Silvicultural Options for Neotropical Migratory Birds

Frank R. Thompson III[1], John R. Probst[2], and Martin G. Raphael[3]

Abstract — We review: factors that affect forest bird populations; basic concepts of silvicultural systems; potential impacts of these systems on neotropical migratory birds (NTMBs); and conclude with management recommendations for integrating NTMB conservation with forest management. We approach this topic from a regional-landscape scale to a forest stand-habitat scale, rather than the traditional stand-level approach. Populations are determined by interactions between local habitat factors such as vegetation structure and regional or landscape features such as total habitat area, amount of edge, habitat context, and biogeography. The four silvicultural systems commonly used in North America are selection, shelterwood, seed tree, and clearcutting systems. Clearcutting, seed tree, and shelterwood systems create a mosaic of evenaged stands; the selection system maintains an unevenaged forest or stand. Evenaged management creates an age-class distribution of forest stands that may differ from landscapes with no timber harvest. Juxtaposition of different aged stands results in increased amounts of edge in the forest which may affect the reproductive success of NTMB, but consequences of this may not be significant compared to alteration of forest age-class structure. Regeneration or harvest cuts result in replacement of a mature forest bird community with a young forest bird community. Selection cutting retains much of the mature forest bird community within a stand as well as providing habitat for some early successional species that use the shrub-sapling layer. Edge effects around group selection cuts may be a concern because these openings, although small, may be numerous and widespread.

NTMBs have diverse requirements for nesting and foraging. We believe the only way to incorporate their diverse needs with other forest resources is a hierarchial, top down, approach that begins at a continental scale, identifies opportunities at regional scales, sets composition and structure goals at a landscape scale and management unit scale, and matches management prescriptions to goals at a habitat-stand scale. We make NTMB management recommendations at each of these scales.

INTRODUCTION

We review common silvicultural systems used in North America and their impacts on forest-dwelling NTMBs. Other papers in this symposia address silvicultural impacts in specific forest types in different regions of the continent; we focus more generally on silvicultural systems and their effects on landscape

[1]*North Central Forest Experiment Station, 1-26 Agriculture Bldg., Univ. of Missouri, Columbia, Missouri 65211.*

[2]*North Central Forest Experiment Station, P. O. Box 898, Rhinelander, Wisconsin 54501-0898.*

[3]*Pacific Northwest Forest and Range Experiment Station, 3625 93rd Avenue, SW, Olympia, Washington 98502.*

pattern and structure, stand structure, and processes that affect populations of NTMB. We review habitat factors that affect breeding forest birds, basic concepts of silviculture, and potential impacts of these systems with emphasis on harvest and regeneration methods. We do not provide a complete review of literature on this topic, but identify what we believe are major impacts and processes impacting NTMBs in managed forests, and document these with representative citations. Most research on silviculture and its impact on birds has occurred at the stand or habitat level, and only occasionally are large-scale inferences made. Given current emphasis on ecosystem management and application of principles of landscape ecology to forest management, we approach this topic from a regional-landscape scale to a stand-habitat scale, rather than the traditional stand-level approach. We conclude by suggesting an approach for integrating NTMB conservation with other forest resource management and some general guidelines for landscape and habitat composition and structure for different segments of the NTMB community.

LANDSCAPE AND LOCAL FACTORS AFFECTING POPULATIONS

Population levels and viability are determined by interactions between local habitat factors and regional or landscape features such as total habitat area, habitat context and biogeography. A large area of suitable habitat will support a larger population, lower local extinction rates, and greater potential to produce excess individuals for dispersal to remote or less productive areas, than will a small habitat patch. Smaller habitat patches not only have higher local extinction rates, but are less likely to be colonized or re-colonized. Such patterns were originally observed in oceanic islands (MacArthur and Wilson 1967) but have been extended to habitat islands as well. Species requiring large patches of fairly homogeneous habitat are said to be "area-sensitive". Many NTMB in the eastern U. S. are considered area sensitive because they are often absent from small habitat fragments (Whitcomb et al 1981, Ambuel and Temple 1983, Blake & Karr 1984, Hayden et al. 1985, Robbins et al. 1989, Faaborg et al. this proceedings). A major reason for NTMB area-sensitivity is that many NTMB have lower reproductive success near forest edges and in edge-dominated forest fragments due to predation and brood parasitism (Gates & Gysel 1978, Brittingham & Temple 1983, Robinson 1992, Temple & Cary 1988). While edge-related declines in reproductive success in forests fragmented by non-forest habitats are a likely cause of area sensitivity (Temple and Cary 1988), the effects of edges created by timber harvest in predominately forested landscapes is unclear.

