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MODELING THE CUMULATIVE EFFECTS OF ASPEN
MANAGEMENT PRACTICES ON TIMBER AND WILDLIFE AT
MULTIPLE SPATIAL AND TEMPORAL SCALES

presented by

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of the requirements for the

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Major Professor's Signature

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MODELING THE CUMULATIVE EFFECTS OF ASPEN MANAGEMENT PRACTICES ON TIMBER AND WILDLIFE AT MULTIPLE SPATIAL AND TEMPORAL SCALES

VOLUME I

By

Alexandra B. Felix

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ABSTRACT

MODELING THE CUMULATIVE EFFECTS OF ASPEN MANAGEMENT PRACTICES ON TIMBER AND WILDLIFE AT MULTIPLE SPATIAL AND TEMPORAL SCALES

By

Alexandra B. Felix

To effectively manage wildlife and timber resources, managers and planners need to understand how different ecological conditions and management practices affect forest characteristics and subsequently how wildlife respond. To address this need, I refined an ecological classification system used to define habitat types, and investigated the potential spatial distribution of aspen, ecological differences associated with aspen in 3 age classes (20–29, 50–59, > 70) and 6 habitat types, avian community associations, ruffed grouse selection of aspen for drumming habitat, and the cumulative effects of aspen management practices on wildlife and timber in a 12,300 km^2 area in Michigan's Upper Peninsula from 2004–2006. The goals of the project were to understand how forest management may affect the structure of vegetation within ecosystems, the distribution of resources within the landscape, and wildlife response to those changes; and to investigate the feasibility of different aspen management scenarios on timber sustainability and maintenance of wildlife habitat.

Differences in vegetation structure and composition were observed among age classes and habitat types ($p < 0.10$); most notable were stem and shrub density, herbaceous cover, and conifer cover. These differences contributed to identification of 7 avian community associations and differences in grouse drumming habitat selection. Grouse selection was higher ($p < 0.05$) for young (0–29-year-old) and old (> 50 years)

aspen and aspen on habitat types supported by mesic loamy soils. Grouse did not select drumming areas in non-aspen vegetation types and in aspen growing on xeric sandy soils.

I used goal programming to develop a timber harvest schedule for 10 decades that minimized the deviation (in terms of area) from meeting the Michigan Department of Natural Resources' goal of establishing and maintaining an even-age class distribution of aspen in 8 age classes in 9 habitat types under 3 management scenarios (i.e., harvest all aspen by 80 years, harvest all aspen > 60 years, and intensively harvest aspen by requiring ≥ 60% to be harvested from the 40-year age class). The spatial feasibility and spatial and temporal consequences of the harvest schedule was evaluated through simulations using the program HARVEST. The goal was feasible by decade 8 under scenario 1 (i.e., harvest by 80 years), it was attainable in 6 habitat types by decade 8 under scenario 2 (i.e., harvest aspen > 60), and it was not attainable under intensive management. Meeting the goal increased habitat availability for most avian communities, but decreased the amount of highly selected grouse drumming habitat. Aspen volume harvested was sustainable at168,000 cords/decade once the goal was met.

Within many state and federal agencies, forest management goals include sustainable management to meet a variety of objectives. The cumulative effects of management decisions are what determine how well long-term forest management goals are being met. The results of this project provide quantitative answers to questions such as how much aspen to cut, where can it be cut, and what are the effects on timber production and wildlife at multiple levels of biological organization. With increasing demands on natural resources, answers to such questions are essential for agencies and other landowners to sustain timber and wildlife resources.

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CHAPTER 1

INTRODUCTION

Wildlife biologists and managers face many issues related to the utilization of forest resources and wildlife relationships within forest ecosystems. Historically, forest management focused primarily on organizing and managing lands to grow and harvest timber products (Kessler et al. 1992, Nyland 2002). Since the mid 1960s, however, a new philosophy of forest management has developed, which includes managing forests to produce timber and sustain viable forest ecosystems for multiple purposes (e.g., wildlife habitat, recreation, timber) (Nyland 2002). Sustaining forest ecosystems to meet a diversity of forest and wildlife objectives is a challenging task for natural resource managers. To meet this challenge, managers need to enhance their understanding of the ecological factors that influence vegetation structure, composition, and distribution; how specific forest manipulations and natural disturbances affect temporal changes in forest characteristics across landscapes; and subsequently, how wildlife that depend on these dynamic systems respond.

DeStefano (2002) reported that there is a national concern among biologists about the alteration of forest vegetation structure due to timber harvesting and its effects on wildlife populations and communities. To address this concern, a high research priority includes obtaining information on wildlife species' life requisites and habitat relationships within forests at multiple spatial (DeStefano 2002) and temporal scales (Bissonette and Storch 2007). There is still much information to be learned about forests, particularly in forests that are not well represented in the landscape, to understand their ecological contributions and functions at multiple levels (i.e., stand, community, landscape). This information especially becomes critical as agencies develop

management plans within an ecosystem management framework. That is, one which considers maintaining ecological processes and properties of systems at multiple spatial scales, and considers social and economic objectives. Kessler et al. (1992), for example, explained that a major challenge facing natural resource scientists is how to sustain natural systems and human commodities in view of the growing human population and its associated demands on natural resources. Therefore, natural resources management and research should focus on understanding function and processes that occur within systems and how they are affected by patterns of resource use and cumulative effects of management (Kessler et al. 1992).

Development and refining of ecosystem management paradigms must incorporate methods to sustain ecosystems but not diminish the importance of products produced by those systems. Aspen (*Populus* spp.), for example, is a commercially valuable timber resource that is used to produce pallets, plywood, and wood pulp for paper, cardboard, and boxes. Aspen [quaking (*P. tremuloides*) and big-tooth (*P. grandidentata*)] comprises 47% of roundwood (i.e., logs, bolts, or other round sections cut from trees) harvested for pulpwood, which in turn constitutes more than half the industrial timber products harvested annually in the Lake States (Piva 2003). The aspen forest type in the western Upper Peninsula (UP) of Michigan ranks second to the beech-maple forest type in area, stem density, and net standing volume (Leatherberry 1994). As such, aspen is important in sustaining pulpwood production in the western UP, which was the top pulpwood-producing region of Michigan in 2002 (i.e., 43% of roundwood pulpwood harvested in Michigan came from this region) (Piva 2003). Additionally, 308,000 cords of aspen pulpwood is produced annually from the western UP (Piva 2003) and is worth approximately $18.5 million [at a value of $60 per cord delivered to the mill (Miller 1998)].

Aspen is a valuable resource not only economically, but also ecologically. Several wildlife species, for example, depend on aspen to meet their life requisites (Stelfox 1995). For instance, ruffed grouse (*Bonasa umbellus*) utilize catkins from mature male aspen as their staple winter food source (Gullion and Svoboda 1972). White-tailed deer (*Odocoileus virginianus*) rely heavily on aspen leaves and new shoots for spring and summer foraging (Kohn and Mooty 1971). Parsons et al. (2003) found that bat species in British Columbia depend on the decay-causing fungus (*Phellinus tremulae*) in old aspen to create cavities for roosting habitat. Pojar (1995) found bird communities including neotropical migrants to be associated with specific aspen seral stages. Other wildlife such as woodcock (*Scolopax minor*), beaver (*Castor canadensis*), woodpeckers, and snowshoe hares (*Lepus americanus*) also obtain some life requisites from aspen stands.

Although aspen may live past 100-years old, most of the aspen in Michigan show signs of deterioration over 60 to 70-years old and lose their commercial value (Graham 1963). If aspen is not harvested, shade tolerant species [e.g., red maple (*Acer rubrum*), American beech (*Fagus grandifolia*), white pine (*Pinus strobus*), balsam fir (*Abies balsamea*)] eventually will dominate the stands. Letting aspen succeed to older age classes where shade tolerant species dominate may make aspen regeneration difficult on those sites. Because aspen is commercially valuable, however, most aspen in the Great Lakes Region are harvested on 40- to 60-year-old rotations depending on site quality (Brinkman and Roe 1975, Nyland 2002). Most aspen stands in the western UP are in the

11 to 20-year-old (27%) and 21 to 30-year-old (22%) age classes, respectively (Doepker et al. 2002). Other age classes of aspen are not as well represented in the landscape. Approximately 8% of all aspen in Iron and Dickinson counties, for instance, is 40 to 60-years old; 20% of aspen is 60 years or older; some may be inaccessible for harvesting because it occurs in lowland habitat types. To increase the diversity of aspen age classes for future timber and wildlife values, Doepker et al. (2002) recommended increasing the amount of 40 to 60-year-old aspen to represent 40% of aspen in the landscape. Although the timber value of older ages classes depreciates, old aspen stands still are likely to provide critical wildlife habitat components (Stelfox 1995). Because 40 to 60-year-old aspen stands are typically harvested, older age classes of aspen are not as well represented in the landscape and wildlife values and ecosystem integrity associated with occurrence of these age classes, in turn, may not be represented. Subsequently, Michigan Department of Natural Resource (MDNR) managers in the western UP are developing plans to maintain a diversity of aspen age classes within the landscape to sustain timber yield, wildlife values, ecosystem integrity, and social and economic values associated with the aspen forest (R. Doepker, MDNR, personal communication).

In addition to maintaining a diversity of aspen age classes in landscapes, another one of Michigan's aspen management objectives is to maintain the old aspen component for wildlife use, biodiversity, and to meet ecosystem-management goals without compromising timber harvest yield (Doepker et al. 2002). It would be beneficial, then, to quantify the structure and composition of old aspen (> 50 years), determine its importance to wildlife and its role in ecosystems, and model the effects of aspen harvest strategies on wildlife species and communities. This information would help managers understand the impacts of applied aspen management practices on biological processes and the wildlife communities which depend on them. This information will also assist managers in managing Michigan's forest at a sustainable level and maintain certification through the Forest Stewardship Council and the Sustainable Forestry Initiative.

The following are the overall goals of this project: 1) Quantify landscape composition, distribution and temporal changes of habitat types that could support aspen in the western UP of Michigan. 2) Determine how habitat suitability, and thus wildlife species and communities respond to changes in aspen management practices at the stand and landscape levels. 3) Quantify the effects of harvest simulations on wildlife habitat suitability, and selected wildlife species (e.g., white-tailed deer, ruffed grouse), communities (e.g., plant, avian), and timber production.

The first chapter of this dissertation describes procedures used to quantify landscape composition, distribution of habitat types, and structure and composition of aspen within different age classes and habitat types. The information presented demonstrates the value of understanding spatial patterns and temporal changes of aspen forests in the western Upper Peninsula for planning ecosystem-based management objectives.

The second and third chapters quantify differences in wildlife communities, species, and timber potential within aspen in different habitat types and age classes. These chapters relate vegetation structure and composition within various aspen stands to population-level performance measures such as ruffed grouse drumming activity; species-level measures such as presence/absence and frequency of occurrence; and community-level measures such as songbird species richness.

In the fourth chapter, I describe development of aspen harvest simulation models and projections of harvest strategies on wildlife communities over time and discuss the importance of these simulations for addressing Michigan's ecosystem management objectives. In this chapter, units of measurement are expressed in English units to reflect use by forest managers who typically use English units. The representation of data in different units reflects use of the research results by multiple stakeholders.

STUDY AREA

The study area was a 12,300 km^2 area located in the western Upper Peninsula (UP) of Michigan, which includes Baraga, Dickinson, Iron, and Marquette counties (Figure 1.1). Sites selected for assessment were located within the Escanaba River State Forest and the Copper Country State Forest. This region of Michigan accumulated 76.2-86.4 cm of precipitation annually and averaged 4.5 °C (Sommers 1977). Soils in the western UP were dominantly spodosols and bedrock rich in iron occurred throughout much of the area.

Well-drained sands and loams typically supported hardwood forests dominated by maple (*Acer* spp.) in late-successional stages. Spruce (*Picea* spp.) and balsam fir (*Abies balsamea*) occurred frequently as components of hardwood stands growing on sandy soils. Other sub-dominant species in hardwood stands on loamy soils included basswood (*Tilia americana*), ironwood (*Carpinus caroliniana*), or American elm (*Ulmus americana*). Dry, sandy soils supported oak (*Quercus* spp.), white pine (*Pinus strobus*), and red pine (*Pinus resinosa*). Poorly-drained areas were interspersed throughout the region and were typically dominated by northern-white cedar (*Thuja occidentalis*), spruce, fir, and tamarack (*Larix laricina*; Albert 1986). Early successional and aspen (*Populus* spp.)-dominated forests were also interspersed throughout much of the area (Sommers 1977).

Prior to European settlement, natural disturbances in the western UP were most frequently from wind or ice storms, which created gaps within stands. Less common stand-replacing disturbances such as tornadoes or other intense storm systems occurred at 1000-year intervals (Frelich and Lorimer 1991). Historical disturbance patterns resulted in presettlement forests dominated by mixed conifers interspersed with northern hardwoods, wetlands, and xeric pinelands. Changes in land use and disturbances over the past 150 years has increased the proportion of maple and aspen, and resulted in the decline of mesic conifers, beech (*Fagus grandifolia*), and yellow birch (*Betula alleghaniensis*; Zhang et al. 2000). According to current land cover data (MDNR 2003), approximately 11% of the study area occurs in northern hardwood vegetation types, 13% is dominated by pines, and 20% occurs in upland mixed coniferous/deciduous vegetation (Table 1.1). This study focused on those areas in northern hardwood vegetation types.

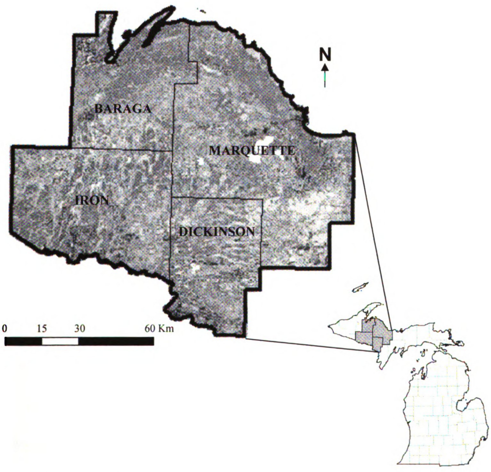

Figure 1.1. Location of a 12,3000 km^2 study area in the western Upper Peninsula of Michigan.

Table 1.1. Percent of study area (Baraga, Dickinson, Iron, and Marrquette counties) in different of cover types in the western Upper Peninsula, Michigan circa 1999.

Cover Type[1]	**Percentage**[1]
urban	1.95
agriculture	5.34
herbaceous openland	1.80
upland shrub/low density trees	28.69
northern hardwood	10.56
oak association	0.54
aspen association	4.89
upland deciduous	5.48
pines	12.77
other upland conifers	3.08
upland mixed forest	20.45
water	0.14
lowland forest	3.83
floating aquatic	0.05
lowland shrub	0.42
	100.00

[1]Information was obtained from IFMAP/GAP data, Michigan Department of Natural Resources, Forest, Mineral and Fire Division available at http://www.mcgi.state.mi.us/mgdl/?rel=thext&action=thmname&cid=5&cat=Land+Cover+2001.

CHAPTER 1

QUANTIFYING COMPOSITION, DISTRIBUTION AND TEMPORAL CHANGES OF HABITAT TYPES THAT CAN SUPPORT ASPEN IN THE WESTERN UPPER PENINSULA, MICHIGAN

The spatial and temporal distribution and availability of ecological resources in landscapes has important implications for wildlife and forest management. It is difficult, for instance, to understand the dynamic relationships between wildlife and their habitats without understanding the underlying regulatory mechanisms within landscapes and the processes by which habitat within landscapes changes over time. This type of information is especially critical as natural resources agencies develop management plans within an ecosystem management framework to sustain forests for multiple purposes.

Current land-cover classifications and maps are used widely by natural resource managers and planners to understand wildlife-habitat relationships and plan management activities, but they do not identify vegetation structure, potential vegetation trends and successional dynamics, or vegetation types on distinctive soils that may have different wildlife values (Felix et al. 2007). Consequently, it is difficult to use only land cover to evaluate wildlife species responses to management or to ecosystem changes because assumptions about potential vegetation and successional dynamics can lead to unrealistic predictions.

Recently developed approaches using habitat type classifications allow evaluations of land-use and land-cover based on biotic and abiotic properties of ecosystems. Daubenmire (1966:296) was regarded as the first to define "habitat type". He stated that habitat types have "equivalent climax potentialities" because they occur in areas with the same ecological, geological, and climatic attributes (Daubenmire 1966:

297). Habitat-type classifications group communities and their environments into categories useful for management interpretation (Kotar and Burger 2000). These classifications allow an understanding of successional trajectories and distribution of ecological communities that reflect inherent site capabilities, disturbances, and potential response to management.

A useful approach for assessing spatial and temporal changes in vegetation is to use ecological classification systems (e.g., habitat-type classification) to describe the potential and current ecological conditions affecting vegetation patterns. Abiotic ecological characteristics such as climate, landforms, and soil characteristics (e.g., nutrient content, moisture, texture) influence differences in vegetation structure, composition, and successional patterns within different habitat types (Crawford 1950, Daubenmire 1966). Although the boundaries and dynamics of habitat types are not static, they define a relatively narrow range of environmental conditions (Kotar and Burger 2000) that can provide a basis for predicting vegetation change over time within natural successional pathways or as a result of certain land-use and management practices. Understanding temporal changes in vegetation distribution, composition, and structure is critical for developing forest management models, which can be used for planning and evaluating effective practices to meet ecosystem management objectives.

Because Michigan Department of Natural Resources (MDNR) managers in the western Upper Peninsula (UP) are developing plans to maintain a diversity of aspen age classes for multiple management objectives, it would be beneficial to use habitat-type classification systems to identify areas that can potentially support aspen, and determine how the structure and composition of aspen may change throughout time. Understanding the ecology of habitat types that can support aspen will help facilitate more ecologically-based management prescriptions.

OBJECTIVES

Specific objectives for this chapter were to

1) Identify the distribution and potential successional pathways of habitat types in the western UP, Michigan.

2) Assess differences in aspen stand structure and composition within and among different age classes and habitat types.

3) Determine successional changes of aspen in different habitat types.

METHODS

Landscape classification

Areas that can potentially support aspen were identified from a habitat-type database that described ecological boundaries and successional trajectories for the western UP (Felix 2003). Habitat type boundaries were updated with spatial information (IFMAP; Integrated Forest Monitoring and Assessment Prescription) that became available in 2003 (MDNR 2003), and validated with 70 random points ground-truthed during the 2004 summer field season. Habitat types were classified based on the Coffman et al. (1980) guide to habitat type classification for the western UP. The distribution of current aspen stands throughout the study area was determined from IFMAP. Locations, and ages of specific aspen stands on state lands were identified from Operations Inventory datasets obtained from the MDNR. Most forest compartments have been digitally mapped within the study area. From these datasets, I used ArcView 3.2 and determined the proportion of state lands in different aspen age classes and habitat types.

Selection of stands and experimental design

Aspen occurs as early successional vegetation in several habitat types in the western UP. For example, habitat types characterized by poorly-drained soils that support cedar *(Thuja canadensis),* white spruce *(Picea glauca*), black spruce (*Picea mariana*), and balsam fir (*Abies balsamea*) in mid- to late-successional stages support aspen in early stages (Coffman et al. 1980). Aspen also represents early stages of habitat types characterized by well-drained soils that support northern hardwoods (Coffman et al. 1980). Aspen stands growing in lowland habitat types in the western UP likely will not undergo any forest manipulation because it is not feasible to operate logging equipment in these poorly-drained soils (R. Doepker, MDNR, personal communication). Therefore, aspen stands were selected in upland habitat types that have been logged in the past or may be logged in the future.

To characterize the range of conditions of different age classes of aspen within different habitat types across the western region of the UP, I selected replicated stands of different age classes within distinct upland habitat types. The selected habitat types were named with a genus of a tree species that showed the strongest tendency to dominate a community on that site in the absence of disturbance, and the genus of characteristic understory species (Coffman et al. 1980). *Tsuga-Maianthemum* (TM; hemlock-wild lily-of-the-valley) occured on well-developed sands to loam textured mesic soils, *Acer-Tsuga-Dryopteris* (ATD; maple-hemlock-fern spp.) occured on very fine podizolized mesic to well-drained sand, and *Acer-Viola Osmorhiza* (AVO; maple-violet-sweet cicely) occured on loam to silt loam mesic to well-drained soils (Coffman et al. 1980) (Table 2). Within each habitat type, I investigated 3 age classes of aspen (20 to 29-years, 50 to 59-years, >70-years), with at least 3 replicate stands in each age class. The 20-year age class was selected to represent conditions prior to typical harvest age. The 50-year age class was selected to represent conditions at typical harvest age, and older aspen was selected to represent late-successional aspen.

Specific stands for the study were selected based on similar management objectives and dominant overstory type as indicated from the Operations Inventory data,

and similar interior:edge ratios. In all selected stands, aspen was the management objective and dominant overstory type. I used FRAGSTATS (McGarigal et al. 2002) to calculate interior:edge ratios for all stands in the Operations Inventory database. Potential stands to sample in the 2004–2005 and 2005–2006 field seasons were selected based on similar interior:edge ratios to minimize differences deviating from edge effects. Potential stands were visited prior to final stand selection to assess accessibility and validate habitat type and age class assignment. Occasionally, a stand was eliminated as a candidate for analysis because I determined that it obviously occurred in a habitat type other than the 3 initially selected for this study, it was incorrectly classified as aspen, or it had been harvested. Different stands were selected for the 2004–2005 and 2005–2006 field seasons.

In the initial study design (described above), I selected aspen stands within 3 upland habitat types that were the most predominant in the western UP landscape (as determined from the spatial habitat type database developed by Felix 2003). Following field data collection that quantified vegetation composition and structure, availability of IFMAP data, and initial data analysis, I determined that selected stands actually represented 6 distinct habitat types instead of only the original 3 (TM, ATD, AVO). Additional samples occurred in *Acer-Osmorhiza-Caulophyllum* (AOC; maple-sweet cicely-blue cohosh), *Acer-Quercus-Vaccinium* (AQV; maple-oak-blueberry spp.), and *Quercus-Acer-Epigaea* (QAE; oak-maple-trailing arbutus) habitat types. The AOC habitat type occurred on loam to silt-loam mesic soils similar to those of the AVO habitat type. The AQV and QAE habitat types occurred on more xeric, well-drained sandy soils.

Vegetation Sampling

Several vegetation variables were selected to measure the range of ecological conditions among different aspen age classes and habitat types. Variables quantifying live vegetation structure included basal area (m^2/ha) and stem density (#/ha) of overstory coniferous and deciduous trees, diameter and height of overstory trees, shrub height, shrub density, and percent vertical cover of coniferous and deciduous overstory trees, vegetation in the shrub layer (2–5m), and herbaceous vegetation. Variables quantifying structure of dead vegetation included decay, density, and volume (m^3/ha) of down woody debris (DWD); decay, density, diameter (cm), and height (m) of snags; and decay, density, diameter (cm), and height (cm) of stumps. Dead vegetation was considered DWD if it was > 10 cm in diameter and > 30.5 cm long. Variables quantifying species composition included stem density and basal area of each overstory tree species within each sampled age class and habitat type.

Three points were randomly selected within each stand at which all sampling occurred. Points were > 100 m away from the edge and were considered the center of each sampling plot. I used a plot design and line intercepts to measure forest attributes. Density of snags and tree stems was measured in 10 x 50-m plots (Table 1.2). Shrub stem density, density of stumps and down woody debris, and tree diameter was measured within 10 x 25-m plots. I used a clinometer to measure height of trees within 10 x 25-m plots; shrub height was measured with a meter stick. Canopy cover was measured using the line-intercept method (Canfield 1941), with 25-m intercepts. Diameter at breast height (DBH) was measured with a Biltmore stick. Basal area (m^2/ha) was determined using a 10-factor prism and also was calculated from DBH (diameter at breast height) and stem density data for comparison (Table 1.2). Decay status of snags, DWD, and stumps was determined following procedures from United States Department of Agriculture, Forest Service (Table 1.3). Decay status ranged from 1–5; an assignment of 1 indicated that bark was still intact and twigs were present, 2 indicated that twigs were absent and texture of wood was partially soft, 3 indicated little bark present and wood had a soft texture, 4 indicated that no bark was present and wood texture was small, blocky pieces, and 5 indicated that the wood was soft and powdery.

To compare timber volume between and among age classes and habitat types, I joined the Operations Inventory database with the habitat type database and determined volume (cords) within different stands. I calculated average volume (m^3/ha, as calculated from number of cords/acre in the database; 1 cord = 3.63 m^3 of bark, wood, and air space) and standard errors for different age classes and habitat types. I used the Operations Inventory datasets to increase the sample size for analysis, and to use volume data that was collected by DNR personnel, because those data will continue to be collected by DNR personnel for the Operations Inventory database. Stands in the 20-year age class were excluded from this analysis because they typically are not harvested that young.

Data analysis

In the initial study design, each stand represented the evaluation unit. It was assumed that each stand would represent characteristics of a specific habitat type and stand boundaries would not overlap > 1 habitat type. After the first field season, however, I observed that some stands overlapped 2 habitat types or vegetation types

(Figure 1.2). For example, 2 of 3 sampling points within a stand may have represented 50-year-old aspen in a specific habitat type. The third point however, may have represented a different habitat type or vegetation type.

Two primary problems occurred upon observing that some stands overlapped > 1 vegetation type or habitat type. First, averaging values of 3 samples taken within each stand would not accurately reflect the range of conditions of vegetation structure and composition within a specific age class and habitat type. Second, if I used data from only the 2 points that most represented characteristics of a specific age class and habitat type, I would be throwing out data and would not have adequate sample size (≥ 3) for statistical analyses. Therefore, to address these problems, in 2005 I decided to make age classes of specific habitat types (versus stands) the evaluation unit, and the pre-established points within different aspen age classes were considered the samples.

A problem that emerged by making the evaluation unit age class of specific habitat types was that of spatial autocorrelation. Spatial autocorrelation essentially means that samples occurring near each other are more related than more distant samples. Because samples were initially selected with stands, they were "clustered" together within a specific habitat type and age class (Figure 1.2). Clustering (or autocorrelation) may mean that all samples were not truly independent because they occurred in stands with potentially different management. Having non-independent samples violates the assumptions of independence for assessing differences using analysis of variance (ANOVA). However, because I initially selected stands with the same management objective (i.e., aspen) and management history (i.e., clearcuts), I assumed points were still independent.

I used the Shapiro-Wilk procedure to test for normality of vegetation attribute data. Many of the variables tested were non-normally distributed, so I used appropriate nonparametric tests (i.e., the Kruskal-Wallis one-way ANOVA) to compare vegetation structure and composition among age classes and habitat types. Mean values and standard errors of vegetation attributes were calculated and presented for each age class and habitat type to make comparisons to data in the literature regarding wildlife-habitat relationships that may be occurring across the study region.

Table 1.2. Methods used to measure forest stand attributes in aspen stands in Michigan's Upper Peninsula.

Forest Attribute	Method
tree stem density (#/ha)	10 x 50 m plots
shrub stem density (#/ha)	10 x 25 m plots
canopy height (>5 m)	Haga altimeter in 10 x 25 m plots
shrub height (<5 m)	meter stick in 10 x 25 m plots
snag density (#/ha)	10 x 50 m plots
% canopy cover (>5 m)	25 m line intercepts
% shrub cover (<5m)	25 m line intercepts
% herbaceous cover (<1 m)	20 m line intercepts
tree dbh (cm)	10 x 25 m plots
density of stumps and DWD	10 x 25 m plots
basal area (m^2/ha)	calculated from stem density, dbh

Table 1.3. Codes for determining decay status of down woody debris, snags, and stumps. These were adapted from decay class codes used by the United States Department of Agriculture, Forest Service.

Code	Description
1	Bark intact, twigs present. Texture is intact. Wood is original color.
2	Bark intact, twigs absent. Texture is intact to partially soft. Wood is original color.
3	Trace of bark. Twigs are absent and texture is hard large pieces. Color of wood is original to faded
4	Bark and twigs are absent. Texture of wood is small, soft, blocky pieces. Wood is light brown to faded brown or yellowish.
5	Bark and twigs are absent. Texture of wood is soft and powdery. Color of wood is faded to light yellow or gray.

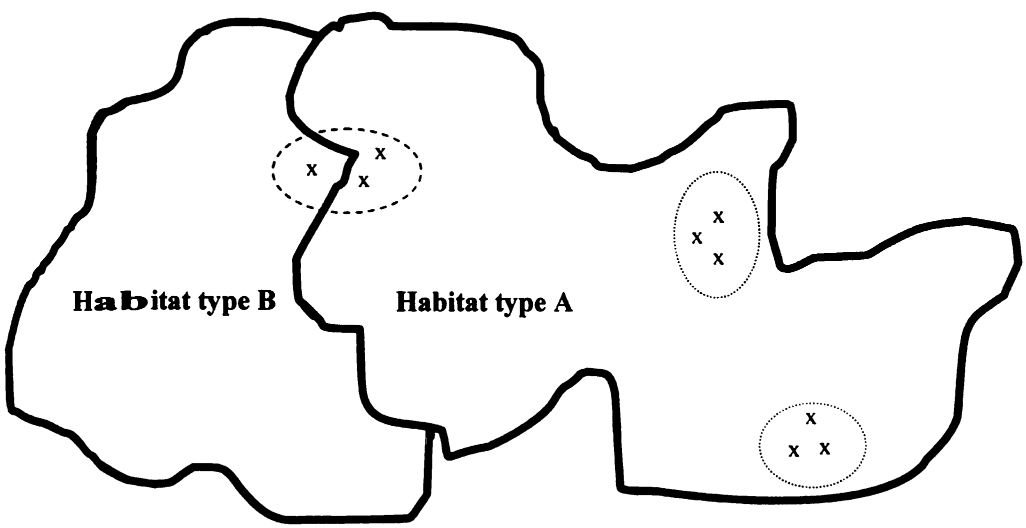

Figure 1.2. Example of a stand (represented by a dashed ellipse) that overlaps boundaries of 2 habitat types. Samples (x) within such stands would not represent the range of conditions of one specific age class and habitat type. If stand boundaries were ignored for analysis, sampled points would not be independent and thus would not represent the ecological conditions of their respective treatments.

RESULTS

Landscape classification

Sixteen habitat types were identified in the study area from the Coffman et al. (1980) classification guide (Figure 1.3, Table 1.4). Habitat types characterized by xeric, excessively-drained sandy soils included: *Pinus-Vaccinium-Deschampsia* (PVD; pine-blueberry-hair grass), *Pinus-Vaccinium-Carex* (PVC; pine-blueberry-sedge spp.), *Quercus-Acer-Epigaea* (QAE; oak-maple-trailing arbutus), *Acer-Quercus-Vaccinium* (AQV; maple-oak-blueberry), and *Tsuga-Maianthemum-Vaccinium* (TMV; hemlock-wild lily-of-the-valley-blueberry) habitat types. The PVD and PVC habitat types were dominated by jack pine and/or red pine, and may have contained some white pine as a minor component of the overstory. Sedges, blueberry species, sweet fern, bracken fern, and wintergreen frequently occurred in the understory of PVD and PVC habitat types. Red oak and red maple dominated later successional stages of QAE habitat types, and white spruce and pine species were present as minor components. Bracken fern, wintergreen, blueberry, and grasses frequently occurred in the understory. The AQV habitat type had a similar composition as the QAE habitat type, but balsam fir and white spruce could comprise more of the understory in AQV than in QAE. In the TMV habitat type, hemlock and red maple dominated overstory composition of climax stages. Sugar maple, white spruce, balsam fir, and red oak were minor components of stands in the TMV habitat type. Understory vegetation was dominated by bracken fern.

Mesic habitat types characterized by well-drained soils included: *Tsuga-Maianthemum* (TM; hemlock-wild lily-of-the-valley), *Acer-Tsuga-Drypoteris* (ATD; maple-hemlock-spinulose shield fern), Acer-Viola-Osmorhiza (AVO; maple-violet spp.-

sweet cicely), *Acer-Osmorhiza-Caulophyllum* (AOC; maple-sweet cicely-blue cohosh), and *Tsuga-Acer-Mitchella* (TAM; hemlock-maple-partridgeberry) habitat types. All of the mesic habitat types supported typical northern hardwood species in late successional stages including: red maple, sugar maple, beech, basswood, white spruce, and balsam fir. The TM habitat type, however, supported more spruce and fir than other hardwood habitat types. The ATD, AVO, and AOC habitat types supported more basswood, black cherry, American elm, and white ash than TM habitat types. Because AVO and AOC habitat types occurred on more loamy soils, the understory of those habitat types tended to be thick. The TAM habitat type occurred on clay soils and was not common in the study area. Wild lily-of-the-valley was a characteristic understory plant of the TM habitat type. Spinulose shield fern was characteristic of the ATD habitat type, and sweet cicely and violet species were characteristic of AVO and AOC habitat types.

Habitat types on poorly-drained soils included: *Tsuga-Maianthemum-Coptis* (TMC; hemlock-wild lily-of-the-valley-goldthread), *Fraxinus-Mentha-Carex* (FMC; ash-mint-sedge), *Fraxinus-Impatiens* (FI; ash-jewelweed), *Tsuga-Thuja-Mitella* (TTM; hemlock-cedar-miterwort), *Tsuga-Thuja-Sphagnum* (TTS; hemlock-cedar-sphagnum moss), and Picea-Chamadaphne-Sphagnum (PCS; spruce-leatherleaf-sphagnum moss). The TMC habitat type supported various amounts of balsam fir, white spruce, northern white cedar, black spruce, red maple, and sugar maple. The FMC and FI habitat types were characterized by lowland deciduous species such as white ash, black ash, and red maple. The TTM, TTS, and PCS habitat types occurred on poorly-drained silty or organic soils and supported lowland conifers such as tamarack, cedar, black spruce, spruce, and balsam fir.

Most (20%) of the study area was in the TM habitat type (Table 1.4, Figure 1.3). The ATD and AVO habitat types comprised 15% and 9% of the study area, respectively. Other sampled habitat types, AOC, AQV, and QAE each comprised < 5% of the western UP landscape.

Landscape-level characteristics and distribution of aspen

Most (54.24%) of the aspen on state lands in the study area was ≤ 30 years old (Figure 1.4). Approximately 15% of aspen was in the 30-year age class and 7.6% was in the 40-year age class. Approximately 23% of all aspen was considered "old" (i.e., ≥ 50 years old; Figure 1.4).

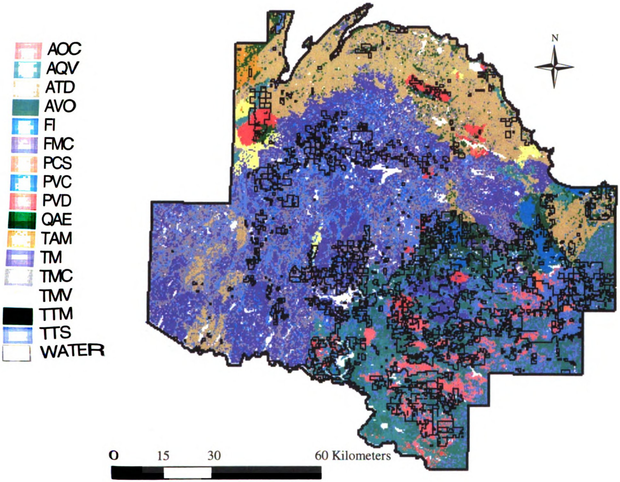

Figure 1.3. Spatial distribution of habitat types in a 12,300 km^2 area in the western Upper Peninsula, Michigan as determined from literature and field data collected between 2004–2006. The study area consisted of Baraga, Dickinson, Iron, and Marquette counties. Dark lines indicate boundaries of state forest land. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; FI = *Fraxinus-Impatiens*; FMC = *Fraxinus-Mentha-Carex*; PCS = *Picea-Chamadaphne-Sphagnum*; PVC = *Pinus-Vaccinium-Carex*; PVD = *Pinus-Vaccinium-Deschampsia*; QAE = *Quercus-Acer-Epigaea*; TAM = *Tsuga-Acer-Mitchella*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*; TMV = *Tsuga-Maianthemum-Vaccinium*; TTM = *Tsuga-Thuja-Mitella*; TTS = *Tsuga-Thuja-Sphagnum*.

Table 1.4. Landscape composition of habitat types in a 12,300 km^2 area in the western Upper Peninsula, Michigan as determined from spatial habitat type delineation from literature and field data collected between 2004–2006. The study area consisted of Baraga, Dickinson, Iron, and Marquette counties.

Moisture	Soil	Habitat type (Coffman et al. 1980)	Abbreviation	Area (km^2)	Percent (%)
Xeric	Sand	*Pinus-Vaccinium-Deschampsia*	PVD	245.01	1.99
		Pinus-Vaccinium-Carex	PVC	170.61	1.39
		Quercus-Acer-Epigaea	QAE	266.68	2.17
		Acer-Quercus-Vaccinium	AQV	612.23	4.98
		Tsuga-Maianthemum-Vaccinium	TMV	138.92	1.13
Mesic	Sand	*Tsuga-Maianthemum*	TM	2417.46	19.66
	Sandy-loam	*Acer-Tsuga-Dryopteris*	ATD	1815.98	14.77
	Loam	*Acer-Viola-Osmorhiza*	AVO	1131.06	9.20
	Silt-loam	*Acer-Osmorhiza-Caulophyllum*	AOC	455.24	3.70
	Clay	*Tsuga-Acer-Mitchella*	TAM	69.00	0.56
Hydric	Loam	*Fraxinus-Impatiens*	FI	336.50	2.74
	Clay	*Fraxinus-Mentha-Carex*	FMC	253.31	2.06
	Silt-loam	*Tsuga-Maianthemum-Coptis*	TMC	1601.94	13.03
		Tsuga-Thuja-Mitella	TTM	266.16	2.16
	Organic	*Tsuga-Thuja-Sphagnum*	TTS	2146.97	17.46
		Picea-Chamadaphne-Sphagnum	PCS	20.24	0.16
Water		Water	WATER	349.45	2.84
			Total	12,296.76	100.00

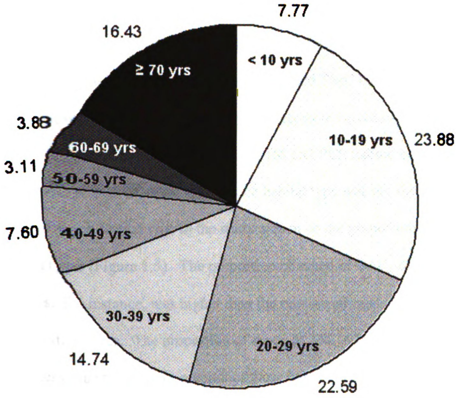

Figure 1.4. Percent of aspen within different age classes on state land in the western Upper Peninsula, Michigan based on Operations Inventory data from the Michigan Department of Natural Resources (2006).

Approximately half (50.35%) of the aspen on state lands occurred on mesic soils on northern hardwood habitat types (i.e., TM, ATD, AVO, AOC) (Table 1.4). Of the northern hardwood habitat types, most (25.45%) aspen occurred in the AVO type, followed by AOC (10.27%) and TM (9.56%). Although the ATD habitat type comprised nearly 15% of the study area (Table 1.4), only 5.07% of aspen occurred in it. Nearly 25% of aspen occurred in habitat types characterized by xeric soils. The QAE and AQV habitat types each supported 11.88% and 11.26% of aspen, respectively. The remaining 25% of aspen occurred on hydric soils with TTS and TMC habitat types supporting the majority of aspen (Table 1.4). Relatively little aspen occurred in xeric PVD, PVC, and TMC habitat types, mesic TAM, or hydric TTM and PCS habitat types (Table 1.4).

The proportion of aspen within each habitat type was not the same as the proportion of each habitat type in the study area or as the proportion of state land within each habitat type (Figure 1.5). The proportion of aspen in QAE, AQV, AOC, and TMC habitat types, for instance, was higher than the relative amount of each of those habitat types in the study area. The proportion of aspen in TM, ATD, FMC, and TTS habitat types was less than the relative amount of those habitat types in the study area. The highest proportion (27.37%) of state land occurred in the poorly-drained TTS habitat type (Figure 1.5), which only supported 11.39% of the aspen (Table 1.5). A greater proportion of aspen occurred in the AVO, QAE, and AQV habitat types than the relative amount of those habitat types on state land. For example, 16.45%, 8.52%, and 4.68% of state land occurred in AVO, QAE, and AQV habitat types, respectively; however, approximately 25% of the aspen occurred in the AVO habitat type, 11.88% occurred in QAE, and 11.29% occurred in AQV (Figure 1.5).

Of all habitat types, most of the aspen < 50 years old occurred in the AVO habitat type (Table 1.6, Figure 1.6). The QAE and TM habitat types contained the second and third highest proportion of aspen < 50 years old (Table 1.6). The AVO habitat type also contained the highest proportion (3.11%) of aspen ≥ 70 years old. The AQV and TTS habitat types had the second (2.68%) and third (2.52%) highest amounts of aspen ≥ 70 years old (Table 1.6). All habitat types on state land except TAM contained some aspen within each age class, but some age classes were not well represented within some habitat types. For instance, the ATD habitat type contained very little (0.04% aspen in the 50-year age class (Table 1.6, Figure 1.6).

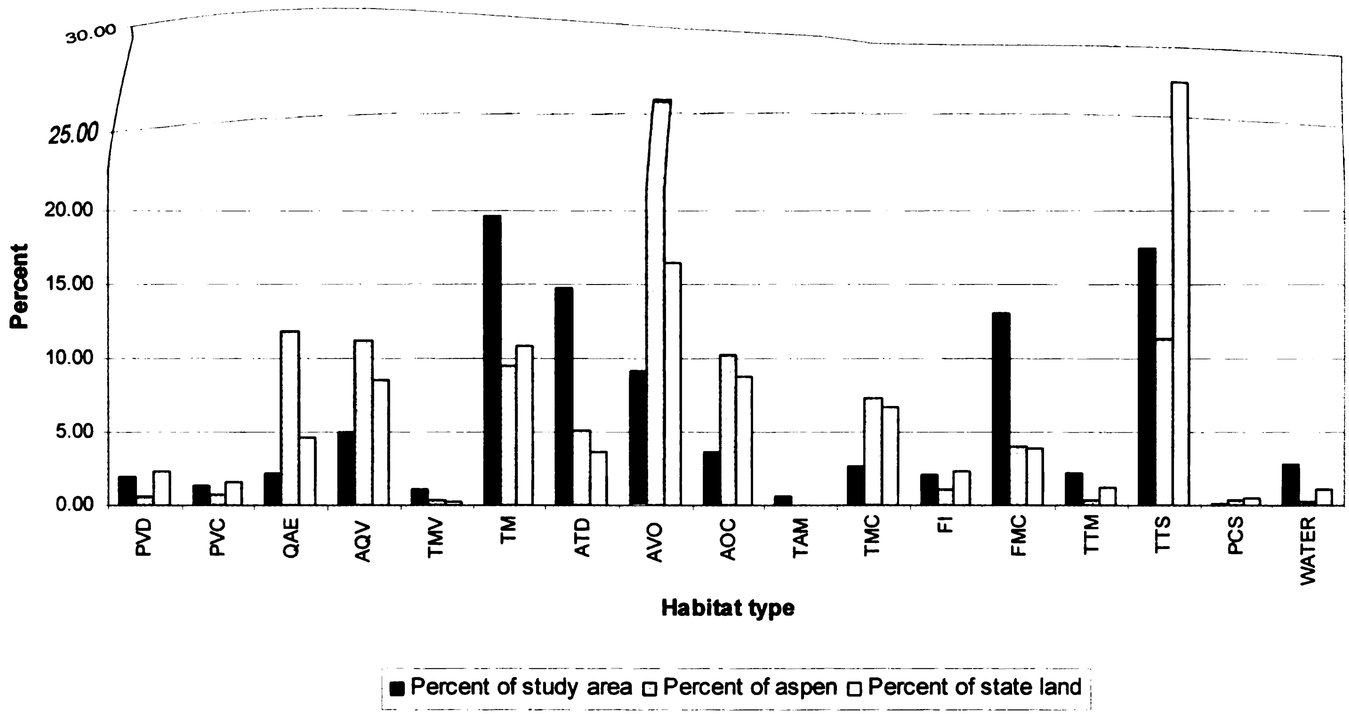

Figure 1.5. Comparison among percent of study area (western Upper Peninsula, Michigan), percent aspen on state land, and percent of state land within different habitat types as determined from literature and field data collected between 2004–2006. The study area consisted of Baraga, Dickinson, Iron, and Marquette counties. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; FI = *Fraxinus-Impatiens*; FMC = *Fraxinus-Mentha-Carex*; PCS = *Picea-Chamadaphne-Sphagnum*; PVC = *Pinus-Vaccinium-Carex*; PVD = *Pinus-Vaccinium-Deschampsia*; QAE = *Quercus-Acer-Epigaea*; TAM = *Tsuga-Acer-Mitchella*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*; TMV = *Tsuga-Maianthemum-Vaccinium*; TTM = *Tsuga-Thuja-Mitella*; TTS = *Tsuga-Thuja-Sphagnum*.

