KIRTLAND'S WARBLER BREEDING BIOLOGY AND HABITAT MANAGEMENT[1]

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ABSTRACT.--The Kirtland's warbler (Dendroica kirtlandii) is an early succession, area-sensitive species seldom found in stands smaller than 30 to 40 ha. This warbler occupies dense jack pine (Pinus banksiana) stands where trees are from 6 to 23 years old and from 1.7 to 5.0 m high growing on poor, sandy soils. Typically, it has been found in areas regenerated naturally by serotinous cones resulting from wildfires. In the past 2 decades, however, Kirtland's warblers have been found in naturally regenerated, unburned jack pine and in densely stocked pine plantations. Stands are managed on a 50-year rotation and clustered into discrete management areas. Extensive dispersal to find suitable habitat reduces breeding opportunities. Currently, about 15 percent of the males abandon territories, and about 15 percent of the resident males do not find mates. Clustering stands into management units and staggering the schedule of stand regeneration should minimize biogeographic dispersal problems. Because Kirtland's warblers colonize patches of taller, dense jack pine before they occupy habitat with shorter or less dense trees, the period of Kirtland's warbler occupancy in a management area can be extended by several methods such as varying tree spacing in a plantation. Researchers and managers have developed a variety of harvest options, site preparation methods, and pine regeneration alternatives for providing suitable Kirtland's warbler habitat. Several options do not require the use of prescribed fire. These management alternatives must not only provide suitable tree stocking and spacing for the Kirtland's warbler but also accommodate their spatial and temporal needs such as the size, chronology, and age diversity of stands.

The Kirtland's warbler (Dendroica kirtlandii) is an Endangered Species that is only known to breed in young, jack pine (Pinus banksiana) habitat in northern Lower Michigan. This warbler migrates to the Bahamas where it winters in low, broadleaf scrub habitat. The known breeding population is censused annually and has averaged 205 males from 1971 through 1987. The breeding population has been remarkably stable, ranging between 200 and 216 males for 12 of the past 17 years. The Kirtland's warbler occupies dense, jack pine stands where trees are from 5 to 23 years old and from 1.7 to 5.0 m tall. Typically, this habitat has been regenerated naturally by serotinous seeding resulting from wildfires in jack pine on sandy, porous soil. In the past 2 decades, however, Kirtland's warblers have been found in naturally regenerated unburned jack pine and in densely stocked pine plantations.

I will review and describe four general areas of Kirtland's warbler biology and management: (1) the habitat requirements of the Kirtland's warbler, (2) the demography of the Kirtland's warbler and the evidence for population regulation by habitat limitation, (3) a hypothesis of how geography of suitable habitat affects stand colonization success and duration of habitat occupancy, and (4) the management strategies and recommendations needed to meet Kirtland's warbler requirements for optimal spatial and temporal distribution of high quality habitat.

KIRTLAND'S WARBLER HABITAT REQUIREMENTS

The most obvious difference between occupied and unoccupied suitably aged jack pine habitat is the dense tree stocking of the stands used by Kirtland's warblers. Areas with less than 20 percent canopy cover rarely are used for breeding. Optimal habitat typically has more than 7,500 stems per hectare and between 35 and 65 percent canopy cover. Tree canopy cover is more useful for evaluating habitat quality than stocking frequency or stem density because it combines tree stocking, spacing, and height factors. In any stand, the stocking should have from 20 to 25 percent tree cover to have a good chance of occupancy. Plantations can be adequately stocked for Kirtland's warbler

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breeding with only a minimum of 2,800 stems per hectare because planted trees are less clumped than those in naturally regenerated areas. Red pine (Pinus resinosa) plantations have had breeding Kirtland's warbler in places where they are planted closely enough to satisfy Kirtland's warbler stocking requirements. Unburned jack pine clearcuts that are stocked from nonserotinous natural seeding have less than 20 percent of the tree density of areas regenerated by wildfire and are almost never stocked enough to be suitable breeding habitat. However, if unburned stands have more than about 2,000 stems per hectare, Kirtland's warbler may breed there at low densities and for a short duration. Jack pine habitat that has low productivity for Kirtland's warbler is characterized by tree foliage volume that is less than that found in areas considered to be suitable habitat. Suitable or optimal habitat is also marginal when it passes through the young stage where trees are short and foliage volume is low. The two classes of marginal habitat have low Kirtland's warbler productivity because of low male density, low pairing success, low site tenacity, and late breeding initiation.