Large scale (regional, landscape) factors may impose important "top down constraints" (Mauer, this proceedings) on the way NTMB respond locally to silvicuture. For instance, the effects of edge and openings created by timber harvest on levels of nest predation and parasitism may depend on the landscape context. Examples of important context considerations for NTMB are the amount of forest versus agricultural land, and the overall level of forest fragmentation. In some fragmented landscapes brood parasitism and predation are extremely high but unrelated to distance to edge. Predator and cowbird numbers may be so high in these landscapes that they saturate forest habitats (Robinson et al. this proceedings). In extensively forested landscapes cowbird and predator numbers may be so low that their influence is limited to forest edges. We discuss edge effects resulting from silviculture later.

At a local or habitat level, birds appear to select nesting and foraging habitats based on an array of factors including vegetation structure; life-forms or presence or volume of vegetative strata; plant or tree species composition; and special features such as snags, streams, or cliffs. Stand or habitat level factors affecting these include forest type, history of disturbance, forest age, and site quality. Forest type and disturbance history determine plant composition and potential vegetation structure. Forest age affects such attributes as tree size, foliage volume, foliage stratification, horizontal patchiness, bark surface area, cavity formation, coarse woody debris, and other special features. Neotropical migrants use forests of all ages, but the importance of different-aged forests to NTMB varies (Fig. 1). Site quality affects forest type composition, successional pathways, the rate of succession, and vegetation structure, especially stature or tree height. Finally, there are cause and effect interactions between vegetation structure and vegetative composition, such as overstory-understory relationships.

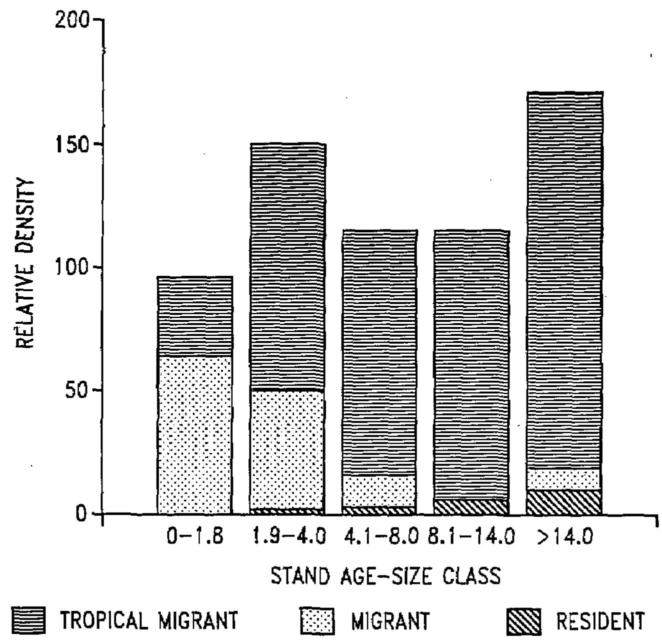

Figure 1. — Comunity compositon by migration status in different age (height) aspen forests. Adapted from Probst et al. (1992).

SILVICULTURE

Silviculture is the theory and practice of controlling forest establishment, composition, structure, and growth (Smith 1962). Silviculture is usually thought of in the context of timber production, though it should be interpreted more broadly to include other possible objectives such as conservation of biological diversity or NTMBs.

Silvicultural treatments are applied at the stand level. A stand is a contiguous group of trees sufficiently uniform in species composition and structure to serve as a management unit. Stands are often equated to animal habitats, communities, or even ecosystems (Hunter 1990). Stands are usually identified by the composition and structure of vegetation currently occupying a site, but sometimes are based on ecological classification systems as well. Management is usually regulated at a larger scale often referred to as the forest, which is a collection of stands administered as a integrated unit (Smith 1962). Often a forest is sub-divided into management compartments.

Silvicultural Systems

A silvicultural system is a program of forest management for an entire rotation of a stand. It includes harvest cutting, regeneration of the stand, and intermediate treatments. Silvicultural systems are often referred to on the basis of the regeneration method used because these practices have such a large impact on the future of a stand. Regeneration methods establish tree reproduction and usually simultaneously harvest timber.