Table 1.5. Percent of aspen on state lands in different habitat types in the western Upper Peninsula, Michigan. Habitat types were determined from spatial habitat type delineation from literature and field data collected between 2004–2006. The study area consisted of Baraga, Dickinson, Iron, and Marquette counties.

Moisture	Soil	Habitat type (Coffman et al. 1980)	Abbreviation	Area (ha)	Percent (%)
Xeric	Sand	*Pinus-Vaccinium-Deschampsia*	PVD	255.18	0.61
		Pinus-Vaccinium-Carex	PVC	318.62	0.76
		Quercus-Acer-Epigaea	QAE	4963.48	11.88
		Acer-Quercus-Vaccinium	AQV	4706.26	11.26
		Tsuga-Maianthemum-Vaccinium	TMV	163.86	0.39
Mesic		*Tsuga-Maianthemum*	TM	3996.67	9.56
	Sandy-loam	*Acer-Tsuga-Dryopteris*	ATD	2117.86	5.07
	Loam	*Acer-Viola-Osmorhiza*	AVO	10,638.52	25.45
	Silt-loam	*Acer-Osmorhiza-Caulophyllum*	AOC	4291.32	10.27
	Clay	*Tsuga-Acer-Mitchella*	TAM	1.71	0.00
Hydric	Loam	*Tsuga-Maianthemum-Coptis*	TMC	3065.40	7.33
	Clay	*Fraxinus-Impatiens*	FI	471.52	1.13
	Silt-loam	*Fraxinus-Mentha-Carex*	FMC	1666.76	3.99
		Tsuga-Thuja-Mitella	TTM	160.87	0.38
	Organic	*Tsuga-Thuja-Sphagnum*	TTS	4760.49	11.39
		Picea-Chamadaphne-Sphagnum	PCS	141.83	0.34
Water[1]			WATER	76.58	0.18
			Total	41,796.91	100.00

[1] Aspen present in areas classified as water was likely due to errors in spatial data used to delineate habitat type boundaries.

Table 1.6. Percent of aspen in different age classes and habitat types on state lands in the western Upper Peninsula, Michigan. Habitat types were determined from spatial habitat type delineation from literature (Coffman et al. 1980) and field data collected between 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; FI = *Fraxinus-Impatiens*; FMC = *Fraxinus-Mentha-Carex*; PCS = *Picea-Chamadaphne-Sphagnum*; PVC = *Pinus-Vaccinium-Carex*; PVD = *Pinus-Vaccinium-Deschampsia*; QAE = *Quercus-Acer-Epigaea*; TAM = *Tsuga-Acer-Mitchella*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*; TMV = *Tsuga-Maianthemum-Vaccinium*; TTM = *Tsuga-Thuja-Mitella*; TTS = *Tsuga-Thuja-Sphagnum*.

			Age class								
Moisture	Soil	Habitat type	< 10	10-19	20-29	30-39	40-49	50-59	60-69	> 70	Total
Xeric	Sand	PVD	0.03	0.14	0.26	0.06	0.04	0.01	0.00	0.06	0.61
		PVC	0.09	0.12	0.21	0.21	0.07	0.03	0.00	0.03	0.76
		QAE	1.13	3.13	2.94	2.26	0.31	0.14	0.30	1.66	11.88
		AQV	0.68	2.07	2.79	1.58	0.72	0.22	0.52	2.68	11.26
		TMV	0.00	0.09	0.00	0.13	0.06	0.02	0.02	0.07	0.39
Mesic		TM	0.96	3.52	1.71	1.00	0.80	0.23	0.12	1.21	9.56
	Sandy-loam	ATD	0.50	1.30	0.82	0.62	0.17	0.04	0.20	1.42	5.07
	Loam	AVO	1.48	5.87	6.33	4.42	2.45	0.81	0.98	3.11	25.45
		AOC	0.67	1.84	1.89	1.74	1.50	0.84	0.56	1.22	10.27
	Clay	TAM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydric	Loam	TMC	0.85	1.37	1.62	0.99	0.28	0.17	0.27	1.79	7.33
	Clay	FI	0.14	0.44	0.30	0.07	0.02	0.01	0.01	0.14	1.13
	Silt	FMC	0.23	1.83	1.07	0.16	0.15	0.10	0.13	0.31	3.99
		TTM	0.07	0.06	0.16	0.02	0.01	0.00	0.00	0.06	0.38
	Organic	TTS	0.88	2.05	2.31	1.38	1.00	0.49	0.75	2.52	11.39
		PCS	0.03	0.05	0.11	0.07	0.00	0.01	0.00	0.06	0.34
Water		WATER	0.01	0.02	0.05	0.02	0.00	0.00	0.01	0.07	0.18
		Total	7.75	23.88	22.59	14.74	7.60	3.13	3.88	16.43	100.00

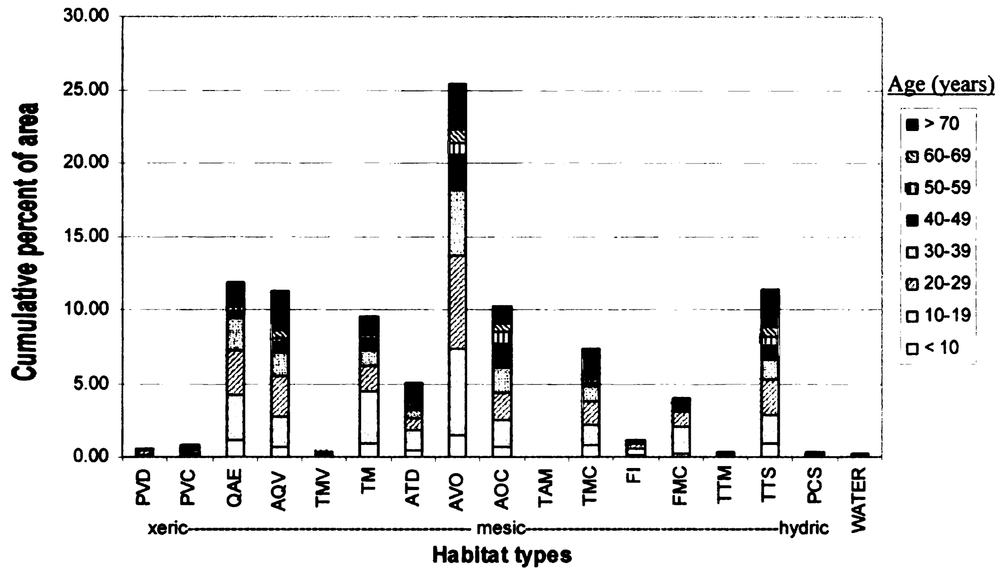

Figure 1.6. Cumulative proportion of aspen within different age classes and habitat types on state land in the western Upper Peninsula, Michigan. Habitat types were determined from spatial habitat type delineation from literature (Coffman et al. 1980) and field data collected between 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; FI = *Fraxinus-Impatiens*; FMC = *Fraxinus-Mentha-Carex*; PCS = *Picea-Chamadaphne-Sphagnum*; PVC = *Pinus-Vaccinium-Carex*; PVD = *Pinus-Vaccinium-Deschampsia*; QAE = *Quercus-Acer-Epigaea*; TAM = *Tsuga-Acer-Mitchella*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*; TMV = *Tsuga-Maianthemum-Vaccinium*; TTM = *Tsuga-Thuja-Mitella*; TTS = *Tsuga-Thuja-Sphagnum*.

Stand-level characteristics of aspen: Comparison among age classes

Live vegetation structure

The structure of live vegetation differed between aspen age classes ($p < 0.10$) among all habitat types (Table 1.7). Aspen stands in the 20-year age class had less basal area ($p < 0.001$), a higher deciduous stem density ($p = 0.001$), shorter overstory height ($p < 0.001$), less percent conifer cover ($p = 0.071$), and greater percent cover of herbaceous plants ($p = 0.010$) than aspen in the 50- or 70-year age classes. Conifer stem density differed only between 20- and 50-year age classes ($p = 0.055$). Diameter of overstory trees was different among all aspen age classes ($p < 0.001$), with diameter increasing with age (Table 1.7).

Mean stand basal area, diameter of overstory trees, overstory height, shrub stem density, and percent conifer cover increased with age, whereas deciduous stem density and herbaceous plant cover decreased with age (Table 1.7). Coniferous stem density, shrub height, percent cover of deciduous trees, and percent shrub cover were highest in the 50-year age class.

Dead vegetation

Characteristics of dead vegetation (i.e., down woody debris [DWD], snags, and stumps) also differed between aspen age classes (Table 1.8). Aspen stands in the 50- and 70-year age classes did not differ in the decay of DWD, average volume per piece of DWD, and total volume of DWD, but values for those variables were lower in aspen within the 20-year age class ($p = 0.002$, $p = 0.015$, $p = 0.001$, respectively). Decay, density, and total volume of DWD were highest in the 50-year age class. Density of

DWD did not differ between 20- and 50-year-old aspen stands, but was lowest in the 70-year age class (Table 1.8).

Snag decay, density, and diameter did not differ between 50- and 70-year-old stands, but were different from 20-year-old stands ($p = 0.020$, $p < 0.001$, $p < 0.001$, respectively) (Table 1.8). Snag decay and diameter were lowest in the 20-year age class and increased with age. Stands in the 20-year age class had the highest snag density ($\bar{x}$ = 549.19/ha, S.E. = 47.31). Snag height was lowest ($\bar{x}$ = 4.30 m, S.E. = 0.44) in 50-year-old age classes, and was different between height of snags in 20- and 70-year age classes ($p = 0.034$).

Density of stumps was highest ($\bar{x}$ = 106.32/ha, S.E. = 70.43) in 70-year-old aspen stands (Table 1.8). Stump density did not differ between 20- and 50-year-old stands, or between 50- and 70-year-old stands; but stump density was different between 20- and 70-year-old age classes ($p = 0.036$). Stump decay, diameter, and height was similar between aspen stands within all age classes (Table 1.8).

<u>Species composition</u>

Stem density of all overstory trees differed between age classes ($p = 0.059$) (Table 1.9). Aspen stands within all age classes had similar densities of most observed tree species; however significant differences in densities of American basswood, balsam fir, paper birch, quaking aspen, red maple, white pine, and white spruce were evident between age classes. Density of American basswood was highest in 70-year-old stands, but was not different between basswood density in 50-year-old stands. Balsam fir density was highest in 50-year-old aspen stands and was different from 20- and 70-year-old age classes ($p = 0.024$). Paper birch, red maple, and white spruce densities generally increased with age, but were not different between 50- and 70-year-old stands. Quaking aspen density decreased with age and differed among all age classes ($p < 0.001$). Density of white pine also differed among all age classes ($p = 0.002$) (Table 1.9) with 70-year-old stands having the greatest density.

Diameter of overstory tree species

Diameter of all overstory trees increased with age ($p < 0.001$) (Table 1.10). However, only diameters of bigtooth aspen, quaking aspen, red maple, sugar maple, and white pine were different among age classes. Several species did not occur frequently enough to run statistical comparisons between age classes. Diameters of bigtooth and quaking aspen increased with age and were different among all age classes (bigtooth aspen, $p = 0.002$; quaking aspen, $p < 0.001$). Red maple and sugar maple diameters increased with age, but were not different between 50- and 70-year age classes. Diameter of sugar maple and red maple only differed between 20- and 70-year-old stands. White pine was not found in any 50-year-old sampled stands, but diameters differed between 20- and 70-year age classes.

Basal area of overstory tree species

Basal area of all overstory species was greater in older stands, but generally did not differ between 50- and 70-year age classes ($p < 0.001$) (Table 1.11). Significant differences in basal area of basswood, paper birch, quaking aspen, red maple, white pine, and white spruce occurred among different age classes ($p < 0.01$). Basal area of

American basswood, paper birch, red maple, and white spruce was low ($< 4.2\ m^2/ha$), but basal area of each species generally was not different between 50- and 70-year-old stands. White pine was not found in 50-year-old sampled stands and, therefore, only differed between 50-year-old stands and other age classes. Quaking aspen had the highest basal area of all species in all sampled age classes. Quaking aspen basal area was highest ($p < 0.001$) in the 50-year age class ($\bar{x} = 13.63\ m^2/ha$, S.E = 1.33) and did not differ between 20- and 70-year-old stands (20-year-old, $\bar{x} = 12.98\ m^2/ha$, S.E = 4.62; 70-year-old, $\bar{x} = 11.18\ m^2/ha$, S.E = 1.70) (Table 1.11).

Table 1.7. Comparison of vegetation attribute variables among different age classes of aspen in the western Upper Peninsula, Michigan during 2004–2006.

	Age class						
	20 (n = 37)		50 (n = 36)		70 (n = 38)		Probability
Variable	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Basal area (m^2/ha)*	**18.85**[a]	3.02	**28.79**[b]	1.46	**33.05**[b]	2.46	0.000
Overstory							
Coniferous stems/ha*	**231.25**[a]	53.56	**627.78**[b]	107.70	**469.47**[ab]	99.92	0.055
Deciduous stems/ha*	**1103.78**[a]	87.26	**854.44**[b]	71.95	**694.74**[b]	65.42	0.001
Diameter (cm)*	**10.19**[a]	0.43	**12.99**[b]	0.45	**16.55**[c]	0.96	0.000
Height (m)*	**25.29**[a]	2.52	**36.20**[b]	2.85	**38.77**[b]	3.49	0.000
Shrub height (m)	**2.25**	0.19	**2.68**	0.27	**2.08**	0.24	0.219
Shrub stems/ha	**3104.32**	721.24	**6785.56**	2040.26	**11,903**	3503.55	0.998
Vertical cover (%)							
Conifer trees*	**3.32**[a]	1.06	**7.97**[b]	1.94	**11.45**[b]	3.10	0.071
Deciduous trees	**55.59**	2.80	**57.56**	3.29	**50.08**	2.67	0.123
Herbaceous plants*	**80.92**[a]	5.51	**67.67**[b]	5.44	**64.34**[b]	5.59	0.010
Shrub layer (2–5 m)	**26.22**	3.63	**40.81**	5.18	**31.37**	5.23	0.153

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.8. Comparison of characteristics of dead vegetation (i.e., down woody debris, snags, stumps) among different age classes of aspen in the western Upper Peninsula, Michigan during 2004–2006.

	Age class						
	20 (n = 37)		50 (n = 36)		70 (n = 38)		Probability
Variable	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Down woody debris							
Decay*	**3.3[a]**	0.13	**3.8[b]**	0.08	**3.7[b]**	0.10	0.002
Density (#/ha)*	**628.10[a]**	42.02	**662.86[a]**	38.49	**444.21[b]**	27.48	0.000
Average volume (m^3)*	**0.02[a]**	0.01	**0.04[b]**	0.01	**0.04[b]**	0.01	0.015
Volume (m^3/ha)*	**18.81**	3.28	**34.14**	4.01	**33.24**	5.44	0.001
Snags							
Decay*	**2.3[a]**	0.10	**2.6[b]**	0.20	**2.6[b]**	0.16	0.020
Density (#/ha)*	**549.19[a]**	47.31	**150.56[b]**	23.75	**153.68[b]**	17.17	0.000
Diameter (cm)*	**7.27[a]**	0.63	**13.70[b]**	1.52	**13.86[b]**	1.56	0.000
Height (m)*	**5.55[a]**	0.27	**4.30[b]**	0.44	**5.18[a]**	0.38	0.034
Stumps							
Decay	**4.1**	0.25	**4.8**	0.09	**4.6**	0.14	0.286
Density (#/ha)*	**81.01[a]**	13.91	**59.43[ab]**	14.30	**106.32[b]**	70.43	0.036
Diameter (cm)	**19.43**	1.94	**25.62**	2.77	**24.59**	2.97	0.256
Height (cm)	**33.89**	3.35	**41.87**	3.20	**40.78**	3.95	0.185

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.9. Average number of stems and standard errors of overstory tree species occurring in different age classes of aspen on state land in the western Upper Peninsula, Michigan during 2004–2006.

Tree species	Age class						Probability
	20 (n = 37)		50 (n = 36)		70 (n = 38)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood* *Tilia americana*	**0**[a]	0	**52.22**[b]	25.64	**81.05**[b]	40.91	0.045
American elm *Ulmus americana*	**3.24**	1.82	**12.22**	7.44	**2.11**	2.11	0.360
Balsam fir* *Abies balsamea*	**181.62**[a]	42.41	**570.00**[b]	100.04	**355.49**[a]	82.06	0.024
Balsam poplar *Populus balsamifera*	**19.46**	13.03	**4.44**	3.48	**21.05**	11.66	0.498
Bigtooth aspen *Populus grandidentata*	**240.00**	84.77	**22.22**	9.88	**51.58**	20.63	0.107
Black cherry *Prunus serotina*	**33.51**	9.23	**28.89**	8.22	**21.05**	11.16	0.182
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**3.16**	3.16	0.383
Ironwood *Carpinus caroliniana*	**9.73**	5.00	**27.78**	12.22	**18.95**	11.36	0.966
Northern red oak *Quercus rubra*	**6.49**	3.96	**0**	0	**3.16**	2.33	0.239
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**1.06**	1.06	0.383

Table 1.9. (Cont.)

Tree species (*Scientific name*)	Age class 20 (n = 37) $\bar{x}$	20 (n = 37) S.E.	50 (n = 36) $\bar{x}$	50 (n = 36) S.E.	70 (n = 38) $\bar{x}$	70 (n = 38) S.E.	Probability level[1]
Paper birch* *Betula papyrifera*	**1.08**[a]	1.08	**61.11**[b]	18.69	**48.42**[b]	18.72	0.000
Quaking aspen* *Populus tremuloides*	**674.60**[a]	76.68	**382.22**[b]	43.83	**193.68**[c]	32.09	0.000
Red maple* *Acer rubrum*	**82.16**[a]	35.44	**205.55**[b]	53.55	**150.53**[b]	35.62	0.040
Red pine *Pinus resinosa*	**2.16**	1.51	**0**	0	**4.21**	2.52	0.249
Sugar maple *Acer saccharum*	**28.11**	15.87	**52.22**	23.47	**101.05**	30.16	0.314
White ash *Fraxinus americana*	**0**	0	**0**	0	**2.11**	2.11	0.383
White pine* *Pinus strobus*	**9.73**[a]	4.49	**0**[b]	0	**49.47**[c]	19.41	0.002
White spruce* *Picea glauca*	**37.84**[a]	21.42	**57.78**[b]	17.99	**55.79**[b]	19.12	0.012
Yellow birch *Betula alleghaniensis*	**5.41**	4.43	**5.56**	3.62	**0**	0	0.219
All species combined	**1335.14**[ab]	102.98	**1482.22**[a]	97.54	**1164.21**[b]	86.29	0.059

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.10. Average diameter at breast height and standard errors of overstory tree species occurring in different age classes of aspen on state land in the western Upper Peninsula, Michigan during 2004–2006.

Tree species	Age class						Probability
	20 (n = 37)		50 (n = 36)		70 (n = 38)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood *Tilia americana*	**0**	0	**16.21**	1.28	**16.09**	2.47	0.855
American elm *Ulmus americana*	**6.35**	2.20	**13.39**	4.18	**17.15**	8.26	0.351
Balsam fir *Abies balsamea*	**9.05**	1.34	**8.95**	0.86	**11.22**	1.43	0.501
Balsam poplar *Populus balsamifera*	**13.40**	1.89	**12.91**	2.75	**18.06**	3.56	0.513
Bigtooth aspen* *Populus grandidentata*	**9.93**[a]	1.13	**15.27**[b]	1.98	**23.71**[c]	3.20	0.002
Black cherry *Prunus serotina*	**6.46**	0.67	**7.53**	0.92	**8.47**	1.75	0.621
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**19.47**	0	.
Ironwood *Carpinus caroliniana*	**8.32**	1.26	**8.77**	0.85	**7.56**	1.17	0.675
Northern red oak *Quercus rubra*	**50.24**	14.28	**0**	0	**20.64**	12.39	0.248
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**40.64**	0	.

Table 1.10. (Cont.)

Tree species	Age class						
	20 (n = 37)		50 (n = 36)		70 (n = 38)		Probability
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Paper birch *Betula papyrifera*	**3.81**	0	**22.04**	5.12	**20.37**	1.87	0.224
Quaking aspen* *Populus tremuloides*	**10.88**[a]	0.50	**21.14**[b]	1.03	**30.45**[c]	2.12	0.000
Red maple* *Acer rubrum*	**7.61**[a]	1.36	**12.01**[b]	2.02	**14.93**[b]	1.88	0.012
Red pine *Pinus resinosa*	**37.47**	1.91	**0**	0	**34.93**	12.26	0.564
Sugar maple* *Acer saccharum*	**7.23**[a]	1.46	**9.79**[ab]	2.63	**11.92**[b]	1.05	0.094
White ash *Fraxinus americana*	**3.49**	0	**0**	0	**5.72**	0	0.317
White pine* *Pinus strobus*	**33.19**[a]	5.92	**0**	0	**17.77**[b]	4.94	0.027
White spruce *Picea glauca*	**17.24**	3.86	**13.23**	2.50	**14.87**	2.08	0.333
Yellow birch *Betula alleghaniensis*	**9.37**	0.80	**14.96**	7.15	**18.42**	0	0.667
All species combined*	**10.19**[a]	0.423	**12.99**[b]	0.453	**16.55**[c]	0.957	0.000

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.11 Average basal area and standard errors of overstory tree species occurring in different age classes of aspen on state land in

Table 1.11. Average basal area and standard errors of overstory tree species occurring in different age classes of aspen on state land in the western Upper Peninsula, Michigan during 2004–2006.

Tree species	Age class						Probability
	20 (n = 37)		50 (n = 36)		70 (n = 38)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood* *Tilia americana*	**0**[a]	0	**1.59**[b]	0.78	**2.42**[b]	1.39	0.044
American elm *Ulmus americana*	**0.01**	0.01	**0.13**	0.07	**0.11**	0.11	0.369
Balsam fir* *Abies balsamea*	**2.72**[a]	1.06	**4.40**[b]	0.81	**2.50**[a]	0.49	0.048
Balsam poplar *Populus balsamifera*	**0.36**	0.24	**0.07**	0.07	**0.75**	0.45	0.474
Bigtooth aspen *Populus grandidentata*	**1.87**	0.66	**0.53**	0.27	**3.16**	1.29	0.195
Black cherry *Prunus serotina*	**0.18**	0.06	**0.71**	0.58	**0.12**	0.06	0.229
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**0.10**	0.10	0.383
Ironwood *Carpinus caroliniana*	**0.06**	0.03	**0.22**	0.12	**0.10**	0.06	0.958
Northern red oak *Quercus rubra*	**1.36**	0.90	**0**	0	**0.10**	0.09	0.233
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**0.14**	0.14	0.383

Table 1.11. (Cont.)

Tree species (*Scientific name*)	Age class 20 (n = 37) $\bar{x}$	S.E.	50 (n = 36) $\bar{x}$	S.E.	70 (n = 38) $\bar{x}$	S.E.	Probability level[1]
Paper birch* *Betula papyrifera*	**<0.01**[a]	<0.01	**3.03**[b]	1.07	**2.91**[b]	1.67	0.000
Quaking aspen* *Populus tremuloides*	**12.98**[a]	4.62	**13.63**[b]	1.33	**11.18**[a]	1.70	0.006
Red maple* *Acer rubrum*	**0.65**[a]	0.40	**2.66**[b]	0.78	**4.2**[b]	1.10	0.006
Red pine *Pinus resinosa*	**0.24**	0.17	**0**	0	**0.39**	0.26	0.249
Sugar maple *Acer saccharum*	**0.16**	0.11	**1.08**	0.61	**2.09**	0.72	0.264
White ash *Fraxinus americana*	**0.01**	0.01	**0**	0	**0.01**	0.01	0.616
White pine* *Pinus strobus*	**1.33**[a]	0.70	**0**[b]	0	**1.28**[a]	0.52	0.003
White spruce* *Picea glauca*	**0.99**[a]	0.60	**1.19**[b]	0.44	**1.43**[b]	0.56	0.012
Yellow birch *Betula alleghaniensis*	**0.04**	0.03	**0.09**	0.08	**0.06**	0.06	0.570
All species combined	**18.85**[a]	3.02	**28.79**[b]	1.46	**33.05**[b]	2.46	0.000

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Stand-level characteristics of aspen: Comparison among habitat types within different age classes

Live vegetation structure

20-year age class. Among habitat types in the 20-year age class, there were differences in basal area ($p = 0.006$), conifer stem density ($p = 0.018$), deciduous stem density ($p = 0.003$), diameter of overstory trees ($p = 0.010$), height of overstory ($p = 0.014$), shrub density ($p = 0.068$), and percent vertical cover of coniferous ($p = 0.006$) and deciduous trees ($p < 0.001$), and percent cover of herbaceous plants ($p = 0.001$) (Table 1.12). Average basal area was highest in TM habitat types, but was not different from basal area of AOC and QAE habitat types. Basal area was also similar among AQV, ATD, and AVO habitat types. Habitat types occurring on sandy soils (i.e., TM and QAE) had higher conifer stem densities than other habitat types. Similarly, AQV, QAE, and TM habitat types also had higher deciduous stem densities and percent deciduous cover than habitat types occurring on sandy loam or loamy soils.

Diameter of overstory trees differed among habitat types in the 20-year age class ($p = 0.010$), but there was much overlap in confidence intervals between several pairs of habitat types (Table 1.12). For instance, differences in tree diameter were found between groups of habitat types, but not within groups. Groups are ordered from largest to smallest diameter: AOC and QAE; AQV and QAE; ATD, AVO and QAE; ATD, AVO and TM. Similarly, although differences in overstory height were evident among habitat types ($p = 0.014$), differences within several groups of habitat types were not significant (AOC, ATD, AVO, and QAE; AQV and ATD; ATD and TM) (Table 1.12).

Shrub height ranged from 2.00 m (S.E. = 0.020) in the ATD habitat type to 3.00 m (S.E. = 0.74) in the AOC habitat type, but was not significantly different among habitat types (Table 1.12). Shrub stem density was highest ($\bar{x}$ = 8495.00/ha, S.E. = 4480.83) in the AOC habitat type, but was not different from shrub densities in AQV, AVO, or TM habitat types. Stands within the AOC habitat type, however, were extremely thick in the understory, and the fact that shrub stem density was not statistically different from other habitat types was likely due to small sample sizes (n = 4). Shrub stem density was lowest in the ATD habitat type ($\bar{x}$ = 470.00/ha, S.E. = 315.54; Table 1.12).

The TM habitat type appeared to have higher percent conifer cover in the overstory ($\bar{x}$ = 7.83%, S.E. = 2.48) than other habitat types due to the presence of balsam fir; however, percent conifer cover was not statistically different from that of stands in ATD and AQV habitat types. All habitat types had similar percent herbaceous cover (74–100%) with the exception of the QAE habitat type, which had sparse herbaceous cover ($\bar{x}$ = 6.33%, S.E. = 4.33). There were not differences in percent shrub cover among habitat types in the 20-year age class (Table 1.12).

<u>50-year age class</u>. There were differences in basal area of overstory trees (p = 0.027), conifer stem density ($p < 0.001$), deciduous stem density (p = 0.018), shrub stem density (p = 0.002), overstory conifer cover (p = 0.012), percent cover of herbaceous plants (p = 0.005), and percent cover in the shrub layer (2–5 m) (p = 0.041; Table 1.13). Basal area of overstory trees in the AVO habitat type ($\bar{x}$ = 25.04 m^2/ha, S.E. = 2.04) was different from that of the TM habitat type ($\bar{x}$ = 33.84, S.E. = 2.11), but basal area of AVO or TM habitat types were different from that of the ATD habitat type ($\bar{x}$ = 29.14, S.E. = 2.66). Conifer stem density was highest in the TM habitat type ($\bar{x}$ = 1172.31, S.E.

= 161.43). The TM habitat type also had the highest percent conifer cover ($\bar{x}$ = 11.00, S.E. = 1.78). Conifer stem density and conifer cover did not differ between ATD and AVO habitat types. Shrub stem density was highest in the AVO habitat type ($\bar{x}$ = 12,571.11, S.E = 3626.74) and was significantly different from shrub densities in ATD or TM habitat types. Percent cover of herbaceous plants was highest in the AVO habitat type ($\bar{x}$ = 83.06, S.E. = 6.46) and lowest in the TM habitat type ($\bar{x}$ = 46.62, S.E. = 8.33). Neither were different from percent herbaceous plants in the ATD habitat type ($\bar{x}$ = 67.00, S.E. = 13.66). The AVO habitat type also had the highest percent cover within the shrub layer ($\bar{x}$ = 82.44, S.E. = 7.58), but was not different from that of the TM habitat type ($\bar{x}$ = 34.08, S.E. = 7.59; Table 1.13).

70-year age class. All variables except basal area, diameter of overstory trees, and shrub height were significant ($p < 0.001$) among habitat types within the 70-year class (Table 1.14). Conifer stem density ($\bar{x}$ = 1007.50/ha, S.E. = 151.84, $p < 0.001$) and conifer cover ($\bar{x}$ = 26.44%, S.E = 5.04, $p < 0.001$) was significantly higher in the TM habitat type than in other habitat types. Deciduous stem density was highest in the AVO habitat type ($\bar{x}$ = 1573.33/ha, S.E. = 127.19) and lowest in the TM habitat type ($\bar{x}$ = 402.50/ha, S.E. = 42.34). Deciduous stem density ranged from 745–880/ha and was not different among AOC, AQV, and ATD habitat types. Overstory trees in the TM habitat type were shortest ($\bar{x}$ = 10.11 m, S.E. = 1.68) but were not different from height of overstory trees in the AOC habitat type ($\bar{x}$ = 10.66 m, S.E. = 2.24). The AVO habitat type supported the tallest overstory ($\bar{x}$ = 16.56, S.E. = 0.57), but height was not different from the overstory of AQV or ATD habitat types (Table 1.14).

Shrub stem density was highest in the AOC habitat type ($\bar{x}$ = 35,850/ha, S.E. = 12,545), but was not statistically different from shrub densities in AQV, ATD, or AVO habitat types (Table 1.14). Shrub stem density was lowest in the TM habitat type ($\bar{x}$ = 485.00/ha, S.E. = 128.20). Deciduous cover was highest in the AQV habitat type ($\bar{x}$ = 68.75/ha, S.E. = 2.27) and lowest in the TM habitat type ($\bar{x}$ = 39.69/ha, S.E. = 3.19), but several groups of habitat types were not different (i.e., AOC and TM; AOC, AVO, and ATD; AVO, AQV, and ATD). Herbaceous cover was significantly lower in the AOC habitat type ($\bar{x}$ = 14.01%, S.E. = 3.13) than in other habitat types. Herbaceous cover was similar among other habitat types. The TM habitat type had the lowest percent cover in the shrub layer ($\bar{x}$ = 12.19%, S.E. = 3.83), although it was not different from percent cover in the ATD habitat type. Other habitat types were similar in the amount of cover within the shrub layer (Table 1.14).

Table 1.12. Averages and standard errors for variable characterizing live vegetation structure of aspen stands in the 20-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum.*

	Habitat types represented in 20-year age class						Probability
Variable	AOC2 (n=4)	AQV2 (n=10)	ATD2 (n=4)	AVO2 (n=4)	QAE2 (n=3)	TM2 (n=12)	level[1]
Basal area (m^2/ha)*	**18.62**[a]	**10.05**[b]	**8.79**[b]	**7.97**[b]	**37.35**[a]	**41.29**[ab]	0.006
(S.E.)	(2.54)	(1.92)	(2.28)	(2.68)	(8.84)	(13.71)	
Overstory							
Coniferous stems/ha*	**50.00**[ab]	**72.00**[ab]	**40.00**[a]	**60.00**[a]	**186.67**[bc]	**556.67**[c]	0.018
(S.E.)	(50.00)	(25.16)	(16.33)	(34.64)	(87.43)	(114.99)	
Deciduous stems/ha*	**990.00**[a]	**1408.00**[ab]	**690.00**[c]	**680.00**[bc]	**1546.67**[a]	**1056.67**[ab]	0.003
(S.E.)	(99.83)	(218.99)	(50)	(99.33)	(109.14)	(137.37)	
Diameter (cm)*	**13.87**[a]	**8.24**[b]	**10.28**[cd]	**9.68**[bcd]	**12.92**[abc]	**10.04**[d]	0.010
(S.E.)	(0.82)	(0.67)	(0.97)	(1.03)	(0.99)	(0.58)	
Height (m)*	**12.11**[a]	**15.27**[b]	**18.62**[abc]	**10.82**[a]	**13.31**[a]	**16.73**[c]	0.014
(S.E.)	(0.71)	(3.25)	(8.47)	(2.40)	(1.43)	(4.25)	
Shrub height (m)	**3.00**	**2.55**	**2.00**	**2.13**	**2.67**	**2.08**	0.421
(S.E.)	(0.74)	(0.38)	(0.20)	(0.13)	(0.17)	(0.42)	
Shrub stems/ha*	**8495.00**[ac]	**3180.00**[abc]	**470.00**[b]	**4060.00**[ac]	**3080.00**[c]	**1810.00**[a]	0.068
(S.E.)	(4480.83)	(1361.56)	(315.54)	(2113.92)	(532.67)	(346.38)	

Table 1.12. (Cont.)

Variable	Habitat types represented in 20-year age class						Probability
	AOC2 (n=4)	AQV2 (n=10)	ATD2 (n=4)	AVO2 (n=4)	QAE2 (n=3)	TM2 (n=12)	level[1]
Vertical cover (%)							
Conifer trees*	**0**[b]	**1.80**[bc]	**1.00**[ab]	**0**[b]	**2.33**[ac]	**7.83**[a]	0.066
(S.E.)	(0)	(0.95)	(0.58)	(0)	(1.45)	(2.48)	
Deciduous trees*	**32.50**[a]	**69.00**[c]	**43.75**	**31.25**[a]	**67.33**[bc]	**61.25**[b]	0.000
(S.E.)	(1.44)	(2.96)	(2.39)	(2.39)	(6.23)	(3.49)	
Herbaceous plants*	**100.00**[a]	**74.00**[b]	**100.00**[a]	**100.00**[a]	**6.33**[c]	**86.25**[ab]	0.004
(S.E.)	(0.00)	(10.59)	(0.00)	(0.00)	(4.33)	(7.96)	
Shrub layer (2–5 m)	**27.75**	**20.50**	**28.00**	**31.25**	**37.67**	**25.33**	0.824
(S.E.)	(16.00)	(4.68)	(10.68)	(17.72)	(6.49)	(6.88)	

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.13. Averages and standard errors for variable characterizing live vegetation structure of aspen stands in the 50-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*.

	Habitat types represented in 50-year age class			Probability
Variable	ATD5 (n=5)	AVO5 (n=18)	TM5 (n=13)	level[1]
Basal area (m^2/ha)*	**29.14**[ab]	**25.04**[b]	**33.84**[a]	0.027
(S.E.)	(2.66)	(2.04)	(2.11)	
Overstory				
Coniferous stems/ha*	**248.00**[a]	**340.00**[a]	**1172.31**[b]	0.000
(S.E.)	(198.96)	(109.82)	(161.43)	
Deciduous stems/ha*	**1256.00**[b]	**857.78**[ab]	**695.38**[a]	0.018
(S.E.)	(161.29)	(113.56)	(77.86)	
Diameter (cm)	**13.92**	**13.22**	**12.32**	0.518
(S.E.)	(1.04)	(0.77)	(0.54)	
Height (m)	**12.99**	**9.52**	**10.11**	0.223
(S.E.)	(0.38)	(1.33)	(1.68)	
Shrub height (m)	**2.40**	**2.81**	**2.62**	0.880
(S.E.)	(0.58)	(0.40)	(0.48)	
Shrub stems/ha*	**600.00**[a]	**12,571.11**[b]	**1153.85**[a]	0.002
(S.E.)	(205.91)	(3626.74)	(289.86)	

Table 1.13. (Cont.)

	Habitat types represented in 50-year age class			Probability
Variable	ATD5 (n=5)	AVO5 (n=18)	TM5 (n=13)	level[1]
Vertical cover (%)				
Conifer trees*	**2.00**[a]	**7.44**[a]	**11.00**[b]	0.012
(S.E.)	(2.00)	(3.55)	(1.78)	
Deciduous trees	**57.00**	**55.56**	**60.54**	0.732
(S.E.)	(6.04)	(4.87)	(5.92)	
Herbaceous plants*	**67.00**[ab]	**83.06**[b]	**46.62**[a]	0.005
(S.E.)	(13.66)	(6.46)	(8.33)	
Shrub layer (2–5 m)*	**16.40**[b]	**52.44**[a]	**34.08**[a]	0.041
(S.E.)	(7.87)	(7.58)	(7.59)	

[1] Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.14. Averages and standard errors for variable characterizing live vegetation structure of aspen stands in the 70-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum.*

	Habitat types represented in 70-year age class					Probability
Variable	AOC7 (n=8)	AQV7 (n=8)	ATD7 (n=3)	AVO7 (n=3)	TM7 (n=16)	level[1]
Basal area (m^2/ha)	**26.40**	**36.94**	**28.25**	**44.89**	**33.12**	0.400
(S.E.)	(4.40)	(8.21)	(2.67)	(9.82)	(2.91)	
Overstory						
Coniferous stems/ha*	**75.00**[a]	**35.00**[a]	**266.67**[a]	**13.33**[a]	**1007.50**[b]	0.000
(S.E.)	(47.47)	(19.18)	(192.30)	(13.33)	(151.84)	
Deciduous stems/ha*	**745.00**[a]	**830.00**[a]	**880.00**[a]	**1573.33**[b]	**402.50**[c]	0.000
(S.E.)	(117.59)	(104.40)	(160.00)	(127.19)	(42.34)	
Diameter (cm)	**19.17**	**17.77**	**13.25**	**16.34**	**15.28**	0.429
(S.E.)	(3.11)	(1.10)	(2.00)	(1.53)	(1.46)	
Height (m)*	**10.66**[ab]	**15.27**[ab]	**15.24**[a]	**16.56**[a]	**10.11**[b]	0.020
(S.E.)	(2.24)	(3.25)	(0.88)	(0.57)	(1.68)	
Shrub height (m)	**2.10**	**2.01**	**2.83**	**2.00**	**1.97**	0.905
(S.E.)	(0.30)	(0.18)	(1.42)	(0.50)	(0.45)	
Shrub stems/ha*	**35850.00**[ab]	**17995.00**[b]	**1453.33**[ac]	**3146.67**[ab]	**485.00**[c]	0.000
(S.E.)	(12545.00)	(4020.66)	(1028.22)	(278.41)	(128.20)	

Table 1.14. (Cont.)

Variable	Habitat types represented in 70-year age class: AOC7 (n=8)	AQV7 (n=8)	ATD7 (n=3)	AVO7 (n=3)	TM7 (n=16)	Probability level[1]
Vertical cover (%)						
Conifer trees*	**0.88**[a]	**0**[a]	**1.67**[a]	**0**[a]	**26.44**[b]	0.000
(S.E.)	(0.40)	(0)	(1.67)	(0)	(5.04)	
Deciduous trees*	**46.00**[ab]	**68.75**[c]	**58.33**[bc]	**58.33**[bc]	**39.69**[a]	0.000
(S.E.)	(4.24)	(2.27)	(9.28)	(6.67)	(3.19)	
Herbaceous plants*	**14.01**[a]	**66.88**[b]	**48.33**[bc]	**95.00**[c]	**44.06**[b]	0.001
(S.E.)	(3.13)	(2.49)	(14.53)	(5.00)	(8.99)	
Shrub layer (2–5 m)*	**45.75**[b]	**45.50**[b]	**37.33**[ab]	**51.67**[b]	**12.19**[a]	0.025
(S.E.)	(96.88)	(10.74)	(22.81)	(23.33)	(3.83)	

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988])

Dead vegetation

20-year age class. Characteristics of DWD, snags, and stumps also differed among habitat types within the 20-year age class. Specifically, differences were evident in the average volume of each piece of DWD ($p = 0.055$), snag decay classes ($p = 0.020$), snag diameter ($p = 0.045$), stump density ($p = 0.054$), and stump diameter ($p = 0.077$) (Table 1.15). Average volume per piece of DWD ranged from 0.01–0.04 m^3 and was highest in QAE and TM habitat types. Snag decay was highest ($\bar{x}$ = 3.2, S.E. = 0.04) in the QAE habitat type. Other habitat types did not differ from each other in degree of snag decay. Snag diameter was largest in the AOC habitat type ($\bar{x}$ = 13.19, S.E. = 3.43), which was not surprising because overstory tree diameter was also highest in the AOC habitat type (Table 1.15). Although stump density and diameter differed among habitat types (Table 1.15), confidence intervals of average stump density and diameter overlapped significantly between different pairs of habitat types. Stump density, for instance, did not differ between AOC, AVO, and TM; ATD and AVO; AQV, ATD, AVO, and QAE habitat types. Diameter of stumps differed from other habitat types only in the ATD habitat type (Table 1.15).

50-year age class. Within the 50-year age class, there were no differences among habitat types in variables characterizing dead vegetation except snag density ($p = 0.012$) and stump diameter ($p = 0.045$; Table 1.16). Snag density was highest in the ATD habitat type ($\bar{x}$ = 200.00/ha, S.E. = 35.78) and was not different between AOC ($\bar{x}$ = 88.89/ha, S.E. – 19.01) and TM ($\bar{x}$ = 46.15/ha, S.E. = 19.13) habitat types. Stump diameter was smallest in the ATD habitat type ($\bar{x}$ = 14.39 cm, S.E. = 1.39) and was not different between AVO ($\bar{x}$ = 23.58 cm, S.E. = 2.19) and TM ($\bar{x}$ = 32.57 cm, S.E. = 7.03) habitat types (Table 1.16).

70-year age class. There were no differences among habitat types in the 70-year age class in variables characterizing dead vegetation except average volume/piece of DWD ($p = 0.002$), snag height ($p = 0.062$), and stump density ($p = 0.042$; Table 1.17). Volume of DWD pieces was smallest in AQV habitat types ($\bar{x}$ < 0.01 m^3, S.E. < 0.01) and largest in the ATD habitat type ($\bar{x}$ = 0.18 m^3, S.E. = 0.07). Volume/piece was not different between AOC and TM, and ATD and AVO habitat types. Snag height was greatest in the AVO habitat type ($\bar{x}$ =7.98 m, S.E. = 0.60) and smallest in the ATD habitat type ($\bar{x}$ = 2.44, S.E. = 1.22). Height was similar among all habitat types except AVO. Stump density ranged from 0 in the AVO habitat type to 182.5 (S.E. = 166.61) in the TM habitat type, but was not different among the following groups: TM, AVO, and AOC; TM and AQV; ATD and AQV; and AQV and AOC (Table 1.17).