Tree Foliage Volume

At least six trends identify tree foliage volume as the major factor of Kirtland's warbler habitat suitability. (1) Areas with dense regeneration are occupied first and those lacking minimal tree stocking are never used. (2) Stands of intermediate tree density are older than dense stands when first used (Buech 1980) and usually support fewer birds. (3) Territory sizes tend to be larger in the more open areas of a stand (Mayfield 1960, Smith 1979). (4) The average density of male Kirtland's warblers is higher in well-stocked plantations or wildfire areas (Probst MS). (5) Kirtland's warblers arrive later in the season in breeding areas with minimal foliage volume (marginal habitat) than in more suitable habitat, and abandon marginal habitat with greater frequency. (6) Pairing success of males in young or poorly stocked habitat is from one-half to two-thirds that in more suitable habitat (Probst and Hayes 1987). Because tree foliage volume is so important to Kirtland's warbler habitat suitability, the occupied habitat can be described by a range of tree heights and tree covers. The composition and height of ground cover become limiting outside the bounds of poor sites selected for Kirtland's warbler management.

I have hypothesized that the well-defined habitat requirements of this species can be explained by its foraging ecology. The upper and lower limits of stand age (tree height), tree density, and ground covers can be related to their foraging heights, sites, and modes. The canopy cover threshold for initial occupancy may be related to minimal foliage volume necessary for Kirtland's warbler foraging requirements. The decline of habitat could be related to a lack of live, lower branches (Probst MS) for fledgling cover and for foraging space for the female (unpublished data).

Stand-Age Population Trends

Populations in burns generally build for 3 to 5 years after first occupancy, level off for 5 to 7 years, and decline rapidly within 3 to 5 years (fig. 1). In general, stands are not colonized by Kirtland's warblers until the average tree height reaches from 1.4 to 2.3 m (Probst MS). Breeding areas support highest male densities during the middle period of Kirtland's warbler occupancy (Probst 1986), at which time stands range from 2.4 to 3.9 m tall. Populations begin to decrease when tree heights reach 3.5 m or more and no live foliage is present below about 1.0 m. During the middle period of occupancy when Kirtland's warbler densities are highest, tree cover is between 27 and 60 percent, a condition found in fire-regenerated stands that typically have stem densities in excess of 5,000 per ha (Probst MS). Because trees are evenly distributed in plantations, optimal tree canopy cover can be produced with a tree density as low as 3,000 stems per ha.

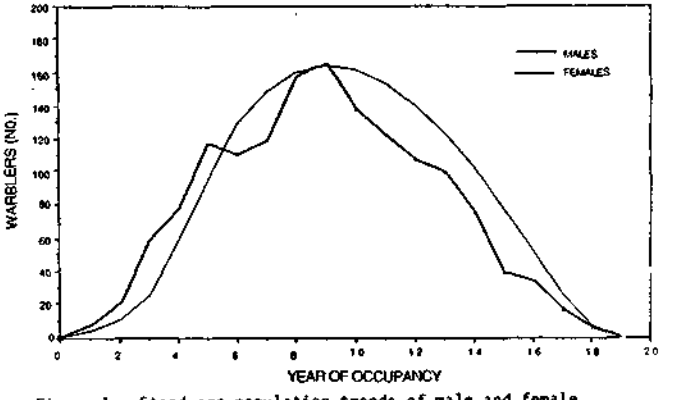

Figure 1.--Stand age population trends of male and female Kirtland's warblers. The male data were averaged from four wildfire areas in Michigan centered about the median year of occupancy. The female curve was inferred from data on pairing success in young versus older habitat (see text).