The four silvicultural systems commonly used in North America are the selection, shelterwood, seed tree, and clearcutting systems (USDA Forest Service 1973). An important distinction among silvicultural systems is whether they maintain evenaged or unevenaged stands. In evenaged stands, trees are the same age class although there may vary in diameter. The diameter distribution of these stands is typically a bell-shaped curve. An unevenaged stand contains at least three age classes. Often the height profile of a stand is more characteristic of its age-class distribution than are tree diameters; an evenaged stand tends to have a level canopy while an unevenaged stand is distinctly irregular in height. The selection method is used to maintain unevenaged forests; the clearcut, seed tree, and shelterwood methods maintain evenaged stands. Some alternatives to these traditional evenaged practices maintain two-aged stands.

Evenaged Systems

Under evenaged management harvest and regeneration is regulated by area and is a function of rotation age, that is, age at which a stand is regenerated. Rotation age is based on economic, aesthetic, structural, or ecological management objectives. The goal of regulation is usually to provide a sustained yield of products or other uses and values over time. It is important to recognize that this occurs at the forest, not the stand level. Three methods have traditionally been used to harvest or regenerate stands (Smith 1962):

Clearcutting method--Removal of the entire stand in one cutting. Size of the stand varies from small patches (<1 ha) to extensive (>100 ha).

Seed Tree Method--Removal as in clearcutting except a small proportion of the original stand is left to reseed the harvested area.

Shelterwood Method--Gradual removal of the entire stand in a series of partial cuttings which extend over a fraction of the rotation. Regeneration is established under the protection of a partial overstory before the final removal cut.

A number of alternative regeneration methods have recently been tried in attempt to meet public opposition to clearcutting and to address ecological concerns. *Patch cutting* involves creating small clearcuts (<1 ha). It differs from selection cutting because cutting is regulated by area, as with other evenaged practices, and not stand structure as in selection cutting. *Aesthetic shelterwoods* are similar to traditional shelterwoods except the removal cut is done over widely spaced entries, or a final removal is never made and a portion of the original stand is left. *Two-age silviculture* does not fit neatly into unevenaged or evenaged systems, though it most closely resembles evenaged systems in its application. It is accomplished by removing half the stand every half rotation, which results in two distinct age classes present throughout the rotation (Marquis 1989).

Unevenaged Systems

In unevenaged systems, single trees or small groups of trees are periodically harvested. Trees are selected on the basis of age, diameter, vigor, form, and species with the objective of maintaining a relatively consistent stand structure. Sustained yield can be accomplished within a stand if a balanced size-class distribution is maintained within the stand. The desired size class distribution for a balanced stand is defined by the largest desired tree size and the ratio of the number trees in successive diameter classes (q-value). Thus regulation is by volume and diameter rather than by area under evenaged management. There is tremendous variation in the implementation of the selection system though harvest is classified as one of two methods:

1. **Single-tree selection**--Trees are removed as single scattered trees.
2. **Group selection**--Trees are removed in small groups.

Often single-tree selection and group selection are performed together; this is sometimes refered to as selection with groups (Law and Lorimer 1989). Groups may be harvested to establish regeneration of less tolerant species and single trees removed to balance larger diameter classes or regenerate tolerant species.

Silvicultural Practices

Silvicultural practices can be divided into two broad categories: regeneration practices and intermediate treatments. The objective of regeneration practices is to establish a new stand , whereas the objective of intermediate treatments is to regulate stand composition, structure, and growth, as well as provide some early products (Smith 1962). Many other practices associated with silviculture and forest management may affect NTMB such as pest control, salvage, fire management, and road building, but these are beyond the scope of this paper.

Regeneration Practices

Following or during harvest a stand is treated to create conditions favorable for regeneration of desired species. Site preparation may dispose of slash (debris left from harvest cuts), reduce competition from unharvested vegetation, or prepare the soil for the new trees. Slash may be removed to reduce potential fuel for forest fires or because it creates too much shade or physically impedes the regeneration of the stand. Slash disposal commonly occurs in the western forests in combination with planting. Slash is disposed of by broadcast burning, piling and burning, lopping and scattering, or chopping on site. Seedbeed preparation usually consists of exposing the mineral soil by removing the organic matter. Predominant methods are prescribed burning and scarification, that is, the mechanical removal or mixing of the organic matter with mineral soil. Competing vegetation may be controlled by prescribed burning, mechanical treatment, or herbicides. Presribed burning may also be used to promote desireable species that are adapted to or dependent on fire. Artificial regeneration occurs by planting young trees or seeding before or after removing the old stand. Artificial regeneration is most commonly used for conifers because the probability of success and high financial yield are often greater than for hardwoods. Natural regeneration occurs from natural seeding or from stump and root sprouts. The essential step in natural regeneration is to ensure that there is an adequate seed source, advanced reproduction, or potential for sprouting. Advance reproduction is natural reproduction that is present before a stand is regenerated.

