts are nearly uniform blackish-plumbeous, with only a faint tinge of greenish on the back, which is essentially concolor with the crown. In these respects the bird resembles *V. plumbeus*, but its coloring above is darker and dingier, its sides strongly yellowish as in *solitarius*."

In his study of the primary song of the eastern populations of *Vireo solitarius*, Martindale (1977) found that although there was considerable overlap in the use of notes between birds in different regions, there were geographic differences in songs. Birds were grouped into three regions: New England, Tennessee, and Virginia. Martindale (1977) states that Tennessee and Virginia birds were extremely dissimilar to one another, and to all other birds as well.

## ***Habitat***

*Vireo solitarius solitarius* prefers large tracts of mature, mixed coniferous-deciduous forest, where there is typically a continuous canopy (James 1988). It is usually found in higher latitudes or at high elevations southward (James 1988). James (1973) noted that most territories were on hillsides with a 20 to 45% slope, and shallow, mesic soils. *Vireo solitarius alticola* usually inhabits the higher elevations (approximately 760 m or higher) of the southern Appalachian mountains in pure deciduous forest. Both of these races need scattered understory trees or shrubs for nesting substrate (Davie 1898, James 1988).

Both western subspecies (*V. s. cassinii* and *V. s. plumbeus*) are associated with pinyon-juniper or oak woodlands (Sibley and Monroe 1990). James (1973) states that *V. s. plumbeus* is frequently found in coniferous forest, but some individuals may be found in riparian deciduous woods. *V. s. repetens* is found in dry mixed deciduous and coniferous woodlands (Barlow *pers. comm.*). *V. s. notius* usually occurs in deciduous forests, however it has also been found in coniferous areas in Belize (James 1973, Barlow *pers. comm.*).

## ***Pairing and nesting***

In his description of the courtship display of *Vireo solitarius solitarius*, Bent (1965) reports that the male fluffs out his yellow flank feathers, bobs and bows to the female and sings repeatedly with many variations to the song. This display was observed in an unmated *V. s. alticola* male attempting to attract a female during this study as well.

James (1978) also describes a nest building display which he states is one of several displays given at the time of pair formation. Unmated males wander as much as 0.5 km from a central point and sing consistently from high points in the canopy throughout

the day. Males search for suitable nest sites prior to the arrival of the females and may also begin to build nests at several of these sites. These nest sites then become places in which males display for the females when they arrive on the territories (James 1978). Territory size for Solitary Vireos in western Oregon and Washington (*V. s. cassinii*) is estimated at 1.7 hectares (Hansen and Urban 1992). Once paired, the birds confine their activity to a smaller area (James 1973).

During the nest building display, the male crouches with his bill pointed vertically downward. His body may be horizontal or slightly tilted forward. At the time of pairing, he may fluff out his body feathers during the display, but otherwise they are sleeked. The male may rotate his body from side to side and the head is moved in different directions in a jerky fashion. Usually there is no nest material in his bill. This display mimics actual nest building but it is more rapid and repetitious than the methodical movements used in construction of the nest (James 1978). It has been hypothesized that the nest building display is important in attracting a female as a potential mate and may assist in pair formation. In addition, it may stimulate nest building by the female (James 1978). The nest building display is performed after the female has supplanted the male from the nest site during building. The duration and frequency of the display decreases as the nest nears completion (James 1978).

Nest building lasts approximately 3 days. In the early building stages, the male takes a more active role than the female, but his role decreases until about the 6th day, when the female takes over most of the building. The male accompanies the female to the nest on each trip. Copulation only takes place after the nest has been largely completed, usually on the 7th day (James 1973, 1978).

The nesting period in southwestern Virginia begins in early May and lasts through late June or early July (pers. obs.). In this study the last dates of fledging were July 18th

in 1994, and July 20th in 1995. Extreme breeding dates in the ridge and valley province of Virginia are May 7 to June 28 (eggs) (Virginia Society of Ornithology 1987). Solitary vireos build cup-like or pensile nests suspended from the rim in the fork of a branch. Most nests are placed from 2 to 6 meters above the ground. They are constructed of strips of inner bark, soft plant fibers, grasses, weed stems, rootlets and hair and are lined with mosses, conifer needles, fine grasses, and vine tendrils. They often are decorated externally with lichens or paper from hornets' nests (Harrison 1975). Spider webbing is used as an adhesive agent. Conifers are more commonly used as nest tree in northern populations (Godfrey 1986, James 1988). James (1973) found nests in Ontario in balsam fir (*Abies balsamia*), eastern hemlock (*Tsuga canadensis*), and white cedar (*Thuja occidentalis*). Commonly used tree species in the southern (*V. s. alticola*) populations include: black birch (*Betula lenta*), red maple (*Acer rubrum*), mountain laurel (*Kalmia latifolia*), rhododendron (*Rhododendron maximum*), cucumber magnolia (*Magnolia acuminata*) and hickory species (*Carya sp.*) (pers. obs). In addition to these species, nests in the present study were also found in sourwood (*Oxydendrum arboreum*), shadbush (*Amelanchier arborea*), red oak (*Quercus rubra*), American chestnut (*Castanea dentata*), and witch hazel (*Hamamelis virginiana*) (n = 33). Average height of nests was 3.2 meters (min = 1.5 m, max = 6.0 m, n = 18).

Clutch size ranges from 3 to 5 eggs, commonly 4. The white shell is smooth with no gloss and is sparingly spotted with brown or black, usually at the larger end (Harrison 1975). The average size of eggs is 19.5 x 14.4 mm (Harrison 1975). Both sexes assist in incubation of the eggs, and the male develops a partial brood patch. Incubation lasts from 13 to 14 days and begins after the last egg is laid. The nestling period lasts 12 days (pers. obs). Nestlings have pink skin, yellow gape flanges and develop gray down (pers. obs). Juvenal plumage matches the adults but is duller (Bent 1965). Young Solitary Vireos may

remain with the adults until the fall migration. They are totally dependent on the parents for approximately two weeks after fledging, although they may continue to beg and take food from the adults for a month or more (James 1973). The birds may range up to 1.5 km during the post nesting season (James 1973), and some of the young follow each parent as they leave the nest area (James 1978).

### ***Nest success***

In a study in Colorado, Marvil and Cruz (1989) found a fledging success rate (number of vireo fledglings per total eggs laid) of 49% for 3 years combined (n = 67). Using the Mayfield method (Mayfield 1961, 1975), I found only a 12% nest success rate in 1994 (n = 17). The success rate in 1995 was calculated as 22% (n = 16).

Solitary Vireos are parasitized by the Brown-headed Cowbird (*Molothrus ater*). Marvil and Cruz (1989) found parasitism rates of 45% in 1984 (9 nests parasitized out of 20), 50% in 1985 (12 nests parasitized out of 24) and 50% in 1986 (17 nests parasitized out of 34) for a population of *V. s. plumbeus*. Unparasitized nests had an 83% success rate while parasitized nests had a 29% success rate. Their study area was characterized by widely spaced ponderosa pine (*Pinus ponderosa*) and scattered Douglas fir (*Pseudotsuga menziesii*). In this study of a population of *V. s. alticola*, I found a 23.5% rate of parasitism (4 nests parasitized out of 17) in an extensive mature eastern hardwood forest landscape in 1994 and an 18.75% rate (3 nests parasitized out of 16) in 3 areas harvested by group selection in 1995.

### ***Pairing success***

In 1994, I found a pairing success rate of 88% (15/17) for males in an extensively forested eastern hardwood landscape. The area within a 10 km radius of this site is

approximately 70-90% forested. In 1995, in 3 areas harvested by the group selection method with openings less than 5 years old, I found a pairing success rate of 66.7% (18/27).