Ground Cover

Previous explanations of Kirtland's warbler habitat suitability have centered about the bird's nesting biology (Mayfield 1960, Walkinshaw 1983). The Kirtland's Warbler Recovery Team (appointed under authority of the Endangered Species Act of 1973) has emphasized the importance of fire to provide appropriate ground cover for nests, which are always on the ground. However, recent data show that on the very poor quality sites that characterize Kirtland's warbler habitat, ground cover does not appear to be limiting to Kirtland's warblers habitat selection. Both occupied and unoccupied stands almost always have a low, light cover of shrubs and grass-sedge interspersed with moss, lichen, and bare ground. Although initial post-fire ground cover species composition differs between burned and unburned stands, these differences decrease as stands mature (Abrams and Dickman 1982). This trend toward convergent succession of ground cover vegetation

when the stand is from 3 to 5 years of age has been confirmed in longer-term comparisons within sites that have varied fire and shade histories (unpublished data). Thus, I propose that ground cover vegetation on these poor-quality jack pine sites is not significantly altered by fire because most plant species present are fire adapted and regenerate quickly from underground roots or runners. The primary factors that influence ground cover species composition, instead of fire history, are site quality and recent shade history.

Broadleaf Coppice

Because the Kirtland's warbler has been found frequently in nearly pure jack pine stands, it has been thought that sprout growth from Northern pin oak (Quercus ellipsoidalis), big tooth aspen (Populus grandidentata), black cherry (Prunus serotina), and choke cherry (P. virginiana) would make the habitat unsuitable. However, it is likely that Kirtland's warblers are adapted to moderate amounts of oak, and they have been found at maximum densities in breeding areas with as much as 20 percent oak (Smith 1979). Broadleaf coppice is actively used for foraging, so it should not be detrimental if jack pine stocking is adequate. Broadleaf sprout-growth is beneficial in marginally stocked jack pine stands because it provides supplemental foliage volume for Kirtland's warbler foraging.

POPULATION REGULATION

Cowbirds

It is possible to conduct a comprehensive census of singing male Kirtland's warblers during the breeding season because of their distinct habitat requirements and restricted breeding range. Such censuses were done in 1951, 1961, 1971, and every year thereafter.

The population of singing males decreased from 502 to 201 between 1961 (Mayfield 1962) and 1971 (Mayfield 1972). The major reason for this population decrease appeared to have been nest parasitism by the brown-headed cowbird (Molothrus ater) (Ryel 1981). However, the population has stabilized since cowbird control beginning in 1971 cut parasitism rates from more than 66 percent of the nests (Walkinshaw and Faust 1974) to less than 3 percent (Kelly and DeCapita 1982). Productivity increased from less than 1 to 3.1 fledglings per pair (Walkinshaw 1983).

Fledgling survival rate may be as high as 75 percent per year (Probst 1986), so high winter mortality (Ryel 1981) is an unlikely explanation for the failure of the population to increase since 1971. The factors that may now be limiting population growth are habitat maturation and fragmentation, incomplete pairing success, fledgling mortality, and yearling dispersal to less suitable habitat or places outside the known breeding range.

Habitat

Strong evidence exists that the availability of suitable breeding habitat has been the principal factor limiting Kirtland's warbler population since cowbird control was begun. Because habitat is only suitable for a 10- to 16-year period, habitat maturation forces young birds to find new breeding areas. Thus, populations can be maintained or increased only if new breeding colonies are established to replace existing areas. Suitable breeding habitat available to the Kirtland's warbler has decreased since 1961 (Ryel 1981, Probst 1986). The amount of jack pine habitat in the 8 to 20 year stand-age range has not decreased much since 1951, but indirect evidence exists that the amount of suitable habitat (adequately stocked with jack pine) has declined significantly during the past 35 years. The density of male Kirtland's warblers in all suitably aged habitat fell from 3.0 males per 40 ha in 1961 to 1.0 males per 40 ha in 1984 (Probst MS). However, warbler densities in occupied habitat were similar in 1951 and the period from 1981 to 1985, even though the entire population has declined about 40 percent since 1951. This implies that the Kirtland's warbler population might have been filling most of the suitable habitat in recent years, with some overflow into less suitable or marginal habitat.