Intermediate Treatments

Intermediate treatments are those done between regeneration periods. Release cuttings are used to free desirable trees in a young stand not past the sapling stage from the competition. Three types of release cuttings are: weeding, which removes all competitors; cleaning, which removes overtopping competitors of the same age; and liberation, which removes overtopping competitors that are older. Because competing vegetation often resprouts if simply cut or girdled, herbicides are often used alone or in combination with cutting or girdling.

Thinnings are selective removal of trees in stands past sapling stage. They harvest some trees that normally die from competition in immature stands and perhaps more importantly, they redirect and accelerate growth on selected trees that are released. There are two general types of thinnings. Low thinning removes trees from lower crown classes, salvaging trees that would normally die, and possibly reducing root competition. Crown thinning removes trees from middle and upper portion of the canopy to favor development of selected trees.

IMPACTS ON HABITAT AND BIRDS

Evenaged Systems

Landscape Composition

Evenaged management creates a specific age-class distribution of forest habitats that usually differs from forests with no timber harvest. Assuming timber harvest is regulated to provide sustained yield over time, rotation age will determine the amount of forest in any given age class and overall proportion of forest stands in young versus older age-classes. Forests managed by evenaged management could have more or less early successional forest than natural landscapes depending on rotation age and frequency of natural disturbances. For instance, an oak-hickory forest managed by regulated clearcutting on a 100-year rotation would be comprised of approximately 10% regeneration (stands 1-10 years old). Managed forests often contain more early successional forests and NTMB than historically before logging (Fig. 2), or than unmanaged forests. For example, Raphael et al. (1988) modeled large scale changes in bird populations in Douglas-fir forests of

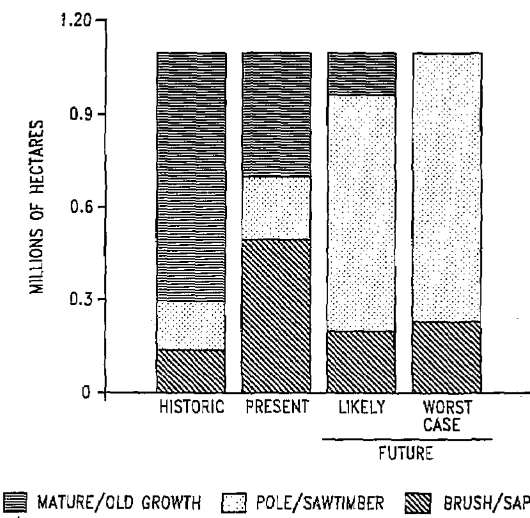

Figure 2. — Forest area occupied by three seral stages of Douglas-fir forest in northwestern California in historic times, at present, and under two projected trends (Raphael et al. 1988).

Northwestern California based on the impacts of forest management on landscape composition. They compared presettlement, present day, and future bird populations given current management trends. They concluded that early seral species were currently at a peak compared to historic levels, and that mature forest species had declined and would continue to do so. Thompson et al. (1992) compared NTMB in landscapes managed by clearcutting to those in wilderness areas with no timber harvest. Total density of early successional NTMBs were much greater, and forest interior NTMBs slightly lower in landscapes managed by clearcutting (Figure 3).