### ***Song***

As defined by Mulligan (1966), a song phrase is a general term for a natural section of song, such as a trill, note or note complex. A note complex consists of an unrepeated group of notes, bounded either by trills, or the beginning or end of the song. James (1973) defines primary song as the typical song of a species, usually given only by the male.

The song of the Solitary Vireo is long, consisting of distinct phrases separated by short pauses of a few seconds (Bent 1965, James 1973). It has the highest pitch of all the vireos of the eastern United States (Bent 1965). The phrases are given more rapidly than the Yellow-throated Vireo (*Vireo flavifrons*), but slower than the Red-eyed Vireo (*Vireo olivaceus*) (Bent 1965). Unmated males have more varied songs than mated males, but once mated, they may sing as few as two phrases repeatedly and usually use fewer than 10 phrases. Individual birds rarely sing more than 20 phrases. Unmated males on average use about 15 phrases, whereas mated males on average use nine (James 1981). Unmated males sing throughout the day at a rate of approximately one phrase per two seconds. The continuity of the song decreases noticeably after mating and when nest building begins (James 1973). Primary song is used to establish a territory and repel conspecific males as well as to attract a female (James 1973). When in close proximity to a mate, especially before copulation, males sing a song composed of primary song phrases, however the bird does not pause between the phrases, producing a continuous warble. This song often consists of a larger number of slightly different phrases from that of the primary song.

Occasionally a bird may add other vocalizations as well (James 1973). Solitary Vireos have been observed singing on migration and on the wintering grounds (James 1981). In his observations of *V. s. solitarius* in Ontario, James (1973) never noticed a female using the primary song.

Although populations that are closer together share the greatest number of phrases, there are some shared phrases among widely separated groups and subspecies (Martindale 1980, James 1981). There are no abrupt changes in phrase use between subspecies except where there is geographic isolation, such as in *V. s. leucasanus* (James 1981). James (1981) found a gradual change from frequency modulated phrases in the west, to pure tone phrases in the east (*V. s. solitarius* and *V. s. alticola*). This gradual change, he suggests, links these two broad groups. In addition, he found no major differences in primary song between the grayish and yellowish forms.

#### *Contact notes*

Solitary vireos have three types of contact notes, all of which are low in volume and can be heard only at close range (James 1973). They are used in several different situations, such as when a pair is foraging or searching for nesting material together, when the adults and young are together during the late summer, when adults are switching places on the nest, and when adults approach the nest to feed young. Males may also interject contact notes occasionally into their primary song (James 1973).

#### *Food habits, foraging strategies*

Solitary Vireos forage extensively on bark substrates, such as the branches and trunks of trees (James 1979, Holmes and Robinson 1981, Robinson and Holmes 1982). Leaves made up only 30-40% of the substrates used by *Vireo solitarius* in the Hubbard

Brook forest in New Hampshire (Robinson and Holmes 1982). In addition, Solitary Vireos forage along the inner branches and foliage, whereas Red-eyed (*Vireo olivaceus*) and Philadelphia (*Vireo philadelphicus*) vireos use the outer foliage (Sabo 1980, Robinson and Holmes 1982). Solitary Vireos tend to be slow searchers, changing perches fewer than 10 times per minute and having a prey attack rate of only 1.4 times per minute (Robinson and Holmes 1982). However, Solitary Vireos take a higher proportion of larger prey than other songbird species (Robinson and Holmes 1982). Hovering and gleaning make up the majority of attack moves (James 1979, Robinson and Holmes 1982). James (1979) found that Solitary Vireos in Ontario primarily used deciduous trees for foraging, although they typically occupied mixed coniferous/deciduous habitat. Yet Holmes and Robinson (1981) found conifers to be used extensively by Solitary Vireos in the Hubbard Brook forest.

Both larval and adult forms of Lepidoptera made up the majority (approximately 93%) of the adult diet in the Hubbard Brook forest. Species of Coleoptera and Arachnida made up the remainder of the diet (Robinson and Holmes 1982). Chapin (1925) showed that Lepidoptera and Hemiptera made up the majority of the adult diet. Other insect foods included Plecoptera (stoneflies), Odonata (dragonflies), and Orthoptera (grasshoppers, crickets, and locusts). A small percentage of the diet included fruits such as wild grape (*Vitis sp.*), dogwood (*Cornus sp.*), viburnum (*Viburnum sp.*) and wax myrtle (*Myrica cerifera*).

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## CHAPTER 3: METHODS

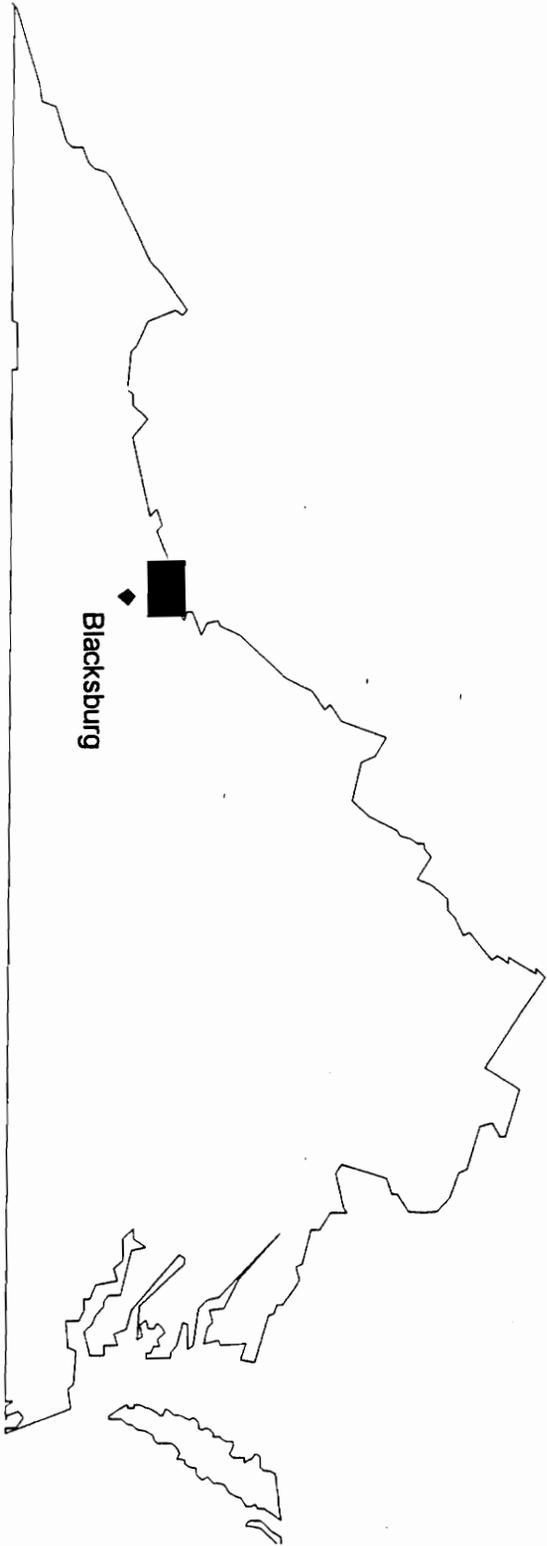
### Study Areas:

The study areas were located in the Blacksburg Ranger District of the Jefferson National Forest, in Giles County, Virginia (Figure 1). In 1994, I worked in a 60 hectare area, located on Fork Mountain, Giles County, Virginia (37° 27' 46" lat, 80° 30' 52" long, elevation 1060 m). This area represented an extensively forested landscape (70-90% forested within a 10 km radius, estimated from topographical maps), but was scheduled to have timber removed using group selection harvests, in the fall of 1994 (Figure 2). The harvest did not take place on schedule; alternatively three areas that had been harvested previously, using group selection harvests, were studied in 1995. These sites were approximately 5.5 (Nettle Hollow, elevation 850 m), 7 (Cherokee Flats, elevation 780 m) and 10 km (Butt Mountain, elevation 1240 m), respectively, from the 1994 study area (Figure 2). The dominant forest type was oak. The harvest openings were approximately 4 years old and had significant amounts of regeneration.