The population stability since 1971 could be related to population regulation by a fairly constant area of habitat. The minor population fluctuations that have been observed during the past 17 years have been related to a synchronous increase or decrease at maturing colonies (Probst 1986) and higher or lower proportions of Kirtland's warblers in suitable versus marginal habitat (Probst and Hayes 1987). The recent concentration of Kirtland's warblers into a small portion of the available suitably aged habitat is further evidence of population affected by the amount of suitable habitat. In the period from 1977 to 1983, three-fourths of the male population (between 155 and 180 males) was located in five or six major breeding areas (Ryel 1981, Probst 1986) whose combined total area represented only about one-third of the entire occupied habitat. This population concentration suggests that highly suitable habitat was limited to five large burns and one management area. Finally, the within-season movement pattern of Kirtland's warblers suggests that many birds are not breeding but are searching for better quality habitat (see below).

BIOGEOGRAPHY AND HABITAT UTILIZATION

Habitat area may affect colonization success, arrival dates, territorial establishment, and fledging dates. A scarcity of quality habitat may result in more territory being abandoned because birds may have to search for better nesting territories in order to secure a permanent pairing. In 1982 and 1983 about 15 percent of the resident males did not find mates (Probst and Hayes 1987). Any

dispersal to find more suitable habitat may reduce breeding opportunities. Delays in the initiation of breeding may cause birds to miss food resource peaks or sacrifice opportunities for renesting or second nesting. In 1987, about 22 percent of the male Kirtland's warblers abandoned territories established before 21 June. They could not have raised broods by that date. However, the colonization and dispersal patterns differ between marginal and suitable habitat. A higher proportion of males abandon territories in marginal habitat than in suitable habitat (1987 data in Fig. 2). In 1986, 93 percent of the territories in suitable habitat were occupied by 5 June, but only 52 percent of the less suitable Kirtland's warbler locations were occupied by that date. By 5 June, 84 percent of the adult males were established, in contrast to 73 percent of the subadult males. Higher proportions of subadult males were in marginal habitat (44 percent) than in more suitable habitat (23 percent) in 1986. Only 8 percent of the males vacated territories by the end of June in suitable habitat, but 19 percent of the males abandoned territories in marginal habitat. These trends indicate that young birds have difficulty establishing territories in crowded, more suitable habitat, and may delay breeding because of their late arrival. Current research results suggest that stand colonization is affected by stand size and distance from occupied breeding areas, as would be expected from within-season dispersal.

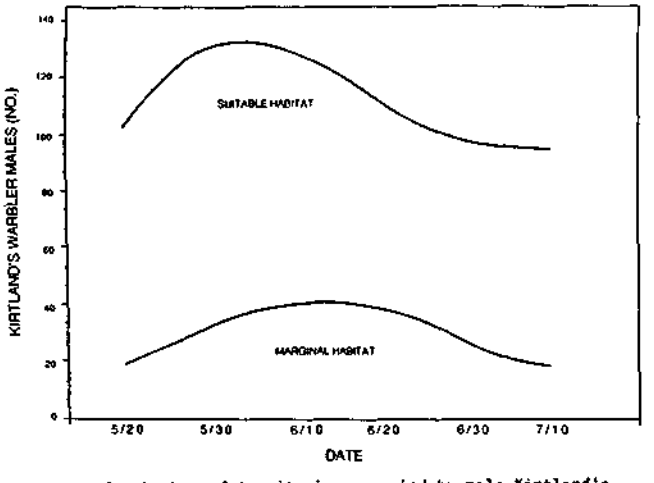

Figure 2.--Number of territories occupied by male Kirtland's warblers in marginal and suitable habitat during the 1987 breeding season. Trends were extrapolated to the entire known population (N=167 males) from a sample of males in suitable (N=58) and marginal (N=41) habitat.