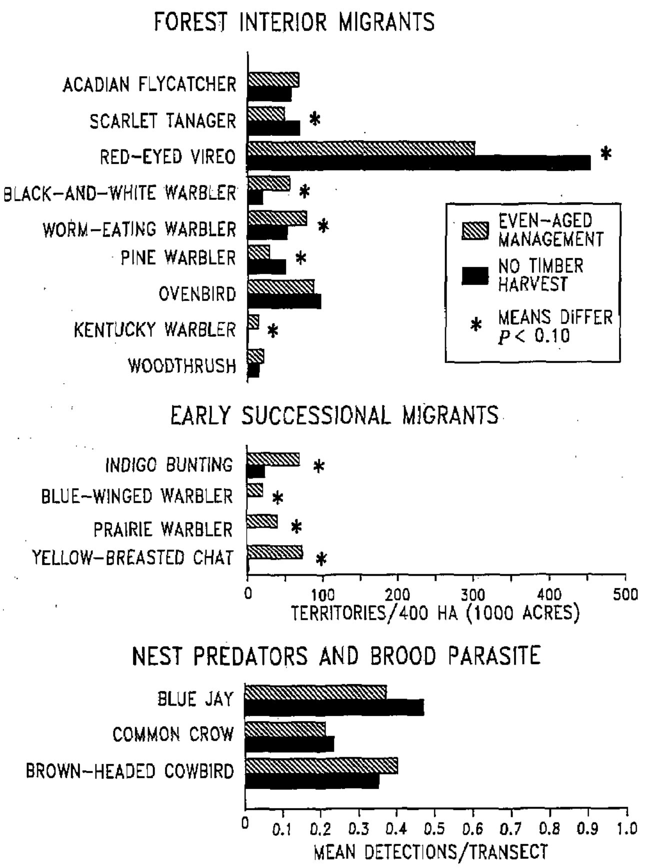

Figure 3. — Numbers of forest interior neotropical migrants and early successional neotropical migrants in forested landscapes managed by clearcutting and landscapes with no timber harvest (Thompson et al. 1992).

Spatial Distribution and Edge Effects

The spatial distribution of different aged stands also may impact NTMB. Stand size determines size of habitat patches created by regeneration cuts, and is usually 5-20 ha. Natural disturbances and openings occur much more frequently at small scales than at large scales, but have a wide range of sizes (Hunter 1990). Without special considerations, evenaged management results in a unnatural uniformity of habitat patch size, excluding small and very large patches.

Juxtaposition of different aged stands in managed forests may result in increased forest edge, which may effect reproductive success of NTMB (Wilcove 1988). It is not clear, however, how edges created by timber harvest affect NTMB. Several studies have found higher nest parasitism or predation near openings created by timber harvest (Brittingham and Temple 1983, Yahner and Scott 1988, D. Whitehead unpubl.data), while others have not (Ratti and Reese 1988). In highly fragmented forests in agricultural landscapes parasitism and predation rates may be high throughout the forest, with no relation to edges of clearcuts or wildlife openings, because cowbirds and predators may be so abundant they saturate the forest (Robinson et al. this proceedings). While many forest interior species remain abundant in managed forests (Thompson et al. 1992), it is possible that these are population sinks where reproduction is insufficient to compensate for adult mortality (Pulliam 1988, Robinson 1992). Simulation modeling suggests a forest interior bird population that occupies mature forest could decline up to 60% in landscapes managed by clearcutting. However, most of this decline was due to conversion of older stands to younger stands and not edge effects (Thompson In Press). The extent to which silvicultural practices exacerbate cowbird parasitism and nest predation will depend on the landscape context and whether edges created by these practices function as true ecological traps (Robinson et al. this proceedings, and Freemark et al. this proceedings).

Temporal Distribution of Forest Age-Classes

Management for sustained and constant yield of timber requires the maintenance of a balanced stand age-class distribution. This also provides a relatively constant availability of habitats. However, on lands with an unbalanced age class distribution the amount of early versus late successional habitats may vary greatly through time.

Species Turnover Within Stands

Regeneration or harvest cuts remove a mature forest community and replace it with a young forest community. Numerous studies have documented bird species turnover associated with regeneration practices (e.g. Conner and Adkisson 1975, Webb et al. 1977, Conner et al. 1979, Crawford et al. 1981, Franzreb and Ohmart 1978, Thompson and Fritzell 1990, and many others). These changes are largely due to changes in vegetation structure resulting from stand regeneration.

Tree species composition may also change with stand regeneration. The most obvious example is use of artificial regeneration where the composition of the future forest is largely determined by selection of planting stock. Planting stock can potentially be anything a site can support, including exotics. Past practices of converting low quality hardwood stands to pine, and the use of exotic tree species (because of greater potential timber yields), have been largely abandoned on public lands. However, artificially regenerated stands are still usually planted with few species. Changing the forest type or reducing tree species richness may change the NTMB community and reduce species richness. NTMB are often associated with hardwoods in conifer plantations, so control of competing hardwood vegetation may further limit the diversity of NTMB. Closed-canopy plantations often have limited vertical and horizontal vegetative-structural diversity, and as a result low NTMB diversity. Selection of a regeneration method can also affect natural regeneration. Regeneration methods range from clearcutting, which favors shade intolerant trees, to single tree selection which favors shade tolerant species. Small changes in tree species composition in eastern deciduous forests probably have little effect on breeding birds because of high tree species diversity and because similar vegetative-structure or life forms are maintained.