### Year 1

Two parallel transects were established in year 1, which ran the length of the study area and had marked flagging every 25 meters. These transects allowed us to relocate territories as well as nests.

Pairing success observations were divided into two 2-week time periods. During period 1, males were observed until we found evidence of a mate (observing male with a female on his territory, finding an active nest, or observing adults feeding fledglings on the territory) or until 90 minutes of track time was accrued. Track time is defined as the time for which an individual bird is observed without losing visual or auditory contact (Probst



**Figure 1: Location of study within the state of Virginia**

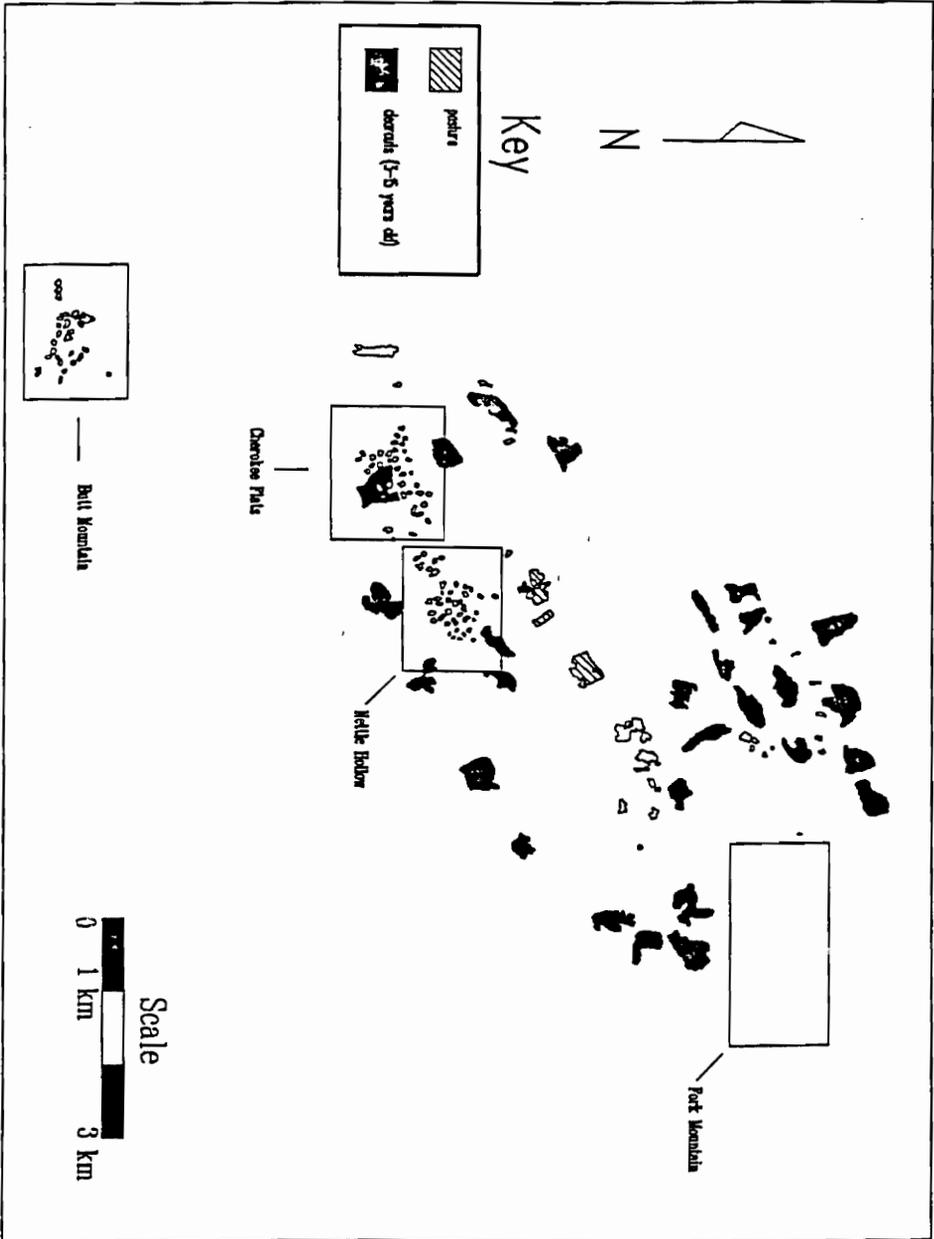


Figure 2: Schematic of study areas

and Hayes 1987). Using observation curves, Probst and Hayes (1987) estimated that pairing success could be determined for most male Kirtland's Warblers (*Dendroica kirtlandii*) within 90 minutes of elapsed time or 60 minutes of track time.

Pairing observations began in the early morning. If a male was determined to be unpaired during period 1, his territory was revisited in period 2. This ensured that late pairing males were not misclassified as unpaired. If a male was determined as unpaired in period 2, he was classified as unmated. Pairs were recognized only by their territory because they were not banded.

Once a male was determined as paired, nest searching was conducted on his territory. Nest searching began after morning pairing observations and lasted into the afternoon. Pairing observations sometimes facilitated nest finding, specifically if a bird was observed carrying nesting material. Flagging was placed on a nearby tree with a compass bearing and distance, to facilitate relocating the nest. Nests were then monitored for fledging success and rates of parasitism. Each nest was revisited approximately every three to four days to determine its status. Care was taken not to attract predators by approaching the nests from different paths, never leaving dead end trails to the nest, using a mirror pole to check nests, and checking nests quickly (Ralph et al. 1993). Any predation or parasitism events were recorded as well. Nests that fledged at least one young were considered successful. Nest success was also calculated using the Mayfield method (Mayfield 1961, 1975), to account for nests found at different stages.

## **Year 2**

The study areas used in year 2 were timber sale harvested in 1991. Some salvage logging also was conducted in 1991 on the Butt Mountain site after windthrow damage. Some pairing success observations were conducted on Fork Mountain in 1995.

Using observation curves similar to those of Probst and Hayes (1987), I determined in year 1, that pairing success for male solitary vireos (*Vireo solitarius alticola*) could be determined within 60 minutes of track time. Therefore in year 2, a male was considered unpaired after 60 minutes of track time, if no evidence of a mate was observed. Unpaired males were revisited again approximately two weeks later to again ensure that late pairing males were not misclassified. Flagging was placed on a tree at the spot where a male was first observed. This point was considered to be an indication of territory location. Each first observation point was pinpointed with a global positioning system (GPS) and mapped onto a geographical information system (GIS).

Nest monitoring followed the methods in year 1 and, again, nest success was calculated using the Mayfield method. Nest locations were pinpointed with a GPS (global positioning system) and mapped onto a geographical information system for further analysis. First observation points and nest locations were overlaid onto a map of the study area, including cut locations, and the following variables were measured: distance to the nearest edge (DIST), size of the nearest harvest opening (SIZE), amount of edge within a 100, 200 and 500 meter radius (EDGE100, EDGE200, EDGE500), and amount of harvest opening within a 100, 200 and 500 meter radius (OPEN100, OPEN200, OPEN500).

### **Vegetation sampling**

Vegetation samples were conducted during year 2 and were centered on the nest. Therefore samples were not taken until after the young had fledged or the nest had failed. Two 10 meter ropes were laid in a cross with the center under the nest. This provided a circular sampling area with a 5 meter radius around the nest. Species and height of shrubs less than 8 cm DBH (using the following height classes: 0.5-1m (TOT\_1), 1-2 m

(TOT\_1\_2), 2-4 m (TOT\_2\_4), 4-6 m (TOT\_4\_6), and >6m (TOT\_6)) were measured in 2 meter width transects following the crosspieces. Within each plot we also measured the following: species and DBH of any tree >8 cm (TREENUM); nest tree species, DBH (NTREEDBH) and height of nest tree (NTREEHGT); nest height (NESTHGT); distance of the nest from the trunk (NDIST); and canopy closure (PCOVER) using the point intercept method. The mean basal area (MEANBA) and mean DBH (MEANDBH) of trees within each 5m radius plot were also calculated. Nest concealment (MEAN\_COV) was estimated following the methods of Martin and Roper (1988).