In summary, habitat utilization by the Kirtland's warbler apparently is affected by both habitat quality and biogeography. Kirtland's warblers present a unique opportunity to study population regulation by habitat limitation because of their small breeding range, their concentration into 16-30 stands, and the facility of censusing their entire known population every year.

HABITAT MANAGEMENT

Kirtland's warbler land managers must supply a sufficient area of suitable habitat in the right locations to maintain a viable breeding population. Within management units, stand prescriptions should strive to maximize the number of breeding pairs for the entire period of occupancy. The highest possible production of fledglings from a stand will be achieved by maximizing the duration of occupancy without compromising the average annual breeding density. In most circumstances, this objective can be achieved by increasing the probability of early stand colonization and by extending the period a stand is suitable for new colonists. However, an anticipated habitat shortage may be alleviated by managing only for early occupancy (near-term shortage) or late occupancy (long-term shortage).

Large-scale Considerations

The area set aside for Kirtland's warbler management totals 51,700 ha in 16 areas owned by the State of Michigan (30,000 ha) and 7 areas owned by the USDA Forest Service (21,700 ha in the Huron-Manistee National Forest). This land is being managed on a 50-year Kirtland's warbler management and commercial timber rotation. The Recovery Plan calls for regenerating about 1,030 ha per year so that about 10 times that area is always suitably aged for Kirtland's warblers. If this habitat objective is maintained, an overall density of 3.8 males per 40 ha would achieve a viable population of 1,000 males. The average density in all occupied Kirtland's warbler habitat has been less than two males per 40 ha from 1981 to 1985 (Probst MS). If this density continues, the population would be about one-half the target figure. However, the future managed habitat could allow a higher average density of males. If 75 percent of the Kirtland's warbler habitat (10,340 ha) were occupied at five males per 40 ha, the objectives of the Kirtland's Warbler Recovery Plan developed for this Endangered Species could be attained. More than 6,100 ha of wildfire and plantation habitat should be available in 1993 to provide carrying capacity for 300 to 750 male Kirtland's warblers.

Clustering stands into 23 State and Federal management units with staggered scheduling of stand regeneration should minimize most biogeographic dispersal problems. Each management area will have to be large enough to support a population that is sufficient to maintain a colony during the 8 to 12 years a stand is suitably aged for Kirtland's warblers. For example, at a density of 3 males per 40 ha (data in Mayfield 1962), from 240 to 335 ha of habitat would be required to support about 20 males. When jack pine is managed on a 50-year commercial rotation, five such stands totalling from 1,200 to 1,600 ha would be needed for each management area. The majority of the 23 Kirtland's Warbler Management Areas (KWMA's) are more than 2,000 ha in size, so the minimum area should be present in most of them. The minimum habitat specified above assumes occasional recolonization from other management areas and regular colonization of young stands from

adjacent occupied habitat.

The Kirtland's warbler is an early succession, area-sensitive species that is rarely found in stands smaller than 32 ha. The reasons for this minimum habitat size requirement are unclear, however, it appears that larger habitat patches support Kirtland's warblers for a longer time. This fact is probably related to both higher populations of Kirtland's warblers and the diversity of habitat patches generally present in larger areas. The current practice of managing contiguous blocks of more than 80 ha of similarly aged habitat should accommodate the habitat area requirement of the Kirtland's warbler.

Most adult migrant bird species (including Kirtland's warblers) return to the same breeding area each year (Berger and Radabaugh 1968, Greenwood and Harvey 1982, Walkinshaw 1983). Juvenile and yearling birds may stay on their natal grounds or disperse from there in late summer or the following spring. If few young birds randomly find habitat during migration, discovery of new habitat probably will be affected by distance from established breeding areas (see above). Thus, Kirtland's warbler habitat management should be directed primarily toward the current breeding range. Expanding the range should be attempted only near the periphery of the current range. Because establishing breeding populations is so difficult, it is imperative to keep each occupied KWMA close to its rotation schedule.