Table 1.15. Averages and standard errors for variable characterizing structure of down woody debris, snags, and stumps within aspen stands in the 20-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*.

	Habitat types represented in 20-year age class						Probability
Variable	AOC2 (n=4)	AQV2 (n=10)	ATD2 (n=4)	AVO2 (n=4)	QAE2 (n=3)	TM2 (n=12)	level[1]
Down woody debris							
Decay	**3.6**	**3.2**	**3.0**	**3.3**	**4.6**	**3.0**	0.144
(S.E.)	(0.147)	(0.216)	(0.318)	(0.33)	(0.58)	(0.21)	
Density (#/ha)	**990.00**	**576.00**	**470.00**	**580.00**	**640.00**	**616.67**	0.204
(S.E.)	(156.95)	(66.19)	(123.69)	(113.73)	(161.66)	(61.78)	
Volume/piece (m^3)*	**0.02**[ab]	**0.01**[c]	**0.01**[c]	**0.01**[bc]	**0.04**[d]	**0.03**[acd]	0.055
(S.E.)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.02)	
Total volume (m^3/ha)	**21.48**	**11.14**	**19.66**	**9.79**	**29.63**	**24.34**	0.169
(S.E.)	(5.47)	(2.47)	(4.12)	(4.80)	(9.37)	(9.02)	
Snags							
Decay*	**2.4**[a]	**2.2**[a]	**2.1**[ab]	**1.8**[b]	**3.1**[c]	**2.3**[a]	0.020
(S.E.)	(0.153)	(0.11)	(1.12)	(0.12)	(0.04)	(0.25)	
Density (#/ha)	**630.00**	**540.00**	**570.00**	**600.00**	**546.67**	**506.67**	0.927
(S.E.)	(70.00)	(114.27)	(121.52)	(209.76)	(150.26)	(80.05)	
Diameter (cm)*	**13.19**[a]	**5.84**[b]	**7.42**[c]	**7.52**[abc]	**5.96**[bc]	**6.67**[c]	0.045
(S.E.)	(3.43)	(1.02)	(0.83)	(1.62)	(0.54)	(0.80)	
Height (m)	**6.08**	**5.87**	**5.65**	**6.09**	**4.61**	**5.14**	0.713
(S.E.)	(0.66)	(0.61)	(0.54)	(0.66)	(0.47)	(0.55)	

Table 1.15. (Cont.)

Variable	Habitat types represented in 20-year age class						Probability
	AOC2 (n=4)	AQV2 (n=10)	ATD2 (n=4)	AVO2 (n=4)	QAE2 (n=3)	TM2 (n=12)	level[1]
Stumps							
Decay	**4.5**	**4.2**	**2.7**	**3.7**	**5.0**	**4.4**	0.161
(S.E.)	(0.50)	(0.45)	(0.07)	(1.33)	(0.00)	(0.37)	
Density (#/ha)*	**20.00**^{ab}	**92.00**^{c}	**200.00**^{bc}	**70.00**^{abc}	**133.33**^{c}	**43.33**^{a}	0.054
(S.E.)	(11.55)	(21.54)	(71.18)	(30.00)	(13.33)	(18.06)	
Diameter (cm)*	**24.13**^{abc}	**17.81**^{a}	**7.18**^{d}	**23.28**^{abc}	**30.27**^{b}	**19.05**^{abc}	0.077
(S.E.)	(11.43)	(2.72)	(0.75)	(5.20)	(3.04)	(4.12)	
Height (cm)	**41.28**	**28.76**	**49.63**	**28.93**	**34.78**	**33.29**	0.494
(S.E.)	(37.46)	(3.83)	(5.71)	(11.15)	(4.24)	(6.31)	

[1] Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988])

Table 1.16. Averages and standard errors for variable characterizing structure of down woody debris, snags, and stumps within aspen stands in the 50-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

	Habitat types represented in 50-year age class			Probability
Variable	ATD5 (n=5)	AVO5 (n=18)	TM5 (n=13)	level[1]
Down woody debris				
Decay	**3.7**	**3.9**	**3.7**	0.314
(S.E.)	(0.30)	(0.11)	(0.13)	
Density (#/ha)	**752.00**	**642.22**	**655.39**	0.645
(S.E.)	(64.992)	(65.76)	(51.35)	
Volume/piece (m^3)	**0.04**	**0.04**	**0.03**	0.802
(S.E.)	(0.01)	(0.01)	(0.01)	
Total volume (m^3/ha)	**24.92**	**39.97**	**29.22**	0.220
(S.E.)	(5.54)	(5.65)	(7.37)	
Snags				
Decay	**2.5**	**2.5**	**4.8**	0.651
(S.E.)	(0.27)	(0.38)	(0.16)	
Density (#/ha)*	**200.00**[a]	**88.89**[b]	**46.15**[b]	0.012
(S.E.)	(35.78)	(19.01)	(19.13)	
Diameter (cm)	**11.04**	**15.96**	**11.27**	0.140
(S.E.)	(1.75)	(2.80)	(1.29)	
Height (m)	**3.48**	**3.98**	**5.08**	0.354
(S.E.)	(0.65)	(0.73)	(0.59)	

Table 1.16. (Cont.)

	Habitat types represented in 50-year age class			Probability
Variable	ATD5 (n=5)	AVO5 (n=18)	TM5 (n=13)	level[1]
Stumps				
Decay	**5.0**	**4.9**	**4.8**	0.502
(S.E.)	(0.00)	(0.14)	(0.16)	
Density (#/ha)	**40.00**	**75.56**	**46.15**	0.791
(S.E.)	(17.89)	(24.60)	(19.13)	
Diameter (cm)*	**14.39**[b]	**23.58**[a]	**32.57**[a]	0.045
(S.E.)	(1.39)	(2.19)	(7.03)	
Height (cm)	**32.60**	**40.79**	**45.57**	0.468
(S.E.)	(7.84)	(4.28)	(6.19)	

[1] Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988])

Table 1.17. Averages and standard errors for variable characterizing structure of down woody debris, snags, and stumps within aspen stands in the 70-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum.*

	Habitat types represented in the 70-year age class					Probability
Variable	AOC7 (n=8)	AQV7 (n=8)	ATD7 (n=3)	AVO7 (n=3)	TM7 (n=16)	level[1]
Down woody debris						
Decay	**3.6**	**3.5**	**4.3**	**3.9**	**3.6**	0.501
(S.E.)	(0.19)	(0.17)	(0.57)	(0.07)	(0.18)	
Density (#/ha)	**440.00**	**520.00**	**293.33**	**386.67**	**447.50**	0.341
(S.E.)	(55.03)	(68.45)	(58.12)	(26.67)	(44.75)	
Volume/piece (m^3)*	**0.04**[a]	**<0.01**[c]	**0.18**[b]	**0.07**[b]	**0.02**[a]	0.002
(S.E.)	(0.01)	(<0.01)	(0.07)	(<0.01)	(0.01)	
Total volume (m^3/ha)	**24.03**	**28.96**	**61.17**	**25.19**	**36.27**	0.830
(S.E.)	(4.93)	(9.25)	(31.76)	(1.04)	(10.38)	
Snags						
Decay	**2.5**	**2.9**	**2.5**	**1.6**	**2.7**	0.154
(S.E.)	(0.25)	(0.21)	(1.32)	(0.29)	(0.23)	
Density (#/ha)	**175.96**	**165.00**	**40.00**	**106.67**	**167.50**	0.168
(S.E.)	(39.96)	(46.25)	(23.09)	(66.67)	(22.57)	
Diameter (cm)	**15.05**	**14.99**	**17.57**	**14.46**	**11.90**	0.793
(S.E.)	(2.78)	(4.58)	(11.10)	(2.15)	(1.94)	
Height (m)*	**5.41**[ab]	**4.68**[ab]	**2.44**[b]	**7.98**[c]	**5.31**[a]	0.062
(S.E.)	(0.58)	(0.87)	(1.22)	(0.60)	(0.56)	

Table 1.17. (Cont.)

Variable	Habitat types represented in the 70-year age class					Probability level[1]
	AOC7 (n=8)	AQV7 (n=8)	ATD7 (n=3)	AVO7 (n=3)	TM7 (n=16)	
Stumps						
Decay	**4.3**	**4.8**	**5.0**	.	**4.3**	0.187
(S.E.)	(0.25)	(0.11)	(0.04)	.	(0.32)	
Density (#/ha)*	**15.00**[ad]	**65.00**[abc]	**160.00**[b]	**0**[a]	**182.50**[cd]	0.042
(S.E.)	(10.52)	(32.90)	(69.28)	(0)	(166.61)	
Diameter (cm)	**20.64**	**36.29**	**21.33**	.	**17.78**	0.136
(S.E.)	(7.30)	(6.26)	(5.21)	.	(1.24)	
Height (cm)	**36.83**	**47.32**	**38.52**	.	**37.78**	0.598
(S.E.)	(3.81)	(9.77)	(7.42)	.	(6.21)	

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 198

Comparison of species composition among habitat types and age classes

The greatest differences among habitat types within a specific age class were evident when assessing stem densities and basal area of overstory species (Tables 1.18–1.23). Nineteen overstory tree species occurred in vegetation sampling plots across all age classes and habitat types.

American basswood was present in 50- and 70-year age classes and only occurred in AVO and AOC habitat types. Stem density (50-year, $p = 0.031$; 70-year, $p < 0.001$; Tables 1.19–1.20) and basal area (50-year, $p = 0.031$; 70-year, $p < 0.001$; Tables 1.22–23) were higher in the AVO habitat type than in the AOC habitat type.

American elm was only present on loamy soils in AOC and AVO habitat types across all age classes (Tables 1.18–1.20). Significant differences in stem density ($p = 0.027$) and basal area ($p = 0.025$) only occurred among habitat types in the 20-year age class (Tables 1.18, 1.20).

Density of balsam fir was highest in the TM habitat type across all age classes (20-year, $\bar{x} = 426.67$/ha, S.E. = 94.24, $p = 0.020$; 50-year, $\bar{x} = 1067.69$/ha, S.E. = 153.62, $p < 0.001$; 70-year, $\bar{x} = 767.50$/ha, S.E. = 134.57, $p < 0.001$; Tables 1.18–1.20). Not surprisingly, basal area of balsam fir was also highest in the TM habitat type across all age classes (20-year, $\bar{x} = 6.59$ m^2/ha, S.E. = 2.92, $p = 0.008$; 50-year, $\bar{x} = 8.69$ m^2/ha, S.E. = 1.38, $p = 0.001$; 70-year, $\bar{x} = 5.12$ m^2/ha, S.E. = 0.70, $p < 0.001$; Tables 1.21–1.23). Balsam fir density ($\bar{x} = 160.00$/ha, S.E. = 61.10) and basal area ($\bar{x} = 2.70$ m^2/ha, S.E. = 0.99) was also relatively high in the 20-year age class within the QAE habitat type (Tables 1.18, 1.21).

Balsam poplar was not present in AQV or QAE habitat types in any age class. Balsam poplar density and basal area were highest in habitat types characterized by loamy soils (i.e., AOC and AVO) (Tables 1.18–1.20). Differences in balsam poplar densities ($p = 0.025$; Table 1.18) and basal area ($p = 0.022$; Table 1.21) were only significant in the 20-year age class within AOC and AVO habitat types because it was only present in those types.

Bigtooth aspen densities were different among habitat types in the 20-year ($p = 0.54$; Table 1.18) and 70-year ($p = 0.010$; Table 1.20) age classes. Densities appeared to be highest in QAE and AQV habitat types, which occurred in sandy soils. Similarly, bigtooth aspen basal area was highest in 20-year-old QAE stands ($p = 0.040$; Table 1.21) and 70-year-old AQV stand ($p = 0.006$; Table 1.23)

Black cherry occurred in all habitat types and age classes, but the only significant difference in densities were found between AQV and AOC habitat types in the 70-year age class ($p = 0.090$; Table 1.20). The only significant difference in black cherry basal area was found between AOC and TM habitat types in the 70-year age class ($p = 0.085$; Table 1.23).

Eastern hemlock was present only in stands ≥ 70 years within the ATD habitat type. Ironwood densities differed among habitat types within each age class (20-year, $p = 0.055$; 50-year, $p = 0.061$; 70-year $p < 0.001$; Tables 1.18–1.20). In the 20-year age class, ironwood density was highest ($\bar{x} = 66.67$/ha, S.E. = 48.07) in the QAE habitat type, but was not different from densities in AOC or ATD habitat types (Table 1.18). Ironwood basal area followed the same pattern in the 20-year age class (Table 1.18). In the 50- and 70-year age classes, the AVO habitat type supported the highest ironwood densities and basal area, but was not different from AQV or ATD habitat types (Tables 1.19, 1.20, 1.22–1.23).

Northern red oak was only present in AQV and QAE habitat types. The QAE habitat type had higher northern red oak densities ($\bar{x}$ = 40.00/ha, S.E. = 23.09, p = 0.012) and basal area ($\bar{x}$ = 13.87 m^2/ha, S.E. = 9.06, p = 0.006) than the AQV habitat type in the 20-year age class (Tables 1.18, 1.21). Northern red oak density and basal area was not significantly different among habitat types within the 50- or 70-year age classes (Table 1.19–1.20, 1.22–1.23).

Paper birch was present in all habitat types except QAE. In the 50-year age class, the TM habitat type had the lowest paper birch density ($\bar{x}$ = 9.23/ha, S.E. = 4.87, p = 0.079) among habitat types (Table 1.19). Birch densities were not different between 50-year-old stands within ATD ($\bar{x}$ = 160.00/ha, S.E. = 88.54) and AVO ($\bar{x}$ = 71.11/ha, S.E = 38.93) habitat types (Table 1.19). Birch density was not different among habitat types in the 20- and 70-year age classes. Basal area was not different among habitat types within any specific age class.

Quaking aspen densities were significantly different among habitat types within all age classes (20-year, p = 0.056; 50-year, p = 0.004; 70-year p = 0.009; Tables 1.18–1.20). Quaking aspen basal area differed among habitat types in the 20- and 70-year age classes (20-year, p = 0.008; 70-year, p = 0.062), but not in the 50-year age class (Tables 1.21–1.23). In the 20-year age class, quaking aspen densities were similar among all habitat types except QAE. The QAE habitat type supported the lowest density ($\bar{x}$ = 26.67/ha, S. E. = 26.67) and basal area ($\bar{x}$ = 0.36 m^2/ha, S. E. = 0.36). In the 50-year age class, quaking aspen densities were similar between ATD ($\bar{x}$ = 552.00/ha, S.E. = 106.88) and TM ($\bar{x}$ = 507.69/ha, S.E. = 81.57) habitat types and lowest in the AVO habitat type ($\bar{x}$ = 244.44/ha, S.E. = 38.93; Table 1.19). In the 70-year age class, quaking aspen density and basal area were highest in the AOC habitat type (density, $\bar{x}$ = 415.00/ha, S.E. = 91.63; basal area = 17.64, S.E. = 4.79; Tables 1.20, 1.23). Densities and basal area were similar between 70-year-old stands within the AQV and ATD habitat types, and among AQV, AVO, and TM habitat types (Tables 1.20, 1.23).

All habitat types except QAE supported red maple. Red maple densities were different among habitat types in 20-year (p = 0.045) and 70-year (p = 0.001) age classes, but were not different among habitat types in the 50-year age class (Table 1.19). Basal area was also different among habitat types in 20-year (p = 0.035) and 70-year (p = 0.007) age classes. Densities appeared to be highest in the AQV habitat type (20-year, $\bar{x}$ = 204.00/ha, S.E. = 117.67; 70-year, $\bar{x}$ = 410.00, S.E. = 84.09), although densities in the 20-year age class were not different from AOC and TM habitat types (Table 1.18), and densities in the 70-year age class were not different from those in ATD and TM habitat types (Table 1.20). Red maple basal area was similar among all habitat types in the 20-year age class except QAE, and appeared to be highest in 70-year-old stands within AQV and ATD habitat types (Table 1.21–1.23).

Sugar maple was present in all habitat types, but was not present in 20-year-old AVO stands, 50-year-old TM stands, or 70-year-old AQV stands (Tables 1.18–1.20). In the 20-year age class, the QAE habitat type had the highest (p = 0.002) sugar maple density ($\bar{x}$ = 226.67/ha, S.E. = 167.07) followed by the ATD habitat type ($\bar{x}$ = 50.00/ha, S.E. = 37.86). Basal area was also highest in the QAE habitat type ($\bar{x}$ = 1.66 m^2/ha, S.E. = 1.11) followed by ATD ($\bar{x}$ = 0.21 m^2/ha, S.E = 0.18; Table 1.21). In the 50-year age class, all habitat types supported significantly different densities ($p = 0.002$) and basal area ($p = 0.002$) of sugar maple. The ATD habitat type had the highest density ($\bar{x} =$ 200.00/ha, S.E. = 108.07) and basal area ($\bar{x} = 3.93$ m^2/ha, S.E. = 2.14) followed by the AVO habitat type (density, $\bar{x} = 49.89$/ha, S.E. = 32.10; basal area, $\bar{x} = 1.07$ m^2/ha, S.E. = 1.03; Tables 1.19, 1.22). In the 70-year age class, sugar maple density was highest ($p <$ 0.001) in ATD ($\bar{x} = 493.33$/ha, S.E. = 53.33) and AVO ($\bar{x} = 320.00$, S.E. = 128.58) habitat types (Table 1.20). The AOC habitat type had the second highest density ($\bar{x} =$ 100.00, S.E. = 64.59), and TM ($\bar{x} = 37.50$, S.E. = 27.20) and AQV ($\bar{x} = 0$) habitat types had the lowest (Table 1.20). Basal area of sugar maple exhibited similar trends within the 70-year age class (Table 1.23).

White ash was only present in 70-year old stands within the AVO habitat type (p = 0.020; Table 1.20). Basal area was low ($\bar{x} = 0.07 m^2$/ha, S.E. = 0.07) and was not different from 0 (Table 1.23).

White pine only occurred in dry, sandy habitat types (i.e., AQV, QAE, TM) and densities only differed among habitat types in the 70-year age class ($p = 0.045$), with the TM habitat type supporting the highest densities ($\bar{x} = 117.50$/ha, S.E. = 40.41; Table 1.20). White pine basal area was also highest in the TM habitat type, but did not differ significantly from other habitat types (Table 1.23).

White spruce densities differed among habitat types in all age classes and was highest in the TM habitat type within all age classes (20-year, $\bar{x} = 116.67$/ha, S.E. = 61.59; 50-year, $\bar{x} = 104.62$/ha, S.E. = 26.23; 70-year, $\bar{x} = 117.50$/ha, S.E. = 40.41; Table 1.18–23). Similarly, white spruce basal area was also highest in the TM habitat type (20-

year, $\bar{x} = 3.07 m^2/ha$, S.E. = 1.75; 50-year, $\bar{x} = 2.42\ m^2/ha$, S.E. = 0.87; 70-year, $\bar{x} = 2.92\ m^2/ha$, S.E. = 1.22; Tables 1.21–1.23).

Table 1.18. Average number of stems/ha and standard errors for overstory tree species within aspen stands in the 20-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum.*

Tree species	Habitat types represented in the 20-year age class												Probability
	AOC2 (n=4)		AQV2 (n=10)		ATD2 (n=4)		AVO2 (n=4)		QAE2 (n=3)		TM2 (n=12)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood *Tilia americana*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	1.000
American elm* *Ulmus americana*	**10.00**^{a}	10.00	**0**^{ab}	0	**0**^{ab}	0	**20.00**^{a}	11.55	**0**^{ab}	0	**0**^{b}	0	0.022
Balsam fir* *Abies balsamea*	**50.00**^{ab}	50.00	**52.00**^{a}	24.62	**40.00**^{a}	16.33	**60.00**^{ab}	34.64	**160.00**^{bc}	61.10	**426.67**^{c}	94.24	0.020
Balsam poplar* *Populus balsamifera*	**100.00**^{a}	100	**0**^{ab}	0	**0**^{ab}	0	**80.00**^{a}	67.33	**0**^{ab}	0	**0**^{b}	0	0.025
Bigtooth aspen* *Populus grandidentata*	**60.00**^{a}	60.00	**388.00**^{ab}	237.85	**20.00**^{a}	20.00	**10.00**^{a}	10.00	**1186.67**^{b}	93.33	**90.00**^{a}	71.03	0.054
Black cherry *Prunus serotina*	**50.00**	37.86	**44.00**	22.67	**70.00**	44.35	**0**	0	**0**	0	**26.67**	8.99	0.264
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	1.000
Ironwood* *Carpinus caroliniana*	**10.00**^{ab}	10	**0**^{a}	0	**20.00**^{ab}	20.00	**0**^{a}	0	**66.67**^{b}	48.07	**3.33**^{a}	3.33	0.055
Northern red oak* *Quercus rubra*	**0**^{a}	0.00	**12.00**^{a}	12.00	**0**^{a}	0	**0**^{a}	0	**40.00**^{b}	23.09	**0**^{a}	0	0.012
Northern white cedar *Thuja occidentalis*	0	0	**0**	0	0	0	0	0	**0**	0	0	0	1.000

Table 1.18. (Cont.)

Tree species (*Scientific name*)	Habitat types represented in 20-year age class: AOC2 (n=4) $\bar{x}$	AOC2 (n=4) S.E.	AQV2 (n=10) $\bar{x}$	AQV2 (n=10) S.E.	ATD2 (n=4) $\bar{x}$	ATD2 (n=4) S.E.	AVO2 (n=4) $\bar{x}$	AVO2 (n=4) S.E.	QAE2 (n=3) $\bar{x}$	QAE2 (n=3) S.E.	TM2 (n=12) $\bar{x}$	TM2 (n=12) S.E.	Probability level[1]
Paper birch *Betula papyrifera*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**3.33**	3.33	0.837
Quaking aspen* *Populus tremuloides*	**590.00**[a]	115.90	**748.00**[a]	162.43	**530.00**[a]	44.35	**520.00**[a]	51.64	**26.67**[b]	26.67	**903.33**[a]	152.91	0.056
Red maple* *Acer rubrum*	**150.00**[abc]	90.00	**204.00**[b]	117.67	**0**[ac]	0	**10.00**[ac]	10.00	**0**[c]	0	**30.00**[abc]	21.53	0.045
Red pine *Pinus resinosa*	**0**	0.00	**8.00**	5.33	**0**	0	**0**	0	**0**	0	**0**	0	0.352
Sugar maple* *Acer saccharum*	**10.00**[a]	10.00	**12.00**[ab]	12.00	**50.00**[ac]	37.86	**0**[ab]	0	**226.67**[c]	167.07	**0**[b]	0	0.002
White ash *Fraxinus americana*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	1.000
White pine *Pinus strobus*	**0**	0.00	**12.00**	8.54	**0**	0	**0**	0	**26.67**	26.67	**13.33**	10.25	0.656
White spruce* *Picea glauca*	**0**[ab]	0	**0**[b]	0	**0**[ab]	0	**0**[ab]	0	**0**[ab]	0	**116.67**[b]	61.59	0.040
Yellow birch *B. alleghaniensis*	**10.00**	10	**0**	0	**0**	0	**40.00**	40.00	**0**	0	**0**	0	0.189
All species combined*	**1040.00**[a]	216.56	**1480.00**[ab]	216.56	**730.00**[c]	52.60	**740.00**[c]	119.44	**1733.33**[b]	193.68	**1613.33**[b]	186.47	0.007

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 198

Table 1.19. Average number of stems and standard errors for overstory tree species within aspen stands in the 50-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum.*

	Habitat types represented in 50-year age class						
Tree species	ATD5 (n=5)		AVO5 (n=18)		TM5 (n=13)		Probability
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood* *Tilia americana*	**0**[ab]	0	**104.44**[a]	48.84	**0**[b]	0	0.031
American elm *Ulmus americana*	**0**	0	**24.44**	14.51	**0**	0	0.113
Balsam fir* *Abies balsamea*	**232.00**[a]	192.42	**304.44**[a]	101.09	**1067.69**[b]	153.62	0.000
Balsam poplar *Populus balsamifera*	**0**	0	**6.67**	6.67	**3.08**	3.08	0.829
Bigtooth aspen *Populus grandidentata*	**16.00**	16.00	**11.11**	11.11	**40.00**	21.72	0.374
Black cherry *Prunus serotina*	**16.00**	16.00	**35.56**	12.89	**24.62**	13.23	0.773
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**0**	0	1.000
Ironwood* *Carpinus caroliniana*	**0**[ab]	0	**55.56**[a]	22.90	**0**[b]	0	0.061
Northern red oak *Quercus rubra*	**0**	0	**0**	0	**0**	0	1.000
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**0**	0	1.000

Table 1.19. (Cont.)

Tree species (*Scientific name*)	Habitat types represented in 50-year age class: ATD5 (n=5) $\bar{x}$	ATD5 (n=5) S.E.	AVO5 (n=18) $\bar{x}$	AVO5 (n=18) S.E.	TM5 (n=13) $\bar{x}$	TM5 (n=13) S.E.	Probability level[1]
Paper birch* *Betula papyrifera*	**160.00**[a]	88.54	**71.11**[a]	25.17	**9.23**[b]	4.87	0.079
Quaking aspen* *Populus tremuloides*	**552.00**[a]	106.88	**244.44**[b]	38.93	**507.69**[a]	81.57	0.004
Red maple *Acer rubrum*	**288.00**	115.52	**251.11**	98.13	**110.77**	36.84	0.449
Red pine *Pinus resinosa*	**0**	0	**0**	0	**0**	0	1.000
Sugar maple* *Acer saccharum*	**200.00**[a]	108.07	**49.89**[b]	32.10	**0**[c]	0	0.002
White ash *Fraxinus americana*	**0**	0	**0**	0	**0**	0	1.000
White pine *Pinus strobus*	**0**	0	**0**	0	**0**	0	1.000
White spruce* *Picea glauca*	**16.00**[a]	9.80	**35.56**[a]	28.72	**104.62**[b]	26.23	0.000
Yellow birch *Betula alleghaniensis*	**24.00**	24.00	**4.44**	3.05	**0**	0	0.313
All species combined*	**1504.00**[ab]	188.30	**1197.78**[a]	109.73	**1867.69**[b]	164.14	0.024

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.20. Average number of stems and standard errors for overstory tree species within aspen stands in the 70-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Tree species	Habitat types represented in 70-year age class										Probability
	AOC7 (n=8)		AQV7 (n=8)		ATD7 (n=3)		AVO7 (n=3)		TM7 (n=16)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood* *Tilia americana*	**55.00**^{a}	49.53	**0**^{abc}	0	**0**^{ab}	0	**880.00**^{c}	140.48	**0**^{b}	0	0.000
American elm *Ulmus americana*	**10.00**	10.00	**0**	0	**0**	0	**0**	0	**0**	0	0.441
Balsam fir* *Abies balsamea*	**60.00**^{a}	32.95	**10.00**^{c}	10.00	**226.67**^{ab}	206.99	**0**^{b}	0	**767.50**^{d}	134.57	0.000
Balsam poplar *Populus balsamifera*	**45.00**	23.22	**0**	0	**0**	0	**0**	0	**27.50**	24.96	0.194
Bigtooth aspen* *Populus grandidentata*	**15.00**^{a}	15.00	**155.00**^{c}	73.85	**0**^{b}	0	**0**^{b}	0	**37.50**^{ab}	26.20	0.010
Black cherry *Prunus serotina*	**70.00**	48.26	**5.00**	5.00	**0**	0	**40.00**	40.00	**2.50**	2.50	0.090
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**40.00**	40.00	**0**	0	**0**	0	0.020
Ironwood* *Carpinus caroliniana*	**5.00**^{a}	5.00	**0**^{abc}	0	**13.33**^{a}	13.33	**213.33**^{b}	96.15	**0**^{c}	0	0.000
Northern red oak *Quercus rubra*	**0**	0	**15.00**	10.52	**0**	0	**0**	0	**0**	0	0.103
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**0**	0	**0**	0	**2.50**	2.50	0.849

Table 1.20. (Cont.)

Tree species	Habitat types represented in 70-year-old age classes										Probability
	AOC7 (n=8)		AQV7 (n=8)		ATD7 (n=3)		AVO7 (n=3)		TM7 (n=16)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Paper birch *Betula papyrifera*	**15.00**	15.00	**135.00**	74.81	**0**	0	**0**	0	**40.00**	18.97	0.221
Quaking aspen* *Populus tremuloides*	**415.00**^{a}	91.63	**110.00**^{bc}	47.06	**13.33**^{b}	13.33	**66.67**^{c}	26.67	**182.50**^{c}	32.45	0.009
Red maple* *Acer rubrum*	**15.00**^{a}	7.32	**410.00**^{bc}	84.09	**360.00**^{b}	205.26	**26.67**^{ac}	26.67	**72.50**^{c}	26.39	0.001
Red pine *Pinus resinosa*	**0**	0	**0**	0	**0**	0	**0**	0	**10.00**	5.77	0.360
Sugar maple* *Acer saccharum*	**100.00**^{a}	64.59	**0**^{b}	0	**493.33**^{c}	53.33	**320.00**^{c}	128.58	**37.50**^{b}	27.20	0.000
White ash* *Fraxinus americana*	**0**^{ab}	0	**0**^{ab}	0	**0**^{ab}	0	**26.67**^{a}	26.67	**0**^{b}	0	0.020
White pine* *Pinus strobus*	**0**^{a}	0	**15.00**^{b}	7.32	**0**^{ab}	0	**0**^{ab}	0	**110.00**^{b}	42.03	0.045
White spruce* *Picea glauca*	**15.00**^{a}	15.00	**10.00**^{a}	6.55	**0**^{a}	0	**13.33**^{ab}	13.33	**117.50**^{b}	40.41	0.019
Yellow birch *Betula alleghaniensis*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	1.000
All species combined*	**820.00**^{a}	125.58	**865.00**^{a}	113.37	**1146.67**^{ab}	213.33	**1586.67**^{b}	113.92	**1410.00**^{b}	149.29	0.017

[1] Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.21. Average basal area and standard errors for overstory tree species within aspen stands in the 20-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum.*

Tree species	Habitat types represented in 20-year age class												Probability
	AOC2 (n=4)		AQV2 (n=10)		ATD2 (n=4)		AVO2 (n=4)		QAE2 (n=3)		TM2 (n=12)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood *Tilia americana*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	1.000
American elm* *Ulmus americana*	**0.08**^{abc}	0.08	**0**^{ad}	0	**0**^{abcd}	0	**0.04**^{bc}	0.03	**0**^{cd}	0	**0**^{d}	0	0.025
Balsam fir* *Abies balsamea*	**0.27**^{a}	0.27	**0.25**^{a}	0.13	**2.39**^{ab}	2.32	**0.1**^{a}	0.08	**2.7**^{b}	0.99	**6.59**^{b}	2.92	0.008
Balsam poplar* *Populus balsamifera*	**1.48**^{ab}	1.48	**0**^{ad}	0	**0**^{bd}	0	**1.82**^{bc}	1.71	**0**^{acd}	0	**0**^{d}	0	0.022
Bigtooth aspen* *P. grandidentata*	**1.79**^{a}	1.79	**1.61**^{a}	0.93	**0.03**^{a}	0.03	**0.18**^{a}	0.18	**12.33**^{b}	3.30	**0.66**^{a}	0.49	0.040
Black cherry *Prunus serotina*	**0.17**	0.16	**0.26**	0.15	**0.33**	0.21	**0**	0	**0**	0	**0.17**	0.09	0.289
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	1.000
Ironwood* *Carpinus caroliniana*	**0.06**^{ab}	0.06	**0**^{c}	0	**0.18**^{abc}	0.18	**0**^{bc}	0	**0.18**^{a}	0.12	**0.04**^{bc}	0.04	0.093
Northern red oak* *Quercus rubra*	**0**^{a}	0	**0.86**^{a}	0.86	**0**^{a}	0	**0**^{a}	0	**13.87**^{b}	9.06	**0**^{a}	0	0.006
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	1.000

Table 1.21. (Cont.)

Tree species	Habitat types represented in 20-year age class												Probability
	AOC2 (n=4)		AQV2 (n=10)		ATD2 (n=4)		AVO2 (n=4)		QAE2 (n=3)		TM2 (n=12)		
(Scientific name)	x̄	S.E.	x̄	S.E.	x̄	S.E.	x̄	S.E.	x̄	S.E.	x̄	S.E.	level[1]
Paper birch *Betula papyrifera*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**<0.01**	<0.01	0.837
Quaking aspen* *P. tremuloides*	**10.82^{ab}**	2.88	**4.76^{c}**	1.55	**5.66^{ac}**	0.72	**5.34^{c}**	1.06	**0.36**	0.36	**28.70^{b}**	13.33	0.008
Red maple* *Acer rubrum*	**3.85^{a}**	3.48	**0.78^{a}**	0.40	**0^{a}**	0	**0.08^{a}**	0.08	**0^{b}**	0	**0.04^{a}**	0.03	0.035
Red pine *Pinus resinosa*	**0**	0	**0.88**	0.59	**0**	0	**0**	0	**0**	0	**0**	0	0.352
Sugar maple* *Acer saccharum*	**0.01^{a}**	0.01	**0.02^{ab}**	0.02	**0.21^{a}**	0.18	**0^{ab}**	0	**1.66^{c}**	1.11	**0^{b}**	0	0.001
White ash *Fraxinus americana*	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0.143
White pine *Pinus strobus*	**0**	0	**0.63**	0.47	**0**	0	**0**	0	**6.25**	6.25	**2.02**	1.50	0.624
White spruce* *Picea glauca*	**0^{ab}**	0	**0^{a}**	0	**0^{ab}**	0	**0^{ab}**	0	**0^{ab}**	0	**3.07^{b}**	1.75	0.040
Yellow birch *B. alleghaniensis*	**0.08**	0.08	**0**	0	**0**	0	**0.28**	0.28	**0**	0	**0**	0	0.189
All species combined*	**18.62^{a}**	2.54	**10.05^{b}**	1.92	**8.79^{b}**	2.28	**7.97^{b}**	2.68	**37.35^{a}**	8.84	**41.29^{a}**	13.71	0.006

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.22. Average basal area and standard errors for overstory tree species within aspen stands in the 50-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Tree species	Habitat types represented in 50-year age class						Probability
	ATD5 (n=5)		AVO5 (n=18)		TM5 (n=13)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood* *Tilia americana*	**0**^{ab}	0	**3.19**^{a}	1.49	**0**^{b}	0	0.031
American elm *Ulmus americana*	**0**	0	**0.25**	0.14	**0**	0	0.113
Balsam fir* *Abies balsamea*	**1.97**^{a}	1.38	**1.97**^{a}	0.60	**8.69**^{b}	1.38	0.001
Balsam poplar *Populus balsamifera*	**0**	0	**0.13**	0.13	**0.03**	0.03	0.829
Bigtooth aspen *Populus grandidentata*	**0.25**	0.25	**0.19**	0.19	**1.11**	0.69	0.374
Black cherry *Prunus serotina*	**0.02**	0.02	**1.36**	1.16	**0.06**	0.03	0.619
Eastern hemlock *Tsuga canadensis*	**0**	0	**0**	0	**0**	0	1.000
Ironwood* *Carpinus caroliniana*	**0**^{ab}	0	**0.44**^{a}	0.23	**0**^{b}	0	0.061
Northern red oak *Quercus rubra*	**0**	0	**0**	0	**0**	0	1.000
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**0**	0	1.000

Table 1.22. (Cont.)

Tree species (*Scientific name*)	Habitat types represented in 50-year age class: ATD5 (n=5) x̄	ATD5 (n=5) S.E.	AVO5 (n=18) x̄	AVO5 (n=18) S.E.	TM5 (n=13) x̄	TM5 (n=13) S.E.	Probability level[1]
Paper birch *Betula papyrifera*	**2.83**	1.47	**3.89**	1.69	**1.91**	1.79	0.228
Quaking aspen *Populus tremuloides*	**17.13**	2.10	**11.37**	1.74	**15.41**	2.56	0.237
Red maple *Acer rubrum*	**2.87**	1.23	**1.46**	0.70	**4.22**	1.84	0.349
Red pine *Pinus resinosa*	**0**	0	**0**	0	**0**	0	1.000
Sugar maple* *Acer saccharum*	**3.93**[a]	2.14	**1.07**[b]	1.03	**0**[c]	0	0.002
White ash *Fraxinus americana*	**0**	0	**0**	0	**0**	0	1.000
White pine *Pinus strobus*	**0**	0	**0**	0	**0**	0	1.000
White spruce* *Picea glauca*	**0.05**[a]	0.03	**0.61**[a]	0.54	**2.42**[b]	0.87	0.000
Yellow birch *Betula alleghaniensis*	**0.09**	0.09	**0.16**	0.15	**0**	0	0.335
All species combined*	**29.14**[ab]	2.66	**26.09**[a]	2.39	**33.84**[b]	2.11	0.027

[1] Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 1.23. Average basal area and standard errors for overstory tree species within aspen stands in the 70-year age class in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Tree species	Habitat types represented in 70-year age class										Probability
	AOC7 (n=8)		AQV7 (n=8)		ATD7 (n=3)		AVO7 (n=3)		TM7 (n=16)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American basswood* *Tilia americana*	**0.38**[a]	0.32	**0**[ab]	0	**0**[ab]	0	**29.64**[b]	6.93	**0**[c]	0	0.000
American elm *Ulmus americana*	**0.52**	0.52	**0**	0	**0**	0	**0**	0	**0**	0	0.441
Balsam fir* *Abies balsamea*	**1.47**[a]	0.63	**0.02**[b]	0.02	**0.40**[ac]	0.34	**0**[bc]	0	**5.12**[d]	0.70	0.000
Balsam poplar *Populus balsamifera*	**1.77**	1.31	**0**	0	**0**	0	**0**	0	**0.91**	0.86	0.210
Bigtooth aspen* *Populus grandidentata*	**1.30**[ac]	1.30	**9.24**[b]	4.12	**0**[ad]	0	**0**[d]	0	**2.82**[cd]	2.01	0.006
Black cherry* *Prunus serotina*	**0.43**[ab]	0.23	**0.08**[abc]	0.08	**0**[bc]	0	**0.05**[bc]	0.05	**0.02**[c]	0.02	0.085
Eastern hemlock* *Tsuga canadensis*	**0**[ab]	0	**0**[ab]	0	**1.23**[a]	1.23	**0**[ab]	0	**0**[b]	0	0.020
Ironwood* *Carpinus caroliniana*	**0.01**[ab]	0.01	**0**[ab]	0	**0.08**[a]	0.08	**1.21**[c]	0.53	**0**[b]	0	0.000
Northern red oak *Quercus rubra*	**0**	0	**0.48**	0.42	**0**	0	**0**	0	**0**	0	0.103
Northern white cedar *Thuja occidentalis*	**0**	0	**0**	0	**0**	0	**0**	0	**0.32**	0.32	0.849

Table 1.23. (Cont.)

Tree species	Habitat types represented in 70-year age class										Probability
	AOC7 (n=8)		AQV7 (n=8)		ATD7 (n=3)		AVO7 (n=3)		TM7 (n=16)		
(*Scientific name*)	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Paper birch *Betula papyrifera*	**0.23**	0.23	**9.66**	7.48	**0**	0	**0**	0	**1.98**	1.15	0.196
Quaking aspen* *Populus tremuloides*	**17.64**^{a}	4.79	**6.02**^{b}	2.19	**2.98**^{b}	2.98	**9.22**^{ab}	3.40	**12.44**^{a}	2.60	0.062
Red maple* *Acer rubrum*	**1.04**^{a}	0.75	**9.72**^{b}	3.25	**11.87**^{b}	5.92	**0.17**^{a}	0.17	**2.34**^{a}	1.07	0.007
Red pine *Pinus resinosa*	**0**	0	**0**	0	**0**	0	**0**	0	**0.92**	0.60	0.360
Sugar maple* *Acer saccharum*	**2.44**^{a}	2.23	**0**^{b}	0	**10.32**^{a}	1.53	**4.47**^{a}	1.99	**0.97**^{b}	0.76	0.000
White ash* *Fraxinus americana*	**0**^{ab}	0	**0**^{ab}	0	**0**^{ab}	0	**0.07**^{a}	0.07	**0**^{b}	0	0.020
White pine* *Pinus strobus*	**0**^{a}	0	**1.64**^{b}	1.58	**0**^{ab}	0	**0**^{ab}	0	**2.21**^{b}	0.91	0.058
White spruce* *Picea glauca*	**0.35**^{a}	0.35	**0.08**^{a}	0.06	**1.32**^{ab}	1.32	**0.06**^{ab}	0.06	**2.92**^{b}	1.22	0.061
Yellow birch *Betula alleghaniensis*	**0**	0	**0**	0	**0**	0	**0**	0	**0.14**	0.14	0.849
All species combined	**26.40**	4.40	**36.74**	8.21	**28.20**	2.62	**44.89**	9.82	**33.12**	2.91	0.400

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Timber volume

Timber (pulpwood) volume (m^3/ha), as determined from Operations Inventory data was different among habitat types in the 50-year and 70-year age class ($p = 0.069$ and $p < 0.001$ for the 50-year and 70-year age classes, respectively; Table 1.24). Volume of pulpwood in stands within the AQV and ATD habitat types were highest in the 50-year age class, but not different from volume in the AVO habitat type (Table 1.24). In the 70-year age class, volume was highest within the ATD and TM habitat types (Table 1.24). Volume of pulpwood in stands within the QAE and AOC habitat types were generally lowest in both age classes. All stands increased volume in 50 to 70 years, but stands in the TM habitat type increased the most.

Table 1.24. Average volume (cords/ac and m^3/ha) and standard errors for overstory tree species within aspen stands in the 50- and 70-year age classes in different habitat types on state land in the western Upper Peninsula, Michigan during 2004–2006. Volume in m^3/ha was calculated by converting the cords/ac values recorded in the Michigan Department of Natural Resources Operations Inventory database. One cord = 3.62 m^3 and includes bark, wood, and air space in a 4-ft x 4-ft x 100-in stack of logs. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum.*

	Habitat types represented in 50-year age class												
	AOC (n=49)		AQV (n=54)		ATD (n=8)		AVO (n=104)		QAE (n=10)		TM (n=40)		Probability level[1]
	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	
Volume													
(m^3/ha)	**64.77**[a]	4.21	**82.15**[b]	5.00	**78.44**[ab]	5.81	**73.90**[ab]	2.89	**58.40**[a]	7.06	**67.10**[a]	4.13	0.069
(cords)	**17.86**	1.16	**22.68**	1.38	**21.63**	1.60	**20.38**	0.80	**16.10**	1.95	**18.5**	1.14	

	Habitat types represented in 70-year age class												
	AOC (n=50)		AQV (n=96)		ATD (n=42)		AVO (n=184)		QAE (n=73)		TM (n=70)		Probability level[1]
	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	
Volume													
(m^3/ha)	**77.94**[a]	1.58	**86.57**[bc]	1.72	**100.84**[d]	3	**81.61**[be]	1.29	**79.57**[ae]	2.14	**87.98**[c]	1.62	<0.001
(cords)	**21.49**	0.44	**23.87**	0.47	**27.80**	0.83	**22.50**	0.31	**21.94**	0.59	**24.26**	0.45	

[1] Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

DISCUSSION

Traditionally, effects of forest management decisions were only considered at the stand-level. Only relatively recently have forest managers begun to examine effects of management within a different spatial (Crow and Gustafson 1997) and temporal (Bissonette and Storch 2007) context. Although harvest or other forest management practices occurs at the stand-level, it is important to recognize that stand-level treatments may have implications at broader spatial scales, such as the removal of unique features of vegetation types or changing the spatial arrangement of vegetation types within a landscape, and thereby potentially restricting their availability to wildlife. First, however, it is critical to have knowledge of the potential variations in vegetation composition and structure due to abiotic spatial characteristics (e.g., soils) and successional changes among habitat types. These results describe the composition, distribution, and temporal changes of the aspen vegetation type within various habitat types and provide a foundation for understanding the distribution of areas that can potentially provide specific characteristics of aspen, how aspen physiognomy may change temporally within different habitat types, and how well aspen management strategies on public land are meeting ecosystem-based objectives. This understanding contributes to improving knowledge upon which sound forest management decisions are based.