#### **Data analysis:**

Stepwise logistic regression (SAS 1989) was used to examine the relationship between the landscape and vegetation variables and rates of nest success and pairing success. The rate of cowbird parasitism was also analyzed using regression techniques. While performing multiple univariate tests on variables can sometimes lead to spurious results (ie: finding significance simply by chance), I decided to perform Wilcoxon Rank Sum tests (SAS 1989) after the landscape variables had been graphed against pairing success using bar graphs (Figure 6, Figure 7) to obtain further information about differences that were visible on the graphs.

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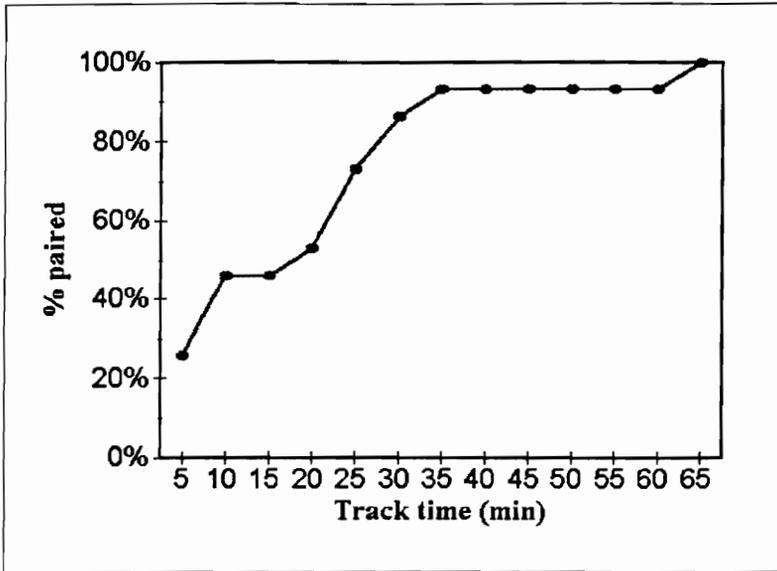
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## CHAPTER 4: PAIRING SUCCESS

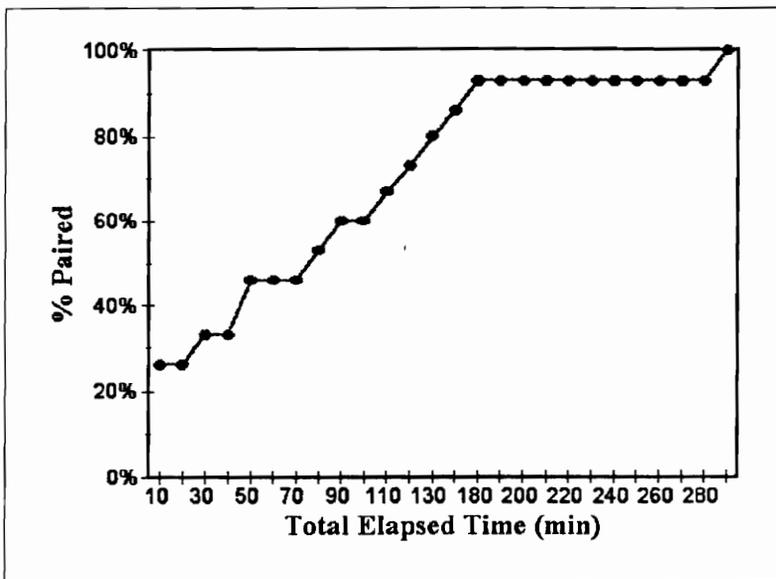
### *Results*

#### **Year 1**

I found 17 males on the study area. Fifteen (88%) of the 17 males were paired (Table 1). Of the 15 paired males, 9 were determined as paired by finding an active nest on the male's territory (60%). This means that some information on reproductive status was found for 40% of the males without actually having to find the nest. Using observation curves similar to those of Probst and Hayes (1987), I found that pairing success could be determined for greater than 90% of paired males within 35 minutes of track time and 180 minutes of elapsed time (Figure 3).



A.



B.

Figure 3. (A.) Cumulative percentage of paired males classified as paired vs. track time on the unharvested area (Fork Mountain) in 1994 (n = 15).  
 (B.) Cumulative percentage of paired males classified as paired vs. elapsed time on the unharvested area (Fork Mountain) in 1994 (n = 15).

## Year 2

I found 26 males on the 3 harvested sites. Fourteen of these males were paired, resulting in a pairing success rate of 53.8% (Table 1). Twelve of the 14 paired males were determined as paired by finding an active nest on the territory (85%). Observation curves for this year show that all of the paired males were classified as paired within 35 minutes of track time and 110 minutes of elapsed time (Figure 4). I was able to do some pairing observations on the unharvested study area, but because of time constraints I was only able to find 9 males. All of these males were paired. Five of these males (55%) were determined as paired by finding the nest. Observation curves for this area were similar to those for the harvested areas (Figure 5).

A comparison of the pairing success rates on the unharvested area (92%, 1994 and 1995 combined) and the harvested areas (53.8%, 1995) using a Chi-square test showed a significant difference ( $X^2 = 9.77$ ,  $p < 0.01$ ). However, this could be the result of a site effect (only 1 unharvested area) or a year effect (only 1 year of data on the harvested areas) and therefore I do not suggest that the difference in pairing success is a result of harvesting activity.

Using stepwise logistic regression, one landscape variable (OPEN200) was found to be significantly related to pairing success on the harvested areas in 1995 ( $p < 0.05$ , Table 2). This variable was positively related to pairing success, i.e. the greater the amount of opening within a 200 meter radius of the first observation point, the more likely a male was to be paired. No other variables met the 0.05 significance level.

From the Wilcoxon Rank Sum tests, the median amount of opening was greater for paired males in both the 100 and 200 meter radius categories ( $p < 0.05$ , Table 3, Figure 6). The median amount of edge was greater for paired males in all the radius categories,

however it was only significantly greater in the 100 meter radius category (Table 3, Figure 7).

Table 1. Reproductive rates of Solitary Vireos (*Vireo solitarius alticola*) on the unharvested (Fork Mountain) and harvested study sites.

	Unharvested Area (1994)	Harvested Areas (1995)
Pairing success	88% (15/17)	53.8% (14/26)
Nesting success*	23.5% (4/17)	25% (4/16)
Depredation	47% (8/17)	25% (4/16)
Parasitism	23.5% (4/17)	18.75% (3/16)
Desertion	17.6% (3/17)	31.25% (5/16)

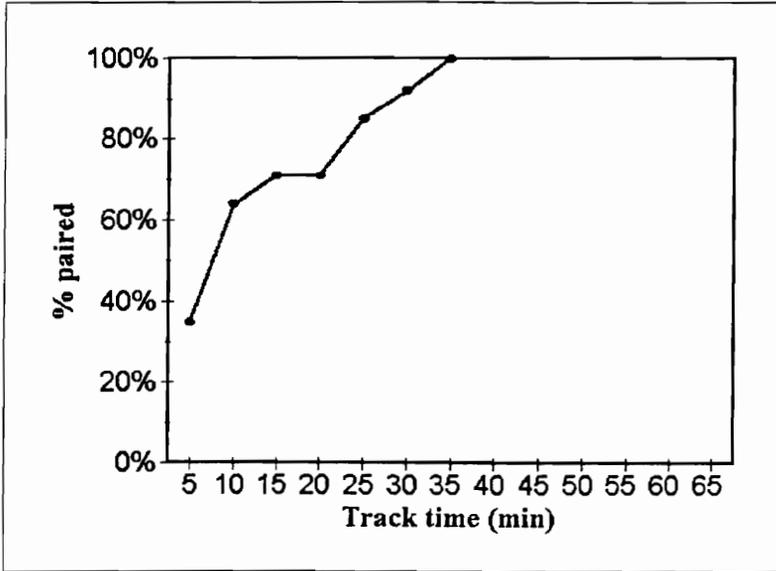
\*nesting success = % of nests that fledged at least one young

Table 2. Logistic regression parameter estimate and significance level for the variable related to pairing success for male Solitary Vireos (*Vireo solitarius alticola*) in the harvested areas in 1995.