Residual Structure

Regeneration practices could result in felling of all trees (including snags) and disposal of slash. This can result in a stand (and forest over a rotation) deficient in downed dead woody material and snags, and with little variation in tree age and structure. Practices such as retention of snags, woody debris, and some live trees from previous stands will result in a more structurally diverse stand and provide habitat features needed by certain species (Dickson et al. 1983).

Rotation Age

Rotation age greatly affects stand structure. Rotation ages have usually been defined to maximize economic returns from a stand and typically range from 30 to 100 years, which is often shorter than the average frequency of natural disturbances. As a result, evenaged management often truncates succession and prevents development of structural characteristics associated with old stands (Edgerton and Thomas 1978, Bunnell and Kemsater 1990). This includes development of large trees, accumulation of downed and standing dead wood, and development of high vertical foliage density due to canopy layering. This could result in fewer cavity-nesting, bark-foraging, foliage-gleaning, or canopy-nesting species resulting in lower within-stand species diversity (Probst 1979).

Stand Succession

Avian density and diversity generally increase with succession following land abandonment (Johnston and Odum 1956, Karr 1971, Shugart and James 1973, Shugart et al. 1975). Bird response to stand regeneration often differs from natural succession. Breeding bird densities in regenerating forests are often similar to or much greater than those in mature stands, with densities often lowest in mid-successional pole-sized stands (Conner and Adkisson 1975, Conner et al. 1979, Dixon and Selquist 1979, Probst 1979, Horn 1984, Yahner 1986, Thompson and Fritzell 1990). Species richness and diversity may also show an early peak in regenerating stands (Conner and Adkisson 1975, Conner et al. 1979, Dixon and Selquist 1979, Probst 1979, Horn 1984, Yahner 1986, Thompson and Fritzell 1990)(Fig. 4). Early peaks in NTMB density and diversity in regeneration stands may be due to dense foliage of seedling-sapling trees and horizontal patchiness resulting from small patches of failed regeneration that create small herbaceous openings, as well as intruding species from adjacent older stands.

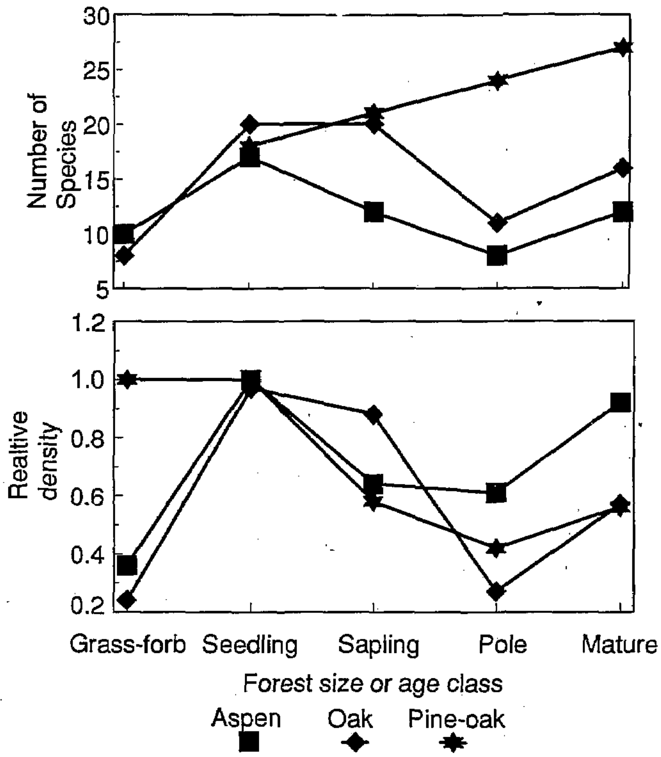

Figure 4. — Numbers of bird species and bird density in different size (age)-class evenaged stands. Results are from studies in aspen forests (Probst et al.1992), mixed oak forests (Conner and Adkisson 1975) and pine-oak forests (Conner et al. 1979). Density values from original papers were rescaled to 0-1.0 to be comparable.

Unevenaged Systems

Comparatively little information exists on forest bird response to unevenaged management or selection cutting. Evenaged regeneration methods result in near complete removal of the previous stand and as a result, a near complete turnover in breeding birds. Selection cutting maintains a specific tree-diameter distribution in the stand through periodic removal of selected trees. Hence, there is less change in vegetation structure and bird communities than under evenaged management. Selectively cut stands typically retain much of the mature forest bird community (although often at lower numbers), and provide habitat for some early successional species that use the ground-shrub-sapling layer. Whereas changes in density of canopy-dwelling species are typically small, they may be significant when summed across the landscape.