In the initial study design of this project, stands represented the evaluation unit, but because some stand boundaries overlapped habitat types (Figure 1.2; this occurred in approximately 20% of my sampled stands), I modified the evaluation unit to be age classes within specific habitat types rather than stands. This modified sampling design probably reduced the variance associated with measured vegetation variables due to clustering of samples. However, significant differences in composition and structure of aspen in different age classes and habitat types were still evident, and the design raised awareness of the significance of maintaining stands within habitat types. It may be difficult, for instance, to implement stand-level management to maintain or enhance habitat conditions for wildlife that require specific stand-level characteristics. For example, a shrub-nesting bird might require 20 ha of interior vegetation. If the stand being managed is 40 ha, 25 ha of which consists of a habitat type with low shrub density and 15 of which is a habitat type that supports high shrub densities, habitat requirements for the bird will not be met with management of this stand. Even though management occurred within one stand, vegetation within different habitat types in that same stand will respond differently to the same treatment. Stand boundaries should be consistent with boundaries of inherent landscape features, or habitat types, so that managers can fully understand and realize the effects of management on resulting within-stand composition and structure, and landscape composition and structure.

Results of this analysis have several implications relating to management of forests for a diversity of structure and compositional characteristics in aspen vegetation types to provide habitat for multiple wildlife species, to maintain timber production, and for maintaining Michigan's certification through the Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI). Three broad issues were evident from the results regarding habitat provisions for a diversity of wildlife species and timber production. First, general structural and compositional differences were evident between and among aspen stands in different age classes and habitat types. Second, managers may need to increase representation of managed lands in certain underrepresented vegetation types. Third, the distribution of aspen within different habitat types and age classes on state land does not reflect its distribution within habitat types and age classes across the landscape. The fact that some habitat types contained very little aspen in certain age classes also may have implications for wildlife habitat and timber sustainability. The information provided through this research can help Michigan enhance forest management plans to maintain certified forests.

Differences in vegetation structural attributes across habitat types

Soil moisture and texture, and landform characteristics contribute to differences in vegetation physiognomy within habitat types. Natural successional processes change vegetation physiognomy between age classes within the same habitat type. The most distinguishing differences among habitat types were evident when evaluating composition (Figure 1.7). Generally, habitat types supported by xeric soils (i.e., QAE, AQV) supported more bigtooth aspen and oak than other habitat types. Spruce and fir were much more prevalent in the TM habitat type than any of the others. Hardwood species such as basswood and elm were significant overstory components of AVO and AOC habitat types; especially in later successional stages. Hemlock was only observed in the ATD habitat type. These compositional differences were more evident in older (≥ 50 years) aspen stands because the aspen is beginning successional transitions to other vegetation types.

Structural differences were also evident among habitat types (Figures 1.8–1.10). The most notable structural differences were the presence of a thick shrub understory in AVO (and AOC) habitat types, a relatively open understory in the ATD habitat type, higher stem densities of coniferous trees in the TM habitat type, and higher aspen stem densities in the TM habitat type (Figure 1.9). Aspen stem densities declined sharply in old (> 70) age classes with the ATD habitat type, most likely due to competition with maple for overstory dominance. Because forests are managed for multiple uses and ecological benefits, representation of all habitat types and their associated vegetation types within the landscape is important to ensure a range of vegetation conditions exist for wildlife habitat and timber production.

It is important for mangers to understand these structural and compositional differences among habitat types when designing management plans to meet multiple objectives because it is contrary to traditional belief regarding relationships between aspen harvest and wildlife habitat suitability. For instance, < 20 years ago, aspen management recommendations to benefit wildlife included harvesting small areas, maintaining stands in various ages of maturity, and shortening harvest rotations to foster favorable wildlife conditions (Kidd and Koelling 1988). These recommendations would likely have provided habitat for deer, grouse, and wildlife preferring edges, but would not have maintained conditions for edge sensitive species and species favoring old aspen. For example, woodpeckers and other cavity nesting species may use snags provided by old aspen stands (Hamelin 1992). Additionally, traditional recommendations did not distinguish among aspen stands in different habitat types that provide various structural and compositional characteristics, to which wildlife may respond differently. For instance, regenerating aspen in QAE and AQV types may experience greater impacts due to deer browsing because bigtooth aspen, which grows in the xeric sandy soils of QAE and AQV habitat types, is preferred over quaking aspen by deer (Heinen and Sharik

1989), and also has lower stand vigor and stocking than quaking aspen at various browsing intensities (Campa et al. 1992).

Today, research has advanced knowledge regarding the relationship of different ages of aspen forests to wildlife, and the relationship of aspen in different habitat types to wildlife. More research is needed, however to continue improving our understanding of wildlife responses to physiognomic differences among aspen in different age classes and habitat types. These relationships are further investigated in Chapter 2.

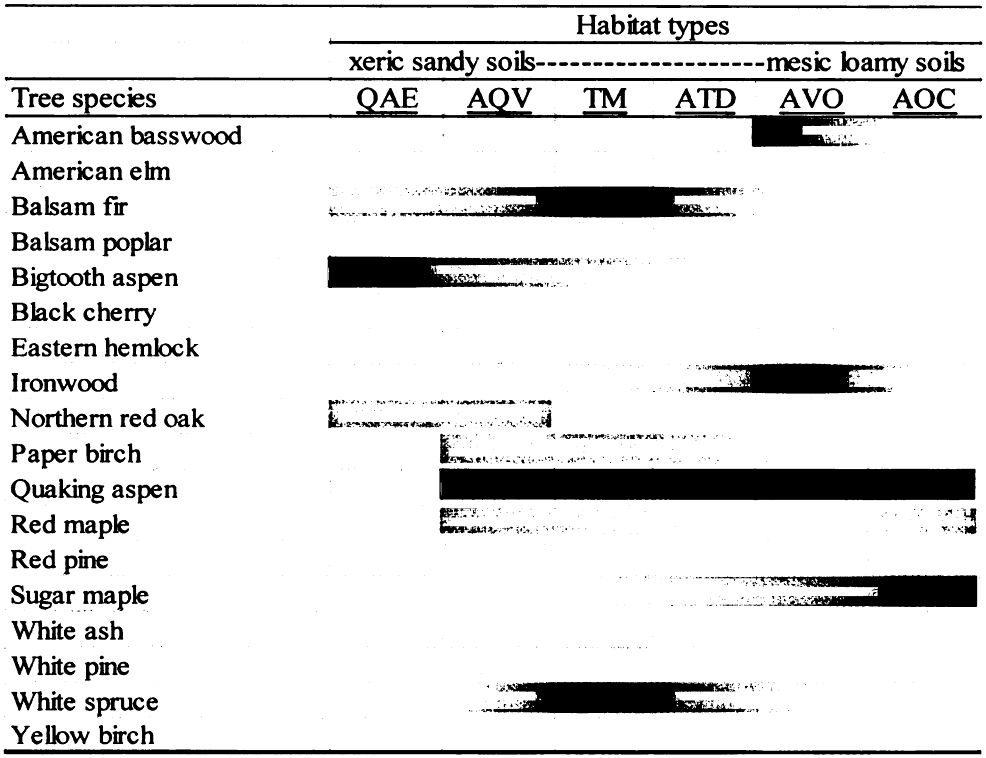

Figure 1.7. Relative differences in overstory tree species presence and dominance across habitat types sampled on state lands in the western Upper Peninsula, Michigan during 2004–2006. The location of bars represents habitat t ypes in which tree species are present. Darker shades indicate dominance. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum.*

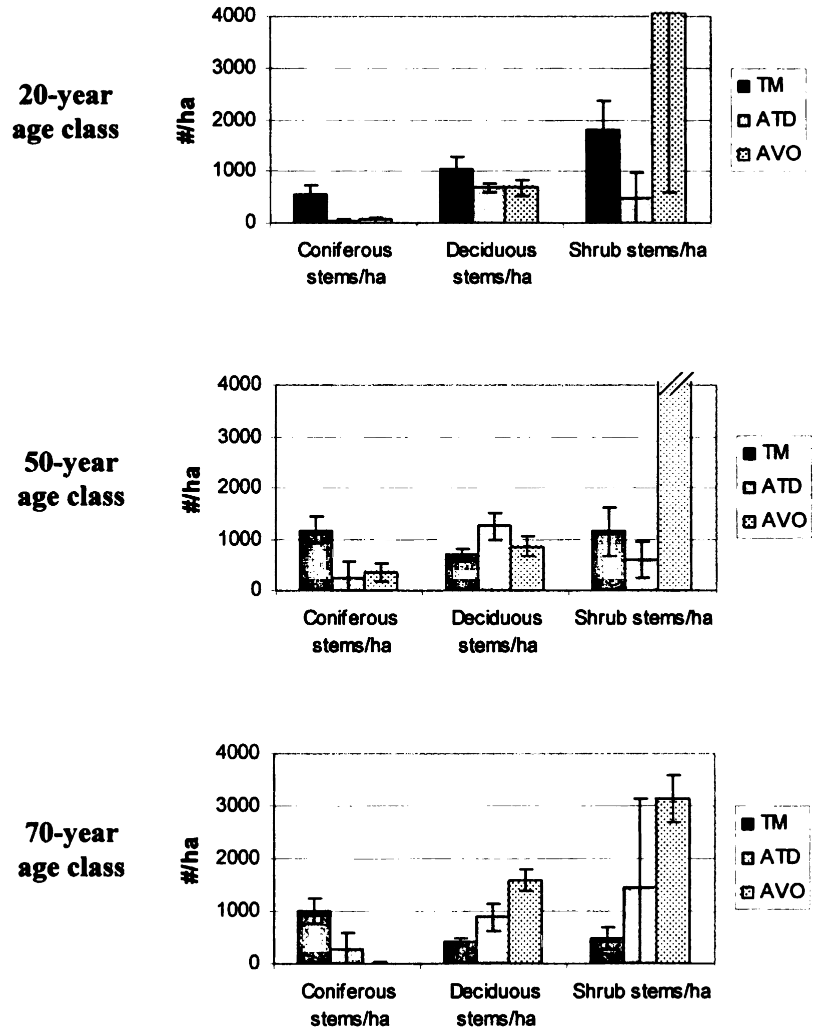

Figure 1.8. Summary of vegetation structural differences among aspen stands within 3 age classes and habitat types in the western Upper Peninsula, Michigan. Vegetation was sampled in 2004–2006. ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Osmorrhiza*, and TM = *Tsuga-Maianthemum*.

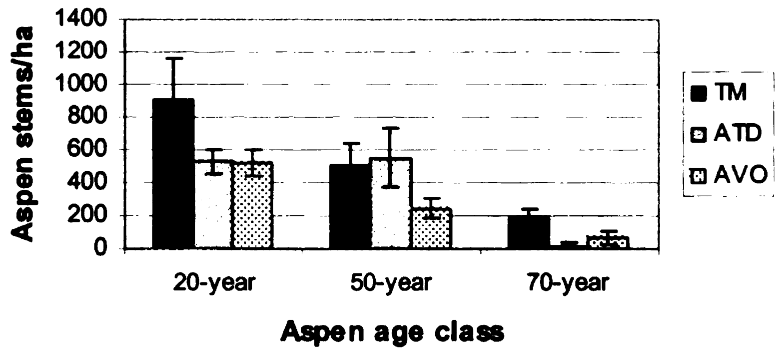

Figure 1.9. Summary of differences in quaking aspen stem density among different age classes and habitat types that can support aspen. Vegetation was sampled in 2004–2006. ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Osmorrhiza*, and TM = *Tsuga-Maianthemum*.

20-year age class

50-year age class

70-year age class

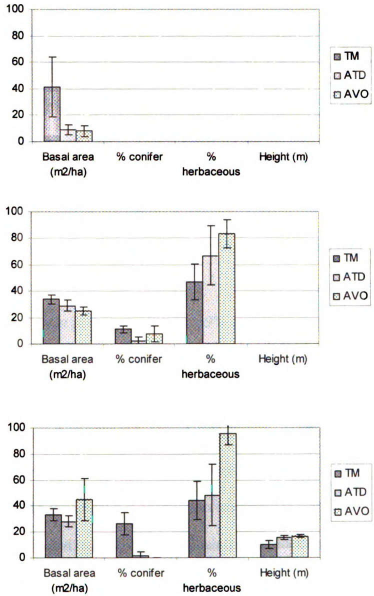

Figure 1.10. Summary of vegetation structural differences among aspen stands within 3 age classes and habitat types in the western Upper Peninsula, Michigan. Variables presented are important in distinguishing habitat types. As aspen stands age, more variables become important in distinguishing vegetation types. Vegetation was sampled in 2004–2006. ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Osmorrhiza*, and TM = *Tsuga-Maianthemum*.

Representation of habitat types

Certain habitat types appear to be underrepresented on public land within the study area. That is, they occur on public land proportionally less then their availability in the landscape. For instance, the relative amount of area in TM, ATD, and FMC habitat types was higher in the entire study area than on public lands within the study area (Figure 1.5). Therefore, the range of vegetation conditions provided by those habitat types for wildlife, biodiversity, and timber are likely underrepresented in the landscape unless private landowners maintain those conditions. This is the case with specific vegetation types such as mesic conifers.

Mesic conifers were dominant in the overstory on 39% of the western UP landscape during presettlement times. In May 2001 however, the DNR estimated that mesic conifers represented 6.7% of the state forest land in the western UP (R. Doepker, MDNR unpublished report). As such, the DNR initiated guidelines to emphasize increasing the mesic conifer component by 100% over the next 20 years on state forestlands in the western UP. These guidelines specify increasing representation of the spruce-fir vegetation type by 50% and increasing area containing hemlock by 1.5 times the current area. Guidelines for white pine and red pine are also specified. The TM and ATD habitat types can be managed to increase mesic conifers because spruce and fir dominate the middle successional stage of the TM habitat type, and the ATD habitat type has the potential to support hemlock. Both of those habitat types, however, are underrepresented on state lands. Approximately 9000 ha or 3.6% of state land occurs in the ATD habitat type (versus 15% of the landscape), and roughly 27,000 ha or 10.8% of state land occurs in the TM habitat type (versus 20%). It is area within those habitat types that could be considered for land acquisition and where management efforts for mesic conifers should focus. Perhaps Michigan State University Extension could work with private landowners to strengthen cooperative programs to help meet the state's mesic conifer and other ecological goals.

Stands within the TM and ATD habitat types generally produced higher basal area (Tables 1.21–1.23) and timber volume (Table 1.24) in the 70-year age classes than in other habitat types. Basal area may be an important habitat component for wildlife species such as ruffed grouse (Zimmerman 2006). Increasing the amount of area on state lands within TM and ATD habitat types through land aquisition may also increase timber potential, which may help in designing management plans for sustainable timber harvest. Additionally, increasing area within TM and ATD habitat types may increase the potential of state lands to provide habitat for wildlife associated with hemlock (e.g., pine siskin [*Carduelis pinus*], evening grosbeak [*Coccothraustes vespertinus*], yellow-bellied sapsucker [*Sphyrapicus varius*]; Yamasaki et al. 1999, see Chapter 2).

The proportion of other habitat types (i.e., QAE, AQV, AVO, AOC, TTS) was higher on state land than within the entire study area, and the proportion of aspen within those habitat types was greater than the proportion of area within each of those habitat types. Therefore, the potential for management of vegetation diversity within those habitat types is greater than within the underrepresented habitat types. Unique characteristics provided by each of those habitat types include dominance of bigtooth aspen on xeric habitat types (QAE), an oak component in QAE and AQV types, thick shrub layer in AVO and AOC types, and wetland components in the TTS habitat type.

Representation of age classes

The representation of aspen in the 50- and 60-year age classes was relatively low (approximately 7%; Figure 1.4); and the representation of these age classes within some habitat types was almost non existent. Most notable, for example, was the small proportion (0.04%) of 50-year-old aspen within the ATD habitat type (Table 1.6, Figure 1.5). The fact that some habitat types contained very little aspen in certain age classes also may have implications for wildlife habitat and timber sustainability. Landscapes without specific age classes of aspen may lack vegetation characteristics important for certain wildlife species. For example, research in western North America has shown that bird species richness and diversity increases with ecological age of the aspen seral stage (Pojar 1995). In eastern North America, declines in several wildlife species such as woodcock (*Philohelo minor*) and bobcat (*Lynx rufus*) have been attributed to maturing of forests and subsequent declines in the amount of early successional forests (e.g., aspen; Trani et al. 2001). My results suggested that wildlife species in Michigan would also respond differently to the significant differences in structure and composition of aspen within different age classes and habitat types. Specifically, older age classes of aspen in all habitat types showed an increase in basal area, DBH, snag decay and diameter, and a decrease in deciduous stem density and herbaceous cover. Cavity-nesters (e.g., woodpeckers, owls, bats) are likely to occur in older age classes of aspen due to those characteristics (Negri 1995). Although stem densities were similar among all age classes and habitat types, the composition of overstory tree species changed with age. In the TM habitat type, balsam fir, white spruce, and maple species increased. Wildlife species (e.g, brown creeper [*Certhia Americana]*, golden-crowned kinglet [*Regulus satrapa*], common yellowthroat [*Geothlypis trichas*]) requiring a mixture of conifer and deciduous cover would likely find habitat components in 50–70-year-old aspen, as it is a transition from aspen to spruce and fir (Blake et al. 1994). In dry, sandy habitat types (e.g., AQV), red oak increased, thus potentially providing a mast component in later stages of aspen succession. In mesic habitat types (ATD, AVO, AOC), hardwood species such as basswood and maple increased. It is plausible that communities of wildlife species would differ within and among age classes and habitat types. Therefore, it is important to consider the range of structures provided by different ages and habitat types and maintain them in forests to meet wildlife habitat objectives.

Problems with consistent or sustainable timber production may also result from lack of representation of aspen in specific age classes. Currently, levels of timber harvesting in the western UP are not sustainable because of the relatively low amount of 50-year-old aspen in the landscape (R. Doepker, MDNR, personal communication). Forest managers have had to start harvesting 40-year-old aspen stands to maintain harvest levels, which will likely lead to future declines in area of aspen stands $\geq$ 50-years old in various habitat types. Managers may need to modify plans and perhaps harvest in older stands for a period of time to allow stand recruitment into the 50-year age class (see Chapter 4).

Implications for Michigan's Forest Certification Initiative

Michigan's forest certification initiative is a comprehensive system of principles, objectives, and performance measures to assist planning and forest management to sustain harvest while conserving wildlife and their habitats (Michigan Forest Products

Council 2006). Specific objectives for sustainable forestry have been identified through the SFI (Michigan Sustainable Forestry Initiative 2004) and the FSC (Forest Stewardship Council 2005), and results of this project can assist in meeting many of the objectives. For example, one objective is "to broaden the implementation of sustainable forestry by ensuring long-term harvest levels based on the use of the best scientific information available" (Michigan Sustainable Forestry Initiative 2004:4). Indicators for meeting this objective include current digital maps and a land classification system.

The habitat type classification is an ecological classification system developed by Felix (2003) and refined in this project that used the most current information available to define boundaries of habitat types. Ecological classification systems can provide maps of land units that have similar biotic and/or abiotic characteristics, provide data that can be used to help describe the potential of geographic areas, and they can integrate biotic and/or abiotic information at multiple spatial scales to help understand dynamics of ecological processes and wildlife-habitat relationships (Felix et al. 2007). This habitat-type classification system, for instance, is useful for understanding spatial distribution of habitat types and temporal changes in vegetation structure and composition throughout succession. It is useful for long-term management and planning because boundaries of habitat types are inherent landscape characteristics defined by soil moisture, texture, and landform characteristics, and explain much of the inherent variation associated with structure, composition, and distribution of potential vegetation throughout landscapes. Although boundaries and dynamics of habitat types are not static, they define a relatively narrow range of environmental conditions (Kotar and Burger 2000) that can provide a basis for predicting vegetation change over time with natural successional pathways or as a result of certain management practices. Linking these predictions with habitat suitability modeling (Chapters 2–3) and timber production (Chapter 4) can aid in developing management plans that ensure long-term harvest levels that are sustainable and consistent with ecosystem-based management goals.

Another objective is to manage the quality and distribution of wildlife habitats and contribute to the conservation of biological diversity by developing and implementing stand- and landscape-level measures that promote biodiversity and conservation (Michigan Sustainable Forestry Initiative 2004:6, Forest Stewardship Council 2005). The standards specify that program participants shall implement programs to promote biodiversity at multiple levels of biological organization including those that identify areas with unique vegetation characteristics, or that provide specific components of wildlife habitat (e.g., snags, mast trees, down woody debris). This project aids in accomplishing that objective 4 by quantifying characteristics of stands within different age classes and habitat types, and linking those data with the habitat type classification system to identify areas in the western UP landscape that can potentially provide specific elements of structure and composition important for wildlife communities over time. Without use of an ecological classification system such as habitat-type classifications, managers cannot effectively predict temporal changes in vegetation as a result of successional processes or certain land-use and management practices. Linking predictions with habitat suitability modeling can aid in evaluating the probability of wildlife species occurrence or persistence, and timber sustainability during a given time frame and location in a landscape. This approach can be useful for identifying areas where management could enhance or maintain wildlife habitat, or unique features important for conservation of biodiversity.

Davis et al. (2001:77) wrote, "The empirical core of our professional claim to manage land scientifically and to ensure that owner objectives are met lies in our ability to predict the conditions and outcomes of current and future stands and stand types when managed under a specified prescription." In essence, if managers cannot predict with acceptable accuracy the conditions and outcomes associated with implementing management prescriptions, it will be difficult to determine the extent to which ecosystem management goals are being met. The habitat-type classification is a tool for understanding temporal changes in vegetation structure and composition within ecological units and across landscapes, and for quantifying potential changes in wildlife habitat suitability and timber production potential. As such, managers can use habitat-type classifications for planning management activities, predicting and evaluating management outcomes, and sustaining functional forest ecosystems while meeting human demands for resources.

CHAPTER 2

WILDLIFE-HABITAT RELATIONSHIPS: SPATIAL AND TEMPORAL VARIATIONS IN DISTRIBUTION OF WILDLIFE COMMUNITIES THAT USE ASPEN

The conservation of biodiversity is a high priority for resource managers and conservationists (Lindenmayer and Franklin 2002), and it is one of the foundation principles of ecologically sustainable forestry (Hunter 1990, Carey and Curtis 1996, Noss 1999). Whereas historically, forest management took a very narrow focus by prioritizing production (Stearns 1990), research today attempts to help managers understand and consider ecological processes (e.g., succession) and ecological relationships within forests (Haufler 1990). Within the past decade, researchers have identified important questions addressing topics critical to managing sustainable forests, conserving biodiversity (Lindenmayer 1999), and maintaining production important for human use (Kessler et al. 1992). Reoccurring topics include identifying and validating indicator species in forest planning, understanding community relationships, assessing spatial and temporal variation in forest structure and composition, and evaluating wildlife response to such changes.

To help address these challenges in forest management and planning, Haufler et al. (2002) suggest the use of performance measures. Ecological performance measures are metrics used to assess how well management is succeeding at meeting specific ecological objectives. For example, Haufler et al. (2002) explain how specific metrics can be identified to assess diversity of ecosystems within landscapes, the range of structural, compositional, and functional conditions as well as processes within ecosystems, and species and genetic diversity. Performance measures can be identified for multiple levels of biological organization and can help managers identify specific targets, goals, and priorities for ecosystem management.

At the landscape-level, Haufler et al. (2002) recommended a coarse-filter approach (Noss 1987) to characterize the planning landscape in terms of the range of ecosystem types that occurred historically and that allow for ecosystem integrity and biodiversity to be maintained if all communities are adequately represented. At the ecosystem-level, performance measures should describe structure, composition, function, and processes to identify the range of conditions that can occur within ecosystems and whether or not the entire range is represented within a landscape (Haufler et al. 2002). Community-level performance measures may include measures of species richness or diversity. A fine-filter assessment includes measures of species habitat suitability, and presence and productivity of species that select different ecosystem types to meet specific habitat requirements.

Identifying performance measures and quantifying the range of conditions necessary for maintaining wildlife habitat conditions in ecosystems and landcapes is a complex process. At the landscape-level, ecological classification systems, such as habitat-type classifications can identify boundaries of areas with similar geological characteristics and successional pathways (Daubenmire 1966). Knowledge of the spatial distribution of habitat types within landscapes can help biologists and managers understand the potential of landscapes to provide specific ecological conditions. These ecological conditions can be described using performance measures that define spatial and temporal variations in structure and composition within habitat types resulting from natural disturbances or management (Haufler et al. 2002). Understanding temporal changes can provide a basis for predicting vegetation change over time within habitat types. Linking these predictions with community- and species-level performance measures can aid in evaluating the probability of species persistence during a given time frame and location within a landscape.

Birds, especially neotropical migrants, are highly sensitive to ecological and landscape changes because many tend to have low birth rates and relatively long lifetimes (Maurer 1993). Although bird species showing declines in numbers are primarily neotropical migrants (Robbins et al. 1989, Brewer et al. 1991), many short-distance migrants (species that winter in temperate regions) and year-round resident species also have shown declines primarily due to declines in habitat area or quality (Brewer et al. 1991). As such, using performance measures of community structure and composition of birds that use forest resources for all or part of the year, and assessing habitat suitability of certain species can indicate ecological integrity (Haufler et al. 1996). Relating species metrics such as habitat suitability, and bird community characteristics (e.g., species richness, proportion of community that is threatened, endangered, or sensitive; proportion of neotropical migrants, short-distance migrants, or nonmigratory species; number and relative abundance of habitat specialists) to differences in vegetation physiognomy of different aspen age classes and habitat types can help managers answer questions about the potential of habitat types to provide habitat conditions for specific bird species, communities, and for species diversity. Spatial projection of habitat potential for birds can help managers understand the capability of areas within landscapes to provide specific habitat conditions for avian species and for wildlife using similar habitat components.

Biologists and forest managers in the Great Lakes Region can be challenged with developing forest management plans that sustain timber harvest and also maintain habitat conditions for a diversity of wildlife species. In Michigan, for instance, biologists are attempting to design plans to maintain current levels of aspen harvest, and simultaneously maintain the range of vegetation conditions provided by aspen in different age classes and habitat types. It is currently unknown, however, what ecological conditions are provided by different aspen age classes, specifically old aspen (i.e., $\geq$ 50 years), what wildlife species and communities may benefit from those conditions, and how conditions may change temporally. Applying the use of performance measures at landscape-, ecosystem-, community-, and species-levels can be useful for recognizing areas that can provide unique habitat components for specific species and avian communities, and other wildlife species using similar habitat components, identifying areas that may be currently below their potential for providing specific habitat components, and developing forest management models, which can be useful for planning and evaluating effective practices to meet ecosystem management objectives.

OBJECTIVES

Specific objectives for this chapter were to

1) Identify and apply ecosystem-level performance measures to characterize the variation in vegetation composition within different aspen age classes and habitat types in the western Upper Peninsula.
2) Relate community-level performance measures for communities of avian species to successional changes in aspen within different habitat types.
3) Relate species-level performance measure to describe specific ecological conditions provided by different aspen age classes and habitat types.

METHODS

Sampling of vegetation and avian communities

I selected sampling points in aspen communities within 3 age classes (20 to 29 years, 50 to 59 years, and > 70 years) and within 6 upland habitat types that were the most predominant in the western UP landscape and characterized a range of soil conditions from dry and sandy to mesic loamy soils (Felix 2003). These habitat types included *Acer-Quercus-Vaccinium* (AQV; maple-oak-blueberry spp.) and *Quercus-Acer-Epigaea* (QAE; oak-maple-trailing arbutus) on dry sandy soils, *Tsuga-Mainthemum* (TM; hemlock-wild lily-of-the-valley) on dry sand or sandy-loams, *Acer-Tsuga-Dryopteris* (ATD; maple-hemlock-fern spp.) on mesic sandy soils, *Acer-Viola-Oshorhiza* (AVO; maple-violet-sweet cicely) on mesic loamy soils, and *Acer-Osmorhiza-Caulophyllum* (AOC; maple-sweet cicely-blue cohosh) on mesic loamy or silty soils.

Several avian species were selected as indicators of the range of ecological conditions within aspen forests in different habitat types. These species were selected because research has described that they utilize various structural and compositional characteristics of forests (Table 2.1), and are sensitive to changes in ecological conditions. I quantified several habitat variables that described the food, cover, or reproductive requirements associated with the selected species (Table 2.1, Table 2.2) to determine the range of conditions that the aspen vegetation type could potentially provide within different habitat types. Each variable was measured within 10-m x 25-m plots established at ≥ 3 sampling points within each age class and habitat type.

The yellow-rumped warbler (*Dendroica coronata*) was selected because it has a strong association with conifer cover in the shrub layer (2.5–5 m) and high overstory cover (>5 m) (Westworth & Associates 1984). Hagan et al. (1997) observed that yellow-rumped warblers were most abundant in medium-aged (e.g., 20–60 years) and relatively old softwood forests dominated by balsam fir, spruce, or white pine. Aspen stands in which balsam fir and spruce or white pine are components of the canopy may potentially provide nesting requirements for the yellow-rumped warbler (Hanaburgh 2001). The American redstart (*Stophaga ruticilla*) was selected because it frequently utilizes vegetation in the 2.5–5 m strata for nesting (Westworth & Associates 1984) and prefers forests with high stem densities (Bond 1975, Hanaburgh 2001). Hobson and Bayne (2000a) observed American redstarts in numerous aspen age classes, most of which were >50 years). Veeries (*Catharus fuscescens*) are ground-nesting birds that prefer to nest in forests with a dense understory (Winnett-Murray 1991). Second-growth aspen may provide the dense understory necessary for veery habitat (Winnett-Murray 1991). Ovenbirds (*Seiurus aurocapillus*) were selected because they prefer to nest on the ground in forests with an open understory (Westworth & Associates 1984). The pileated woodpecker (*Dryocopus pileatus*) and black-capped chickadee (*Parus atricapillus*) are both cavity-nesters, but require different sizes of snags to meet their life requisites. For example, snags suitable for pileated woodpecker habitat in the eastern portion of their range should be >38 cm in diameter (Schroeder 1983a), while chickadees can utilize snags 10–25 cm in diameter (Schroeder 1983b). Yellow-rumped warblers, American redstarts, veeries, and ovenbirds utilized Michigan forests during the breeding season (i.e., May–June), while pileated woodpeckers, and chickadees, were indicators of winter habitat conditions as well as breeding habitat conditions.

To evaluate wildlife responses to differences in aspen structure among age classes and habitat types, I conducted bird surveys during the breeding seasons and during the winter to quantify bird community composition throughout the year. I attempted to conduct bird surveys at each point where vegetation was sampled once during the winter (January–March), and once during territory establishment and breeding (May–June); however, due to limitations in personnel and vehicles, I was not able to survey every point. Bird surveys were 10 minutes long following a 1-minute settling period and were conducted during fair weather conditions (i.e., no rain or fog, winds < 20 kph, cloud cover <70%) (Hanaburgh 2001). Species presence was recorded at each point where a species was heard or visually observed.

Winter bird surveys were conducted in 2005 (February 11–13 and March 7–12) and 2006 (February 26–March 7). Breeding bird surveys were conducted in 2004 and 2005 during the last week in May and first 2 weeks in June each year. Because of limited sample sizes for bird surveys each year, data were pooled to better represent differences in bird communities using various aspen age classes and habitat types.

Data analysis

I used principal components analysis (Morrison 1990) to examine multivariate relationships among vegetation structure and composition variables in different age classes and habitat types. This analysis was also used to identify groupings of variables that account for the variability in vegetation structure and composition observed among different age classes and habitat types, and to define variables that were most important in describing differences among age classes and habitat types. Results of the principal components analysis were used to identify vegetation attributes that explained the distribution of birds observed in different aspen age classes and habitat types.

I assessed frequency of bird occurrence observed during the winter and during the breeding season, and compared differences among age classes and habitat types with the Kruskal-Wallis one-way analysis of variance using SYSTAT (2002). I classified bird species according to nesting preference (i.e., cavity or non-cavity nesters) and migration status (i.e., year-round residents, short-distance migrants, neotropical migrants [Blake et al. 1994]), and compared average numbers of birds within each classification among age classes and habitat types using the Kruskal-Wallis one-way analysis of variance. Significance was determined at the $\alpha = 0.10$ level.

To evaluate habitat suitability for indicator species, I used habitat suitability index models for the American redstart (Minnis and Haufler 1994), black-capped chickadee (Schroeder 1983b), ovenbird (Roloff 1994), pileated woodpecker (Schroeder 1983a), veery (Sousa 1982), and yellow-rumped warbler (Hanaburgh 2001). I compared average scores among age classes and habitat types for each species and related them to frequency of occurrence for the indicator to assess utility of them as indicators of conditions within various aspen age classes and habitat types.

To identify groups of birds that associate with similar vegetation characteristics, I integrated principal component scores with bird observational data and graphed the first and second principal component scores at each observation for each bird species recorded. I then connected outer points of polygons created from graphing principal component scores to determine the range of vegetation conditions that might be influential in determining species presence. I combined information from graphing principal component scores (i.e., identifying the range of vegetation conditions used by different bird species) and frequency of occurrence data to identify final bird communities that used specific aspen age classes and habitat types similarly. This procedure allowed identification of "clusters" or groupings of birds that could be explained by vegetation variables that distinguished different aspen age classes and habitat types.

Table 2.1. Forest attributes that are important for feeding and reproductive requirements of bird species that may use various age classes of aspen to meet their life requisites. Dbh = diameter at breast height. DWD = down woody debris.

Forest Attribute	ovenbird (Roloff 1994)	pileated woodpecker (Schroeder 1983a)	veery (Sousa 1982)	black-capped chickadee (Schroeder 1983b)	yellow-rumped warbler (Hanaburgh 2001)	American redstart (Minnis and Haufler 1994)
stem density (#/ha)						
deciduous						reproduction
coniferous						
shrub (<5 m)	reproduction				feeding	reproduction
stems >51 cm dbh		reproduction/ feeding				
canopy height (>5 m)				feeding	feeding	
shrub height (<5 m)			reproduction			
snag density (#/ha)						
of trees 10-25 cm				reproduction		
of trees >38 cm		reproduction				
% canopy cover (>5 m)						reproduction/ feeding
deciduous		feeding		feeding	reproduction	
coniferous					reproduction	reproduction
% shrub cover (<5m)			reproduction			

Table 2.1. (Cont.)

Forest Attribute	ovenbird (Roloff 1994)	pileated woodpecker (Schroeder 1983a)	veery (Sousa 1982)	black-capped chickadee (Schroeder 1983b)	yellow-rumped warbler (Hanaburgh 2001)	American redstart (Minnis and Haufler 1994)
% herbaceous cover (<1 m)			reproduction			
tree dbh (cm)			reproduction			
snag dbh		reproduction		reproduction		
density of stumps and DWD		feeding				
basal area (m^2/ha)	feeding/ reproduction					

Table 2.2. Structure of forest attributes and habitat requirements for bird species that may use various age classes of aspen to meet their life requisites. Dbh = diameter at breast height. DWD = down woody debris.

Forest Attribute	ovenbird (Roloff 1994)	pileated woodpecker (Schroeder 1983a)	veery (Sousa 1982)	black-capped chickadee (Schroeder 1983b)	yellow-rumped warbler (Hanaburgh 2001)	American redstart (Minnis and Haufler 1994)
stem density (#/ha)						
deciduous						325-350/ha
coniferous						
shrub (<5 m)	2000-4000				<2000	>650
stems >51 cm dbh		75/ha				
canopy height (>5 m)				>15 m	>20 m	
shrub height (<5 m)			1.5-3m			
snag density (#/ha)						
of trees 10-25 cm				>5/ha		
of trees >38 cm		0.4/ha				
% canopy cover (>5 m)						60-80%
deciduous		>75%		50-70%	>70%	
coniferous					>30%	<40%
% shrub cover (<5m)			>70%			
% herbaceous cover (<1 m)			>90%			

Table 2.2. (Cont.)

Forest Attribute	ovenbird (Roloff 1994)	pileated woodpecker (Schroeder 1983a)	veery (Sousa 1982)	black-capped chickadee (Schroeder 1983b)	yellow-rumped warbler (Hanaburgh 2001)	American redstart (Minnis and Haufler 1994)
tree dbh (cm)			>38 cm			
snag dbh		>38 cm		10-25 cm		
density of stumps and DWD		>25/ha				
basal area (m^2/ha)	>10 m^2/ha					

RESULTS

Principal components analysis for vegetation variables

Results of the principal components analysis on 25 vegetation variables showed that there were distinct differences in vegetation characteristics among age classes and habitat types. The first 3 principal components explained 41% of the variability in vegetation characteristics, and adding the fourth component explained 50% of the variability. Principal component 1 accounted for 15.5% of the variability and represented a contrast between an ecological community characterized by high herbaceous cover, taller shrubs, and less decay of down woody debris on the positive end. Communities on the negative end of the gradient were characterized by greater conifer stem densities, higher overstory conifer canopy cover and total canopy cover, and fewer total stems/ha. The extreme positive end of the gradient described aspen in the 20-year age class within the AVO habitat type (Figure 2.1b). Samples at the negative end of the gradient described aspen $\geq$ 50 years old within the TM habitat type (Figure 2.1c).

The second principal component, which accounted for 12.8% of the variability in vegetation conditions, described a gradient between forest types characterized by average tree diameter and tree height (positive end), and deciduous stem density and total stem density (negative end). Communities in the 70-year age class within all habitat types were represented at the positive end (Figure 2.1) and were characterized by larger diameter and taller trees. Aspen communities in the 20-year age class were represented at the negative end of the gradient because trees in this age class were smaller, had more deciduous stems, and higher total stem density than older age classes.

The third principal component accounted for 12.3% of the variability in vegetation characteristics and represented a gradient between communities characterized by lower basal area, shorter shrubs, and moderate shrub stem density on the positive end, and communities characterized by larger and taller snags with more decay on the negative end. Scores for principal component 3 were on the extreme positive end for aspen communities in the 50-year age class within the AVO habitat type and young (e.g., 20-year age class) communities within the TM habitat type (Figure 2.1). Communities on the negative end of the gradient were ≥ 50-years old and specifically included communities within the AVO and ATD habitat type (Figure 2.1).

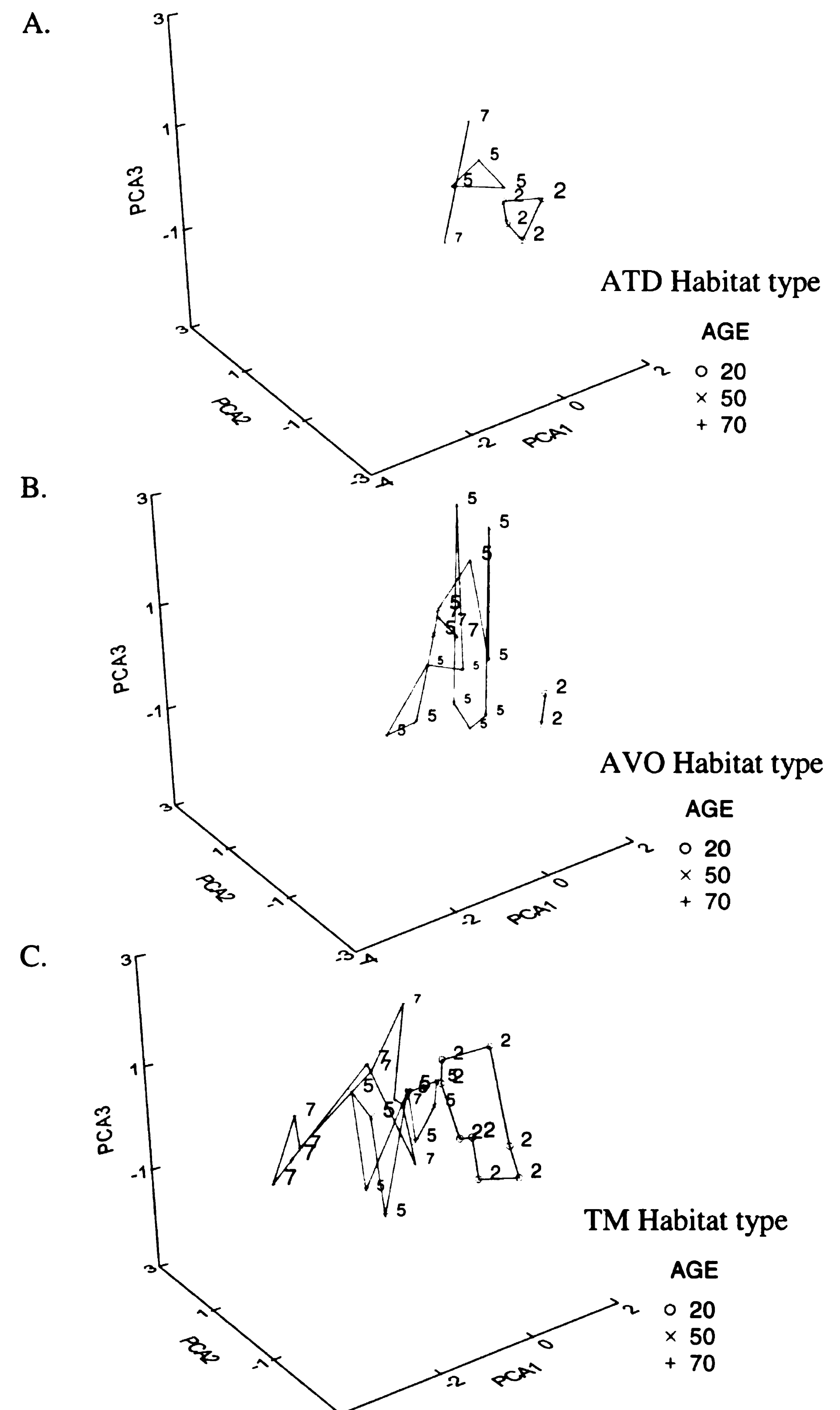

Figure 2.1. Scores for the first 3 principal components describing the variability among 25 vegetation variables measured in aspen stands within 20-year, 50-year, and 70-year age classes occurring within 3 different habitat types in the western Upper Peninsula, Michigan in 2005. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum.*

Frequency of occurrence of breeding bird species among aspen age classes

During the study, a total of 41 bird species were recorded on the study sites (Tables 2.3, 2.4). Aspen in the 20-year age class (n = 22) had the lowest species richness (30 species; Table 2.3). Species richness of stands in the 50-year age class (n = 26) was 36, and richness of aspen ≥ 70 years old was 34 (Table 2.3).

Twenty-seven species occurred in stands in all age classes and 8 were detected in only 1 age class (Table 2.3). The common yellowthroat (*Geothlypis trichas*) and pine warbler (*Dendroica pinus*) only occurred in aspen in the 20-year age class. The brown-headed cowbird (*Molothrus ater*), golden-winged warbler (*Vermivora chrysoptera*), mourning dove (*Zenaida macroura*), and northern parula (*Parula americana*) were only observed in aspen in the 50-year age class. The American robin (*Turdus migratorius*) and brown creeper (*Certhia americana*) were recorded only in aspen ≥ 70 years old (Table 2.3).