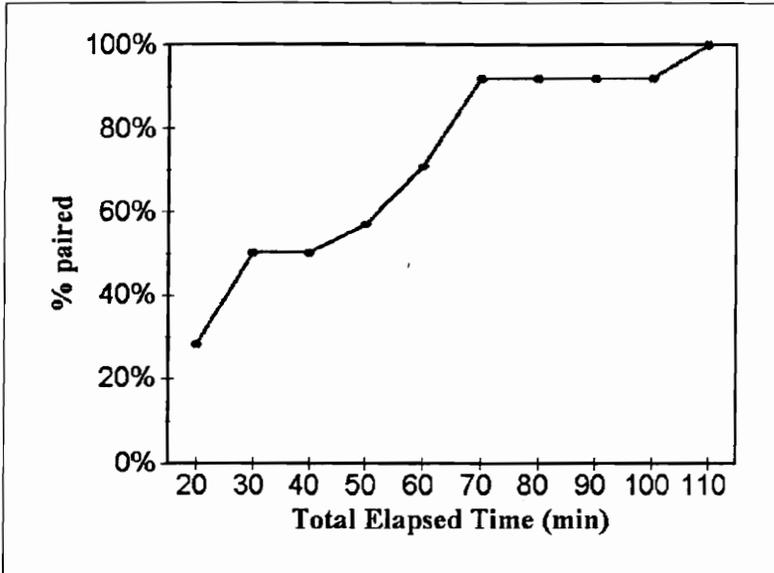
Variable	Parameter estimate	Standard error	p-value
OPEN200	1.4976	0.5879	0.0108

Concordant pairs 83.3%

Discordant pairs 16.7%



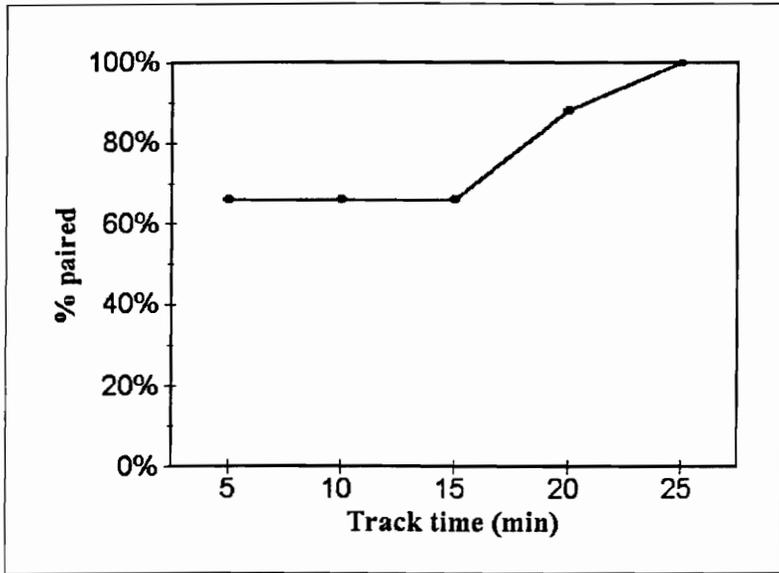
A.



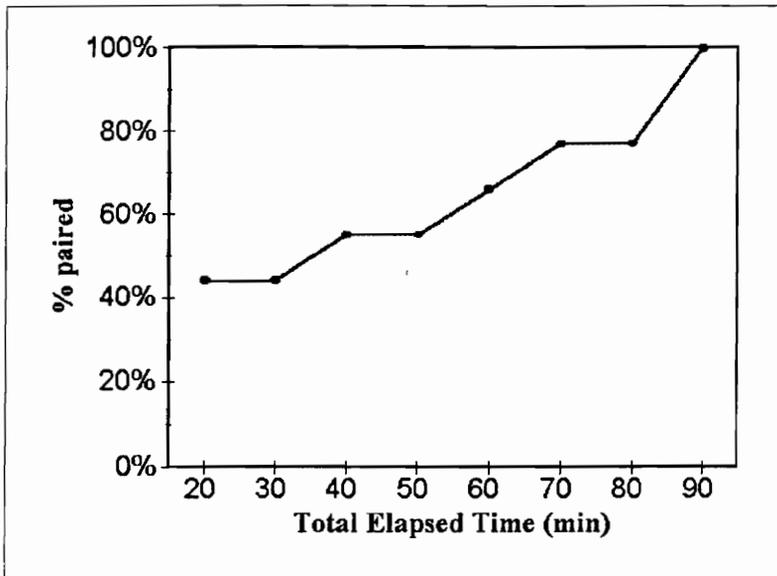
B.

Figure 4. (A.) The cumulative percentage of paired males classified as paired vs. track time on the harvested study areas in 1995 ( $n = 14$ ).

(B.) The cumulative percentage of paired males classified as paired vs. elapsed time on the harvested study areas in 1995 ( $n = 14$ ).



A.



B.

Figure 5. (A.) The cumulative percentage of paired males classified as paired vs. track time on the unharvested study area (Fork Mountain) in 1995 (n = 9). (B.) The cumulative percentage of paired males classified as paired vs. elapsed time on the unharvested study area (Fork Mountain) in 1995 (n = 9).

Table 3. Median values of landscape variables for paired (n = 14) and unpaired (n =12) Solitary Vireo (*Vireo solitarius alticola*) males on harvested sites in 1995. P-values are from Wilcoxon rank sum tests.

Variable	Paired	Unpaired	Prob >  Z
DIST (m)	31.5	35.0	0.9999
SIZE (ha)	0.23	0.275	0.4548
OPEN100 (ha)	<b>0.95</b>	<b>0.29</b>	<b>0.0363</b>
OPEN200 (ha)	<b>2.435</b>	<b>1.05</b>	<b>0.0043</b>
OPEN500 (ha)	13.34	13.565	0.8977
EDGE100 (m)	<b>432.49</b>	<b>163.075</b>	<b>0.0322</b>
EDGE200 (m)	1205.97	631.355	0.0605
EDGE500 (m)	5371.67	3629.015	0.0972