Landscape level impacts

Unlike evenaged management, selection cutting maintains a mature tree component at all times and does not create a mosaic of different-aged stands. This may benefit forest interior species because large tracts of forest with mature trees can be maintained. Selection cutting does not provide landscape-level temporal and spatial diversity that evenaged management does. This may benefit area sensitive or forest interior species that prefer mature forests but it will not provide habitat for species that require larger openings, evenaged stands, early seral conditions, or a diversity of evenaged stands.

Single and Multi-tree Gaps

Canopy gaps resulting from harvest of single trees or groups of trees provide habitat for a variety of migrant birds associated with young second-growth forests or gaps. In the Midwest , for example, the hooded warbler, Kentucky warbler, white-eyed vireo, and indigo bunting appear to be able to make use of small gaps created by single-tree and group selection whereas other species such as yellow-breasted chats, blue-winged warblers, and prairie warblers require large openings more typical of clearcuts (S.Robinson, unpubl. data, F. Thompson pers. obsv.). Species such as the Kentucky and hooded warbler are generally considered forest interior, area sensitive species adapted to internal forest disturbances such as tree-fall gaps. There is a dearth of information on the area-sensitivity of species requiring early successional forest or gaps. These canopy gaps may also be attractive to cowbirds and result in higher levels of brood parasitism. Cowbirds occur in greater numbers in selectively cut stands in Illinois and Missouri (S. Robinson unpubl data, Ziehmer 1992) than in uncut mature forest. Brittingham and Temple (1983) found increased brood parasitism near edges of forest openings as small as 0.2 ha, which is comparable to small group-selection openings. Brood parasitism and nest depredation were higher for a few species in selectively cut stands than uncut stands in Illinois (S. Robinson unpubl. data). If edge effects occur around group selection openings they could drive a local population to extinction; because while small, these openings could be much more numerous and widely dispersed than those created by clearcutting (Thompson, In Press).

Change in Stand Structure

Uneven aged stands have a well-developed understory and sub-canopy because of frequent canopy gaps. Presence of several well-developed vegetation levels and more complex habitat structure than in evenaged stands results in higher within-stand bird species diversity than in evenaged stands. Maintenance of a mature tree component at all times should provide habitat for canopy dwelling species at all times. However the loss of some large trees and potential large snags, is likely to result in lower densities of bark foragers, canopy-foliage gleaners, and cavity nesting species (e.g. Raphael et al. 1987). The few studies that have compared selection cutting or partial cuts to unlogged stands have in fact found that some bark foragers and foliage gleaners decrease and some ground and shrub foragers or nesters increase (Medin 1985, Medin and Booth 1989, S.Robinson unpublished data).

Species Composition

Single tree selection will primarily maintain shade tolerant trees and group selection tolerant and intermediate tolerant trees. As previously discussed, tree species composition may impact bird communities.

RECOMMENDATIONS

Populations are determined by an interaction between local habitat factors, the landscape context of habitats, and regional or continental context of habitat biogeography and population levels. We believe the only way to incorporate diverse needs of neotropical migratory birds with other resources, such as timber, is a hierarchial approach that begins at a continental scale, identifies opportunities at regional scales, sets composition and structure goals at a landscape scale and management unit scale, and matches management prescriptions to goals at a habitat-stand scale. Single resource or single species approaches (including indicators) originating at stand or management unit level scales will not yield a holistic, comprehensive management strategy. We present this approach in the context of incorporating NTMB needs into forest management but it is valid for all resources including biodiversity in general.

Step 1: Establish Regional Context. (Scales: multi-state, province, eco-region).

Establish the management area in a regional context by identifying the spatial patterns of ecosystems and NTMB ranges in the region. Locate or prepare a complete list of NTMB for the region with information on their status, habitat associations, and geographic location. Determine desired regional ecosystem-vegetation patterns. Consider historical and current vegetation patterns, trends in vegetation types, and habitat needs of NTMB on the regional list and their status. Finer scale, local level management should occur with knowledge of species or ecosystems status in the region, and should complement regional goals.

Step 2: Determine Desired Landscape Composition and Structure (Scales: landform, watershed, mountain range, national forest or refuge).

Determine the desired amounts and distribution of forest types, forest age classes, and non-forest habitats. These should complement regional goals. Consider natural tendencies such as site capability, natural disturbance frequency and pattern, and successional pathways. Next consider NTMB needs in terms of habitats including spatial relationships (size, shape, juxtaposition).