Ovenbirds were the most frequently observed species in all age classes (Table 2.3). The red-eyed vireo (*Vireo olivaceus*) was among the 3 most frequently observed species in all age classes. Pileated woodpeckers were among the most frequently observed species in aspen in the 50-year and 70-year age classes, and the black-throated-green warbler (*Dendroica virens*) was among the 3 most frequently observed species in aspen in the 20-year age class (Table 2.3).

Of the 5 bird species identified as potential indicators of specific forest characteristics, only the pileated woodpecker exhibited differences in absolute frequency among age classes ($p = 0.017$; Table 2.3). Pileated woodpeckers were most common in aspen ≥ 70 years old and least common in young (< 50 years) aspen stands.

Breeding bird species that were more abundant in old (≥ 50 years) aspen, included the black-and-white warbler (*Mniotticta varia*; p = 0.089), brown creeper (p = 0.065), Eastern peewee (*Contopus virens*; p = 0.020), Northern flicker (*Colaptes auratus*; p = 0.091), pileated woodpecker (p = 0.017), pine siskin (*Carduelis pinus*; p = 0.079), red-breasted nuthatch (*Sitta canadensis*; p = 0.094), red-headed woodpecker (*Melanerpes erythrocephalus*; p = 0.002), and white-breasted nuthatch (*Sitta carolinensis*; p = 0.094).

Frequency of occurrence of breeding bird species among habitat types

TM, ATD, and AVO habitat types had representation in all 3 age classes. Of those habitat types, the TM habitat type (n = 30) had the highest species richness (36 species), followed by the AVO habitat type (n = 20) with 35 species. The ATD habitat type (n = 9) had the fewest observed bird species during the breeding season (24 species; Table 2.4).

Twenty species occurred in stands within all habitat types, and 7 were found in only 1 habitat type (Table 2.4). The American robin, brown creeper, and yellow-rumped warbler only occurred in the TM habitat type. The brown-headed cowbird, magnolia warbler (*Dendroica magnolia*), mourning dove, and northern parula were only observed in the AVO habitat type. No breeding bird species were unique to stands in the ATD habitat type (Table 2.4).

Ovenbirds were the most frequently observed breeding bird species among all habitat types. The pileated woodpecker and black-throated-green warbler were the second and third most common species in the TM habitat type. The black-throated-green warbler and red-eyed vireo were the second and third most frequently observed species in the AVO habitat type.

Of the 5 indicator species, the ovenbird did not exhibit differences in frequency of occurrence among habitat types (Table 2.4). The American redstart was not observed in the TM habitat type ($p = 0.043$). Frequency of occurrence of pileated woodpeckers was highest in the TM habitat type ($\bar{x} = 72.7$, S.E. = 7.9), but did not differ from frequency in the AVO habitat type ($\bar{x} = 55.0$, S.E. = 11.4). Pileated woodpecker frequency was lowest ($\bar{x} = 11.1$, S.E.= 11.1, $p = 0.004$) in the ATD habitat type. The veery was most common ($p = 0.058$) in aspen stands within the AVO habitat type (Table 2.4). The yellow-rumped warbler was only observed in the TM habtiat type.

Other bird species with higher frequency of occurrence in the TM habitat type than in other habitat types included black-and-white warbler ($p = 0.079$), pileated woodpecker ($p = 0.004$), and brown creeper, although it was not significantly different. Species observed more frequently in the ATD habitat type included the black-throated-green warbler ($p = 0.050$) and the eastern wild turkey, although frequency of turkeys was not significantly different from that in the AVO habitat type (Table 2.4). Frequency of occurrence of the blue jay (*Cyanocitta cristata*; $p = 0.086$), chestnut-sided warbler (*Dendroica pensylvanica*; $p = 0.002$), eastern peewee ($p = 0.002$), and scarlet tanager (*Piranga olivacea*; $p = 0.058$) was lower in the TM habitat type than in other habitat types (Table 2.4).

Table 2.3. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in 3 age classes of aspen during the breeding season in the Upper Peninsula, Michigan in 2004–2005.

	Age classes						
	20-year (n=22)		50-year (n=26)		70-year (n=25)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**31.8**	10.2	**42.3**	9.9	**29.6**	9.0	0.595
American redstart	**0.0**	0.0	**7.7**	5.3	**7.4**	5.1	0.420
American robin	**0.0**	0.0	**0.0**	0.0	**7.4**	5.1	0.165
Black-and-white warbler*	**0.0**[a]	0.0	**15.4**[b]	7.2	**11.1**[ab]	6.2	0.089
Black-capped chickadee	**36.4**	10.5	**30.8**	9.2	**48.1**	9.8	0.420
Black-throated-blue warbler	**18.2**	8.4	**19.2**	7.9	**14.8**	7.0	0.908
Black-throated-green warbler	**63.6**	10.5	**50.0**	10.0	**44.4**	9.7	0.401
Blue jay	**27.3**	9.7	**34.6**	9.5	**11.1**	6.2	0.126
Brown creeper*	**0.0**[a]	0.0	**0.0**[a]	0.0	**11.1**[b]	5.8	0.065
Brown-headed cowbird	**0.0**	0.0	**3.8**	3.8	**0.0**	0.0	0.390
Chestnut-sided warbler	**18.2**	8.4	**26.9**	8.9	**22.2**	8.2	0.772
Common yellowthroat*	**9.1**[a]	6.3	**0.0**[b]	0.0	**0.0**[b]	0.0	0.087
Downy/hairy woodpecker	**13.6**	7.5	**7.7**	5.3	**14.8**	7.0	0.703
Eastern peewee*	**4.5**[a]	4.5	**23.1**[b]	8.4	**25.9**[b]	8.6	0.089
Eastern wild turkey	**18.2**	8.4	**7.7**	5.3	**7.4**	5.1	0.402
Golden-crowned kinglet	**18.2**	8.4	**11.5**	6.4	**11.1**	6.2	0.731
Golden-winged warbler*	**0.0**[a]	0.0	**15.4**[b]	7.2	**0.0**[a]	0.0	0.020
Hermit thrush	**45.5**	10.9	**73.1**	8.9	**55.6**	9.7	0.145

Table 2.3. (Cont.)

	Age classes						
	20-year (n=22)		50-year (n=26)		70-year (n=25)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Magnolia warbler	**4.5**	4.5	**0.0**	0.0	**3.7**	3.7	0.575
Mourning dove	**0.0**	0.0	**3.8**	3.8	**0.0**	0.0	0.390
Nashville warbler	**22.7**	9.1	**30.8**	9.2	**40.7**	9.6	0.404
Northern flicker*	**0.0**[a]	0.0	**15.4**[b]	7.2	**11.1**[b]	5.8	0.091
Northern parula	**0.0**	0.0	**3.8**	3.8	**0.0**	0.0	0.390
Ovenbird	**95.5**	4.5	**88.5**	6.4	**100.0**	0.0	0.175
Pileated woodpecker*	**45.5**[a]	10.9	**50.0**[ab]	10.0	**81.5**[bc]	7.6	0.017
Pine siskin*	**9.1**[a]	6.3	**15.4**[ab]	7.2	**29.6**[b]	9.0	0.079
Pine warbler	**9.1**	6.3	**0.0**	0.0	**0.0**	0.0	0.110
Raven	**13.6**	7.5	**7.7**	5.3	**22.2**	8.2	0.328
Red-breasted nuthatch*	**22.7**[a]	9.1	**46.2**[b]	10.0	**51.9**[b]	9.8	0.094
Red-eyed vireo*	**54.5**[a]	10.9	**80.8**[b]	7.9	**63.0**[ab]	9.5	0.087
Red-headed woodpecker*	**4.5**[a]	4.5	**34.6**[b]	9.5	**3.7**[a]	3.7	0.002
Rose-breasted grosbeak	**9.1**	6.3	**3.8**	3.8	**0.0**	0.0	0.276
Ruffed grouse	**9.1**	6.3	**26.9**	8.9	**11.1**	6.2	0.172
Scarlet tanager	**4.5**	4.5	**11.5**	6.4	**7.4**	5.1	0.670
Veery	**13.6**	7.5	**23.1**	8.4	**3.7**	3.7	0.120
White-breasted nuthatch*	**0.0**[a]	0.0	**3.8**[ab]	3.8	**14.8**[b]	7.0	0.094
White-throated sparrow*	**27.3**[a]	9.7	**7.7**[b]	5.3	**14.8**[a]	7.0	0.183
Winter wren	**4.5**	4.5	**11.5**	6.4	**14.8**	7.0	0.508
Wood thrush	**18.2**	8.4	**3.8**	3.8	**7.4**	5.1	0.219

Table 2.3. (Cont.)

	Age classes						
	20-year (n=22)		50-year (n=26)		70-year (n=25)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Woodpecker (unidentified)*	**0.0**[a]	0.0	**3.8**[a]	3.8	**14.8**[b]	7.0	0.094
Yellow-bellied sapsucker	**4.5**	4.5	**11.5**	6.4	**7.4**	5.1	0.670
Yellow-rumped warbler	**4.5**	4.5	**3.8**	3.8	**3.7**	3.7	0.988

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.4. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in 3 habitat types supporting aspen during the breeding season in the Upper Peninsula, Michigan in 2004–2005. TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Drypoteris*, AVO = *Acer-Viola-Osmorhiza*.

	TM (n=31)		ATD (n=9)		AVO (n=20)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**42.4**	8.7	**11.1**	11.1	**40.0**	11.2	0.220
American redstart*	**0.0**[a]	0.0	**22.2**[b]	14.7	**10.0**[b]	6.9	0.043
American robin	**3.0**	3.0	**0.0**	0.0	**0.0**	0.0	0.644
Black-and-white warbler*	**18.2**[a]	6.8	**0.0**[b]	0.0	**5.0**[ab]	5.0	0.079
Black-capped chickadee	**39.4**	8.6	**44.4**	17.6	**20.0**	9.2	0.276
Black-throated-blue warbler*	**6.1**[a]	4.2	**33.3**[b]	16.7	**25.0**[b]	9.9	0.063
Black-throated-green warbler*	**63.6**[a]	8.5	**77.8**[a]	14.7	**35.0**[b]	10.9	0.050
Blue jay*	**27.3**[a]	7.9	**0.0**[b]	0.0	**40.0**[a]	11.2	0.086
Brown creeper	**9.1**	5.1	**0.0**	0.0	**0.0**	0.0	0.256
Brown-headed cowbird	**0.0**	0.0	**0.0**	0.0	**5.0**	5.0	0.350
Chestnut-sided warbler*	**6.1**[a]	4.2	**11.1**[a]	11.1	**45.0**[b]	11.4	0.002
Common yellowthroat	**3.0**	3.0	**11.1**	11.1	**0.0**	0.0	0.298
Downy/hairy woodpecker	**9.1**	5.1	**22.2**	14.7	**10.0**	6.9	0.536
Eastern peewee*	**6.1**[a]	4.2	**11.1**[a]	11.1	**45.0**[b]	11.4	0.002
Eastern wild turkey*	**3.0**[a]	3.0	**33.3**[b]	16.7	**10.0**[ab]	6.9	0.026
Golden-crowned kinglet*	**24.2**[a]	7.6	**22.2**[a]	14.7	**0.0**[b]	0.0	0.061
Golden-winged warbler	**3.0**	3.0	**0.0**	0.0	**15.0**	8.2	0.163
Hermit thrush	**63.6**	8.5	**33.3**	16.7	**60.0**	11.2	0.263
Magnolia warbler	**0.0**	0.0	**0.0**	0.0	**5.0**	5.0	0.350
Mourning dove	**0.0**	0.0	**0.0**	0.0	**5.0**	5.0	0.350

Table 2.4. (Cont.)

Common name	TM (n = 31) $\bar{x}$	TM S.E.	ATD (n = 9) $\bar{x}$	ATD S.E.	AVO (n = 20) $\bar{x}$	AVO S.E.	Probability level[1]
Nashville warbler	**33.3**	8.3	**11.1**	11.1	**30.0**	10.5	0.432
Northern flicker	**3.0**	3.0	**11.1**	11.1	**15.0**	8.2	0.287
Northern parula	**0.0**	0.0	**0.0**	0.0	**5.0**	5.0	0.350
Ovenbird	**97.0**	3.0	**100.0**	0.0	**90.0**	6.9	0.403
Pileated woodpecker*	**72.7**[a]	7.9	**11.1**[b]	11.1	**55.0**[a]	11.4	0.004
Pine siskin	**27.3**	7.9	**22.2**	14.7	**5.0**	5.0	0.139
Raven	**18.2**	6.8	**0.0**	0.0	**5.0**	5.0	0.179
Red-breasted nuthatch	**42.4**	8.7	**44.4**	17.6	**40.0**	11.2	0.972
Red-eyed vireo	**51.5**	8.8	**66.7**	16.7	**80.0**	9.2	0.115
Red-headed woodpecker	**12.1**	5.8	**33.3**	16.7	**20.0**	9.2	0.325
Rose-breasted grosbeak	**6.1**	4.2	**0.0**	0.0	**5.0**	5.0	0.757
Ruffed grouse	**18.2**	6.8	**11.1**	11.1	**20.0**	9.2	0.844
Scarlet tanager	**6.1**	4.2	**11.1**	11.1	**15.0**	8.2	0.564
Veery*	**6.1**[a]	4.2	**0.0**[a]	0.0	**25.0**[b]	9.9	0.058
White-breasted nuthatch	**6.1**	4.2	**0.0**	0.0	**5.0**	5.0	0.757
White-throated sparrow	**18.2**	6.8	**11.1**	11.1	**10.0**	6.9	0.685
Winter wren	**12.1**	5.8	**0.0**	0.0	**20.0**	9.2	0.331
Wood thrush	**12.1**	5.8	**22.2**	14.7	**0.0**	0.0	0.141
Woodpecker (unidentified)	**6.1**	4.2	**0.0**	0.0	**5.0**	5.0	0.757
Yellow-bellied sapsucker	**9.1**	5.1	**0.0**	0.0	**15.0**	8.2	0.449
Yellow-rumped warbler	**3.0**	3.0	**0.0**	0.0	**0.0**	0.0	0.644

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Frequency of occurrence of breeding bird species among age classes and habitat types

Breeding bird surveys in aspen in the 20-year age class occurred within the QAE (n = 2), AQV (n = 5), TM (n = 9), ATD (n = 4), and AVO (n = 2) habitat types. In the 50-year age class, surveys occurred in the TM (n = 11), ATD (n = 3), and AVO (n = 12) habitat types. Surveys in aspen stands ≥ 70 years old were conducted within AQV (n = 3), TM (n = 11), ATD (n = 2), AVO (n = 6), and AOC (n = 3) habitat types.

Only the ovenbird was observed in aspen stands within all habitat types represented in the 20-year age class (Table 2.5). Three additional species were common to 20-year-old aspen in the TM, ATD, and AVO habitat types (black-capped chickadee, black-throated green warbler, and hermit thrush). Six bird species were observed in stands in the 20-year age class within the QAE habitat type. Eight species were found in AVO. Species richness in the AQV and ATD habitat types was 17, and was 25 within the TM habitat type (Table 2.5).

Within the 20-year age class, frequency of occurrence of chestnut-sided warblers was highest ($p = 0.026$) within the AVO habitat type. Eastern wild turkey frequency was highest ($p = 0.033$) in the ATD habitat type. Frequency of occurrence of other bird species was not significantly different among habitat types represented in the 20-year age class.

In the 50-year age class, 8 bird species were observed in aspen stands in all habitat types represented: TM, ATD, and AVO. These species included black-capped chickadee, black-throated-green warbler, hermit thrush, Nashville warbler, ovenbird, red-breasted nuthatch, red-eyed vireo, and red-headed woodpecker (Table 2.6). Among stands in the 50-year age class, species richness was highest in the AVO habitat type

(31), followed by the TM habitat type (25), and the ATD habitat type (12). The eastern peewee was the only species exhibiting statistically significant differences in absolute frequency among habitat types represented in the 50-year age class ($p = 0.013$), which was only observed in the AVO habitat type, and the red-breasted nuthatch ($p = 0.072$), which was observed most frequently in the TM habitat type. This difference was not significant in comparison to the ATD habitat type, however. Other noticeable, but not statistically significant patterns included presence of the American redstart, brown-headed cowbird, eastern wild turkey, mourning dove, northern parula, and red-breasted grosbeak in only the AVO habitat type. The winter wren, wood thrush, and yellow-rumped warbler only occurred in the TM habitat type (Table 2.6).

The eastern peewee, ovenbird, red-breasted nuthatch, and red-eyed vireo occurred in all habitat types represented in the 70-year age class (Table 2.7). Bird species richness was highest (28 species) in the TM habitat type, followed by the AVO habitat type (21 species). Richness was 17, 16, and 9 in the AQV, AOC, and ATD habitat types, respectively (Table 2.7). Eight species using aspen ≥ 70 years old were unique to only 1 habitat type. The American redstart was only observed in the ATD habitat type ($p = 0.004$). The black-and-white warbler ($p = 0.060$), brown creeper ($p = 0.060$), golden-crowned kinglet, and veery were unique to the TM habitat type. The magnolia warbler and red-headed woodpecker were only found in the AVO habitat type, and the Eastern wild turkey was only heard in the AOC habitat type ($p = 0.002$).

Other notable differences in frequency of occurrence of bird species among habitat types represented in the 70-year age class included the absence of black-capped chickadees in the AVO habitat type ($p = 0.021$), presence of chestnut-sided warblers only in hardwood habitat types (i.e., AQV, AVO, AOC), and their more frequent occurrence in the AQV habitat type ($p = 0.001$). Absolute frequency of northern flickers was highest in the AQV habitat type ($p = 0.033$). Pileated woodpeckers were not recorded in the ATD habitat type ($p = 0.032$). The red-eyed vireo was observed in all habitat types, but was lowest ($p = 0.019$) in the TM habitat type. White-breasted nuthatches occurred in the AQV and TM habitat types, but were most common ($p = 0.092$) in the AQV habitat type.

Table 2.5. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen in the 20-year age class within different habitat types during the breeding season in the Upper Peninsula, Michigan in 2004–2005. QAE = *Quercus-Acer-Epigaea*, AQV = *Acer-Quercus-Vaccinium*, TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Osmorhiza*.

	Habitat types represented in 20-year age class										
	QAE2 (n=2)		AQV2 (n=5)		TM2 (n=9)		ATD2 (n=4)		AVO2 (n=2)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**0.0**	0.0	**20.0**	20.0	**55.6**	17.6	**25.0**	25.0	**0.0**	0.0	0.354
Black-capped chickadee	**0.0**	0.0	**40.0**	24.5	**33.3**	16.7	**50.0**	28.9	**50.0**	50.0	0.807
Black-throated-blue warbler	**0.0**	0.0	**40.0**	24.5	**11.1**	11.1	**0.0**	0.0	**50.0**	50.0	0.356
Black-throated-green warbler	**0.0**	0.0	**40.0**	24.5	**77.8**	14.7	**75.0**	25.0	**100.0**	100.0	0.162
Blue jay	**0.0**	0.0	**20.0**	20.0	**55.6**	17.6	**0.0**	0.0	**0.0**	0.0	0.168
Chestnut-sided warbler*	**0.0**[a]	0.0	**0.0**[a]	0.0	**22.2**[a]	14.7	**0.0**[a]	0.0	**100.0**[b]	0.0	0.026
Common yellowthroat	**0.0**	0.0	**0.0**	0.0	**11.1**	11.1	**25.0**	25.0	**0.0**	0.0	0.723
Downy/hairy woodpecker	**0.0**	0.0	**20.0**	20.0	**11.1**	11.1	**25.0**	25.0	**0.0**	0.0	0.873
Eastern peewee	**0.0**	0.0	**0.0**	0.0	**11.1**	11.1	**0.0**	0.0	**0.0**	0.0	0.836
Eastern wild turkey*	**0.0**[a]	0.0	**0.0**[a]	0.0	**11.1**[a]	11.1	**75.0**[b]	25.0	**0.0**[ab]	0.0	0.033
Golden-crowned kinglet	**0.0**	0.0	**0.0**	0.0	**22.2**	14.7	**50.0**	28.9	**0.0**	0.0	0.331
Hermit thrush	**0.0**	0.0	**60.0**	24.5	**44.4**	17.6	**25.0**	25.0	**100.0**	0.0	0.294
Magnolia warbler*	**50.0**[a]	50.0	**0.0**[ab]	0.0	**0.0**[ab]	0.0	**0.0**[ab]	0.0	**0.0**[ab]	0.0	0.040
Nashville warbler	**0.0**	0.0	**20.0**	20.0	**33.3**	16.7	**0.0**	0.0	**50.0**	50.0	0.547
Ovenbird	**100.0**	0.0	**80.0**	20.0	**100.0**	0.0	**100.0**	0.0	**100.0**	0.0	0.493
Pileated woodpecker	**50.0**	50.0	**60.0**	24.5	**55.5**	17.6	**25.0**	25.0	**0.0**	0.0	0.556
Pine siskin	**0.0**	0.0	**0.0**	0.0	**11.1**	11.1	**25.0**	25.0	**0.0**	0.0	0.723

Table 2.5. (Cont.)

	Habitat types represented in 20-year age class										
	QAE2 (n=2)		AQV2 (n=5)		TM2 (n=9)		ATD2 (n=4)		AVO2 (n=2)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Pine warbler	**50.0**	50.0	**20.0**	20.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	0.200
Raven*	**100.0**[a]	0.0	**0.0**[b]	0.0	**11.1**[b]	11.1	**0.0**[b]	0.0	**0.0**[b]	0.0	0.008
Red-breasted nuthatch	**0.0**	0.0	**40.0**	24.5	**11.1**	11.1	**50.0**	28.9	**0.0**	0.0	0.378
Red-eyed vireo	**100.0**	0.0	**80.0**	20.0	**55.6**	17.6	**25.0**	25.0	**0.0**	0.0	0.166
Red-headed woodpecker	**0.0**	0.0	**0.0**	0.0	**11.1**	11.1	**0.0**	0.0	**0.0**	0.0	0.836
Rose-breasted grosbeak	**0.0**	0.0	**0.0**	0.0	**22.2**	14.7	**0.0**	0.0	**0.0**	0.0	0.552
Ruffed grouse	**0.0**	0.0	**0.0**	0.0	**11.1**	11.1	**25.0**	25.0	**0.0**	0.0	0.723
Scarlet tanager	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**25.0**	25.0	**0.0**	0.0	0.343
Veery*	**0.0**[a]	0.0	**20.0**[b]	20.0	**0.0**[b]	0.0	**0.0**[b]	0.0	**0.0**[b]	0.0	0.006
White-throated sparrow	**0.0**	0.0	**40.0**	24.5	**33.3**	16.7	**25.0**	25.0	**0.0**	0.0	0.737
Winter wren*	**0.0**[ab]	0.0	**0.0**[ab]	0.0	**0.0**[a]	0.0	**0.0**[ab]	0.0	**50.0**[ab]	50.0	0.040
Wood thrush	**0.0**	0.0	**20.0**	20.0	**11.1**	11.1	**50.0**	28.9	**0.0**	0.0	0.441
Yellow-bellied sapsucker	**0.0**	0.0	**0.0**	0.0	**11.1**	11.1	**0.0**	0.0	**0.0**	0.0	0.836
Yellow-rumped warbler	**0.0**	0.0	**20.0**	20.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	0.493

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.6. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen in the 50-year age class within different habitat types during the breeding season in the Upper Peninsula, Michigan in 2004–2005. TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Osmorhiza*.

	Habitat types represented in 50-year age class						
	TM5 (n=11)		ATD5 (n=3)		AVO5 (n=12)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**45.5**	15.7	**0.0**	0.0	**50.0**	15.1	0.296
American redstart	**0.0**	0.0	**0.0**	0.0	**16.7**	11.2	0.297
Black-and-white warbler	**27.3**	14.1	**0.0**	0.0	**8.3**	8.3	0.348
Black-capped chickadee	**36.4**	15.2	**33.3**	33.3	**25.0**	13.1	0.842
Black-throated-blue warbler	**0.0**	0.0	**33.3**	33.3	**33.3**	14.2	0.113
Black-throated-green warbler	**63.6**	15.2	**66.7**	33.3	**33.3**	14.2	0.303
Blue jay	**27.3**	14.1	**0.0**	0.0	**50.0**	15.1	0.225
Brown-headed cowbird	**0.0**	0.0	**0.0**	0.0	**8.3**	8.3	0.558
Chestnut-sided warbler*	**0.0**[a]	0.0	**33.3**[b]	33.3	**50.0**[b]	15.1	0.029
Downy/hairy woodpecker	**9.1**	9.1	**0.0**	0.0	**8.3**	8.3	0.871
Eastern peewee*	**0.0**[a]	0.0	**0.0**[a]	0.0	**50.0**[b]	15.1	0.013
Eastern wild turkey	**0.0**	0.0	**0.0**	0.0	**16.7**	11.2	0.297
Golden-crowned kinglet	**27.3**	14.1	**0.0**	0.0	**0.0**	0.0	0.108
Golden-winged warbler	**9.1**	9.1	**0.0**	0.0	**25.0**	13.1	0.435
Hermit thrush	**81.8**	12.2	**66.7**	33.3	**66.7**	14.2	0.700
Mourning dove	**0.0**	0.0	**0.0**	0.0	**8.3**	8.3	0.558
Nashville warbler	**36.4**	15.2	**33.3**	33.3	**25.0**	13.1	0.842
Northern flicker	**0.0**	0.0	**33.3**	33.3	**25.0**	13.1	0.178
Northern parula	**0.0**	0.0	**0.0**	0.0	**8.3**	8.3	0.558

Table 2.6. (Cont.)

Common name	Habitat types represented in 50-year age class: TM5 (n=11) $\bar{x}$	TM5 (n=11) S.E.	ATD5 (n=3) $\bar{x}$	ATD5 (n=3) S.E.	AVO5 (n=12) $\bar{x}$	AVO5 (n=12) S.E.	Probability level[1]
Ovenbird	**90.9**	9.1	**100.0**	0.0	**83.3**	11.2	0.692
Pileated woodpecker	**63.6**	15.2	**0.0**	0.0	**50.0**	15.1	0.160
Pine siskin	**27.3**	14.1	**33.3**	33.3	**0.0**	0.0	0.138
Raven	**18.2**	12.2	**0.0**	0.0	**0.0**	0.0	0.242
Red-breasted nuthatch*	**72.7**[ab]	14.1	**33.3**[ab]	33.3	**25.0**[a]	13.1	0.072
Red-eyed vireo	**72.7**	14.1	**100.0**	0.0	**83.3**	11.2	0.555
Red-headed woodpecker*	**27.3**[a]	14.1	**100.0**[b]	0.0	**25.0**[a]	13.1	0.046
Rose-breasted grosbeak	**0.0**	0.0	**0.0**	0.0	**8.3**	8.3	0.558
Ruffed grouse	**36.4**	15.2	**0.0**	0.0	**25.0**	13.1	0.458
Scarlet tanager	**18.2**	12.2	**0.0**	0.0	**8.3**	8.3	0.622
Veery	**9.1**	9.1	**0.0**	0.0	**41.7**	14.9	0.118
White-breasted nuthatch	**0.0**	0.0	**0.0**	0.0	**8.3**	8.3	0.558
White-throated sparrow	**9.1**	9.1	**0.0**	0.0	**8.3**	8.3	0.871
Winter wren	**27.3**	14.1	**0.0**	0.0	**0.0**	0.0	0.108
Wood thrush	**9.1**	9.1	**0.0**	0.0	**0.0**	0.0	0.506
Woodpecker (unidentified)	**0.0**	0.0	**0.0**	0.0	**8.3**	8.3	0.558
Yellow-bellied sapsucker	**9.1**	9.1	**0.0**	0.0	**16.7**	11.2	0.692
Yellow-rumped warbler	**9.1**	9.1	**0.0**	0.0	**0.0**	0.0	0.506

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.7. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen in the 70-year age class within different habitat types during the breeding season in the Upper Peninsula, Michigan in 2004–2005. AQV = *Acer-Quercus-Vaccinium*, TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Osmorhiza*, AOC = *Acer-Osmorhiza-Caulophyllum*.

	Habitat types represented in 70-year age class										
	AQV7 (n=3)		TM7 (n=11)		ATD7 (n=2)		AVO7 (n=6)		AOC7 (n=3)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**0.0**	0.0	**30.8**	13.3	**0.0**	0.0	**33.3**	21.1	**66.7**	33.3	0.410
American redstart*	**0.0**[a]	0.0	**0.0**[a]	0.0	**100.0**[b]	0.0	**0.0**[a]	0.0	**0.0**[a]	0.0	0.000
American robin	**0.0**	0.0	**7.7**	7.7	**0.0**	0.0	**0.0**	0.0	**33.3**	33.3	0.451
Black-and-white warbler*	**0.0**[a]	0.0	**23.1**[b]	12.2	**0.0**[a]	0.0	**0.0**[a]	0.0	**0.0**[a]	0.0	0.060
Black-capped chickadee*	**100.0**[a]	0.0	**46.2**[a]	14.4	**50.0**[a]	50.0	**0.0**[b]	0.0	**100.0**[a]	0.0	0.021
Black-throated-blue warbler*	**33.3**[ab]	33.3	**7.7**[a]	7.7	**100.0**[b]	0.0	**0.0**[a]	0.0	**0.0**[a]	0.0	0.008
Black-throated-green warbler	**0.0**	0.0	**53.8**	14.4	**100.0**	0.0	**16.7**	16.7	**66.7**	33.3	0.110
Blue jay	**0.0**	0.0	**7.7**	7.7	**0.0**	0.0	**33.3**	21.1	**0.0**	0.0	0.406
Brown creeper*	**0.0**[a]	0.0	**23.1**[b]	12.2	**0.0**[a]	0.0	**0.0**[ab]	0.0	**0.0**[a]	0.0	0.060
Chestnut-sided warbler*	**100.0**[a]	0.0	**0.0**[b]	0.0	**0.0**[b]	0.0	**16.7**[bc]	16.7	**66.7**[c]	33.3	0.001
Common yellowthroat	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	1.000
Downy/hairy woodpecker	**33.3**	33.3	**7.7**	7.7	**50.0**	50.0	**16.7**	16.7	**0.0**	0.0	0.490
Eastern peewee	**33.3**	33.3	**7.7**	7.7	**50.0**	50.0	**50.0**	22.4	**33.3**	33.3	0.324
Eastern wild turkey*	**0.0**[a]	0.0	**0.0**[a]	0.0	**0.0**[a]	0.0	**0.0**[a]	0.0	**66.7**[b]	33.3	0.002
Golden-crowned kinglet	**0.0**	0.0	**23.1**	12.2	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	0.478
Hermit thrush	**66.7**	33.3	**61.5**	14.0	**0.0**	0.0	**33.3**	21.1	**100.0**	0.0	0.185
Magnolia warbler	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**16.7**	16.7	**0.0**	0.0	0.478

Table 2.7. (Cont.)

	Habitat types represented in 70-year age class										
	AQV7		TM7		ATD7		AVO7		AOC7		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
Nashville warbler	**66.7**	33.3	**30.8**	13.3	**0.0**	0.0	**33.3**	21.1	**100.0**	0.0	0.137
Northern flicker*	**66.7**[a]	33.3	**7.7**[b]	7.7	**0.0**[b]	0.0	**0.0**[b]	0.0	**0.0**[b]	0.0	0.033
Ovenbird	**100.0**	0.0	**100.0**	0.0	**100.0**	0.0	**100.0**	0.0	**100.0**	0.0	1.000
Pileated woodpecker*	**66.7**[a]	33.3	**92.3**[a]	7.7	**0.0**[b]	0.0	**83.3**[a]	16.7	**100.0**[a]	0.0	0.032
Pine siskin	**33.3**	33.3	**38.5**	14.0	**0.0**	0.0	**16.7**	16.7	**33.3**	33.3	0.776
Raven	**0.0**	0.0	**23.1**	12.2	**0.0**	0.0	**16.7**	16.7	**66.7**	33.3	0.310
Red-breasted nuthatch	**66.7**	33.3	**38.5**	14.0	**50.0**	50.0	**83.3**	16.7	**33.3**	33.3	0.427
Red-eyed vireo*	**100.0**[a]	0.0	**30.8**[b]	13.0	**100.0**[a]	0.0	**100.0**[a]	0.0	**66.7**[ab]	33.3	0.019
Red-headed woodpecker	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**16.7**	16.7	**0.0**	0.0	0.478
Rose-breasted grosbeak	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	1.000
Ruffed grouse	**33.3**	33.3	**7.7**	7.7	**0.0**	0.0	**16.7**	16.7	**0.0**	0.0	0.667
Scarlet tanager	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**33.3**	21.1	**0.0**	0.0	0.122
Veery	**0.0**	0.0	**7.7**	7.7	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	0.898
White-breasted nuthatch*	**66.7**[a]	33.3	**15.4**[b]	10.4	**0.0**[b]	0.0	**0.0**[b]	0.0	**0.0**[b]	0.0	0.092
White-throated sparrow	**33.3**	33.3	**15.4**	10.4	**0.0**	0.0	**16.7**	16.7	**0.0**	0.0	0.801
Winter wren	**0.0**	0.0	**7.7**	7.7	**0.0**	0.0	**50.0**	22.4	**0.0**	0.0	0.111
Wood thrush	**0.0**	0.0	**15.4**	10.4	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	0.692
Woodpecker (unidentified)*	**66.7**[a]	33.3	**15.4**[b]	10.4	**0.0**[b]	0.0	**0.0**[b]	0.0	**0.0**[b]	0.0	0.092
Yellow-bellied sapsucker	**0.0**	0.0	**7.7**	7.7	**0.0**	0.0	**16.7**	16.7	**0.0**	0.0	0.855
Yellow-rumped warbler*	**0.0**[a]	0.0	**0.0**[ab]	0.0	**0.0**[a]	0.0	**0.0**[a]	0.0	**33.3**[a]	33.3	0.092

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Frequency of occurrence of breeding bird species throughout succession

Within the TM habitat type

Throughout succession (i.e., from 20-year-old aspen to aspen ≥ 70 years old), bird species richness remained relatively constant (25 species in 20- and 50-year age classes; 28 species in aspen ≥ 70 years old). Sixteen species were common to all 3 age classes, and 11 species were found only in one age class of aspen within the TM habitat type (Table 2.8). The chestnut-sided warbler, common yellowthroat, Eastern wild turkey, and rose-breasted grosbeak were only observed in the 20-year age class; however, only the frequency of occurrence of the chestnut-sided warbler and rose-breasted grosbeak differed significantly ($p < 0.10$) from 0 (Table 2.8). The yellow-rumped warbler was only observed in the 50-year age class, but absolute frequency was not significantly different from 0. Species only observed in aspen stands ≥ 70 years old included the American robin, brown creeper, magnolia warbler, northern flicker, white-breasted nuthatch, and unidentified woodpeckers. Of those species, only the frequency of occurrence of the brown creeper differed from 0 ($p = 0.085$).

Within the ATD habitat type

Within the ATD habitat type, bird species richness decreased over time in aspen stands from 16 species observed in 20-year-old stands to 9 species observed in stands ≥ 70 years old. Five species were common to all 3 age classes in the ATD habitat type. Eight species were only observed in the 20-year age class, including the common yellowthroat, eastern wild turkey, golden-crowned kinglet, pileated woodpecker, ruffed grouse, scarlet tanager, white-throated sparrow, and wood thrush. Of those species, only absolute frequency of the eastern wild turkey statistically differed from 0 ($p = 0.082$;

Table 2.9). Four species were observed only in the 50-year age class of aspen in the ATD habitat type, including the chestnut-sided warbler, Nashville warbler, northern flicker, and red-headed woodpecker. Of these species, the Nashville warbler and red-headed woodpecker differed from 0 ($p = 0.050$ and $p = 0.018$, respectively). The American redstart was only recorded in stands ≥ 70 years old within the ATD habitat type ($p = 0.018$; Table 2.9).

Within the AVO habitat type

Within the AVO habitat type, species richness of birds during the breeding season was highest (31 species) in aspen stands in the 50-year age class. Species richness was 21 in aspen ≥ 70 years old, and lowest (8 species) in aspen in the 20-year age class (Table 2.10). The black-throated-green warbler, chestnut-sided warbler, hermit thrush, Nashville warbler, and ovenbird were observed in all aspen age classes within the AVO habitat type. Eleven species were only observed in the 50-year age class, including the American redstart, black-and-white warbler, brown-headed cowbird, eastern wild turkey, golden-winged warbler, mourning dove, northern flicker, northern parula, rose-breasted grosbeak, veery, and white-breasted nuthatch. Of these species, only the absolute frequency of the veery significantly differed from 0 ($p = 0.071$). Three species (i.e., the magnolia warbler, pine siskin, and raven) were unique to aspen ≥ 70- years, but the absolute frequency of none of these species significantly differed from 0 (Table 2.10).

Table 2.8. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen within the *Tsuga-Maianthemum* habitat type during the breeding season in the Upper Peninsula, Michigan in 2004–2005.

	Age classes						
	20-year (n = 9)		50-year (n = 11)		70-year (n = 11)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**55.6**	17.6	**45.5**	15.7	**30.8**	13.3	0.507
American redstart	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	1.000
American robin	**0.0**	0.0	**0.0**	0.0	**7.7**	7.7	0.463
Black-and-white warbler*	**0.0**[a]	0.0	**27.3**[b]	14.1	**23.1**[ab]	12.2	0.098
Black-capped chickadee	**33.3**	16.7	**36.4**	15.2	**46.2**	14.4	0.812
Black-throated-blue warbler	**11.1**	11.1	**0.0**	0.0	**7.7**	7.7	0.506
Black-throated-green warbler	**77.8**	14.7	**63.6**	15.2	**53.8**	14.4	0.528
Blue jay*	**55.6**[a]	17.6	**27.3**[a]	14.1	**7.7**[b]	7.7	0.051
Brown creeper*	**0.0**[a]	0.0	**0.0**[a]	0.0	**23.1**[b]	12.2	0.085
Brown-headed cowbird	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	1.000
Chestnut-sided warbler*	**22.2**[a]	14.7	**0.0**[b]	0.0	**0.0**[b]	0.0	0.064
Common yellowthroat	**11.1**	11.1	**0.0**	0.0	**0.0**	0.0	0.264
Downy/hairy woodpecker	**11.1**	11.1	**9.1**	9.1	**7.7**	7.7	0.964
Eastern peewee	**11.1**	11.1	**0.0**	0.0	**7.7**	7.7	0.566
Eastern wild turkey	**11.1**	11.1	**0.0**	0.0	**0.0**	0.0	0.264
Golden-crowned kinglet	**22.2**	14.7	**27.3**	14.1	**23.1**	12.2	0.960
Golden-winged warbler*	**0.0**[a]	0.0	**9.1**[b]	9.1	**0.0**[a]	0.0	0.040
Hermit thrush	**44.4**	17.6	**81.8**	12.2	**61.5**	14.0	0.230
Nashville warbler	**33.3**	16.7	**36.4**	15.2	**30.8**	13.3	0.960
Northern flicker	**0.0**	0.0	**0.0**	0.0	**7.7**	7.7	0.460

Table 2.8. (Cont.)

Common name	20-year (n = 9)		50-year (n = 11)		70-year (n = 11)		Probability level[1]
	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	
Northern parula	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	1.000
Ovenbird	**100.0**	0.0	**90.9**	9.1	**100.0**	0.0	0.368
Pileated woodpecker	**55.5**	17.6	**63.6**	15.2	**92.3**	7.7	0.124
Pine siskin	**11.1**	11.1	**27.3**	14.1	**38.5**	14.0	0.378
Raven	**0.0**	0.0	**18.2**	12.2	**23.1**	12.2	0.780
Red-breasted nuthatch*	**11.1**[a]	11.1	**72.7**[b]	14.1	**38.5**[ab]	14.0	0.022
Red-eyed vireo*	**11.1**[a]	11.1	**72.7**[b]	14.1	**30.8**[ab]	13.0	0.045
Red-headed woodpecker*	**55.6**[a]	17.6	**27.3**[a]	14.1	**0.0**[b]	0.0	0.049
Rose-breasted grosbeak*	**22.2**[a]	14.7	**0.0**[b]	0.0	**0.0**[b]	0.0	0.064
Ruffed grouse*	**11.1**[a]	11.1	**36.4**[b]	15.2	**7.7**[a]	7.7	0.092
Scarlet tanager	**11.1**	11.1	**18.2**	12.2	**0.0**	0.0	0.127
Veery	**0.0**	0.0	**9.1**	9.1	**7.7**	7.7	0.672
White-breasted nuthatch	**0.0**	0.0	**0.0**	0.0	**15.4**	10.4	0.204
White-throated sparrow	**33.3**	16.7	**9.1**	9.1	**15.4**	10.4	0.367
Winter wren*	**0.0**[a]	0.0	**27.3**[b]	14.1	**7.7**[a]	7.7	0.098
Wood thrush	**11.1**	11.1	**9.1**	9.1	**15.4**	10.4	0.893
Woodpecker (unidentified)	**0.0**	0.0	**0.0**	0.0	**15.4**	10.4	0.204
Yellow-bellied sapsucker	**11.1**	11.1	**9.1**	9.1	**7.7**	7.7	0.368
Yellow-rumped warbler	**0.0**	0.0	**9.1**	9.1	**0.0**	0.0	0.964

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.9. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen within the *Acer-Tsuga-Drypoteris* habitat type during the breeding season in the Upper Peninsula, Michigan in 2004–2005.

	20-year (n = 4)		50-year (n = 3)		70-year (n = 2)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**25.0**	25.0	**0.0**	0.0	**0.0**	0.0	0.535
American redstart*	**0.0**[a]	0.0	**0.0**[a]	0.0	**100.0**[b]	0.0	0.018
Black-capped chickadee	**50.0**	28.9	**33.3**	33.3	**50.0**	50.0	0.905
Black-throated-blue warbler*	**0.0**[a]	0.0	**33.3**[ab]	33.3	**100.0**[b]	0.0	0.069
Black-throated-green warbler	**75.0**	25.0	**66.7**	33.3	**100.0**	0.0	0.700
Chestnut-sided warbler	**0.0**	0.0	**33.3**	33.3	**0.0**	0.0	0.368
Common yellowthroat	**25.0**	25.0	**0.0**	0.0	**0.0**	0.0	0.535
Downy/hairy woodpecker	**25.0**	25.0	**0.0**	0.0	**50.0**	50.0	0.456
Eastern peewee	**0.0**	0.0	**0.0**	0.0	**50.0**	50.0	0.174
Eastern wild turkey*	**75.0**[a]	25.0	**0.0**[b]	0.0	**0.0**[b]	0.0	0.082
Golden-crowned kinglet	**50.0**	28.9	**0.0**	0.0	**0.0**	0.0	0.240
Hermit thrush	**25.0**	25.0	**66.7**	33.3	**0.0**	0.0	0.311
Nashville warbler*	**0.0**[a]	0.0	**33.3**[b]	33.3	**0.0**[a]	0.0	0.050
Northern flicker	**0.0**	0.0	**33.3**	33.3	**0.0**	0.0	0.368
Ovenbird	**100.0**	0.0	**100.0**	0.0	**100.0**	0.0	1.000
Pileated woodpecker	**25.0**	25.0	**0.0**	0.0	**0.0**	0.0	0.535
Pine siskin	**25.0**	25.0	**33.3**	33.3	**0.0**	0.0	0.700
Red-breasted nuthatch	**50.0**	28.9	**33.3**	33.3	**50.0**	50.0	0.905
Red-eyed vireo*	**25.0**[a]	25.0	**100.0**[b]	0.0	**100.0**[b]	0.0	0.082
Red-headed woodpecker*	**0.0**[a]	0.0	**100.0**[b]	0.0	**0.0**[a]	0.0	0.018
Ruffed grouse	**25.0**	25.0	**0.0**	0.0	**0.0**	0.0	0.535

Table 2.9. (Cont.)