Landscape Design of Management Areas

Kirtland's warblers colonize taller and denser jack pine patches before they occupy habitat with shorter or less dense trees. It is possible to extend the period of Kirtland's warbler occupancy in a management area by several methods such as varying the timing of stand regeneration or the tree spacing in a plantation.

Current management guidelines prescribe maintaining 20 percent of each KWMA in each 10-year age class. Normally, cutting blocks are scheduled for harvest regularly throughout each 10-year period, but regeneration is not always on schedule. To ensure several years overlap in stand utilization by Kirtland's warblers, I emphasize that date of origin between cutting blocks should differ by about 5 years. This temporal overlap should make it unnecessary to maintain local populations by long-distance recolonization.

Site quality variability within a stand or unit can increase the period of occupancy by Kirtland's warblers because it creates a pattern of patches with varied foliage volume. Managers should be aware of the importance of this variety when scheduling planting or prescribing tree densities. For example, tree densities should be more uniform in areas with site variety because differences in height growth alone may provide the necessary variety in foliage volume without requiring tree stocking differences.

Although the Kirtland's warbler is an early-succession, area-sensitive species, little evidence has been found to relate Kirtland's warbler densities or productivity to stand shape and configuration. However, I hypothesize that at least two Kirtland's warbler nest predators -- red squirrel (Tamiasciurus hudsonicus) and blue jay (Cyanocitta cristata) -- may be less common in stands with trees shorter than about 4 m. It seems reasonable to assume that predation rates might be higher near edges of stands bordered by more mature trees. Thus, it would be prudent to avoid long, narrow stands to minimize such edges. A majority of stands managed for Kirtland's warbler in the recent past tend toward minimal edge.

Improving Habitat Quality

Most recommendations for improving Kirtland's warbler habitat center about increasing natural regeneration and optimizing tree spacing in plantations. Kirtland's warblers do not commonly colonize a stand until tree canopy cover exceeds 20 percent. Maximum male populations were recorded in stands with 40 to 60 percent canopy cover. Jack pine areas with 20 to 60 percent canopy cover have more than 6,250 stems per hectare in naturally regenerated stands and at least 2,700 stems per ha in plantations. However, plantations should have about 5,000 stems per hectare to attract colonists at the earliest possible stand age. This prescribed tree density is best achieved with a 1.3- by 2-m spacing pattern. A rectangular spacing pattern has more variety in the timing of thicket formation among the trees than a square pattern and should provide a longer period of Kirtland's warbler occupancy. Experimentation with opening sizes is needed. I suspect that openings should be smaller and more numerous than in past plantations where they averaged about 25 percent of the stand area.

Duration of Stand Occupancy. Recommendations for maintaining KWMA populations (above) stressed a variety of large habitat patches in both the temporal and spatial scales. The same strategy can be employed to extend the stand utilization period by Kirtland's warblers. The following seven alternatives are suggested to extend the length of stand occupancy:

1) Plantations with a variety of tree densities should attract Kirtland's warbler colonists both early and late in stand life. Experimentation with alternative tree densities is recommended. Because the Michigan Department of Natural Resources is currently using variable spacing of 1.3 by 1.3 m combined with 1.3 by 2.6 m, I recommend that the USDA Forest Service use 1.3 by 2 m and 1.7 by 2.3 m.

2) In stands with more than 1,250 stems per hectare of tree stocking, it may be feasible to plant dense 0.8- to 1.3-ha patches on 20 percent of a stand, and avoid the expense of full

(large-scale) planting.

3) It may be possible to regenerate dense 0.4- to 1.3-ha patches by leaving small clumps of standing mature jack pine during prescribed burns. (The Michigan Department of Natural Resources has had some success burning strip cuts in jack pine.)

4) In unburned areas lacking appreciable advance regeneration, a shelterwood cut followed by supplemental planting could provide high-quality habitat, but this would be more expensive than other options.

5) Plant from 20 to 30 percent of some stands with red pine at the same spacing as in item #1 above.