Because of diverse habitat needs and edge or area sensitivity of NTMB, landscape-level forest planning is extremely important to NTMB conservation. At this level, the simplest approach is a coarse filter approach that assumes that a representative variety of ecosystems will contain the vast majority of species in a region (Hunter et al. 1988, Hunter 1990). For instance, management and restoration efforts might be directed toward regionally rare ecosystems such as bottomland hardwoods, lowland conifers, oldgrowth, and savannahs. This will address needs of regionally rare species, including NTMB. However, concerns for impacts of forest fragmentation and edge on NTMB, population size and viability, as well as source-sink relationships require careful spatial planning for even common habitats such as upland forest. In extensively forested regions or landscapes cowbirds and predator numbers may be sufficiently low that edge effects are not a concern. In these areas, silviculturally sound, regulated harvest that maintains natural forest types should be compatible with NTMB conservation. In highly fragmented, edge dominated landscapes, forest habitats may already be saturated with cowbirds and predators, and edge effects resulting from timber harvest inconsequential. However, in the wide range of landscapes between these extremes careful spatial planning may be required. For instance, some large blocks of unfragmented forest should be reserved from timber harvest and other anthropogenic disturbances to support productive, source populations of forest interior NTMB. Harvest and other activities could be concentrated in more fragmented parts of these landscapes. This planning would produce a diversity of landscapes, some with undisturbed, mature-contiguous forest and others with successional diversity.

On areas where timber is harvested a balance of selection cutting and evenaged systems should be used to create small openings for gap species, large openings for early successional forest migrants, and a balanced age-class distribution to maintain sufficient mature forest habitats. Where late successional or edge-sensitive species are featured single-tree selection or evenaged systems with long rotations should be used. Larger regeneration cuts and longer rotations will increase amount of late successional forest and decrease amount of early successional forest and their edges in the landscape.

Step 3: Establish Management Unit Goals (Scales: An administrative unit, compartment, *group of habitats*).

Set vegetation composition and structural goals across the management unit including forest age classes, vertical stratification, horizontal pattern and special features. These may be uniform or varied based on species needs and management unit context. Maximizing diversity at this scale could compromise landscape and regional diversity by fragmenting mature forest or homogeneous forest habitats. Instead, manage to meet landscape and regional diversity goals for forest types and ageclasses, and to compliment management in other management units. Maintain natural forest type diversity. Examine spatial relationships of stands based on elements of structure and composition. Group regeneration cuts to minimize impacts on area and edge-sensitive NTMB. In coniferous forest types maintain deciduous components where it is declining. Mix silvicultural options across units unless specific concerns dictate otherwise.

Step 4: Develop Stand-Habitat Level Management Prescriptions (Scale: habitat or stand).

At this level the manager needs to use the best practices to compliment goals established for the management unit and landscape, and to match site capabilities and natural tendencies. Prescriptions should address NTMB diversity and habitat requirements of priority species. Priority species will vary depending on landscape and region as established in steps 1-3. For instance, in many Midwest landscapes forest interior and prairie species will be priority while in some New England landscapes early successional migrants may be more important. We offer the following suggestions for enhancing specific components of the NTMB community as well as diversity at the stand level. However, we reiterate the need to manage stands to address goals set at larger scales.

<u>NTMB Diversity</u> . Do not maximize within-stand diversity at the expense of landscape or regional diversity. For example, selection cutting may produce high within-stand diversity but an entire landscape of selectively cut unevenaged forest would be lacking some NTMB. A better approach might be to use a mix of silvicultural practices (even and unevenaged) and reserve some areas from harvest. Maintain deciduous and coniferous components in mixed stands. Limit control of hardwoods in regenerating conifer plantations. Use variable and wider spacing in conifer plantations.

<u>Area or edge-sensitive NTMB</u>. Increase stand size and regeneration cuts to benefit early and late successional species. Cluster regeneration cuts when possible. Emphasize evenaged systems and single-tree selection cuts. Reserve some of the least fragmented areas from timber harvest.

Cavity nesting and bark foraging NTMB. Lengthen rotation ages in evenaged systems and increase proportion of larger trees (decrease q-values) in unevenaged systems. Retain snags and live residual trees in regeneration cuts.

Canopy gleaners. Lengthen rotation ages in evenaged systems and increase proportion of larger trees (decrease q-values) in unevenaged systems.

Ground foragers and understory gleaners. Mix silvicutural systems to provide regenerating evenaged stands and selectively cut unevenaged stands. Use wide and variable spacing in plantations with minimum hardwood control.

Early successional species. Use evenaged systems . Shorten rotations.

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