Common name	20-year (n = 4)		50-year (n = 3)		70-year (n = 2)		Probability level[1]
	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	
Scarlet tanager	**25.0**	25.0	**0.0**	0.0	**0.0**	0.0	0.535
White-throated sparrow	**25.0**	25.0	**0.0**	0.0	**0.0**	0.0	0.535
Wood thrush	**50.0**	28.9	**0.0**	0.0	**0.0**	0.0	0.240

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.10. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen within the *Acer-Viola-Osmorhiza* habitat type during the breeding season in the Upper Peninsula, Michigan in 2004–2005.

	20-year (n = 2)		50-year (n = 12)		70-year (n = 6)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**0.0**	0.0	**50.0**	15.1	**33.3**	21.1	0.397
American redstart	**0.0**	0.0	**16.7**	11.2	**0.0**	0.0	0.495
Black-and-white warbler	**0.0**	0.0	**8.3**	8.3	**0.0**	0.0	0.717
Black-capped chickadee*	**50.0**[a]	50.0	**25.0**[a]	13.1	**0.0**[b]	0.0	0.083
Black-throated-blue warbler*	**50.0**[a]	50.0	**33.3**[a]	14.2	**0.0**[b]	0.0	0.083
Black-throated-green warbler*	**100.0**[a]	100.0	**33.3**[b]	14.2	**16.7**[b]	16.7	0.089
Blue jay	**0.0**	0.0	**50.0**	15.1	**33.3**	21.1	0.397
Brown-headed cowbird	**0.0**	0.0	**8.3**	8.3	**0.0**	0.0	0.717
Chestnut-sided warbler*	**100.0**[a]	0.0	**50.0**[b]	15.1	**16.7**[b]	16.7	0.049
Common yellowthroat	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	1.000
Downy/hairy woodpecker	**0.0**	0.0	**8.3**	8.3	**16.7**	16.7	0.768
Eastern peewee	**0.0**	0.0	**50.0**	15.1	**50.0**	22.4	0.422
Eastern wild turkey	**0.0**	0.0	**16.7**	11.2	**0.0**	0.0	0.495
Golden-winged warbler	**0.0**	0.0	**25.0**	13.1	**0.0**	0.0	0.327
Hermit thrush	**100.0**	0.0	**66.7**	14.2	**33.3**	21.1	0.205
Magnolia warbler	**0.0**	0.0	**0.0**	0.0	**16.7**	16.7	0.311
Mourning dove	**0.0**	0.0	**8.3**	8.3	**0.0**	0.0	0.717
Nashville warbler	**50.0**	50.0	**25.0**	13.1	**33.3**	21.1	0.768
Northern flicker	**0.0**	0.0	**25.0**	13.1	**0.0**	0.0	0.327
Northern parula	**0.0**	0.0	**8.3**	8.3	**0.0**	0.0	0.717
Ovenbird	**100.0**	0.0	**83.3**	11.2	**100.0**	0.0	0.495

Table 2.10. (Cont.)

Common name	20-year (n = 2) $\bar{x}$	20-year S.E.	50-year (n = 12) $\bar{x}$	50-year S.E.	70-year (n = 6) $\bar{x}$	70-year S.E.	Probability level[1]
Pileated woodpecker*	**0.0**[a]	0.0	**50.0**[b]	15.1	**83.3**[b]	16.7	0.049
Pine siskin	**0.0**	0.0	**0.0**	0.0	**16.7**	16.7	0.311
Raven	**0.0**	0.0	**0.0**	0.0	**16.7**	16.7	0.311
Red-breasted nuthatch*	**0.0**[a]	0.0	**25.0**[b]	13.1	**83.3**[c]	16.7	0.033
Red-eyed vireo*	**0.0**[a]	0.0	**83.3**[b]	11.2	**100.0**[b]	0.0	0.011
Red-headed woodpecker	**0.0**	0.0	**25.0**	13.1	**16.7**	16.7	0.707
Rose-breasted grosbeak	**0.0**	0.0	**8.3**	8.3	**0.0**	0.0	0.717
Ruffed grouse	**0.0**	0.0	**25.0**	13.1	**16.7**	16.7	0.707
Scarlet tanager	**0.0**	0.0	**8.3**	8.3	**33.3**	21.1	0.327
Veery*	**0.0**[a]	0.0	**41.7**[b]	14.9	**0.0**[a]	0.0	0.071
White-breasted nuthatch	**0.0**	0.0	**8.3**	8.3	**0.0**	0.0	0.717
White-throated sparrow	**0.0**	0.0	**8.3**	8.3	**16.7**	16.7	0.768
Winter wren*	**50.0**[a]	50.0	**0.0**[b]	0.0	**50.0**[a]	22.4	0.028
Woodpecker (unidentified)	**0.0**	0.0	**8.3**	8.3	**0.0**	0.0	0.717
Yellow-bellied sapsucker	**0.0**	0.0	**16.7**	11.2	**16.7**	16.7	0.830

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Community characteristics

Nesting preference

Cavity-nesting birds in the study area included the black-capped chickadee, brown creeper, downy woodpecker, hairy woodpecker, northern flicker, pileated woodpecker, red-breasted nuthatch, red-headed woodpecker, white-breasted nuthatch, winter wren, and yellow-bellied sapsucker. Several notable differences in numbers of cavity-nesting birds and non-cavity-nesting birds were observed among age classes and habitat types. The average number of cavity-nesters per observation was significantly less ($p < 0.10$) than the average number of non-cavity-nesters in all age classes and habitat types, except for aspen stands ≥ 70 years in the AQV habitat type (Figure 2.2). The average number of cavity-nesters, however, did not differ among habitat types within the same age class. The average number of non-cavity-nesting birds did not differ among habitat types represented in the 20-year age class; however significant differences among habitat types in other age classes were evident. For instance, aspen in the 50-year age class within the ATD habitat type had fewer ($\bar{x} = 4.67$, S.E. = 0.34) non-cavity-nesting birds per observation than stands in the AVO ($\bar{x} = 7.17$, S.E. = 0.37) and TM ($\bar{x} = 6.18$, S.E. = 0.48) habitat types. In aspen stands ≥ 70 years old, differences in the average number of non-cavity-nesting birds were only significant between the AVO and AOC habitat types. There were fewer ($\bar{x} = 5.33$, S.E. = 0.21) non-cavity-nesters in the AVO habitat type than in the AOC habitat type ($\bar{x} = 8.33$, S.E. = 1.33).

A.

B.

C.

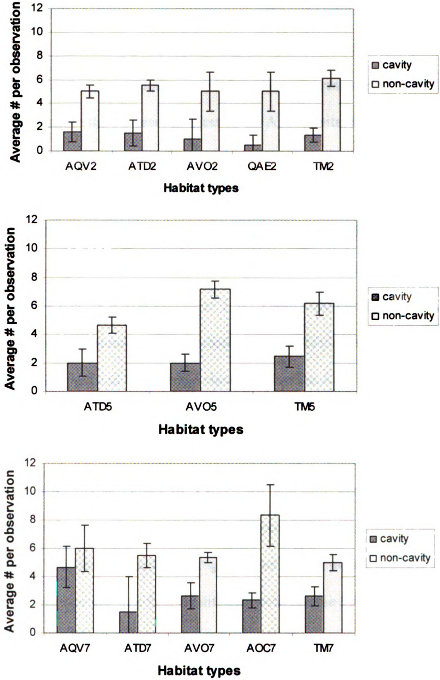

Figure 2.2. Number of cavity-nesting and non-cavity-nesting birds in 20-year (A), 50-year (B), and 70-year (C) age classes of aspen in different habitat types in the western Upper Peninsula, Michigan during 2004–2005. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Migratory status

The number of short-distance migrants was significantly lower ($p < 0.10$) than the number of year-round residents and neotropical migrants per observation in aspen within the 50-year and 70-year age classes and among habitat types represented in those age classes (except for aspen in the 50-year age class in the ATD habitat type). In the 20-year age class, the differences were only significant when compared to the number of neotropical migrants observed in all habitat types represented (Figure 2.3).

Within the ATD habitat type, the average number of year-round residents per observation was highest ($\bar{x} = 2.75$, S.E. = 0.95) in the 20-year age class, and lowest in the 50-year age class ($\bar{x} = 0.67$, S.E. = 0.33; Figure 2.3). These differences, however, were not significant. The average number of short-distance migrants observed per observation was similar between 20-year and 50-year age classes within the ATD habitat type, but none were observed in the 70-year age class. The average number of neotropical migrants increased with age in the ATD habitat type (20-year: $\bar{x} = 3.00$, S.E. = 0.71; 50-year: $\bar{x} = 4.00$, S.E.= 0; 70-year: $\bar{x} = 5.50$, S.E.= 0.50), and were significantly different ($p < 0.10$) between the 50- and 70-year age classes (Figure 2.3).

Within the AVO habitat type, the average number of year-round resident birds increased with age, but was not significantly different between the 50-year and 70-year age classes (Figure 2.3). The numbers of short-distance and neotropical migrants stayed relatively consistent among all age classes within the AVO habitat type.

Within the TM habitat type, the average number of year-round resident birds, short-distance migrants, and neotropical migrants stayed relatively consistent with increasing age (Figure 2.3). No differences were observed in the number of birds observed within each migration class across age classes.

Sensitive species

Four species were observed in the study that were defined as sensitive based on the Audubon Society's Watch List and species with the greatest population declines in Michigan over the past 40 years (Brewer et al. 1991, Audubon Society 2002). Those species included the golden-winged warbler, pine siskin, red-headed woodpecker, and wood thrush. There were no statistical differences ($p > 0.10$) in the numbers of sensitive species observed among age classes and habitat types; however some trends were observed. Generally, the average number of sensitive species recorded per observation was highest in the 50-year age class (50 year: $\bar{x} = 0.54$, S.E. = 0.11; 20-year: $\bar{x} = 0.23$, S.E. = 0.09; 70-year: $\bar{x} = 0.11$, S.E.= 0.06). On average, a greater number of sensitive species were also observed in the ATD habitat type ($\bar{x} = 0.56$, S.E. = 0.18) than either the TM ($\bar{x} = 0.27$, S.E. = 0.09) or AVO ($\bar{x} = 0.35$, S.E. = 0.11) habitat types.

Among age classes and habitat types, the average number of sensitive species observed per observation was highest in the 50-year aspen age class within the ATD habitat type ($\bar{x} = 1.0$, S.E. = 0), followed by 50-year-old aspen within the AVO habitat type ($\bar{x} = 0.50$, S.E. = 0.15), 20-year-old aspen in the ATD type ($\bar{x} = 0.50$, S.E .= 0.29), and 50-year-old aspen in the TM type ($\bar{x} = 0.46$, S.E. = 0.21). No sensitive species were observed in the 20-year-old age class within the QAE, AVO, and AOC types. Similar numbers of sensitive species were observed in 20-year-old aspen within the AQV ($\bar{x} = 0.20$, S.E. = 0.20) and TM ($\bar{x} = 0.22$, S.E. = 0.15) habitat types, and aspen ≥ 70 years within the TM ($\bar{x} = 0.15$, S.E. = 0.10) and AVO ($\bar{x} = 0.17$, S.E. = 0.17) habitat types.

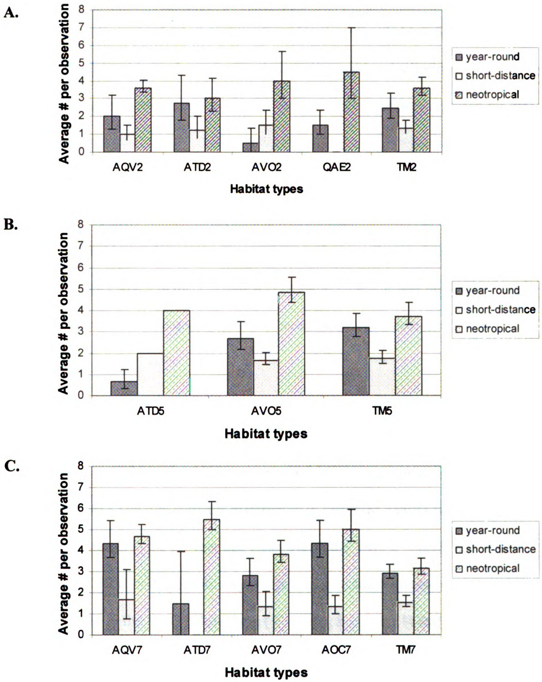

Figure 2.3. Number of year-round resident birds, short-distance migrants, and neotropical migrants in 20-year (A), 50-year (B), and 70-year (C) age classes of aspen in different habitat types in the western Upper Peninsula, Michigan during 2004–2005. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Habitat suitability for indicator species

Overall habitat suitability scores were based on breeding habitat for all indicator species except the pileated woodpecker. Food was not considered a limiting factor for those species. Therefore, scores of foraging habitat suitability are only reported for the pileated woodpecker.

Veery

Habitat suitability for the veery was highest ($\bar{x}$ = 0.70, S.E. = 0.0) in aspen ≥ 70 years old within the AVO habitat type (Figure 2.4), and generally was higher than suitability across age classes in the TM and ATD habitat types. It was only significantly ($p < 0.10$) higher, however, compared to habitat suitability of stands in the TM habitat type.

Ovenbird

Ovenbird habitat suitability was high (≥ 0.60) in stands within all age classes and habitat types, but was highest (> 0.90) in aspen ≥ 70 years old within all habitat types assessed (Figure 2.4). The most notable differences in ovenbird habitat suitability occurred between stands in the 20-year age class within the TM ($\bar{x}$ = 0.93, S.E. = 0.04) and ATD ($\bar{x}$ = 0.76, S.E. = 0.06) habitat types ($p = 0.014$); and between aspen stands in the 50-year age class in the AVO habitat type ($\bar{x}$ = 0.60, S.E. = 0.11) and the TM ($\bar{x}$ = 0.94, S.E. = 0.01) and ATD ($\bar{x}$ = 0.91, S.E. = 0.02) habitat types ($p < 0.10$).

Yellow-rumped warbler

Aspen stands ≥ 70 years old within the TM habitat type provided better ($p < 0.10$) habitat conditions for the yellow-romped warbler ($\bar{x}$ = 0.54, S.E. = 0.08) than other age classes and habitat types (Figure 2.4). Habitat suitability was also higher ($p < 0.10$) in the

TM habitat type than in other habitat types across all age classes. Suitability was < 0.15 in all other age classes and habitat types, and was 0 in aspen stands in the 20-year and 70-year age classes.

American redstart

Habitat suitability for the American redstart was generally higher in aspen stands within the hardwood (i.e., ATD and AVO) habitat types than in the TM habitat type (Figure 2.4). Also, older (> 50-year-old) stands within the ATD and AVO habitat types provided better habitat conditions than stands in the 20-yeaer age class. Differences in American redstart habitat suitability were not significant ($p > 0.10$) between the ATD and AVO habitat types within the 50-year and 70-year age classes (Figure 2.4).

Black-capped chickadee

There were no significant differences in black-capped chickadee habitat suitability when compared among age classes, habitat types, and age classes within habitat types. Habitat suitability was higher on average, however, in aspen > 50 years old, and within the AVO habitat type (Figure 2.4).

Pileated woodpecker

Habitat suitability for the pileated woodpecker was low (< 0.17) in all age classes and habitat types. It was 0.0 for all stands in the 20-year age class, all stands within the TM habitat type, 50-year-old stands within the ATD habitat type, and stands ≥ 70 years old within the AVO habitat type (Figure 2.4).

Foraging habitat suitability scores for the pileated woodpecker were generally higher than reproductive habitat suitability. Foraging habitat suitability was highest in stands ≥ 70 years old within all habitat types (ATD: $\bar{x} = 0.56$, S.E. = 0.04; TM: $\bar{x}$ =

0.55, S.E. = 0.02; AVO: $\bar{x}$ = 0.44, S.E. = 0.02). Stands in the 20-year age class within the ATD habitat type also provided moderate foraging habitat for the pileated woodpecker ($\bar{x}$ = 0.48, S.E. = 0.03). Stands in the 20-year age class within other habitat types, however, did not provide foraging habitat for pileated woodpeckers. Average foraging habitat suitability for aspen stands in the 50-year age class in the AVO and TM habitat types was 0.35 (S.E. = 0.03) and 0.39 (S.E. = 0.04), respectively. Suitability for 50-year-old stands within the ATD habitat type was 0.0.

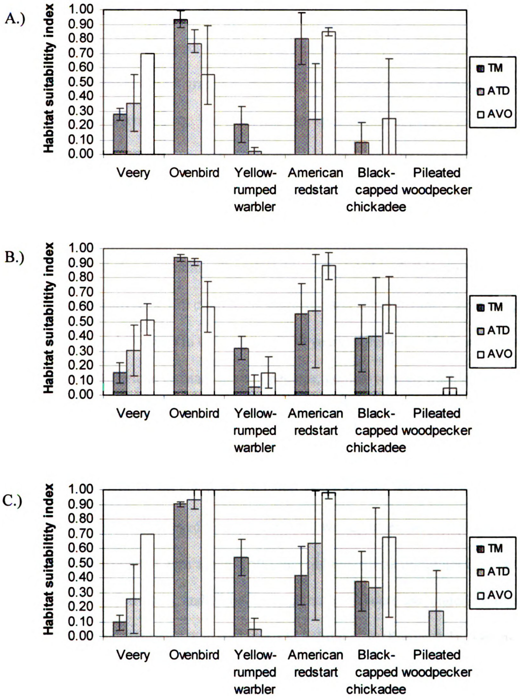

Figure 2.4. Habitat suitability scores for bird species in 20-year (A), 50-year (B), and 70-year (C) age classes of aspen in different habitat types in the western Upper Peninsula, Michigan during 2004–2005. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Avian communities

Groupings of bird species associated with similar aspen age classes or habitat types were evident based on graphs of principal component scores (Figures 2.5–2.11) and frequency of occurrence data. For instance, bird species that appeared to be associated with younger (e.g., 20–50-year old) aspen stands within the AVO and ATD habitat types included the black-throated blue warbler, chestnut-sided warbler, eastern wild turkey, and rose-breasted grosbeak (Figure 2.5). Based on vegetation attribute results from Chapter 1, threshold levels for vegetation characteristics associated with this community were > 70% herbaceous cover, < 100 coniferous stems/ha, and shrub height > 2.1 m. Species generally observed in aspen in older aspen (>50 years) within the AVO or ATD habitat types were the American redstart, eastern peewee, golden-winged warbler, red-headed woodpecker, scarlet tanager, and veery (Figure 2.6). Vegetation attributes associated with this community were overstory dbh 13–15 cm, height > 9.5 m, 850–1200 deciduous stems/ha, ,< 350 coniferous stems/ha, and coniferous canopy cover < 7.5%. The blue jay, red-breasted nuthatch, red-eyed vireo, red-headed woodpecker, and white-breasted nuthatch were associated with aspen ≥ 50 years old regardless of habitat type, although the blue jay, red-eyed vireo, and white-breasted nuthatch were associated more with AVO and ATD habitat types than with the TM habitat type (Figure 2.7). Defining vegetation attributes for this community included shrub height ≥ 2.4 m, 600–1200 stems deciduous stems/ha, and tree diameter 13–15 cm dbh. The wood thrush and yellow-bellied sapsucker were mostly associated with aspen stands < 50 years old within the TM habitat type, but also occurred in younger stands within the other habitat types (Figure 2.8). It was unclear what defining vegetation attributes were for this community because there was no clear distinction in occurrence of birds among younger habitat types. Birds associated with aspen ≥ 70 years old within the TM habitat type included the black-and-white warbler, brown creeper, and yellow-rumped warbler (Figure 2.9). The pine siskin also was associated with aspen ≥ 70 years old, but used stands in the 50-year age class as well. This community was associated with > 10% overstory conifer cover, trees > 12 cm dbh, and > 1000 coniferous stems/ha. Other species associated with the TM habitat type regardless of age include the golden-crowned kinglet, white-throated sparrow, and winter wren (Figure 2.10).

Several birds were considered generalists because they were found in all sampled aspen age classes and habitat types. These generalist species included the black-capped chickadee, black-throated green warbler, downy woodpecker, hermit thrush, Nashville warbler, northern flicker, and pileated woodpecker (Figure 2.11). Other generalists not include in the figure were the ovenbird, American crow, and raven.

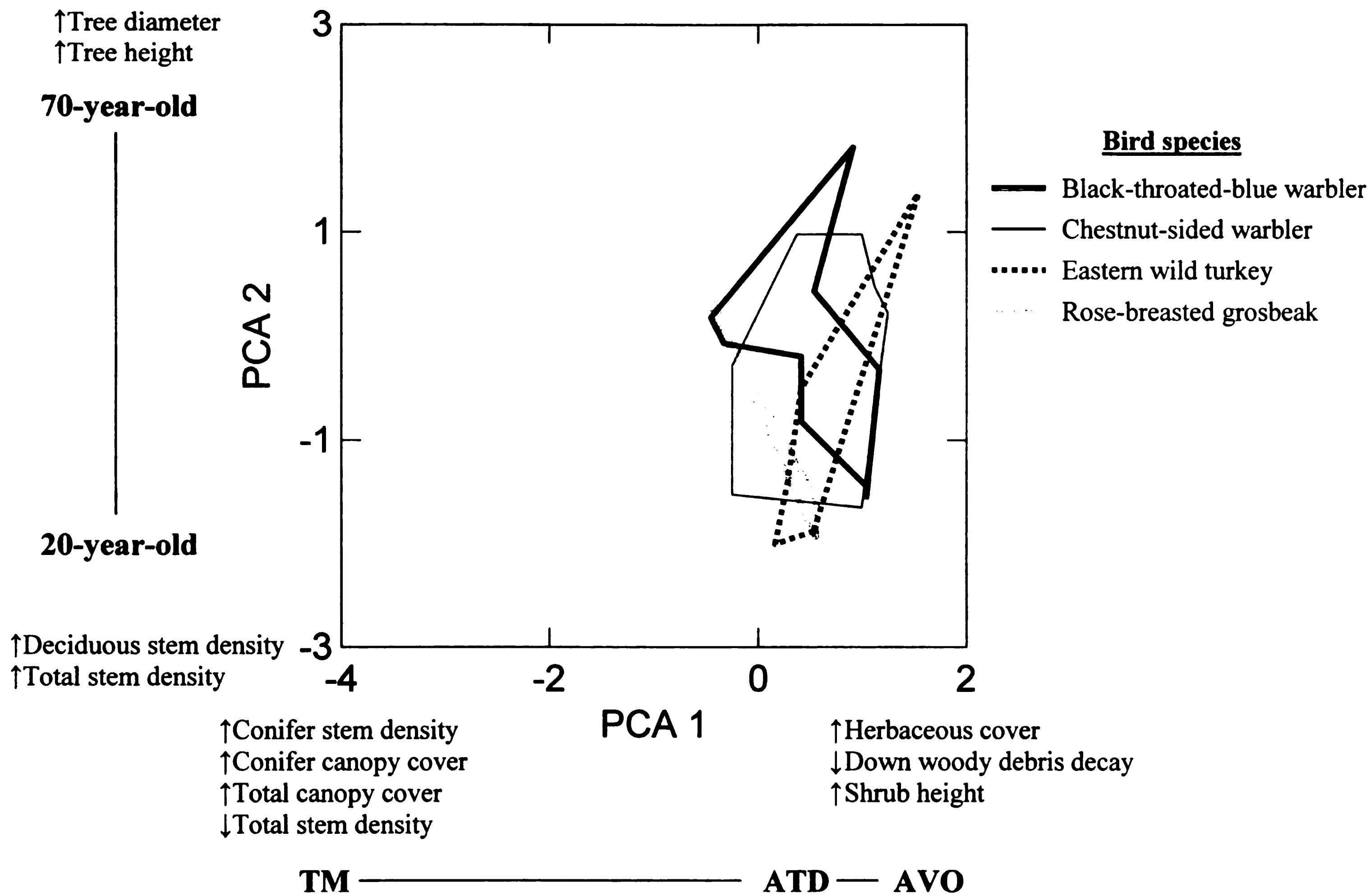

Figure 2.5. Avian community associations with 20–50-year-old aspen within the ATD and AVO habitat types in the western Upper Peninsula, Michigan. TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Drypoteris*, and AVO = *Acer-Viola-Osmorhiza*.

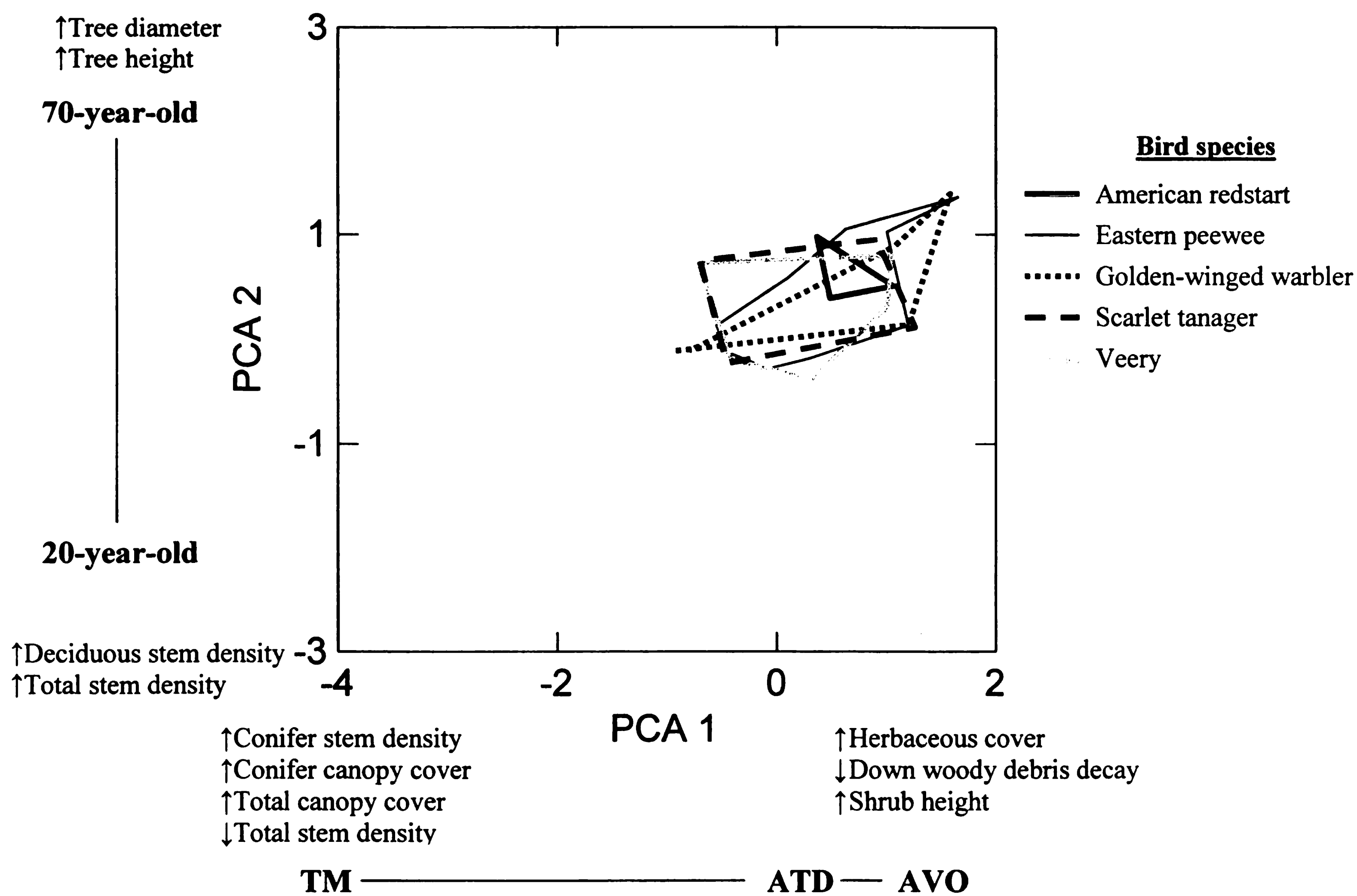

Figure 2.6. Avian community associations with 50-year-old aspen within the ATD and AVO habitat types in the western Upper Peninsula, Michigan. TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Drypoteris*, and AVO = *Acer-Viola-Osmorhiza*.

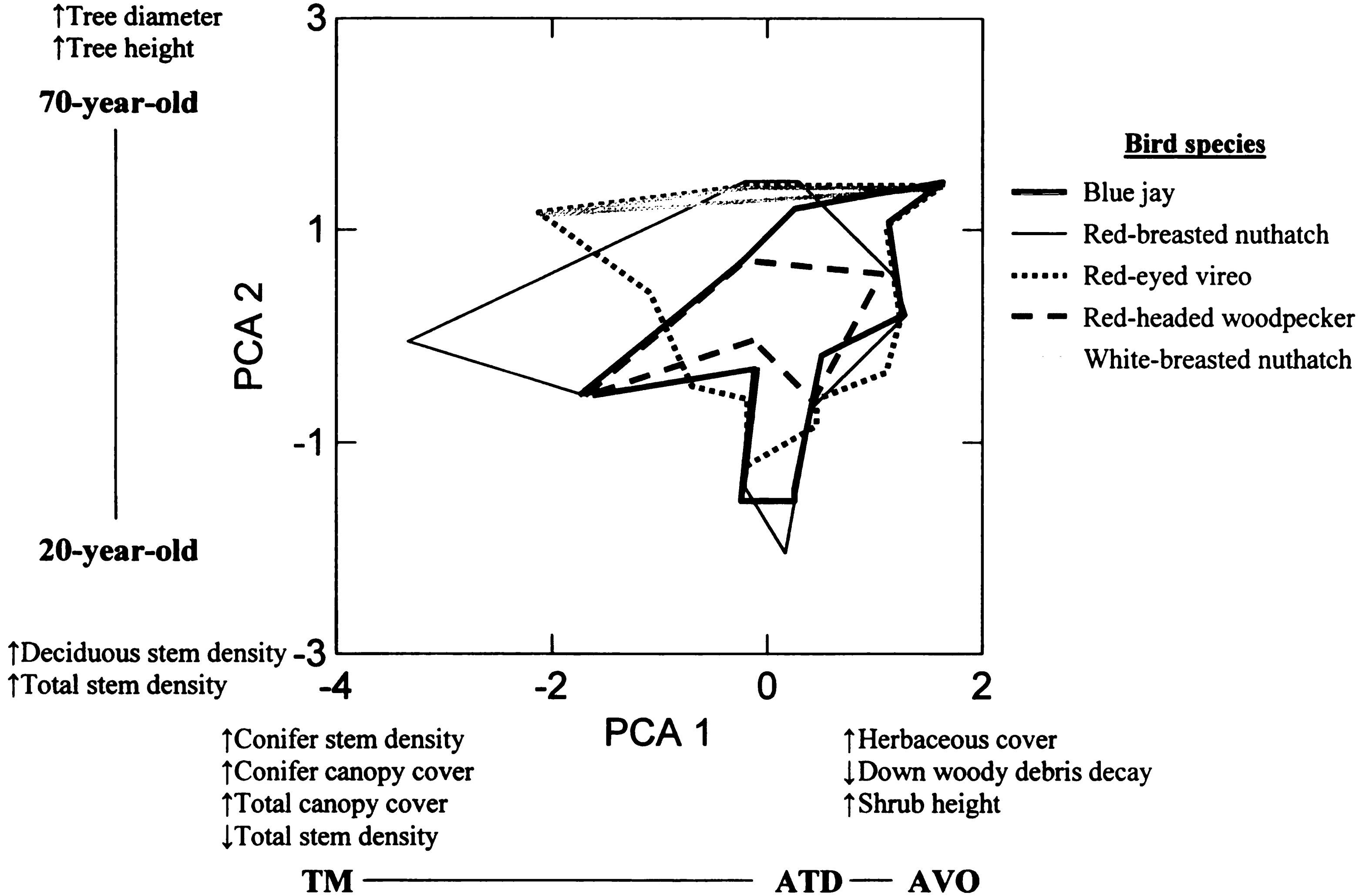

Figure 2.7. Avian community associations with 50-year-old aspen in the western Upper Peninsula, Michigan. TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Drypoteris*, and AVO = *Acer-Viola-Osmorhiza.*

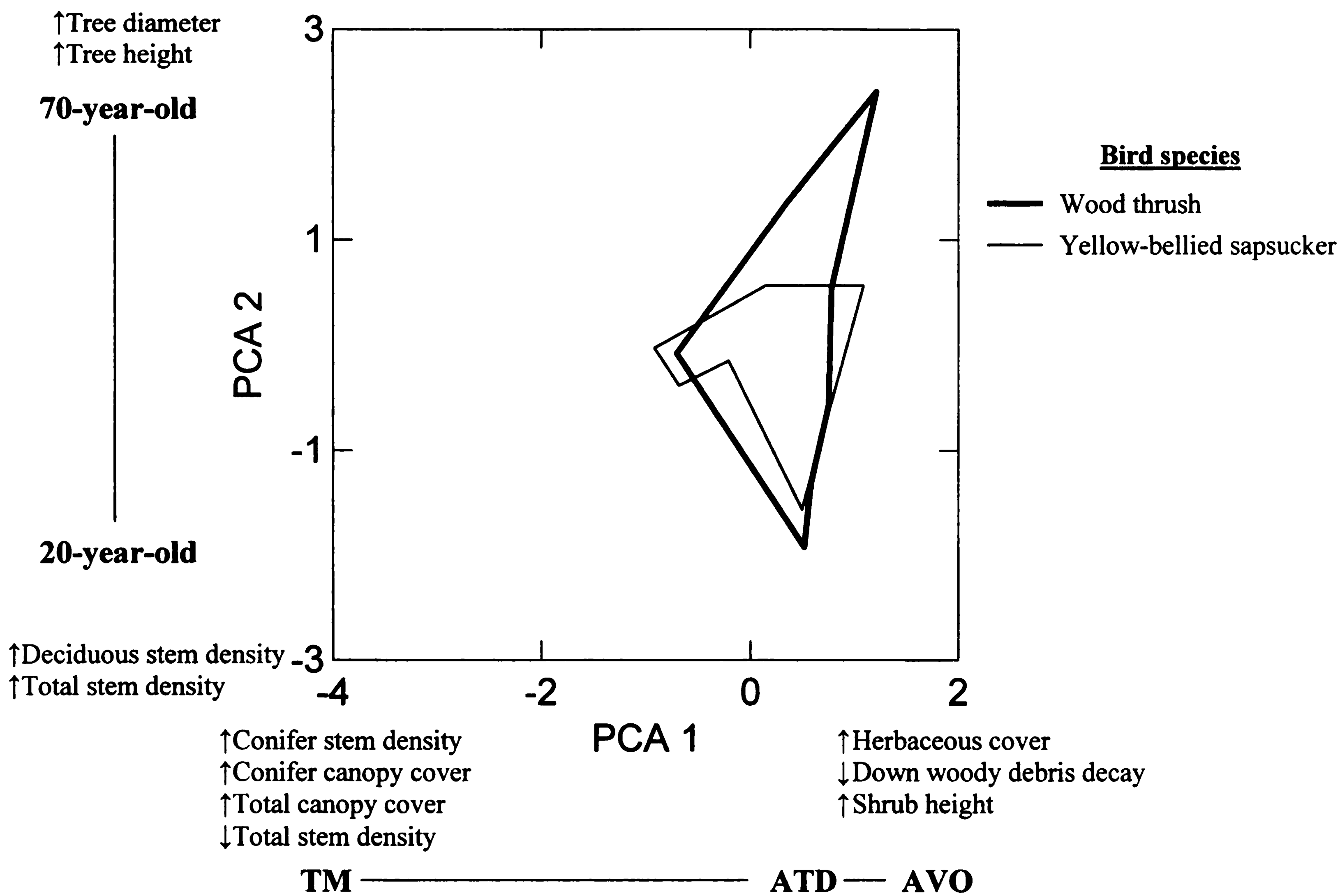

Figure 2.8. Avian community associations with 20-year-old aspen within the *Tsuga-Maianthemum* (TM) habitat type in the western Upper Peninsula, Michigan. ATD = *Acer-Tsuga-Drypoteris*, and AVO = *Acer-Viola-Osmorhiza*.

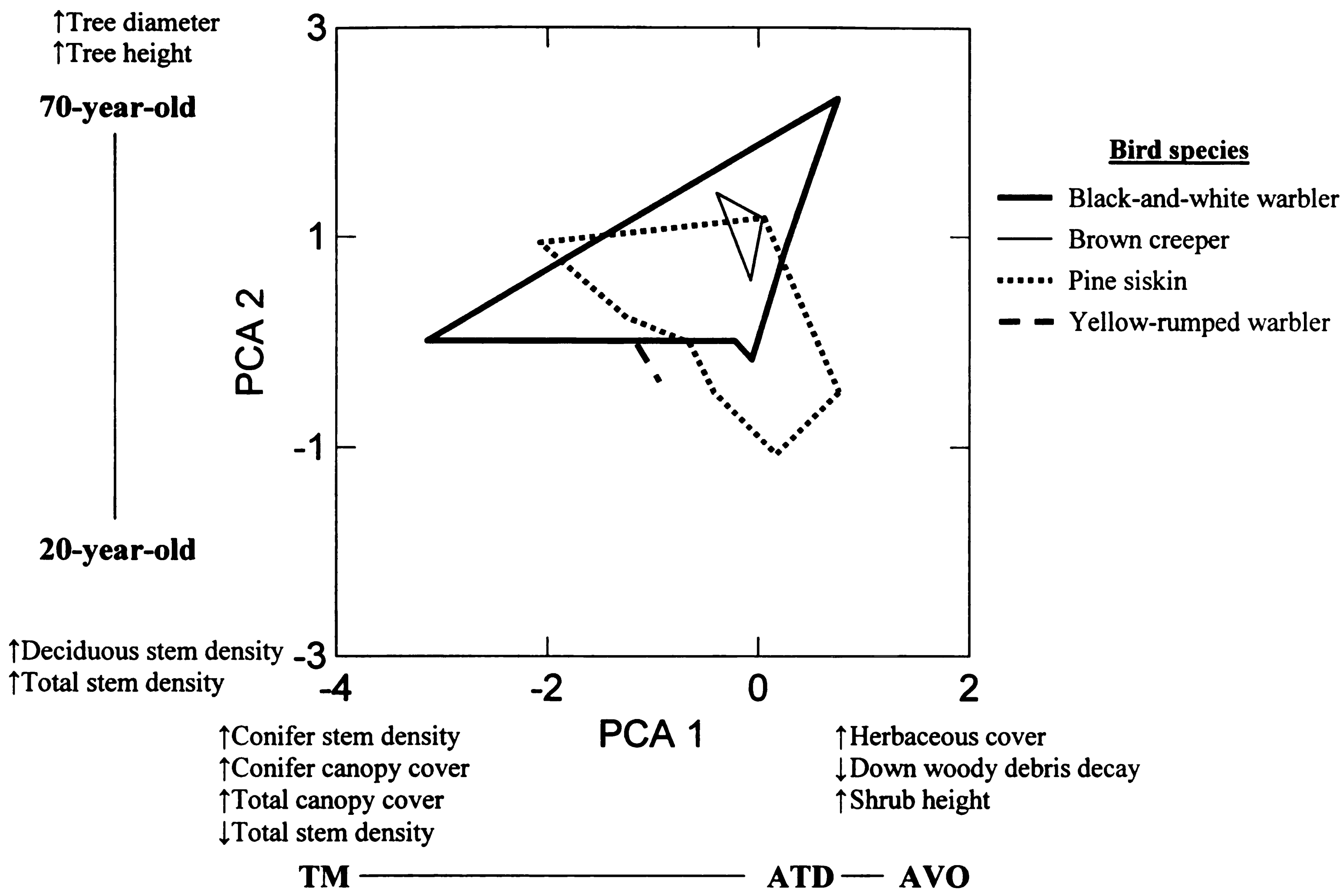

Figure 2.9. Avian community associations with aspen ≥ 70 years old within the *Tsuga-Maianthemum* (TM) habitat type in the western Upper Peninsula, Michigan. ATD = *Acer-Tsuga-Drypoteris*, and AVO = *Acer-Viola-Osmorhiza*.

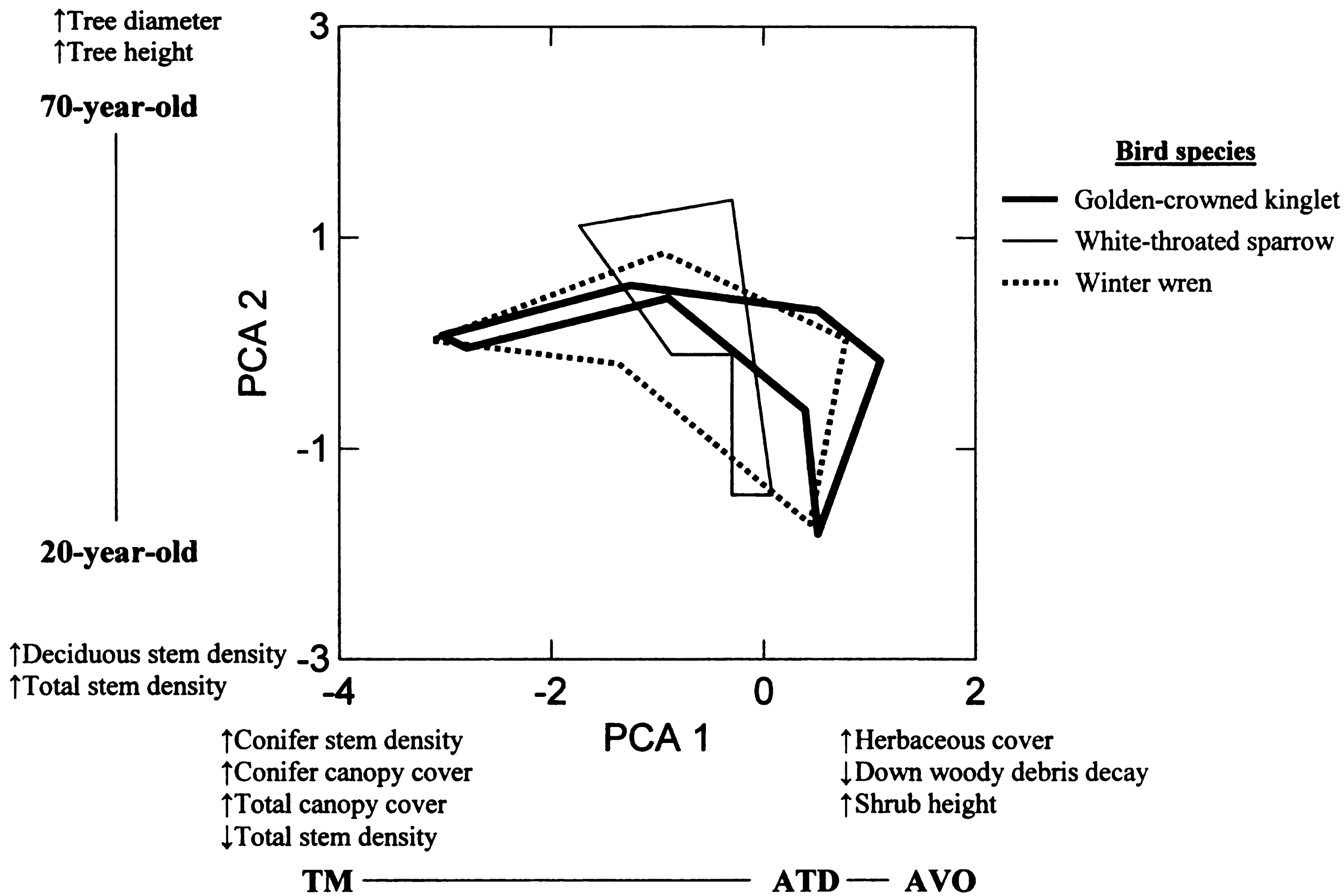

Figure 2.10. Avian community associations with aspen within the *Tsuga-Maianthemum* (TM) habitat type in the western Upper Peninsula, Michigan. ATD = *Acer-Tsuga-Drypoteris*, and AVO = *Acer-Viola-Osmorhiza*.