6) Large residual patches (greater than 15-m wide) of mature trees within wildfire areas may have advance regeneration that can be released by removing the overstory from 6 to 8 years after a burn. These patches could extend stand occupancy. Such areas have been used for nesting at Muskrat Lake Burn in Oscoda County, Michigan.

7) Very poorly stocked areas in burns greater than 8 ha could be fill-in planted about 5 or 6 years after the fire at 1.7 by 2-m spacing. Because the Mack Lake Burn has so much well-stocked habitat, additional planting should be delayed there until 1988 to 1992.

Kirtland's warblers require a dense layer of foliage from 0-1 m up to 1.7-4 m in height. If tree ages in a stand are too diverse, few thickets will be at the proper heights. Thus, fill-in planting should be scheduled before the existing trees are from 1- to 1.2-m tall. In some places the interplanted pines were established too late to affect habitat quality. This is especially true in cases where red pine was used as fill-in stock (see below).

Tree Species Other Than Jack Pine. Red pine is suitable for Kirtland's warbler plantations but not for fill-in planting. Red pine appears to have been beneficial to Kirtland's warblers in three stands because it extended their occupancy period by keeping live, lower foliage longer than jack pine. However, red pine can grow too slowly in the first 10 years on these poor sites and this can complicate scheduling considerations. Furthermore, red pine is more sensitive to microsite differences, and its growth is less predictable than jack pine. The slow, unpredictable early growth of red pine makes it unsuitable for fill-in planting. I recommend that managers experiment with planting red pine at densities prescribed for Kirtland's warbler on appropriate sites adjacent to KWMA's now managed for red pine.

The presence of northern pin oak Quercus ellipsoidalis), choke cherry (Prunus virginiana), or black cherry (P. serotina) may not be disadvantageous to Kirtland's warblers when dense jack pine thickets also are present. Broadleaf coppice is actively used for Kirtland's warbler foraging. In places where jack pine regeneration is marginal, oak sprout-growth should not be sprayed because it may help provide the minimum foliage volume required for Kirtland's warbler foraging. Kirtland's warblers have been found at high densities in stands (Damon Burn) with up to 20 percent oak (Smith 1979).

Snags and Residual Trees. Snags and residual trees that escape wildfire or harvest can be valuable song perches for Kirtland's warblers and are clearly beneficial where cowbirds are controlled. When cowbirds are not controlled, nest parasitism is higher near snags (Anderson and Storer 1976). Residual oak and pine trees are used for both singing and foraging. We have no data on the maximum volume of overstory tolerated by Kirtland's warblers, but the trees or stringers must be widely spaced or habitat will not be utilized. Overstory removals in Kirtland's warbler habitat are difficult to evaluate because habitat maturation always accompanies the removals. Scattered pine or oak residuals may be important in attracting the first males to a breeding area because some individual male Kirtland's warblers spend a majority of their time foraging in isolated trees, stringers, or the edges of mature forests. However, the scattered trees should probably not exceed 5 percent of the canopy.

Slash. Slash and logging debris are used extensively for Kirtland's warbler foraging. At present, we do not know how much logs and slash add to habitat quality and how much this use of debris as a foraging substate is strictly facultative. However, almost all foraging in openings or in dense ground cover is on logs, stumps, or slash, so managers should use caution when prescribing whole-tree harvesting on unburned stands. Removing most logging debris from unburned Kirtland's warbler stands will preclude a direct, incisive comparison of the suitability of unburned and prescribe-burned plantations. Therefore, I recommend that each Kirtland's warbler unit have at least one of its unburned cutting blocks harvested by conventional cutting.

Ground Cover Composition. Kirtland's warbler appear to accept most ground cover communities associated with dense jack pine stands on very poor sites. (The rejection by Kirtland's warblers of unburned stands with Carex sedges as a dominant ground cover is probably related to the open tree cover of stands with dominant Carex). If the ground cover requirements of the Kirtland's warbler are no more specific than a low, light cover of shrubs, grasses, and sedges, it should be possible to generate suitable habitat without fire (Table 1). If future patterns of habitat occupancy indicate a more specific ground cover requirement, steps can be taken to maintain or increase the xeric shrubs and/or retard ground cover succession on the better sites. Mechanical disturbance such as plowing or discing breaks up sod and low shrubs such as blueberry (Vaccinium sp.). This treatment is probably more effective than fire for altering ground cover composition. If

optimal tree densities are achieved in unburned stands, shade should be sufficient to help favor shrubs over grass and sedge.