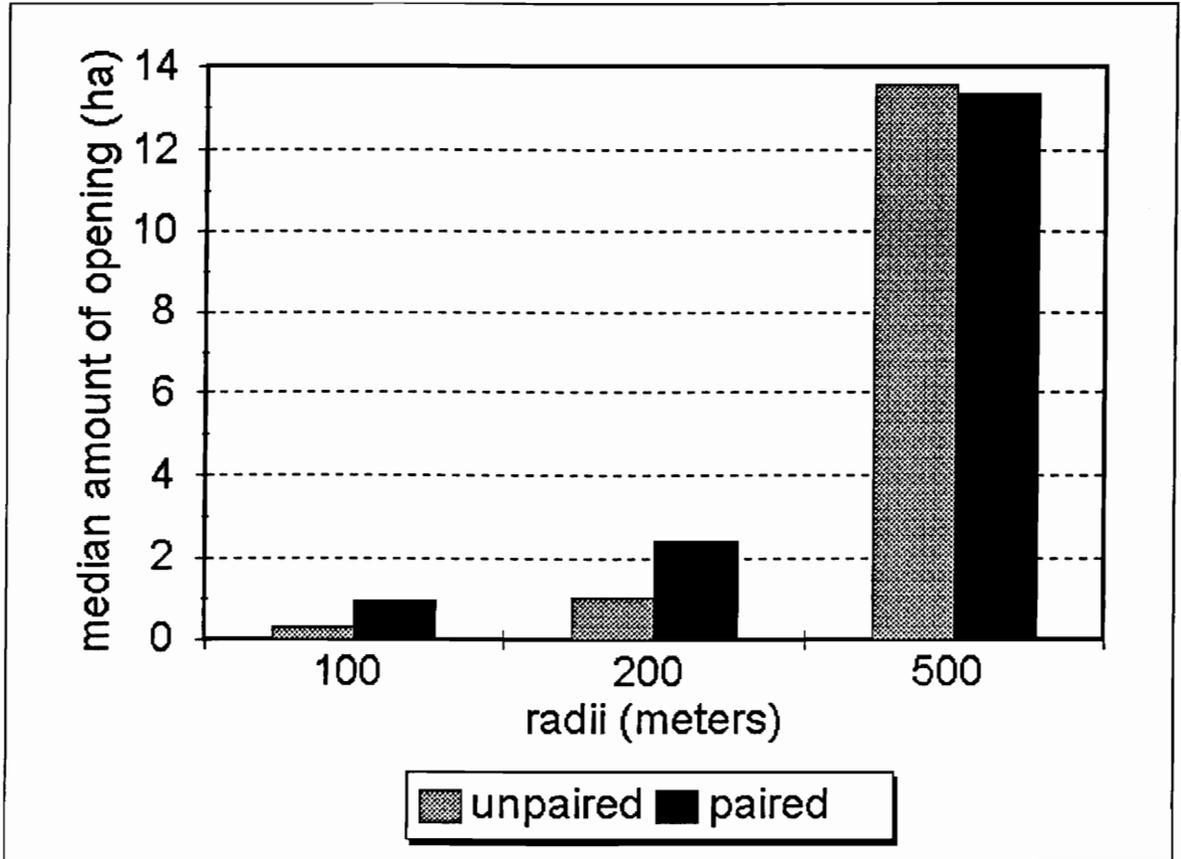


Figure 6. Median amount of opening within different radii around first observation points of paired and unpaired males.

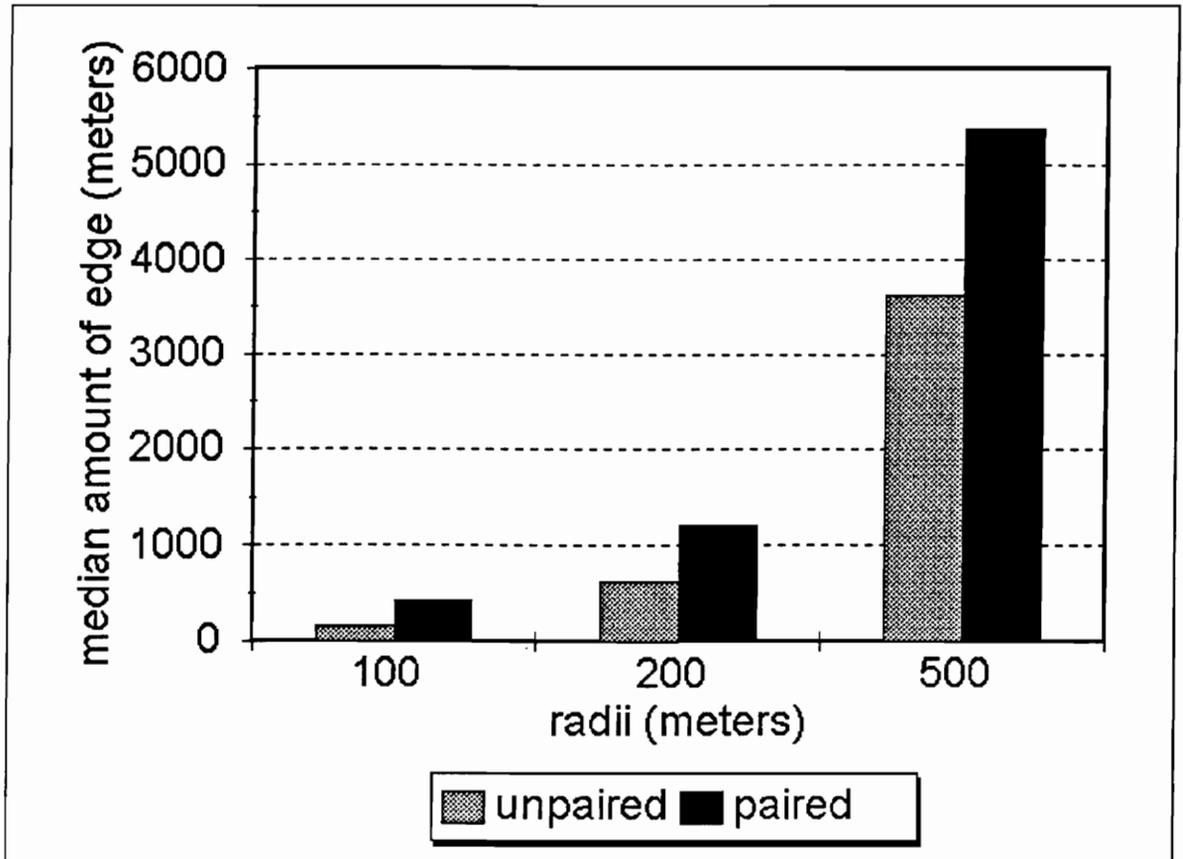


Figure 7. Median amount of edge within different radii around first observation points of paired and unpaired males.

## *Discussion*

Density can often be a misleading indicator of habitat quality (VanHorne 1983, Vickery et al. 1992). Therefore results of point counts, transect estimates, and spot maps may not be enough to indicate the relative quality of habitat. Pairing success can be a useful index of reproductive success for species, such as Ovenbirds, for which nest finding is often difficult and time consuming. For example, in this study it took approximately one and a half hours to acquire 60 minutes of track time for male Solitary Vireos. By spending this short amount of time on a territory, I acquired information on the breeding status of the male without having to search for a nest and, if no indication of a female was present, then I did not search for a nest on that territory.

For the Solitary Vireo, however, pairing success observations often led to finding the nest. By using behavioral cues, such as less frequent singing by the male, the use of call notes, or a sudden cessation of singing, I frequently could ascertain when I was near a nest. Throughout the duration of this study, 55 to 85% of males were determined to be paired by finding the nest. This method may be a more efficient way to find nests than by random searches.

This index can be used to compare different types of habitat. For example, Probst and Hayes (1987) compared habitat types for the Kirtland's Warbler and found one type to be "marginal" while the other type was more suitable. Wenny et al. (1993) found that Ovenbirds in small forests ( $\approx 300$  ha) experienced lower pairing success than Ovenbirds in a large forest ( $> 800$  ha) in Missouri. Hagan et al. (1996) also observed this trend on an industrial forest landscape in northern Maine. In this study, I found a higher pairing success on an unharvested tract of forest than in three areas that had been harvested using the group selection method. Pairing success on the unharvested site was 88% in 1994 and 100% in 1995 and pairing success on the harvested sites was 53.8% in 1995. Any bias

from incompletely sampling the unharvested site in 1995 should have resulted in my finding more unpaired males, since they tend to sing more frequently (James 1973, Ziehm 1993). These estimates are consistent with the hypothesis that females may be making direct or indirect assessments of habitat quality (Lenington 1980, Alatalo et al. 1986, Villard et al. 1993), and that the unharvested area is a higher quality habitat. Sherry and Holmes (1989) also found that in American Redstarts (*Setophaga ruticilla*), all unpaired territorial males were yearlings, who had been excluded from the best territories by older males. However, it was not clear whether these males were excluded from breeding opportunities because of their territories or because older males are more attractive to females.