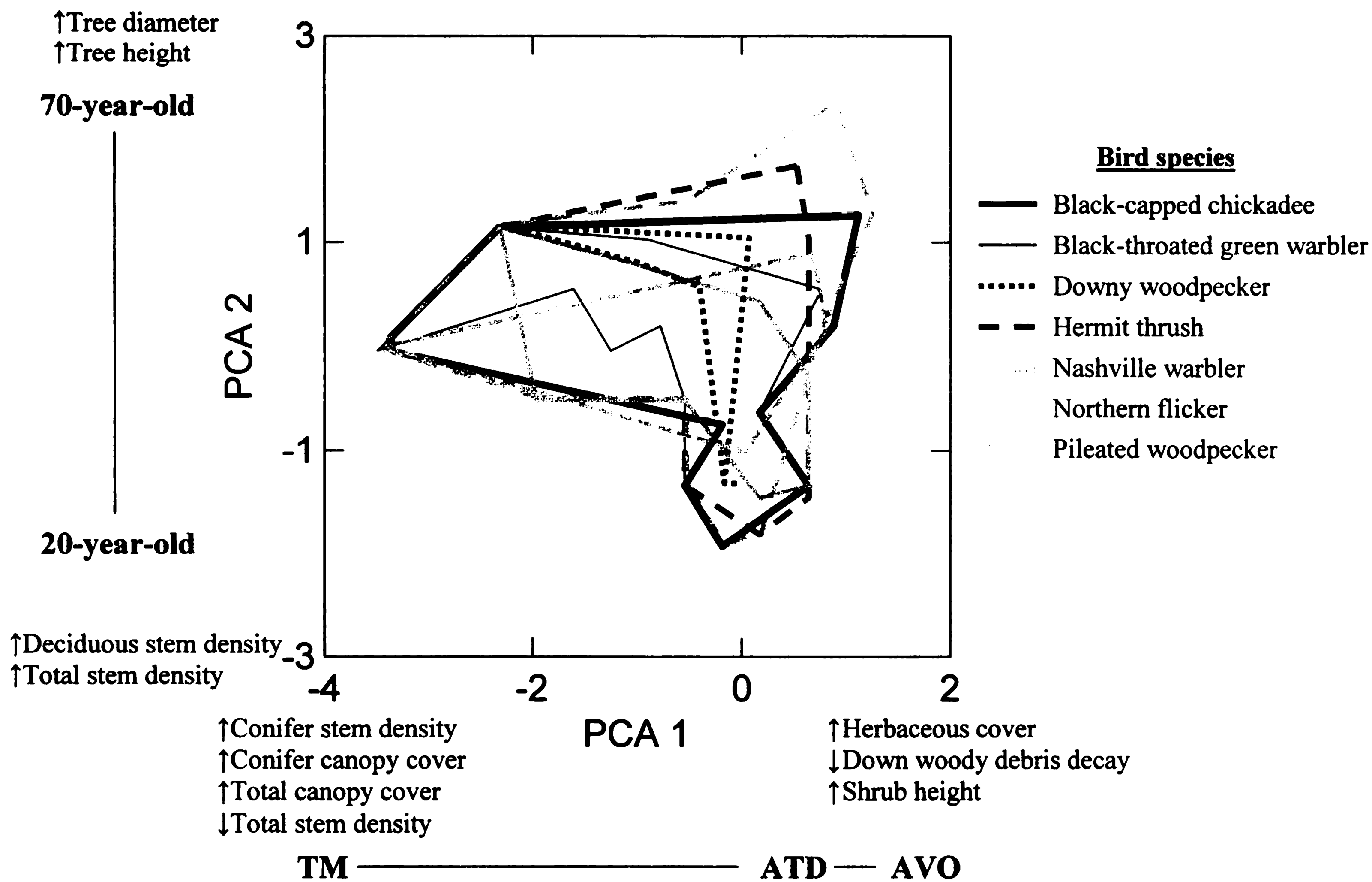

Figure 2.11. Avian community associations with aspen within multiple age classes and habitat types habitat type in the western Upper Peninsula, Michigan. TM = *Tsuga-Maianthemum,* ATD = *Acer-Tsuga-Drypoteris*, and AVO = *Acer-Viola-Osmorhiza.*

Winter resident birds

Ten bird species were observed during the winter bird surveys and included the American crow, black-capped chickadee, blue jay, downy and hairy woodpeckers, pileated woodpecker, raven, red-breasted nuthatch, ruffed grouse, and white-breasted nuthatch. Species richness was similar in all age classes, with the only difference being absence of ruffed grouse recorded in stands within the 70-year age class.

Very few differences were evident in frequency of occurrence of winter resident bird species among aspen age classes and habitat types. When comparing among age classes, the black-capped chickadee, pileated woodpecker, and raven exhibited differences in occurrence, however the differences were barely significant at the $\alpha = 0.10$ level ($p = 0.974$, 0.091, and 0.099, respectively; Table 2.11).

Within the 20-year age class, observations were made in the AQV ($n = 3$), TM ($n = 6$), ATD ($n = 6$), AVO ($n = 5$), and AOC ($n = 3$). When comparing across habitat types in this age class, the American crow only was found in the ATD habitat type ($p = 0.053$), the black-capped chickadee was observed more frequently in the AQV, AOC, and ATD habitat types ($p = 0.041$) and the downy or hairy woodpecker was observed most frequently in the AQV habitat type ($p = 0.023$; Table 2.12). Within the 50-year age class, the only samples occurred in the TM ($n = 9$) and AVO ($n = 15$) habitat types. Of these 2 habitat types, the blue jay was more prevalent ($p = 0.031$) in the TM habitat type (Table 2.13). Within the 70-year age class, samples were taken in the AQV ($n = 7$), TM ($n = 11$), and AVO ($n = 6$) habitat types. The only difference among these habitat types occurred in the TM habitat type, with higher frequency of occurrence of the raven ($p = 0.048$) and red-breasted nuthatch ($p = 0.058$; Table 2.14).

Table 2.11. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in 3 aspen age classes during the winter (February–March) in the Upper Peninsula, Michigan in 2005–2006.

	20-year (n=23)		50-year (n=24)		70-year (n=21)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**13.0**	7.2	**20.8**	8.5	**14.3**	7.8	0.742
Black-capped chickadee*	**39.1**[a]	10.4	**58.3**[ab]	10.3	**71.4**[b]	10.1	0.097
Blue jay	**39.1**	10.4	**20.8**	8.5	**14.3**	7.8	0.142
Brown creeper	**0.0**	0.0	**8.3**	5.8	**9.5**	6.6	0.338
Downy/hairy woodpecker	**60.9**	10.4	**50.0**	10.4	**33.3**	10.5	0.191
Pileated woodpecker*	**26.1**[a]	9.4	**54.2**[b]	10.4	**28.6**[a]	10.1	0.091
Raven*	**38.4**[ab]	10.2	**50.0**[a]	10.4	**19.0**[b]	8.8	0.099
Red-breasted nuthatch	**4.3**	4.3	**25.0**	9.0	**23.8**	9.5	0.124
Ruffed grouse	**4.3**	4.3	**4.2**	4.2	**0.0**	0.0	0.635
White-breasted nuthatch	**17.4**	8.1	**4.2**	4.2	**14.3**	7.8	0.344

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.12. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen in the 20-year age class within different habitat types during the winter (February–March) in the Upper Peninsula, Michigan in 2005–2006. AQV = *Acer-Quercus-Vaccinium*, TM = *Tsuga-Maianthemum*, ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Osmorhiza*, AOC = *Acer-Osmorhiza-Caulophyllum*.

	Habitat types represented in 20-year age class										
	AQV2 (n=3)		TM2 (n=6)		ATD2 (n=6)		AVO2 (n=5)		AOC2 (n=3)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow*	**0.0**[a]	0.0	**0.0**[a]	0.0	**50.0**[b]	22.4	**0.0**[a]	0.0	**0.0**[a]	0.0	0.053
Black-capped chickadee*	**100.0**[a]	0.0	**16.7**[bc]	16.7	**50.0**[ac]	22.4	**0.0**[b]	0.0	**66.7**[ac]	33.3	0.041
Blue jay*	**100.0**[ab]	0.0	**66.7**[bc]	21.1	**33.3**[cd]	21.1	**0.0**[d]	0.0	**0.0**[d]	0.0	0.023
Downy/hairy woodpecker	**33.3**	33.3	**33.3**	21.1	**66.7**	21.1	**80.0**	20.0	**100.0**	0.0	0.249
Pileated woodpecker	**66.7**	33.3	**50.0**	22.4	**0.0**	0.0	**20.0**	20.0	**0.0**	0.0	0.122
Raven	**33.3**	33.3	**33.3**	21.1	**33.3**	21.1	**40.0**	24.5	**33.3**	33.3	0.999
Red-breasted nuthatch	**33.3**	33.3	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	0.155
Ruffed grouse	**0.0**	0.0	**0.0**	0.0	**16.7**	16.7	**0.0**	0.0	**0.0**	0.0	0.586
White-breasted nuthatch	**0.0**	0.0	**16.7**	16.7	**16.7**	16.7	**20.0**	20.0	**33.3**	33.3	0.888

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.13. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen in the 50-year age class within different habitat types during the winter (February–March) in the Upper Peninsula, Michigan in 2005–2006. TM = *Tsuga-Maianthemum*, AVO = *Acer-Viola-Osmorhiza.*

	Habitat types represented in 50-year age class				
	TM5 (n=9)		AVO5 (n=15)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**33.3**	16.7	**13.3**	9.1	0.253
Black-capped chickadee	**66.7**	16.7	**53.3**	13.3	0.530
Blue jay*	**44.4**[a]	17.6	**6.7**[b]	6.7	0.031
Brown creeper	**11.1**	11.1	**6.7**	6.7	0.709
Downy/hairy woodpecker	**33.3**	16.7	**60.0**	13.1	0.216
Pileated woodpecker	**55.6**	17.6	**53.3**	13.3	0.918
Raven	**55.6**	17.6	**46.7**	13.3	0.680
Red-breasted nuthatch	**33.3**	16.7	**20.0**	10.7	0.475
Ruffed grouse	**0.0**	0.0	**6.7**	6.7	0.439
White-breasted nuthatch	**0.0**	0.0	**6.7**	6.7	0.439

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

Table 2.14. Mean absolute frequencies (percent of points at which species occurred) and standard errors (S.E.) of bird species surveyed in aspen in the 70-year age class within different habitat types during the winter (February–March) in the Upper Peninsula, Michigan in 2005–2006. AQV = *Acer-Quercus-Vaccinium*, TM = *Tsuga-Maianthemum*, AVO = *Acer-Viola-Osmorhiza*.

	Habitat types represented in 70-year age class						
	AQV7 (n=7)		TM7 (n=11)		AVO7 (n=6)		Probability
Common name	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	level[1]
American crow	**14.3**	14.3	**18.2**	12.2	**0.0**	0.0	0.739
Black-capped chickadee	**100.0**	0.0	**54.5**	15.7	**66.7**	33.3	0.125
Blue jay	**28.6**	18.4	**9.1**	9.1	**0.0**	0.0	0.403
Brown creeper	**0.0**	0.0	**18.2**	12.2	**0.0**	0.0	0.384
Downy/hairy woodpecker	**57.1**	20.2	**27.3**	14.1	**0.0**	0.0	0.192
Pileated woodpecker	**28.6**	18.4	**27.3**	14.1	**33.3**	33.3	0.980
Raven*	**0.0**[a]	0.0	**36.4**[b]	15.2	**0.0**[a]	0.0	0.048
Red-breasted nuthatch*	**0.0**[a]	0.0	**45.5**[b]	15.7	**0.0**[a]	0.0	0.058
White-breasted nuthatch	**28.6**	18.4	**9.1**	9.1	**0.0**	0.0	0.326

[1]Probability levels reported were calculated with the Kruskal-Wallis one-way analysis of variance (Siegel and Castellan 1988).

*Values on the same line with the same letter are not different ($p > 0.10$) (Kruskal-Wallis multiple comparison statistic [Siegal and Castellan 1988]).

DISCUSSION

Vegetation structural differences among age classes and habitat types

Although there were differences in vegetation characteristics among aspen age classes and habitat types, there was much overlap in terms of vegetation structural attributes (i.e., 41% of the vegetation variability was explained with the first 3 principal components). This overlap likely was evident because age and habitat types occur on a continuum, but have boundaries that are somewhat arbitrarily defined. For instance, age class designations were 20–29, 50–59, and ≥ 70 years old. The 20- and 50-year age classes contained stands that may have been 9 years apart in age. The oldest age class contained stands 70–93 years old. Thus, there is inherent variability between the youngest and oldest stands within an age class that may account for the wider distributions in ranges of vegetation conditions than if the classes included a more narrow range of ages.

Likewise, vegetation conditions within a habitat type vary on an ecological gradient defined by geological conditions (e.g., soil and topography). Habitat type boundaries are defined to represent a "relatively narrow segment of environmental variation" (Kotar and Burger 2000:4). However, spatial heterogeneity of soil conditions within a spatial extent defining the boundaries of a particular habitat type could create patches that increase variability in structural characteristics of that habitat type.

Nevertheless, despite the overlap in variability of vegetation conditions among aspen age classes and habitat types, results of the principal components analysis indicated that differences in vegetation structure among age classes and habitat types were still evident (Figure 2.1). The first principal component generally described the variation among habitat types, while the second principal component described variation among age classes. The third principal component characterized differences in understory structure (e.g., horizontal cover defined by basal area, shrub density, and height) and overstory snag characteristics. The most defining characteristic of the TM habitat type was the presence of conifers (i.e., spruce and fir), especially in older age classes due to the dry sandy to sandy-loam soils, which promote spruce and fir growth (Coffman et al. 1980). The most defining characteristic of the AVO habitat type was prevalence of a dense shrub layer, which persists because of the high nutrient content in the loamy soils of the AVO type (Coffman et al. 1980). The ATD habitat type had characteristics in the middle of the gradient. Older age classes had larger, taller trees, and younger age classes had higher total stem densities and densities of deciduous trees.

Older (e.g., ≥ 70 years) age classes of aspen within the TM habitat type were more distinguishable in structure than older stands within other age classes. Aspen communities in the 20-year age class within the TM habitat type were more similar to structure of younger stands within the ATD and AVO habitat type. This may have implications for management in retaining conifers in stands within the TM habitat type to increase diversity of structure within aspen in the 20-year age class.

Avian species associations with aspen age classes and habitat types

The vegetation attributes that explained differences in aspen age classes and habitat types also explained the distribution of birds observed in different age classes and habitat types (Table 2.4). For example, species with stronger associations to 20–50-year old aspen without the presence of conifers included the black-throated blue warbler, chestnut-sided warbler, eastern wild turkey, and rose-breasted grosbeak. These species frequently occurred in older age classes within the AVO and ATD habitat types (Figure 2.5), but the black-throated blue warbler and chestnut-sided warbler were associated more with the AVO habitat type. These results are consistent with habitat requirements found in the literature that suggest common habitat components for all these species are mature mesic deciduous forests with closed canopy or other overhead structure for nesting cover (Brewer et al. 1991), which is characteristic of aspen ≥ 50 years old within the ATD and AVO habitat types. The black-throated blue warbler and chestnut-sided warblers also require dense shrub cover for nesting (Walkinshaw and Dyer 1953), which likely explains their stronger association with the AVO habitat type (see Chapter 1).

Species with strong associations with aspen communities ≥ 50 years old included the American redstart, eastern peewee, golden-winged warbler, northern flicker, scarlet tanager, and veery (Figure 2.6). These species prefer to nest in mature dry to mesic forests containing hardwood species (e.g., maple or beech) with a dense understory (Brewer et al. 1991, Hobson and Bayne 2000b). The golden-winged warbler prefers to nest in early successional vegetation types such as old fields, but also prefers to nest in areas with a scrubby, well developed understory (Confer and Kapp 1981), which may explain their occurrence in the AVO habitat type.

Researchers suggest that the blue jay, red-headed woodpecker, and white-breasted nuthatch prefers to nest in mature dry to mesic hardwood forests (Hagan and Meehan 2002, Rodewald et al. 2005), which explains their association with older (≥ 50 years old) aspen stands in the AVO and ATD habitat types (Figure 2.7). These vegetation types provided snags for cavity-nesters, and relatively less herbaceous cover, which is important for nesting success of the red-eyed vireo (Siepielski et al. 2001).

Avian species found in this study to be associated with aspen communities ≥ 70 years old within the TM habitat type included the black-and-white warbler, brown creeper, pine siskin, and yellow-rumped warbler (Figure 2.8). Researchers suggest that conifers (e.g., spruce and fir species) are important components of communities providing habitat for the pine siskin and yellow-rumped warblers for nesting and foraging (Brewer et al. 1991, Hagan et al. 1997, Hanaburgh 2001). Black-and-white warblers have also been associated with mixed aspen and conifer forests throughout its breeding range (Paszkowski et al. 2005), but have shown flexibility using different vegetation types across its range (Dettmers et al. 2002). Brown creepers have been found to nest behind slabs of loose bark associated with older or dead trees in conifer or mixed forests (Franzreb 1985).

Species associated with the TM habitat type regardless of age included the golden-crowned kinglet, red-breasted nuthatch, white-throated sparrow, and winter wren (Figure 2.9). These bird species also appear to associate with the conifer component within the TM habitat type (Pettingill 1974, Brewer et al. 1991). Mature (i.e., ≥ 80 years old) conifer forests containing spruce and fir provide the best habitat conditions for the golden-crowned kinglet and winter wren (Titterington et al. 1979), however, forests with 20–50% spruce and fir canopy cover can provide at least marginal habitat conditions for the golden-crowned kinglet and winter wren (Salt and Salt 1976, Titterington et al. 1979). The white-throated sparrow and red-breasted nuthatch have also been found in other studies to have higher abundances in mixed aspen forests (Hobson and Bayne 2000b).

The wood thrush and yellow-bellied sapsucker appeared to be associated with younger stands within the TM habitat type (Figure 2.10), but these results were not consistent with the literature. Other researchers describe that the wood thrush prefers to nest near streams in wet and mesic deciduous forests with a dense understory (Bertin 1977). Yellow-bellied sapsuckers showed no preference for conifers or deciduous forests for nesting, but preferred birch trees for foraging (Kilham 1964). The association of these birds to young stands within the TM habitat type in this study was likely due to low sample sizes (n = 6 and 5 for the wood thrush and yellow-bellied sapsucker, respectively), or they were possibly using marginal habitat.

Avian species observed in all age classes and habitat types were the black-capped chickadee, black-throated green warbler, downy and hairy woodpeckers, hermit thrush, Nashville wabler, ovenbird, and pileated woodpecker (Figure 2.11). Mature forests typically provide better nesting habitat requirements for cavity-nesting species (e.g., black-capped chickadee, woodpeckers) because of increased snag availability (Schroeder 1983a, Schroeder 1983b); however chickadees and woodpeckers were recorded foraging in younger aspen age classes on snags smaller (e.g., $\leq$ 10 cm) than those required for nesting (Schroeder 1983b). Generally, their prevalence was higher in older age classes; thus they had a stronger association with aspen $\geq$ 50 years for nesting requirements (Table 2.3, Figure 2.2). The black-throated green warbler, hermit thrush, Nashville warbler, and ovenbird appeared to show no difference in occurrence for aspen $\geq$ 20 years old within the TM, ATD, and AVO habitat types. This is not to say, however, that these species are habitat generalists. They may just show no difference in prevalence among different aged aspen communities within those habitat types, but may, in fact, prefer vegetation conditions within other habitat types. For instance, the Nashville warbler and hermit thrush have been documented to co-occur broadly and nest in dense ground cover in mesic mixed or dry coniferous forests (Evers 1991). The relatively higher frequency of occurrence of those birds in the dry AQV habitat type supports this habitat association (Table 2.5). The black-throated-green warbler and ovenbird, however, do appear to be generalists and have been documented elsewhere to occur in a wide variety of vegetation types, as well (Brewer et al. 1991, Hanaburgh 2001).

Three avian species that were observed in the study were not put into groups associated with aspen age classes and habitat types because they were only observed once. These included the brown-headed cowbird, magnolia warbler, and pine warbler. The mourning dove, American robin, American crow, and raven were omitted because they tend to be abundant throughout their ranges in Michigan and are not of management concern. The northern parula was omitted because although it was only recorded in aspen in the 50-year age class within the AVO habitat type, it prefers to nest in wet coniferous areas or near hardwoods with hemlock or fir where the hanging *Usnea* lichen, which is important for nest construction, typically grows (Pettingill 1974). Thus, the northern parula is not strongly associated with the AVO habitat type, but more likely was observed because the sampling point was adjacent to a wetter area.

The distribution of birds grouped by migratory status was slightly higher for neotropical migrant species in all age classes and habitat types, but was not different among age classes and habitat types (Figure 2.3). This suggests that neotropical migrants as a group may not exhibit associations with forest characteristics that reflect different aspen age classes and habitat types. Year-round resident species were more prevalent in older age classes regardless of habitat type (Figure 2.3). This result is likely because 5 of the 8 birds classified as year-round residents were also cavity nesters, which were more prevalent in older age classes. Hanaburgh (2001) found similar results for northern hardwood stands in the Upper Peninsula. Species classified as short-distance migrants occurred more frequently in the 50-year age class than in other age classes, but prevalence did not differ among age classes within habitat types (Figure 2.3).

Similarly, the number of sensitive species recorded at each observation was highest in the 50-year age class and specifically within the ATD habitat type. Therefore, the 50-year aspen age class (especially within the ATD habitat type) is providing features important for short-distance migrants and species of conservation concern. This has important management implications for retaining 50-year-old aspen in the landscape, especially within the ATD habitat type. Currently, aspen in the 50-year age class is the least available (3.11%) in the landscape (Doepker et al. 2002), and the prevalence of the ATD habitat type on state lands in the western Upper Peninsula is lower than other habitat types (e.g., AVO, TM, AOC, AQV).

Fine-filter assessment of habitat suitability

It was evident that different avian species were associated with a specific aspen age class and habitat type, however, individual species may be associated with a particular vegetation type for different ecological reasons. As part of a fine-filter assessment of aspen ecosystems, I selected 6 species *a priori,* evaluated habitat suitability, and compared it with frequency of occurrence to investigate the utility of those species as indicators of specific ecological conditions that distinguish different age classes and habitat types. The veery, yellow-rumped warbler, and American redstart were good indicators of specific vegetation conditions associated with age classes and habitat types. For example, frequency of occurrence and habitat suitability for the veery was highest in the AVO habitat type (Figure 2.4) because of the relatively thicker shrub layer (> 4,000 shrub stems/ha) than within other habitat types. Yellow-rumped warbler habitat suitability and frequency of occurrence was highest within the TM habitat type; specifically, stands ≥ 70 years old with greater conifer cover (> 10%) and stem density (> 1000 stems/ha; see Chapter 1, Table 1.14).

Habitat suitability for the American redstart was highest in the AVO habitat type because it supports higher shrub cover for nesting than other habitat types. Habitat suitability for the American redstart was also relatively high (0.80) in aspen in the 20-year age class within the TM habitat type due to higher deciduous stem densities (> 1000 stems/ha). American redstarts, however, were not observed in that vegetation type. They were only observed in older stands (> 50 years) within the ATD and AVO habitat type. Another variable in the habitat suitability model was percent overstory conifer cover, which was lowest in young vegetation types within the TM habitat type and within the ATD and AVO habitat types. Therefore, presence of American redstarts in an area likely indicates low (< 40%) conifer cover and relatively higher (> 650 stems/ha) stem densities (Table 2.2).

The ovenbird was not a good indicator of specific vegetation conditions and was not useful to distinguish characteristics among the aspen vegetation types within the AVO, TM and ATD habitat types in this study. The ovenbird had high (> 90%) frequency of occurrence in all areas sampled (Tables 2.3–2.10), and had high habitat suitability scores in all age classes and habitat types represented (Figure 2.4).

The black-capped chickadee and pileated woodpeckers were selected as indicators of snag density and size. Habitat suitability for the black-capped chickadee increased with increasing age and was highest in the AVO habitat type in all age classes, and habitat suitability for the pileated woodpecker was low in all age classes and habitat types (Figure 2.4). These habitat suitability trends were not reflected with frequency of occurrence data. For instance, frequency of occurrence of black-capped chickadees was similar in all age classes and habitat types, except in aspen $\geq$ 70 years old within the AVO habitat type, in which it was not observed. Frequency of pileated woodpeckers was generally higher in older stands. As noted earlier, occurrence of chickadees and pileated woodpeckers in younger age classes may have been due to foraging activity. Research has shown that reproductive success of cavity nesters is higher in areas with sufficient snag size and density (Schroeder 1983a, Schroeder 1983b), which is characteristic of older age classes. Therefore, the black-capped chickadee and pileated woodpecker might still be used as indicators of snag presence in the aspen vegetation type, but productivity (e.g., numbers of nesting pairs) should be measured and related to those characteristics.

Although presence of the veery, American redstart, yellow-rumped warbler, black-capped chickadee, and pileated woodpecker can indicate specific ecological conditions, this group of species does not collectively represent the range of vegetation conditions within sampled aspen age classes and habitat types. For example, characteristics of 20–50-year-old stands within the hardwood habitat types (ATD, AVO) are not represented by the selected indicator species. The chestnut-sided warbler might potentially be an indicator of vegetation conditions represented within those vegetation types because the warblers prefer early successional forests with relatively high shrub and stem densities (Richardson and Brauning 1995). Perhaps the white-breasted nuthatch may be an indicator of conditions provided by mature hardwoods (Pravosudov and Grubb 1993).

Conclusions

Management for multiple objectives (e.g., timber harvest, biodiversity) requires a hierarchical approach to better understand ecological patterns at multiple spatial scales and levels of biological organization (Sampson and Knopf 1982, Haufler et al. 2002) because ecological processes and species selection of habitat conditions occurs hierarchically. That is, managers must first be aware of the ecological potential of landscapes, describe conditions within ecosystems and communities, and then relate ecological conditions to species presence, distribution, and productivity. The following questions can help managers understand landscape potential: what types of ecosystems (e.g. vegetation types) have occurred historically in landscapes and what types of ecosystems are currently present? Are there any ecosystems that are not represented? This coarse-filter approach should identify ecosystems on which management efforts should focus—either to increase or decrease representation for biodiversity conservation.

Maintaining a representative array of ecosystems should subsequently maintain habitat for the majority of native species (Noss 1987). Habitat type classifications and quantification of vegetation structure and compositional characteristics of different successional stages can help identify ecological representation.

A limitation to only using the coarse-filter approach is that no ecological classification system is comprehensive enough to account for every species (Noss 1987). This is evident when investigating age class and habitat associations of rare or sensitive species (e.g., red-headed woodpecker, golden-winged warbler) or ones with otherwise low frequency of occurrence (e.g., black-and-white warbler [Paszkowski et al. 2004]). Fine-filter assessments become important to derive mechanistic relationships and understand what specific characteristics of ecosystems affect species presence and viability (Marzluff et al. 2002).

It would be valuable to develop models (e.g., logistic) to quantify relationships between species presence and aspen age classes and habitat types to assess the predictive ability of forest management models on the effects of wildlife (Marzluff et al. 2002). In this study, however, insufficient sample sizes prevented development of quantitative models, but did still allow determination of avian species associations with aspen age classes, habitat types, and vegetation characteristics. Defining these descriptive associations is an important step in developing future assessment models for forest management.

The Michigan Department of Natural Resources has assumed a leadership role in implementing ecosystem management to conserve, protect, and manage Michigan's natural resources for current public benefits and future opportunities (MDNR 2007). The ecosystem management plan relies, in part, on scientific-based approaches as a foundation for understanding natural resource relationships and sustaining ecological systems (MDNR 2007). As such, the MDNR has appointed management teams for different ecoregions of Michigan to develop strategies to sustain and enhance representative ecosystems within Michigan. The hierarchical approach to ecosystem management described in this project will help the MDNR develop those strategies. For example, the habitat type classification system described in Chapter 1 allows implementation of a coarse-filter approach to ecological assessment, and to understand the availability and spatial distribution of habitat types (e.g., landscape-level performance measures). Results of the vegetation analysis and principal components analysis characterized the range of structural and compositional characteristics as well as potential function (e.g., wildlife habitat) and processes (i.e., successional changes) that can occur within habitat types (i.e., ecosystem-level performance measures). Ecosystem-level performance measures describe vegetation conditions provided by different successional stages within habitat types that can explain wildlife community structure.

My results indicate that different aspen age classes and habitat types provide unique vegetation features important to different assemblages of avian communities. Without representation of all aspen age classes within all habitat types, it is evident that certain ecological features would be missing that directly affect presence of specific avian species or communities. Determining the appropriate representation of aspen age classes within habitat types, however, should be based on explicitly stated objectives for wildlife habitat, timber, and other human values.

Results of this project determined that species composition of bird community associations with aspen varied among age classes and habitat types. The value of this to forest management lies in the ability to uses the associations to determine likely changes in species presence within forests throughout time or as a result of management activities. As such, the results can be incorporated into planning management activities for avian communities or biodiversity, predicting potential outcomes of management on avian community composition and distribution, and identifying areas within unique feature for management focus. It is through understanding what conditions are provided by different aspen age classes (specifically old aspen $\geq$ 50 years old), how wildlife respond to these conditions, and incorporating this knowledge in timber management plans to meet multiple objectives that Michigan's leadership role in ecosystem management will be sustained.

CHAPTER 3

POTENTIAL OF ASPEN IN DIFFERENT ASPEN AGE CLASSES AND HABITAT TYPES TO PROVIDE DRUMMING HABITAT FOR RUFFED GROUSE

Aspen is an economically valuable resource in Michigan and is also important for providing wildlife habitat components. Specifically, ruffed grouse (a popular upland game bird in Michigan [Frawley 2006]), use of the aspen vegetation type for food, nesting, and drumming has been well documented in the literature (Bump et al. 1947, Svoboda and Gullion 1972). As such, a forest management challenge is when and where to manipulate aspen stands to sustain timber benefits and habitat for grouse.

To design appropriate aspen management plans for grouse, it is necessary for managers to understand habitat relationships contributing to grouse production. State agencies (e.g., Michigan Department of Natural Resources [MDNR]) often use several tools to assess grouse population trends and potential productivity, such as spring drumming surveys, but the surveys do not document vegetation characteristics associated with locations of drumming grouse. This information may be critical for understanding how grouse are distributed throughout landscapes during the breeding season, and may provide insights as to what ecological factors are contributing to the observed distribution.

Researchers in the Lake States (e.g., Gullion 1977, Kubisiak et al. 1980, McCaffery et al. 1996) have documented higher densities of drumming grouse in 6–25 year-old aspen stands than in other vegetation types and age classes. Other studies have also reported grouse use of older (≥ 25 years) aspen and non-aspen (e.g., balsam fir, oak, alder) vegetation types for drumming (Palmer and Bennett 1963, DeStefano and Rusch

1984, McCaffery et al. 1996). In Michigan, Hammil and Moran (1986) observed drumming grouse in lowland conifer vegetation types. Most studies have documented relationships between drumming grouse and broad vegetation categories (e.g., northern hardwoods, young aspen, oak; Cade and Sousa 1985), but few studies have documented how habitat types may influence use by individual drumming grouse. Habitat types are geographic areas with similar ecological characteristics that support the same successional trajectory (Daubenmire 1966). Aspen is an early successional vegetation type occurring in several different habitat types such as those characterized by soil types ranging from poorly-drained loams to well drained sandy soils (Coffman et al. 1980). The structure and composition of aspen varies with habitat type (see Chapter 1), and provides different wildlife habitat components (see Chapter 2). Therefore, it is reasonable to assume that grouse drumming activity may differ among aspen in different habitat types as well as in different age classes.

Additionally, few studies have documented the importance of older (> 25 years) age classes of aspen as alternative drumming habitat for grouse (i.e., secondary to preferred 6–25 year-old aspen). To design long-term sustainable timber harvest plans that benefit ruffed grouse, it may be beneficial to assess grouse use of aspen > 25 year old and grouse preference of aspen in different habitat types. Such information may provide insights for understanding landscape-level characteristics affecting grouse drumming distributions, and identifying specific habitat types and age classes of aspen that may be valuable in providing grouse drumming habitat longer than 25 years.

OBJECTIVES

Specific objectives for this chapter were to

1) Assess ruffed grouse selection of aspen stands in different age classes and habitat types for drumming.
2) Determine the distribution of potential ruffed grouse drumming habitat in the western Upper Peninsula, Michigan based on aspen age class and habitat type.
3) Make recommendations for incorporating ruffed grouse habitat management objectives in aspen management plans.

METHODS

The Operations Inventory (OI) database for stands in state forests in Baraga, Dickinson, Iron, and Marquette counties was obtained from the MDNR. I identified established 10 routes 5–10 km long for grouse drumming surveys based on stand accessibility in a 4-wheel drive truck and to maximize the number of stands assessed during the drumming survey. On each route, I identified specific GPS coordinates (latitude and longitude) adjacent to aspen stands, which were the designated stopping points for the drumming survey. I determined the age class of each aspen stand on the routes from the OI database and assigned each stand to a habitat type classification (see Chapter1). All routes collectively contained stands representative of different aspen age classes ≥ 20 years and habitat types.

Grouse drumming surveys occurred between May 3–16 in 2005 and April 17–26 in 2006, which corresponded with the peak drumming period in the UP (April 20–May 10). A portion of the survey routes were the same in 2005 and 2006. Surveys were conducted according to MDNR protocol for state ruffed grouse drumming surveys. To minimize effects of weather conditions on drumming activity or audibility, surveys were only conducted when the temperature was between -4–4°C with no precipitation and when wind was < 19 kph. I used the Beaufort wind scale to monitor wind speed, which indicates that when small twigs are in constant motion, wind speed is 13–19 kph (NOAA 2007). Surveys began 30 minutes before sunrise and ended around 8:00 am (Petraborg et al. 1958).

At each stop, I walked at least 15 meters away from the vehicle and listened for 4 minutes, which is the average drumming interval for ruffed grouse (Petraborg et al.

1953). I recorded the number of drumming males heard at each stopping point and recorded the compass bearing from the stopping point to the direction where the drumming was heard. I also recorded a qualitative measure of distance: close, medium, or far. "Close" drumming occurred within 60 m of the stopping point, drumming at a "medium" distance occurred 60–130 m from the stopping point.

In ArcView 3.2, I placed a 200-m buffer around each point where drumming was heard. Two-hundred meters was the radius of audibility for drumming ruffed grouse in similar vegetation types in Minnesota (Petraborg et al. 1953). Next, I determined in which age class and habitat type drumming occurred by using the Distance/Azimuth Tools Extension for ArcView 3.x (Jenness 2005), which establishes a point at a specified distance and directional bearing from a point of origin. I assumed the grouse were drumming in the specific age class and habitat type occurring at the point established with the extension.

Within each 200-m radius circle, I determined the proportion of area of young (0–29 years), medium (30–49 years), and old (≥ 50 years) aspen stands in different habitat types, and the proportion of area in vegetation types other than aspen in different habitat types. These vegetation classes represented those found to be frequently used by drumming grouse (i.e., young aspen), and other classes in which drumming has been documented in the Great Lakes region. To evaluate selection of aspen by drumming grouse, I used methods described by Manly et al. (2002) for Design I studies where used, unused, and available resource units (i.e., aspen or other vegetation types of different ages and within different habitat types) were sampled for the entire study area and for the collection of all animals in the study area. Individual animals were not identified.

The following resource selection function (Manly et al. 2002) yielded the relative probability of grouse selection for different vegetation classes:

$$\hat{w}_i = o_i / \pi_i ,$$

where

o_i = the proportion of grouse using the i^{th} vegetation class

π_i = the proportion of area available in the i^{th} vegetation class.

A selection index = 1.0 indicated no selection, < 1 indicated avoidance, and > 1 indicated selection.

The standard error for each $\hat{w}_i$ was approximated with the following equation (Manly et al. 2002):

$$se(\hat{w}_i) = \hat{w}_i \sqrt{\{(1 - o_i)/(o_i u_+) + se(\hat{\pi}_i)^2 / \hat{\pi}_i^2\}} ,$$

where

o_i = the proportion of grouse using the i^{th} vegetation class

u_+ = the total number of grouse sampled

π_i = the proportion of area available in the i^{th} vegetation class

The standard errors were used to determine approximate confidence intervals for the selection indices [$\hat{w}_i \pm z_{(\alpha/2)} se(\hat{w}_i)$ with $\alpha = 0.10$].

The above procedure was conducted by age class, habitat type, and their interaction for data collected in 2005, 2006, and both years combined. A Chi-square test was conducted on the proportion of grouse drumming to determine differences in grouse selection of age classes and habitat types between years ($\alpha = 0.05$). To understand the spatial distribution of selected grouse drumming habitat, I used ArcMap in ArcGIS and mapped the selection indices for different age classes and habitat types on state land within the study area.

RESULTS

In 2005, 78 points were surveyed for drumming grouse. The total area surveyed based on the radius of audibility at each survey point was 816.54 ha. We recorded ≥ 1 grouse drumming at 32 points. Two drumming grouse were documented at 5 points, and 3 grouse were recorded at 1 point. In 2006, 85 points were surveyed and area surveyed totaled 875.42 ha. There was no difference in grouse selection of aspen age classes between years ($p = 0.73$); however, differences were detected in grouse selection of habitat types ($p = 0.02$) and the interaction between age classes and habitat types ($p < 0.001$) between years. We recorded ≥ 1 grouse drumming at 31 points; 2 grouse were documented at 5 points, and 4 grouse were documented at 1 point.

Selection by age class

The highest proportion of all vegetation classes sampled within the range of audibility was in old aspen (31%) in 2005 (Figure 3.1), and medium-aged aspen (37%) in 2006 (Figure 3.2) and for combined years (34%; Table 3.1). The highest proportion of all vegetation classes sampled within the range of audibility was in and medium-aged aspen (34%; Table 3.1). Interestingly, grouse selected young aspen ($\hat{w} = 1.36 \pm 0.39$) and old aspen ($\hat{w} = 1.30 \pm 0.29$) similarly (Table 3.1). The lower confidence limits of the selection indices for young and old aspen were very close to 1.0, indicating selection for those age classes.

There appeared to be no selection or avoidance of medium-aged aspen ($\hat{w} = 0.83 \pm 0.25$), although the upper confidence limit for combined years was close to 1.0 (1.08; Table 3.1). The upper confidence limit for non-aspen vegetation types was < 1, indicating possible avoidance for non-aspen vegetation (Table 3.1). No grouse were observed drumming in non-aspen vegetation types in 2006.

Selection by habitat type

Nine habitat types were represented within the 200-m radius of audibility for each sampling point. These included the QAE, AQV, TM, ATD, AVO, AOC, TMC, FMC, and TTS habitat types (Figures 3.1, 3.2). In 2005, 38 ruffed grouse were observed drumming in the AQV, TM, AVO, AOC, and TTS habitat types (Figure 3.1a). In 2006, 40 grouse were observed in the same 5 habitat types, and additionally in the ATD and FMC habitat types (Figure 3.2a).

Of the habitat types in which grouse were observed drumming, the highest percent of area sampled was within the AVO habitat type in 2005 (28%), in 2006 (27%), and in combined years (31%), followed by the AQV and AOC habitat types (Figures 3.1, 3.2). The QAE, ATD, TMC, and FMC habitat types were the least available (< 5%) within the sampled area (Figures 3.1, 3.2)

Ruffed grouse exhibited selection differences among habitat types for drumming. In 2005 and 2006, grouse showed the strongest selection for areas within the AVO habitat type ($\hat{w} = 1.39 \pm 0.48$, $\hat{w} = 2.37 \pm 0.92$), which was significantly higher than selection indices for the AQV habitat type in both years, and the TTS habitat type in 2006 (Table 3.2). Grouse appeared to select ($\hat{w} > 1$) for the TM habitat type in 2005, 2006, and combined years based the selection indices ($\hat{w}$ = 1.33, 1.17, 1.54, respectively). Other habitat types in which the selection indices were > 1 included TTS in 2005 ($\hat{w}$ = 1.14), AOC in 2006 and combined years ($\hat{w}$ = 1.39 and 1.35, respectively), and FMC in

2006 ($\hat{w}$ = 1.38; Table 3.2). Grouse avoided the AQV habitat type for drumming ($\hat{w}$ = 0.54 ± 0.37 [2005], $\hat{w}$ = 0.17 ± 0.29 [2006], $\hat{w}$ = 0.41 ± 0.23 [combined years]). Avoidance for the TTS habitat type was only evident in 2006 (Table 3.2). No selection was observed within the AOC habitat type in 2005 ($\hat{w}$ = 0.83 ± 0.46), and the ATD habitat type in 2006 ($\hat{w}$ = 0.84 ± 1.36) and for combined years ($\hat{w}$ = 0.64 ± 0.82).

Selection among age classes and habitat types

Although ruffed grouse use of different aspen age classes and habitat types differed between years (p = 0.02), in both years, it was evident that grouse exhibited similar trends in selection of specific age classes and habitat types for drumming. General trends included selection of aspen > 50 years and < 30 years old within habitat types characterized by mesic soils (i.e., AVO, AOC, TM). Medium-aged aspen was typically neither selected nor avoided by drumming grouse in all habitat types. Non-aspen vegetation types and aspen on habitat types characterized by xeric or hydric soils were generally avoided.

In 2005, grouse appeared to drum in old aspen > 50 years more than expected, given its availability in the landscape (Figure 3.1, Table 3.3). Grouse selected aspen ≥ 50 years old within the AVO habitat type more than other age classes and habitat types (Table 3.3), and significantly more than in proportion to availability (because the lower limit of the confidence interval for the selection index was > 1.0). Other vegetation classes in which drumming was observed included non-aspen vegetation types within the AQV (e.g., oak) and TTS (e.g., lowland conifers) habitat types, medium-aged aspen with the TM, AVO, and AOC types, young aspen within the AVO, TTS, AOC, and AQV types, and old aspen within the TTS, TM, and AOC habitat types. The confidence limits for these vegetation classes, however, contained the value 1.0, suggesting no strong selection for or against those vegetation types (Table 3.3).

Despite the lack of statistical significance between vegetation classes in 2005, notable differences in selection of different age classes and habitat types were evident. Generally, grouse selected young and old aspen within the AVO habitat type, non-aspen vegetation types within the AQV habitat type, and medium-aged aspen within the TM habitat type approximately twice as much as if there were no selection (Table 3.3). Old aspen within the TTS and TM habitat types and young aspen within the TTS type were about 1.5 times as likely to be selected as other vegetation classes (Table 3.3). Young aspen within the AOC and AQV habitat types, non-aspen vegetation types within the TTS habitat type, medium-aged aspen within the AOC type, and old aspen within the AOC type were neither selected for or avoided (Table 3.3). Vegetation classes in which no grouse were observed drumming, but which had expected values > 1.0 included medium-aged aspen within the AQV habitat type and non-aspen vegetation within the AVO habitat type.