Table 1.--Prioritizing stands for prescribed burning.

Higher Priority Stands	Lower Priority Stands
1. Many residual jack pines	Significant advance regeneration
2. Abundant slash	Less slash, smaller residual trees
3. Better sites (>50 SI)	Poorer sites (<50 SI)
4. Dense broadleaf undergrowth	Low to moderate hardwood competition
5. No other site preparation anticipated	Good potential for "V-plow" planting or other heavy scarification
6. No fire history during last rotation	Recent history of fire

Natural Regeneration vs. Plantation

Much of the past focus on Kirtland's warbler habitat regeneration has revolved around the need for fire. The future focus should be on the need for natural regeneration on burned or unburned sites (Table 2). Natural regeneration will improve the quality of habitat even in the best stocked plantations. Where natural regeneration is excellent, planting costs can be reduced substantially. For suggestions on improving natural regeneration, see "Duration of Stand Occupancy" under "Improving Habitat Quality".

Seed tree burns have been unsuccessful at regenerating jack pine in Kirtland's warbler habitat. Unacceptable delays have occurred in planting warbler habitat because so few days are suitable for burning in a season. Prescribed fire has the potential to dramatically cut the costs of planting habitat, but safety concerns will have to be addressed. Fire's role in providing ground cover vegetation is complex, and prescribed fire could be used to create changes in vegetation. However, I believe the effects of fire on ground cover are short-term and can be duplicated more effectively with a variety of mechanical means.

Table 2.--Jack pine management options.

Harvest Option	Site Preparation	Regeneration[a/]
Strip-cuts	Prescribe burn Plow	Assess stocking Plant as needed between strips
Shelterwood	Burn and scarify	Assess stocking, plant as needed
	Scarify	Direct seeding Assess stocking
	Plow	Plant as needed
Seed tree	Burn and scarify	Direct seeding, assess stocking, plant as needed
	Roller - chop, plow	Full planting
Conventional clearcut	Roller - chop, plow	Full planting
Whole tree harvesting	Disc/harrow/plow	Full planting

[a/] Kirtland's warbler management requires denser stocking than timber management

The preferred method for regenerating jack pine has been seed tree harvest followed by prescribed burning (Table 2). However, this prescription has not provided adequate natural regeneration, and almost all areas have been stocked by machine planting. Shelterwoods have been mostly unsatisfactory for full regeneration, and windthrows are a serious problem with this option. Future stand regeneration should be modified to achieve more natural tree regeneration. If successful, costs will be lowered, and habitat quality will be raised. Natural tree stocking can be increased by leaving more standing volume before prescribed burns (leave strips or >3.7-m^2 BA) or by using shelterwood where natural regeneration is insufficient.

The recommendations outlined in this paper were made after many years of research and management of Kirtland's warbler habitat. They can be used to improve habitat quality and breeding success. However, successful implementation of these management alternatives will require further experimentation and careful attention to scheduling of stand regeneration. Such an effort will only be possible with the continued cooperation of several government agencies, researchers, and the Kirtland's Warbler Recovery Team.

Many of the ideas presented in this paper were developed with foresters, wildlife managers, and members of the Kirtland's Warbler Recovery Team. I especially wish to thank G. W. Irvine, William Jarvis, David Sorenson, Jerome Weinrich, and the staff on the Huron-Manistee National Forest for their ideas about jack pine management for the benefit of Kirtland's warbler. Michael DeCapita, Cameron Kepler, Mark Nelson, Thomas Nicholls, Ronald Refsnider, Gustav Swanson, and Jerome Weinrich made helpful corrections to the manuscript.

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