Given this conclusion, the result of the logistic regression may appear to be confusing. Males whose territories had more opening within a 200 meter radius were more likely to be paired. Perhaps the females who did settle in this habitat were attracted to the shrub cover in and around the openings. The harvest openings in these areas were 4-5 years old and had significant amounts of regeneration. In addition, these openings allowed light to penetrate further into the edge of the forest, creating a denser shrub layer along the edge. Successful nests did have a higher average number of shrubs in the 1 meter and 2 meter categories, although the result was not significant (Table 4). In addition, successful nests were closer to openings (Table 4), although again, this result was not significant.

Table 4. Means and standard errors for nest variables in harvested areas, 1995.  
 \*distance or height measurements are in meters, area measurements are in hectares

Success?	NO (n=12)		YES (n=4)	
Variables	Mean	Standard error	Mean	Standard error
NESTHGT	3.5	0.401	2.7	0.515
NDIST	1.5	0.232	1.1	0.331
NTREEHGT	6.5	1.415	4.0	1.649
NTREEDBH	6.5	1.413	5.5	1.818
TREENUM	5.5	0.622	6.5	1.265
MEANBA	1586.41	179.89	1350.40	321.53
MEANDBH	19.9	1.148	18.0	2.536
TOTBA	8473.90	1128.53	9654.87	2778.76
PCOVER	82%	5.008	79%	2.778
TOT_1	10.4	2.069	18.0	6.121
TOT_1_2	4.6	1.384	10.0	2.728
TOT_2_4	1.6	0.379	3.0	1.078
TOT_4_6	0.3	0.188	0	0
TOT_6	0.3	0.142	0	0
TOTDEAD	1.0	0.275	1.5	0.422
MEAN_COV	20%	3.179	26%	5.882
DISTANCE	66.6	24.923	20.0	6.843
SIZE	1.42	0.767	0.24	0.080
OPEN100	0.75	0.135	0.68	0.178
OPEN200	3.03	0.465	2.10	0.365
OPEN500	11.60	0.070	12.57	3.606
EDGE100	312.60	56.06	358.66	78.09
EDGE200	1122.35	203.08	1303.80	204.93
EDGE500	5192.40	445.01	5108.84	436.87

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## CHAPTER 5: NEST SUCCESS

### *Results*

#### **Year 1**

I found 17 nests on the study area. Some of these nests (2/17) were located on the territories of birds who had recently experienced nest failure. I assumed that these were renests by the same pair. Eight of the 17 nests (47%) were depredated. Four nests (23%) were parasitized by brown-headed cowbirds (Table 1). Three nests were deserted during the incubation period. Two of the pairs who deserted renested. The third pair did not attempt renesting, presumably because it was late in the breeding season (early July).

Using the Mayfield estimate, the probability of survival for the egg stage was 0.379. The probability of survival for the nestling stage was 0.318 and the probability of survival from incubation to fledging was 0.120 (Table 5).

Table 5. Mayfield estimate calculations for Solitary Vireo (*Vireo solitarius allicola*) nests in 1994 and 1995.

	1994-Fork Mountain (unharvested)			1995- Harvested Areas		
	Incubation ≈14 days	Nesting ≈12 days	Total ≈26 days	Incubation ≈14 days	Nesting ≈12 days	Total ≈26 days
Nest days	133.5	44.0	177.5	109.5	102.5	212
Mortality	0.067	0.091		0.046	0.068	
Survival	0.933	0.909		0.954	0.932	
Probability of survival	0.379	0.318	<b>0.120</b>	0.517	0.430	<b>0.222</b>
Variance	0.00047	0.00187	0.00038	0.00039	0.00062	0.00025
Standard Error	0.022	0.043	0.011	0.0199	0.0249	0.0159

## **Year 2**

I found 16 nests on the three harvested study areas in 1995. Two of these nests were renesting attempts by the same banded pair. Three nests were parasitized by cowbirds (two on the Butt Mountain site and one on the Nettle Hollow site), giving a parasitism rate of 18.75%. Four nests fledged vireo young (Table 1).

Using the Mayfield estimate, the probability of survival for the egg stage was 0.517. The probability of survival for the nestling stage was 0.430 and the probability of survival from incubation to fledging was 0.222 (Table 5).

I used a stepwise logistic regression (SAS 1989) to relate both vegetation and landscape variables to nesting success, however none of the variables met the 0.05 significance level for entry into the model. This may be a function of sample size. Only 4 nests were successful and twelve were unsuccessful. In addition, many of the variables had high standard errors (Table 4).

## ***Discussion***

### **Year 1**

For 17 species of open cup nesting Neotropical migrants with demographic data available (as summarized by Martin 1992), Mayfield estimates of nesting success ranged from 38% to 46% with a mean of 42%. The Solitary Vireos on the site experienced a much lower rate of nesting success. Fall cankerworm (*Alsophila pometaria*) defoliation and some ice storm damage created a relatively open canopy in the summer of 1994. This may have given avian predators and parasites greater visibility.

In addition to the open canopy on the study area, several other features of the landscape may have increased access to the site for Brown-headed Cowbirds. For example, there is an abandoned homestead site approximately 0.6 hectares in size on the

west end of the Fork Mountain study area. There is also a second homestead site 1.2 km to the west, and several wildlife openings (0.4 ha) as close as 1.25 km to the northwest. In addition to these openings, a pasture with approximately 60-80 head of cattle is located approximately 3.6 kilometers to the southwest of the study site. Rothstein et al. (1984) found that cowbirds in the Sierra Nevadas of California were "commuting" daily up to 7 km between feeding and breeding sites. Therefore, it is conceivable that cowbirds may be using this pasture as a feeding area and traveling to the study site to breed. Furthermore, the proximity of several other openings may have attracted cowbirds to the area.

## **Year 2**

The vireos on the study sites in year 2 also experienced a low rate of nesting success (22%, Table 5). These sites were within 1.8 to 6.4 km of the cow pasture. I found two nests on Butt Mountain, both of which were parasitized by cowbirds. This site experienced windthrow damage in 1991, again, allowing better visibility for cowbirds. In addition, there is a pasture located approximately 3 km to the southeast. Only one nest out of 14 on the Nettle Hollow site was parasitized. The parasitism rate on these 3 sites in 1995 was lower than the parasitism rate on the Fork Mountain site in 1994. Jesse Overcash reported a lower density of cowbirds on Fork Mountain in 1995 than in 1994, based on point counts (pers. comm.).

Marvil and Cruz (1989) found a parasitism rate of 48.7% in their study of Solitary Vireos in Colorado. Their study sites had an open canopy, with widely spaced ponderosa pines. Although the vireos on my study areas experienced a lower rate of parasitism (23%, 18.75%), these results indicate that surrounding land use may be an important parameter in the nesting success of birds on large tracts of forest. Marvil and Cruz (1989) reported pockets of high parasitism near settle areas and low pockets of parasitism in more extensive tracts unbroken by settlement. Robinson et al. (1995) suggest that land

managers should seek to minimize cowbird foraging opportunities within large tracts of unfragmented forest.

Three of the five desertions in 1995 were by the same pair (Table 1). They may have deserted the first nest because of human disturbance (parents were netted and banded near the nest). However, they deserted their subsequent nests although I did not approach the nests closer than 20 meters.

In both years, the probability of survival was greater during the incubation stage (Table 5). Predators, therefore, may be using behavioral cues from adults and begging noises from young to find nests (Ratti and Reese 1988). Depredation of nests was the leading cause of nest failure in this study. Predators observed at the study sites included: Blue Jays (*Cyanocitta cristata*), American Crows (*Corvus brachyrhynchos*), Common Ravens (*Corvus corax*), Eastern Chipmunks (*Tamias striatus*), Eastern Gray Squirrels (*Sciurus carolinensis*), Black Rat Snakes (*Elaphe o. obsoleta*). Raccoons (*Procyon lotor*) and Red Foxes (*Vulpes fulva*) may also have been present but were not observed. The majority of depredated nests appeared to have been taken by mammalian predators (7/12), as evidenced by the condition of the nest (torn or destroyed).

Although none of the vegetation or landscape variables were significantly related to nest success, several variables are suggestive of a pattern. For example, the mean number of shrubs in the <1 meter (TOT\_1) and 1-2 meter (TOT\_1\_2) classes show what might be a significant difference had there been a larger sample size (Table 4). Successful nests had higher numbers of shrubs in these two categories within the 5 m radius vegetation plot. This is reminiscent of Martin's (1993) potential prey site hypothesis, which states that increases in the density of plants of the type used by the prey reduces the probability of predation, because it increases the number of potential prey sites that must be searched by a predator. Martin (1993) found support for this hypothesis in studies of

the MacGillivray's Warbler (*Oporornis tolmiei*) and the Hermit Thrush (*Catharus guttatus*), in which nest predation was reduced when the nest patch contained more potential nest sites.

Two of the landscape variables also suggest a pattern. The mean distance (DISTANCE) to the nearest edge was lower for successful nests, again suggestive of a denser shrub layer near the harvest openings (Table 4). Ratti and Reese (1988) also found a lower predation rate on artificial nests in denser shrub cover. However, the size of the nearest opening (SIZE) was smaller for successful nests than for unsuccessful nests (Table 4), indicating that although there may be more nesting cover closer to openings, it is advantageous to nest near small openings rather than large openings. Because these results were not statistically significant, further study must be undertaken in order to come to more definite conclusions.

While I did find some parasitism by cowbirds in this study, parasitism was not the most important factor influencing nest survival. As Robinson et al. (1995) have shown, in the fragmented landscapes of the midwest, cowbird parasitism has become a serious problem for populations of Neotropical migrant songbirds attempting to nest in these areas. Parasitism levels were so high that these areas may be acting as population sinks.

As forests in the eastern region of the country are not nearly as fragmented as those in the midwest, cowbird parasitism is much less of a problem to populations of Neotropical migrant landbirds. For example, the area within a 10 km radius of the Fork Mountain study site was 70-90% forested. Robinson et al. (1995) found that levels of nest predation and parasitism declined with increasing forest cover. In addition, the breeding bird survey has shown significant declines in populations of cowbirds in this region from 1966-1979 (Robbins et al 1986).

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## CHAPTER 6: SUMMARY

Pairing success for Solitary Vireos was highest in the unharvested forest landscape, however nesting success was well below that reported for other species of Neotropical migrant birds (Martin 1992). The combination of nest predation and parasitism contributed most notably to the poor rate of success. In addition to poor nesting success in the harvested areas, vireos also experienced a low rate of pairing success, indicating that these areas may represent "marginal" habitat (Probst and Hayes 1987, Gibbs and Faaborg 1990).

If females select males based on the quality of their territory, as has been suggested by several studies (Lenington 1980, Alatalo 1986), perhaps we should examine habitat selection at many different spatial scales. For example, if the quality territories for Solitary Vireos are those on extensive forests, these territories should be filled first. Later arriving females would then be left to choose the best territories from those in the marginal habitats, or areas with harvest openings, rather than forgo breeding attempts. This would represent habitat selection on a landscape scale. Within the male's breeding territory, a female would then have to choose the best nesting sites, which in this case, appear to be those near a small opening with large numbers of saplings or shrubs in the 1 meter and 1-2 meter height classes. In Solitary Vireos, females may be using the proximate factor of shrub/sapling density to choose a mate and/or nesting site. Anecdotal evidence for this comes from one male on the Nettle Hollow study site, whose territory was not near any of the harvest openings. Based on the pairing success rate on Fork Mountain, an unharvested area, one would expect this male to be paired, if females were simply choosing territories on a landscape scale. However, his territory had an extremely open understory and contained very little nesting substrate, and he remained unpaired throughout the breeding season. Female use of proximate factors in choosing a mate

could also explain a less than 100% pairing success rate on the unharvested study site. More females may have chosen to settle in this area, yet the presence of unpaired males indicates that mate or territory selection may also be operating on a smaller scale as well. This could also be an indication of an uneven sex ratio.

My data cannot adequately address the impacts of internal edges and openings on nest success, because of a small sample size and lack of yearly replication. To further address this question, using a different study design, nesting success in several extensively forested areas could be compared with nesting success in several harvested areas. In addition, surveys for Brown-headed Cowbirds in both types of areas may indicate if the harvest openings attract cowbirds. By comparing parasitism rates between extensive, unharvested forests and forests harvested using the group selection method, one could further test cowbird attraction to harvest openings. The abundance or density of Solitary Vireos in both areas could also be compared to determine if more males were choosing to settle in one habitat type or the other. Aging of males in both habitat types could also determine if younger males were being relegated to the more "marginal" habitats, as was found by Sherry and Holmes (1989) in American Redstarts.

Long term studies should also be conducted to determine the effects of group selection harvesting on forest dwelling birds. Once several harvest rotations have been completed, information is needed on the reproductive success of birds in the uneven-aged stand thus created.

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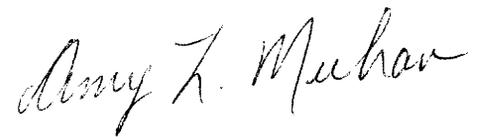
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Appendix I. Landscape and nest vegetation variables measured in harvested areas in 1995 and abbreviations used in text and tables.

Abbreviation	Variable measured
DISTANCE	Distance to nearest edge
SIZE	Size of nearest harvest opening
EDGE100	Amount of edge within a 100 m radius
EDGE200	Amount of edge within a 200 m radius
EDGE500	Amount of edge within a 500 m radius
OPEN100	Amount of opening within a 100 m radius
OPEN200	Amount of opening within a 200 m radius
OPEN500	Amount of opening within a 500 m radius
NESTHGT	Nest height
NDIST	Distance of nest from trunk of nest tree
NTREEHGT	Height of nest tree
NTREEDBH	Diameter at breast height of nest tree
TREENUM	Number of trees > 8cm DBH in circular plot around nest
MEANBA	Average basal area of trees within circular plot around nest
MEANDBH	Average DBH of trees within circular plot around nest
TOTBA	Total basal area of trees within circular plot around nest
PCOVER	Percent canopy cover within plot
TOT_1	Total number of shrubs in the 0.5-1 m height class
TOT_1_2	Total number of shrubs in the 1-2 m height class
TOT_2_4	Total number of shrubs in the 2-4 m height class
TOT_4_6	Total number of shrubs in the 4-6 m height class
TOT_6	Total number of shrubs > 6 meters in height
TOTDEAD	Total number of standing dead trees within plot
MEAN_COV	Average amount of nest concealment (Martin and Roper 1988)

## VITA

Amy L. Meehan was born in 1969 in Portland, Maine. She graduated from Windham High School, Windham, Maine in June of 1987. She attended the University of Maine, Orono, Maine and graduated in 1991 with highest distinction. She then worked as a GIS analyst and research assistant at Manomet Observatory for Conservation Sciences (formerly Manomet Bird Observatory) until January of 1994. She was accepted into the M.S. program at Virginia Polytechnic Institute and State University and began studies in the spring semester of 1994.

A handwritten signature in cursive script that reads "Amy L. Meehan". The signature is written in black ink and is positioned to the right of the main text block.