In 2006, grouse appeared to select aspen > 30 years old within the AVO and AOC habitat types more than in proportion to their availability (Figure 3.4), but the lower confidence limit of the selection index for only old aspen within the AOC habitat type was > 1.0. The selection index for medium-aged aspen within the FMC habitat type was the highest ($\hat{w} = 5.237$), however, the confidence limit was large (0–13.72) and contained the value 1.0, which indicated no selection (Table 3.4). Other habitat types in which grouse were observed drumming, but where selection was not statistically significant included young aspen within the TM, AVO, AOC, ATD, and AQV habitat types, medium-aged aspen within the AVO, AOC, and TM types, and old aspen within the TM, TTS, and AVO habitat types (Table 3.4).

Some trends in 2006 included grouse selection of young aspen within the TM, AVO, and AOC habitat types, and old aspen with the AOC type with > 2 times the probability of being selected than by random chance. Old aspen within the TM habitat type and young aspen within the ATD habitat type were selected similarly. Grouse appeared to exhibit no selection or avoidance of medium-aged aspen within the AVO, AOC, and TM habitat types, or for old aspen within the TTS habitat type (Figure 3.4). A greater number of grouse than expected were observed drumming in young aspen within the AVO habitat type, old aspen within the TM type, and medium-aged aspen within the AVO type (Figure 3.4). As observed in 2005, vegetation classes in which no grouse were observed drumming, but which had expected values > 1.0 included medium-aged aspen within the AQV habitat type and non-aspen vegetation within the AVO habitat type (Appendix 2). Other vegetation types in which no grouse were observed, and thus appeared to have been avoided in 2006 were non-aspen vegetation types within the AQV, TTS, and AOC (e.g., maple) habitat types (expected values = 0.99, 0.84, 0.92, respectively; Appendix 2).

In both years combined, grouse selected for young and old aspen within the AOC habitat type ($\hat{w} = 2.30 \pm 1.27$, $\hat{w} = 1.982 \pm 0.91$, respectively; Table 3.5), although a greater number of grouse than expected were also heard drumming in old aspen within the TM and TTS habitat types, and young aspen within the AVO habitat type. The only non-aspen vegetation types in which grouse were heard drumming occurred within the

AQV and TTS habitat types (Table 3.5). Vegetation types that did not have drumming grouse and were apparently avoided included non-aspen vegetation (e.g., maple) within the AVO and AOC habitat type, and medium-aged aspen within the AQV and TTS habitat types (expected values = 4.09, 1,82, 2.92, 1.41, respectively; Appendix 3).

Spatial distribution of potential grouse drumming habitat

Distinct regional differences in potential ruffed grouse drumming habitat (i.e., based on selection indices of different habitat types) were evident within the study area. In the southern and eastern portion of the study area, selection was relatively high because that area contains loamy soils characteristic of the AVO and AOC habitat types, and sandy-loams characteristic of the TM habitat type (Figure 3.3). The northern portion of the study area had low selection indices because that area is dominated by the ATD habitat type, which tended to have low selection indices (Table 3.2) . The remainder of the study area contained a mosaic of highly selected and avoided habitat types (Figure 3.3).

Table 3.1. Estimation of selection indices for the occurrence of drumming ruffed grouse in old ($\geq$ 50 years), medium-aged (30–49 years), and young (< 30 years) aspen, or non-aspen vegetation types in the western Upper Peninsula, Michigan during 2005 and 2006.

Veg type	ha	Proportion of area sampled	No. of grouse	Proportion of grouse	Expected no. grouse	Selection index ($\hat{w}$)	se($\hat{w}$)	Confidence Limit Lower	Confidence Limit Upper
old aspen	303.93	0.30	30	0.38	23.17	1.30	0.18	1.00	1.59
medium aspen	346.96	0.34	22	0.28	26.45	0.83	0.15	0.58	1.08
young aspen	222.26	0.22	23	0.30	16.94	1.36	0.24	0.96	1.75
non-aspen	150.19	0.14	3	0.04	11.45	0.26	0.14	0.03	0.49
Totals	1023.34	1.00	78	1.00					

Table 3.2. Estimation of selection indices for the occurrence of drumming ruffed grouse in different habitat types in the western Upper Peninsula, Michigan during 2005, 2006, and combined years. AQV = *Acer-Quercus-Vaccinium*; TM = *Tsuga-Maianthemum*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; AOC = *Acer-Osmorhiza-Caulophyllum*; FMC = *Fraxinus-Mentha-Carex*; TTS = *Tsuga-Thuga-Sphagnum.* AQV and TM habitat types occur on dry, sandy soils, ATD occurs on sandy-loamy soils, AVO, AOC, and FMC habitat types occur on mesic, loamy soils, and TTS occurs on hydric organic soils.

HT	ha	Proportion of area sampled	No. of grouse	Proportion of grouse	Expected no. grouse	Selection index ($\hat{w}$)	se($\hat{w}$)	Confidence Limit Lower	Confidence Limit Upper
2005									
AQV	175.29	0.26	5	0.14	9.25	0.54	0.22	0.17	0.91
TM	71.35	0.11	5	0.14	3.76	1.33	0.53	0.46	2.20
AVO	190.53	0.29	14	0.40	10.05	1.39	0.29	0.92	1.86
AOC	159.82	0.24	7	0.20	8.43	0.83	0.28	0.37	1.29
TTS	66.46	0.10	4	0.11	3.51	1.14	0.52	0.28	2.00
Totals	663.45	1.00	35	0.99					
2006									
AQV	168.71	0.29	2	0.05	11.45	0.17	0.17	0.00[1]	0.46
TM	62.99	0.11	5	0.12	4.28	1.17	0.48	0.39	1.95
ATD	17.47	0.03	1	0.03	1.19	0.84	0.82	0.00[1]	2.20
AVO	74.42	0.12	12	0.30	5.05	2.37	0.56	1.46	3.29
AOC	180.41	0.30	17	0.42	12.25	1.39	0.25	0.97	1.80
FMC	10.70	0.02	1	0.03	0.73	1.38	1.23	0.00[1]	3.41
TTS	74.45	0.13	2	0.05	5.05	0.40	0.26	0.00[1]	0.82
Totals	589.15	1.00	40	1.00					

Table 3.2 (Cont.)

HT	ha	Proportion of area sampled	No. of grouse	Proportion of grouse	Expected no. grouse	Selection index ($\hat{w}$)	se($\hat{w}$)	Confidence Limit Lower	Confidence Limit Upper
Combined years									
AQV	192.31	0.23	7	0.09	17.13	0.41	0.14	0.18	0.64
TM	72.96	0.09	10	0.13	6.50	1.54	0.48	0.75	2.33
ATD	17.47	0.02	1	0.01	1.56	0.64	0.50	0.00[1]	1.46
AVO	264.53	0.31	26	0.35	23.56	1.10	0.18	0.81	1.40
AOC	199.01	0.24	24	0.32	17.72	1.35	0.22	0.98	1.72
FMC	11.38	0.01	1	0.01	1.01	0.99	1.00	0.00[1]	2.63
TTS	84.48	0.10	6	0.08	7.52	0.80	0.31	0.28	1.31
Totals	842.13	1.00	75	0.99					

[1]A negative lower limit for the confidence interval has been replaced by 0.00 because negative values for the selection indices are impossible.

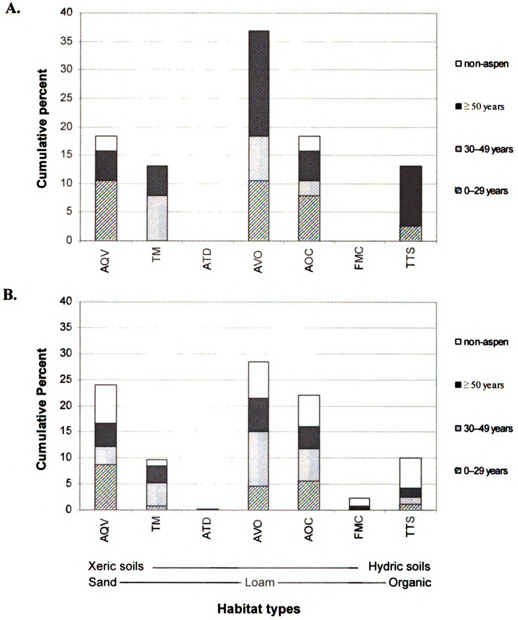

Figure 3.1. Cumulative percent of aspen age classes and habitat types used by drumming ruffed grouse in 2005 (A) and available (B) in the western Upper Peninsula, Michigan. Habitat types listed include those that occur within Baraga, Dickinson, Iron, and Marquette counties. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; FI = *Fraxinus-Impatiens*; FMC = *Fraxinus-Mentha-Carex*; PCS = *Picea-Chamadaphne-Sphagnum*; PVC = *Pinus-Vaccinium-Carex*; PVD = *Pinus-Vaccinium-Deschampsia*; QAE = *Quercus-Acer-Epigaea*; TAM = *Tsuga-Acer-Mitchella*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*; TMV = *Tsuga-Maianthemum-Vaccinium*; TTM = *Tsuga-Thuja-Mitella*; TTS = *Tsuga-Thuja-Sphagnum*.

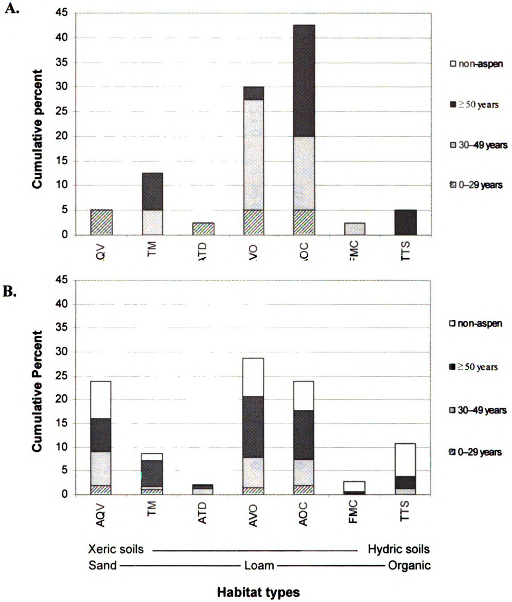

Figure 3.2. Cumulative percent of aspen age classes and habitat types used by drumming ruffed grouse in 2006 (A) and available (B) in the western Upper Peninsula, Michigan. Habitat types that comprise < 5% of the area are not included. Habitat types listed include those that occur within Baraga, Dickinson, Iron, and Marquette counties. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; FI = *Fraxinus-Impatiens*; FMC = *Fraxinus-Mentha-Carex*; PCS = *Picea-Chamadaphne-Sphagnum*; PVC = *Pinus-Vaccinium-Carex*; PVD = *Pinus-Vaccinium-Deschampsia*; QAE = *Quercus-Acer-Epigaea*; TAM = *Tsuga-Acer-Mitchella*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*; TMV = *Tsuga-Maianthemum-Vaccinium*; TTM = *Tsuga-Thuja-Mitella*; TTS = *Tsuga-Thuja-Sphagnum*.

Table 3.3. Estimation of selection indices for the occurrence of drumming ruffed grouse in different age classes and habitat types (HT) in the western Upper Peninsula, Michigan during 2005. Age classes include aspen ≥ 50 years (old), medium-aged aspen (30–49 years; med), young aspen < 30 years (yng), and non-aspen (n-a) vegetation types. AQV = *Acer-Quercus-Vaccinium*; TM = *Tsuga-Maianthemum*; AVO = *Acer-Viola-Osmorhiza*; AOC = *Acer-Osmorhiza-Caulophyllum*; FMC = *Fraxinus-Mentha-Carex*; TTS = *Tsuga-Thuga-Sphagnum*. AQV and TM habitat types occur on dry, sandy soils, AVO and AOC habitat types occur on mesic, loamy soils, and TTS occurs on hydric organic soils.

HT and age	ha	Proportion of area sampled	No. of grouse	Proportion of grouse	Expected no. grouse	Selection index ($\hat{w}$)	se($\hat{w}$)	Confidence Limit Lower	Confidence Limit Upper
oldAVO	65.48	0.08	7	0.18	3.05	2.30	0.79	1.01	3.58
n-aAQV	20.87	0.03	2	0.05	0.97	2.06	1.42	0.00[1]	4.38
medTM	37.10	0.04	3	0.08	1.73	1.74	0.96	0.16	3.32
yngAVO	37.91	0.05	3	0.08	1.76	1.70	0.94	0.15	3.25
oldTTS	41.18	0.05	3	0.08	1.92	1.57	0.87	0.14	2.99
oldTM	27.78	0.03	2	0.05	1.29	1.55	1.07	0.00[1]	3.30
yngTTS	14.10	0.02	1	0.03	0.66	1.52	1.50	0.00[1]	3.99
yngAOC	46.42	0.06	3	0.08	2.16	1.39	0.77	0.13	2.65
n-aTTS	15.62	0.02	1	0.03	0.73	1.38	1.36	0.00[1]	3.60
medAVO	87.14	0.11	4	0.11	4.06	0.99	0.47	0.22	1.75
yngAQV	87.50	0.11	4	0.11	4.07	0.98	0.47	0.22	1.74
oldAOC	53.31	0.07	2	0.05	2.48	0.81	0.56	0.00[1]	1.72
medAOC	60.10	0.07	2	0.05	2.80	0.71	0.49	0.00[1]	1.52
oldAQV	59.05	0.07	1	0.03	2.75	0.36	0.36	0.00[1]	0.95
Totals	653.56	0.81	38	1.00		19.06			

[1] A negative lower limit for the confidence interval has been replaced by 0.00 because negative values for the selection indices are impossible.

Table 3.4. Estimation of selection indices for the occurrence of drumming ruffed grouse in different age classes and habitat types (HT) in the western Upper Peninsula, Michigan during 2006. Age classes include aspen ≥ 50 years (old), medium-aged aspen (30–49 years; med), young aspen < 30 years (yng), and non-aspen (n-a) vegetation types. AQV = *Acer-Quercus-Vaccinium*; TM = *Tsuga-Maianthemum*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; AOC = *Acer-Osmorhiza-Caulophyllum*; FMC = *Fraxinus-Mentha-Carex*; TTS = *Tsuga-Thuga-Sphagnum*. AQV and TM habitat types occur on dry, sandy soils, ATD occurs on sandy-loamy soils, AVO, AOC, and FMC habitat types occur on mesic, loamy soils, and TTS occurs on hydric organic soils.

HT and age	ha	Proportion of area sampled	No. of grouse	Proportion of grouse	Expected no. grouse	Selection index ($\hat{w}$)	se($\hat{w}$)	Confidence Limit Lower	Confidence Limit Upper
medFMC	4.18	0.01	1	0.03	0.19	5.24	5.17	0.00[1]	13.72
yngTM	6.29	0.01	1	0.03	0.29	3.48	3.47	0.00[1]	9.17
yngAVO	23.55	0.03	3	0.08	1.08	2.79	1.55	0.24	5.33
oldAOC	70.67	0.08	9	0.23	3.23	2.79	0.82	1.44	4.13
yngAOC	41.49	0.05	5	0.13	1.90	2.64	1.11	0.83	4.45
oldTM	29.27	0.03	3	0.08	1.34	2.24	1.25	0.20	4.29
yngATD	11.68	0.01	1	0.03	0.53	1.87	1.93	0.00[1]	5.05
medAVO	140.64	0.16	8	0.20	6.43	1.24	0.39	0.60	1.89
oldTTS	44.95	0.05	2	0.05	2.05	0.97	0.67	0.00[1]	2.08
medAOC	68.25	0.08	3	0.08	3.12	0.96	0.53	0.09	1.84
medTM	27.43	0.03	1	0.03	1.25	0.80	0.79	0.00[1]	2.09
yngAQV	73.93	0.08	2	0.05	3.38	0.59	0.41	0.00[1]	1.26
oldAVO	50.87	0.06	1	0.03	2.32	0.43	0.43	0.00[1]	1.13
Totals	593.20	0.68	40	1.00		26.04			

[1]A negative lower limit for the confidence interval has been replaced by 0.00 because negative values for the selection indices are impossible.

Table 3.5. Estimation of selection indices for the occurrence of drumming ruffed grouse in different age classes and habitat types (HT) in the western Upper Peninsula, Michigan during 2005 and 2006. Age classes include aspen ≥ 50 years (old), medium-aged aspen (30–49 years; med), young aspen < 30 years (yng), and non-aspen (n-a) vegetation types. AQV = *Acer-Quercus-Vaccinium*; TM = *Tsuga-Maianthemum*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; AOC = *Acer-Osmorhiza-Caulophyllum*; FMC = *Fraxinus-Mentha-Carex*; TTS = *Tsuga-Thuga-Sphagnum*. AQV and TM habitat types occur on dry, sandy soils, ATD occurs on sandy-loamy soils, AVO, AOC, and FMC habitat types occur on mesic, loamy soils, and TTS occurs on hydric organic soils.

HT and age	ha	Proportion of area sampled	No. of grouse	Proportion of grouse	Expected no. grouse	Selection index ($\hat{w}$)	se($\hat{w}$)	Confidence Limit Lower	Confidence Limit Upper
medFMC	4.21	0.004	1	0.01	0.32	3.16	3.14	0.00[1]	8.320
yngAOC	46.42	0.05	8	0.10	3.48	2.30	0.77	1.03	3.56
oldTM	29.27	0.03	5	0.06	2.20	2.28	0.99	0.66	3.90
yngTM	6.47	0.01	1	0.01	0.49	2.06	2.07	0.00[1]	5.46
yngAVO	40.19	0.04	6	0.08	3.01	1.99	0.78	0.71	3.27
oldAOC	73.99	0.07	11	0.14	5.55	1.98	0.56	1.07	2.89
oldAVO	69.08	0.07	8	0.10	5.18	1.54	0.52	0.70	2.39
medTM	37.22	0.04	4	0.05	2.79	1.43	0.70	0.29	2.58
oldTTS	51.53	0.05	5	0.06	3.87	1.29	0.56	0.38	2.21
othAQV	22.67	0.02	2	0.03	1.70	1.18	0.82	0.00[1]	2.52
yngATD	11.68	0.01	1	0.01	0.88	1.14	1.21	0.00[1]	3.11
medAVO	155.27	0.15	12	0.15	11.65	1.03	0.27	0.58	1.48
yngTTS	14.10	0.01	1	0.01	1.06	0.95	0.94	0.00[1]	2.49
yngAQV	89.25	0.09	6	0.08	6.70	0.90	0.35	0.32	1.47
medAOC	78.60	0.08	5	0.06	5.90	0.85	0.37	0.25	1.45
othTTS	21.58	0.02	1	0.01	1.62	0.62	0.61	0.00[1]	1.63
oldAQV	64.09	0.06	1	0.01	4.81	0.21	0.21	0.00[1]	0.545
Totals	815.60	0.78	78	1.00		24.90			

[1]A negative lower limit for the confidence interval has been replaced by 0.00 because negative values for the selection indices are impossible.

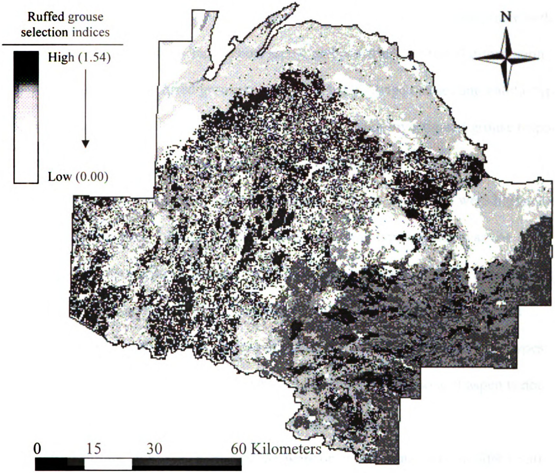

Figure 3.3. Spatial distribution of habitat types ruffed grouse would potentially select for drumming in the western Upper Peninsula, Michigan. Selection indices > 1.0 indicate selection; those < 1.0 indicate avoidance. The area includes Baraga, Dickinson, Iron, and Marquette counties. This figure was based on data collected during mid-April in 2005 and 2006.

DISCUSSION

Results of this project demonstrated that ruffed grouse respond differently to the various ecological conditions that support aspen, and provided additional information useful for understanding ruffed grouse selection of different age classes and habitat types for drumming. To my knowledge, previous research has not investigated grouse response to the successional stages and site conditions that support aspen.

In this study, selection indices for young (< 30 year-old) aspen were higher than those for older aspen age classes and non-aspen vegetation types, which was not surprising given other studies that also reported grouse selection of young aspen stands for drumming (Kubisiak et al. 1981, McCaffery et al. 1996). Also consistent with previous findings was the lower selection or avoidance of non-aspen vegetation types (Gullion 1970). Svoboda and Gullion (1972) stated that in Minnesota, if aspen is not present in an area, breeding ruffed grouse are seldom present.

Interestingly, however, ruffed grouse were observed drumming in older (≥ 50-year) age classes of aspen more than expected in 2005 (n = 15; expected = 11.87), in 2006 (n = 15; expected = 12.09), and in both years combined (n = 30; expected = 23.17; Table 3.1). Use of old aspen by drumming grouse has not been well documented in the literature in habitat selection studies, although DeStefano and Rusch (1984) reported instances where the density of drumming grouse was higher in mature aspen with hardwood shrubs than in young aspen.

A compelling result of this study was the obvious selection differences of aspen among habitat types. In 2005 and 2006, selection for aspen within the AVO habitat type was the highest, followed by the TM and TTS habitat types in 2005, and the AOC, FMC, and TM habitat types in 2006 (Table 3.2). One grouse was observed drumming in the FMC habitat type, which comprised a relatively small proportion (approximately 3%) of the sampled area (Figure 3.2), thus contributing to the high selection index. In combined years, selection for aspen within the TM habitat type was highest, followed by AVO and AOC. In 2005, 2006, and for combined years, aspen within the AQV habitat type was avoided (Table 3.2) by drumming grouse, especially for young and medium-aged aspen although there was some between-year variation (Tables 3.3–3.5). Not enough grouse were observed drumming in the ATD habitat type to determine selection trends.

Selection by age class within habitat types was also evident (Tables 3.3–3.5). For instance, within the AVO and AOC habitat types, grouse tended to select for young and old aspen age classes (Table 3.5). Medium-aged aspen within those habitat types appeared to be neither selected for nor avoided (i.e., selection ratios close to 1.0). Within the TM habitat type, grouse selection of all aspen age classes was evident, but had greater selection of young and old aspen (Table 3.5). Interestingly, within habitat types containing a conifer component (i.e., white spruce and balsam fir within the TM type, and lowland swamp conifers within the TTS type), grouse exhibited greater selection for old aspen than aspen < 50 years old or non-aspen vegetation types. These findings suggest that grouse select aspen differently depending on habitat type even if the aspen within different habitat types is in the same age class.

Important habitat components, which seem to influence whether or not grouse will select a site for drumming are relatively high shrub or sapling densities (Palmer 1963, Gullion 1970, DeStefano and Rusch 1984) and overstory cover (Gullion 1970). For instance, DeStefano and Rusch (1984) reported that alder and aspen vegetation types with saplings or shrub densities 4,000–15,000 stems/ha supported higher densities of drumming grouse in Wisconsin and Minnesota than other vegetation types with fewer stems, but areas devoid of overstory cover did not support drumming males. Optimal drumming habitat provides overhead cover from aerial predators and allows for horizontal surveillance for terrestrial predators (Gullion 1977).

It is evident that structure and composition of vegetation within the aspen type varies within different habitat types (see Chapter 1, Coffman et al. 1980). These vegetation differences likely contribute to the different selection indices observed in various habitat types. It is not likely that the observed selection differences were a factor of differences in detection probability among vegetation types. Zimmerman (2006), for instance, found that temperature change during a survey and the interaction with temperature at the start of a survey influenced grouse detection probabilities.

Selection of habitat by organisms is dependent on their requirements to survive (i.e., nutrition, protection from predators) and reproduce in an area. Selection or avoidance of different vegetation types, age classes, and habitat types by drumming grouse can be explained by their feeding and breeding habitat requirements. For example, the AVO and AOC habitat types support a thick shrubby understory (> 4,000 stems/ha), which is a structural component of optimal drumming habitat (Cade and Sousa 1985). Additionally, Svoboda and Gullion (1972) documented grouse use of aspen for food was greater in areas supported by loamy soils and peat than sandy loams and sand. The AVO and AOC habitat types both are characterized by loamy soils (Coffman et al. 1980). The TM habitat type and the old aspen vegetation within the TTS habitat type likely provide grouse drumming habitat because the conifer cover within those types provides overhead cover and allows for horizontal visibility. Old aspen within the TTS type possibly provides more nutritious food than other habitat types, because of the organic soils (Svoboda and Gullion 1972) characteristic of this site. Grouse avoidance of aspen within the AQV habitat type (Table 3.2) may be attributed to the dominance of bigtooth aspen on the dry, sandy soils characteristic of the AQV habitat type. Svoboda and Gullion (1972) showed a significant ($p < 0.05$) preference for catkins of quaking aspen over bigtooth aspen. In 2005, grouse demonstrated a high selection ($\hat{w} = 2.06$) for non-aspen vegetation types within the AQV habitat type. Red oak occurs after aspen in the successional trajectory of vegetation within the AQV habitat type (Coffman et al. 1981). Kubisiak et al. (1980) documented grouse use of oak in Wisconsin and (Cade and Sousa 1985) documented grouse use of oak in other areas within their range in North America where aspen is absent. The general trend in selection of young aspen and old aspen over medium-aged aspen may also be due to those age classes providing specific characteristics required for drumming behavior (young) and availability and preference of mature trees for feeding (old aspen).

Management implications

It is undisputed that aspen is the key to providing ruffed grouse habitat. Habitat management recommendations in the Upper Midwest historically were to cut aspen in blocks ≤ 4 ha in size to create juxtaposition of stands < 10 years old for brood cover, 10–25 years old for breeding and winter cover, and mature stands for food (Gullion 1977). McCaffery et al. (1996) stated that while small-tract cutting is feasible on private lands or management areas where ruffed grouse is the primary objective, it is not practical on large tracts of public land where timber is the primary objective. Management for timber (e.g., large aspen clearcuts), however, is compatible with ruffed grouse habitat management. McCaffery et al. (1996:32), for instance, observed that a 243-acre aspen clearcut in Wisconsin produced "relatively high densities of drumming grouse during the first half of the aspen rotation."

Knowledge of how grouse select vegetation to meet specific life requisites can help managers identify and maintain areas highly selected by ruffed grouse (Figure 3.3) through timber harvesting. In habitat types where grouse showed greater selection for younger aspen age classes, timber harvest may be implemented at 50 years (i.e., the standard rotation age for aspen in the Lake States). In habitat types where grouse showed greater selection for older aspen (e.g., the TM and TTS habitat types), perhaps harvest age may be lengthened to 70 years in some areas to provide unique vegetation features important for grouse. For instance, to meet grouse management goals, managers may retain areas within the AVO and AOC habitat types to increase the availability of areas selected by drumming grouse.

It is challenging for managers to meet multiple forest objectives, but increased knowledge of ecological relationships and wildlife habitat selection helps managers better understand potential outcomes of manipulation. This study expanded on existing knowledge of ruffed grouse drumming habitat selection within the Great Lakes region, and determined selection indices for different aspen age classes and habitat types. Although selection does not equate with preference, it does give us insight into how grouse use vegetation characteristics and distribute themselves to meet life requisites. The value of assessing grouse selection of habitat types for drumming is evident in planning forest management activities and understanding how grouse may respond to temporal changes in vegetation types through natural succession or manipulation. Future research should address ruffed grouse drumming habitat selection and relate fitness to different aspen age classes and habitat types. Nonetheless, the results of this analysis can help managers understand the breadth of ruffed grouse ecology, establish realistic grouse management goals based on the range of ecological conditions throughout landscapes that support grouse and aspen, or determine how and where timber harvest may benefit grouse over the long term.

MODELING THE CUMULATIVE EFFECTS OF ASPEN MANAGEMENT PRACTICES ON TIMBER AND WILDLIFE AT MULTIPLE SPATIAL AND TEMPORAL SCALES

VOLUME II

By

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CHAPTER 4

SIMULATING EFFECTS OF ASPEN HARVEST STRATEGIES ON WILDLIFE HABITAT AND TIMBER IN NORTHERN MICHIGAN

Forest management involves designing and implementing strategies to meet the current and future objectives of landowners and society. Forest management decisions, therefore, are based on scientific understanding of forest ecology and perceptions of how activities will promote human values (Davis et al. 2001). The understanding of forest ecosystems and human values of forests has dramatically increased since the 1960s when the forest management philosophy changed from maximizing timber products to sustaining forest ecosystems for multiple purposes (e.g., wildlife habitat, recreation, timber; [Kessler et al. 1992, Nyland 2002]). This broader understanding, however, has resulted in identification of areas in which the scientific community lacks knowledge, and the subsequent demand for further knowledge in those areas (Hüttl et al. 2000).

Research has indicated several thematic priorities on which forest research should focus. These included effect of harvest regimes on forest structure, composition, and function, and resulting wildlife habitat (DeStefano 2002), product yields and sustainability, and ecological integrity (Kessler et al. 1992). Although there is still much information to be learned about all forest types, research should focus on those that are not well represented in the landscape either because geographic areas supporting them are limited or because they are exploited by humans.

Aspen, for example, is commercially valuable and is exploited for numerous products. In the Great Lakes States, aspen comprises more than half the industrial products harvested annually (Piva 2003). To maximize its commercial value, most aspen in the Great Lakes region is harvested on a 40–60-year rotation because older aspen begins to show signs of deterioration and loses economic value (Graham 1963, Nyland 2002). As such, 40–60-year-old aspen may not be well represented in the landscape to meet diverse ecological objectives. For instance, currently approximately 8% of all aspen on state lands in the western Upper Peninsula, Michigan is 40–60 years old (Doepker et al. 2002). In 10 to 20 years, the amount of old aspen (≥ 50 years old) will be limited. The Michigan Department of Natural Resources (MDNR) has indicated a desire to maintain a relatively even-age class distribution to sustain the resources and maintain ecological integrity.

Currently, in Michigan and in much of the Great Lakes region, aspen forests are managed similarly (i.e., 40–60-year rotation) regardless of habitat type. Because aspen can grow on several habitat types ranging from poorly-drained organic soils to excessively-drained sand, the structure and composition of aspen forests varies with habitat type and thus provides different wildlife habitat components and timber harvest potential (Chapters 1–3). Habitat types, however, have only recently begun to be considered in forest management (Kotar and Burger 2000).

The low proportion of area in aspen 40–60 years old and the fact that habitat types have not typically been used in forest planning has implications for management including timber harvest sustainability and wildlife habitat suitability. For example, old (> 70 years) aspen forests in Michigan support relatively large-diameter (≥ 15 cm) aspen trees and provide snags necessary for cavity-nesting species, including the red-headed woodpecker, which is listed as a sensitive species by the Audubon Society (see Chapter

2). There is evidence that timber volume also differs among habitat types, even within the same age class (see Chapter 1).

State and federal agencies and many timber companies have begun to implement forest management strategies that seek to balance maintaining ecological integrity while using forests to provide products and services valued by people (Kessler et al. 1992, Pedersen 2005) and thus have supported research to expand knowledge in the thematic priority areas. Specifically, in Michigan, the MDNR has supported forest-related research because as of 2004, Michigan law requires state forests to be certified as being sustainably managed. Thus, the MDNR has assumed a responsibility to clarify the range of choices and consequences that exist for state forests, and develop criteria for making specific choices (Pedersen 2005).

Recently, tools have been developed to help managers understand consequences of management activities and plan future activities. For instance, HARVEST is a timber harvest model developed by Gustafson and Rasmussen (2002) as a strategic research and planning tool that allows assessment of the spatial pattern consequences of forest management activities. HARVEST can be used to project the cumulative effects of management over time and evaluate alternative scenarios by providing comparable projections about how the different scenarios affect landscape structure (Gustafson et al. 2007). HARVEST, however, is not a tactical planning tool and therefore, other methods such as linear or goal programming should be used to determine the best harvesting schedule to meet specific goals (Buongiorno and Gilless 2003).

Because aspen comprises the second largest single share of timber sales (volume) in Michigan (followed by upland hardwoods), and is expected to strongly influence timber harvesting plans on state forests over the next 20–30 years (Pedersen 2005), the MDNR has made it a priority to understand the impacts of applied management practices on aspen communities and take a proactive approach in predicting spatial and temporal consequences of management strategies to establish and maintain an even-age class distribution of aspen (R. Doepker, MDNR, personal communication). The HARVEST simulator can be used, in part, to assess the cumulative effects of aspen management strategies on sustainability of the aspen resource, landscape patterns, and distribution of aspen patches within the landscape matrix. This knowledge can help managers develop realistic expectations regarding future timber harvests and create a harvesting schedule that is sustainable for timber volume and wildlife habitats.

OBJECTIVES

Specific objectives for this chapter were to

1) Model the effects of current aspen management strategies on timber harvest sustainability and wildlife response for the western Upper Peninsula, Michigan.
2) Simulate spatial and temporal effects of aspen harvest strategies, and determine threshold levels for aspen harvest within different habitat types to meet Michigan Department of Natural Resources forest management goals.

METHODS

To model the effects of current aspen management strategies on timber harvest sustainability and wildlife response, I developed a model to simulate the optimum aspen harvesting schedule over 10 decades for different management scenarios specified by the MDNR (M. Mackay, MDNR, personal communication). The harvest schedule was then used in a spatially-explicit simulation model (HARVEST v.6.1 [Gustafson and Rasmusson 2005]) to evaluate landscape-level effects of harvest on wildlife and spatial arrangement of vegetation types. Prior to any simulations, however, I needed to compile data and organize it into a format useful for modeling.

Spatial data compilation

For the harvest simulations, a subset (300 mi^2) of the original 4-county study area was chosen (Figure 4.1). This area was chosen because it represented the most contiguous area of public land (for which forest management goals and activities are known), and fewer assumptions would have to be made in this area about activities occurring on private land. In the 4-county area, 20% comprised state-owned public land, whereas in the selected subset, 60% was public land.

Several data sources were used to compile all the information necessary to simulate timber harvest (i.e., forest type, stand boundaries, age class, habitat type). Because a spatially-explicit stand-level dataset (i.e., OI data) was only available for 77% of state land in the study area, I used IFMAP data to determine cover types for the remaining 23% of state land. I used a 3 x 3 majority kernel filter in ArcInfo to reduce the number of single-cell patches and assumed the IFMAP dataset was an accurate representation of actual stand cover types as determined in OI records. The IFMAP data, however, did not indicate stand age. Therefore, I randomly assigned age classes to aspen stands such that the resulting aspen age class distribution was consistent with that indicated by current MDNR records (Chapter 1). In the new study area, I determined the amount (ac) of aspen occurring in each age class and habitat type on state land. These values were used to initialize the timber harvest scheduling simulations.

For industry-owned, and other privately owned land, I used IFMAP to determine cover types and stand boundaries. Age of aspen stands was probabilistically assigned based on the age distribution of aspen in that region according to United States Department of Agriculture Forest Service Forest Inventory and Analysis (FIA) data. Because I was not evaluating spatial distribution of age classes of non-aspen forest types following simulated harvests, ages for non-aspen stands were not determined. I assumed that areas of non-aspen would remain in the same vegetation type and would not be converted to other vegetation types. I recognize, however, that management goals may change on MDNR and private lands over 10 decades.

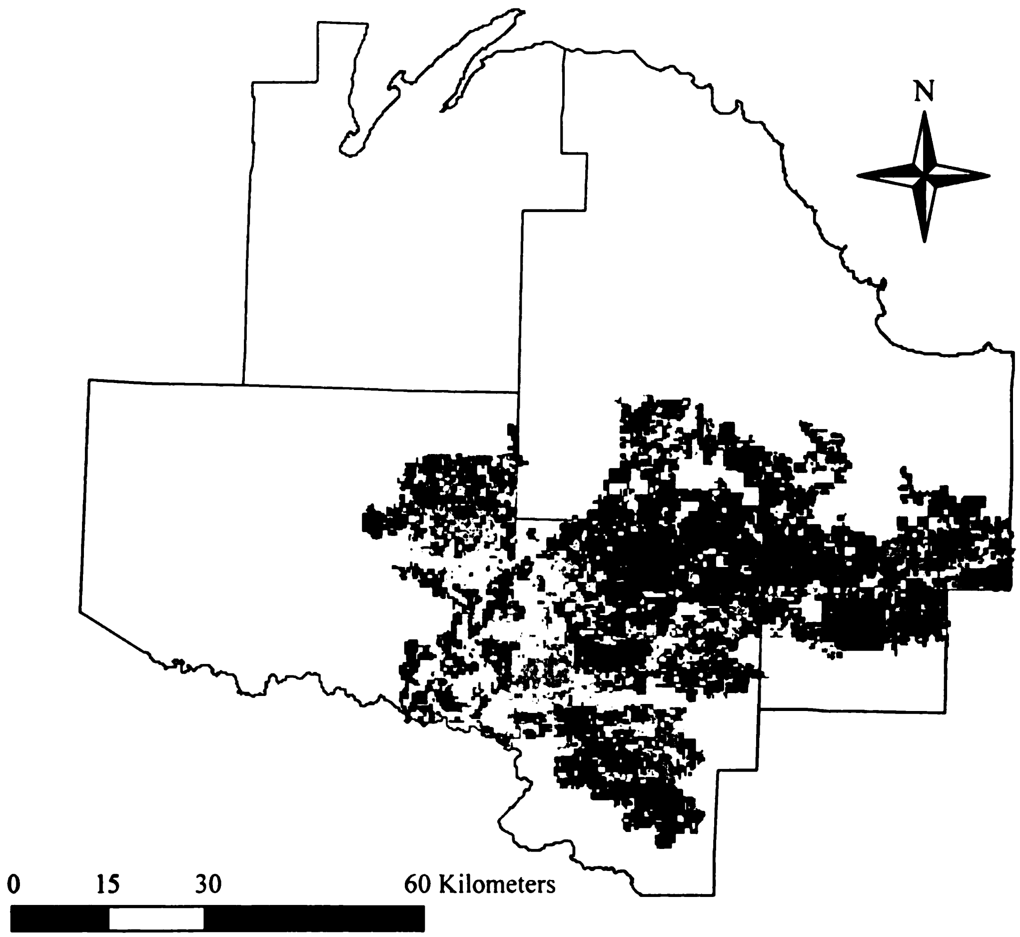


Figure 4.1. Location of study area (approximately 300 mi^2) in the western Upper Peninsula, Michigan for timber harvest simulations. Black areas are public lands managed by the Michigan Department of Natural Resources, dark gray areas are industry-owned forests, and light gray areas are non-industrial private forests.

Development of a harvest scheduling model

To examine the implications of timber harvest scheduling strategies on timber yield and wildlife benefits, I constructed a model in Microsoft Excel and used Premium Solver, an optimization program developed by Frontline Systems, Inc. (Incline Village, NV) to produce a timber harvest schedule. The model uses goal programming to determine the best harvesting schedule over 10 decades that minimizes the deviation from meeting specified forest management goals. Specified MDNR goals for the aspen cover type included maintaining timber harvest, balancing distribution of aspen area over 8 age classes (0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, and > 70 years old), and maintaining wildlife habitat. The main goal, however, was maintaining an even-age class distribution (i.e., 12.5% of aspen in each habitat type should be maintained in each age class) to yield long-term sustainable harvest and maintain representation of all aspen age classes within all habitat types. I used a goal-programming approach to allow flexibility in the goal of equal amount of aspen within each age class. A constraint that imposed strict constancy on that goal would be unrealistic and likely lead to infeasible solutions (Buongiorno and Gilless 2003).

The general goal programming model is described as follows:

Minimize the negative deviation (i.e., amount of area falling short of specified goal) from meeting an even-age class distribution

By changing

Harvest area for aspen on 40-, 50-, 60-, 70-, and 80-year rotations

Amount of area (acres) falling short of goal

Amount of area (acres) exceeding goal

Subject to,

Non-negativity constraints

Acreage constraints

Objective function (Equation 4.1)

$$\text{Min } z = \Sigma(D^{-}_{ijk})$$

Goal variables

H_{ijk} (i = 4, 5, 6, 7, 8)

D^{-}_{ijk}

D^{+}_{ijk}

Subject to,

$$H_{ij} \leq A_{ij} \quad \text{(Equation 4.2)}$$

$$A_{j} = A_{o} \quad \text{(Equation 4.3)}$$

$$H_{ijk} \geq 0 \quad \text{(Equation 4.4)}$$

$$D^{-}_{ijk} \geq 0 \quad \text{(Equation 4.5)}$$

$$D^{+}_{ijk} \geq 0 \quad \text{(Equation 4.6)}$$

$$A_{ijk} + D^{-}_{ijk} - D^{+}_{ijk} = G_{ij} \quad \text{(Equation 4.7)}$$

Where,

D^{-} = amount (acres) by which the resulting area falls short of the desired age class distribution.

D^{+} = amount (acres) by which the resulting area exceeds the desired age class distribution.

i = age class 1–8 (0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, and 70–79 years old).

j = habitat type 1–9

k = decade 1–10

H = harvest (acres)

A = area (acres)

A_0 = initial acres

G = amount of area (acres) needed to establish and maintain desired age class distribution goal

Model inputs and structure

The model determined the amount of aspen harvested on 40-, 50-, 60-, 70-, and 80-year rotations within each habitat type and decade to minimize the amount of area falling short of the desired even-age class distribution goal within habitat types (Figure 4.2). The amount of area potentially available for harvest (i.e., the amount of area in each age class and habitat type during a particular decade) was a function of the amount of aspen harvested in the previous decade (Equations 4.8–4.10). Because the MDNR has expressed no intent to convert vegetation types (e.g., through succession or management) at this time (J. Ferris, MDNR, personal communication), I assumed that all aspen would be harvested before it succeeded to a different vegetation type. A harvest schedule was determined for aspen within 9 habitat types ranging from xeric to mesic soils: PV (which pooled PVD and PVC), QAE, AQV, TM, ATD, AVO, AOC, F (which pooled FI and FMC), TMC. Aspen occurring in hydric soils represents about 10% of aspen occurring in the study area and is typically inaccessible for harvesting (J. Ferris, MDNR, personal communication).

For i = 1 (0–9-year-old aspen),

$$A_{ijk} = H_{j,k-1} \qquad \text{(Equation 4.8)}$$

For i = 2, 3, 4 (10–39-year-old aspen)

$$A_{ijk} = A_{i-1,j,k-1} \qquad \text{(Equation 4.9)}$$

For i = 5, 6, 7 (40–69-year-old aspen),

$$A_{ijk} = A_{i-1,j,k-1} - H_{i-1,j,k-1} \qquad \text{(Equation 4.10)}$$

Where,

i = age class 1–8 (0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, and 70–79 years old)

j = habitat type 1–9

k = decade

A = area (acres)

H = area harvest (acres)

The deviation from the desired age class distribution (i.e., even proportion of area within each aspen age class) was the sum of the amount of area that fell short or exceeded the specified area goal for each age class, habitat type, and within each decade. The negative deviation, or underachievement, was only considered in the minimization of the objective function because 12.5% of aspen area in each age class represented a minimum threshold goal for the amount of aspen to be maintained in each age class. Therefore, the MDNR was concerned about deviations which fell short of that goal.

The total yield per decade was determined from the product of area harvested and average volume per area (Table 4.1) for each habitat type and age class. Volume per area for age class within each habitat type was determined from a regression relationship between age class (x) and cords per acre (y) as determined from OI data (Table 4.2).

$$Y_{ijk} = H_{ijk} * V_{ij} \qquad \text{(Equation 4.11)}$$

Where,

i = age class 1–8 (0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, and 70–79 years old)

j = habitat type 1–9

k = decade

H = area harvest (acres)

V = average volume per area

Y = total yield

Initial acres for each habitat type were the following: PV = 2076 ac, QAE = 12983 ac, AQV = 22384 ac, TM = 20230 ac, ATD = 784 ac, AVO = 44184 ac, AOC = 21129 ac, F = 5248 ac, TMC = 11204 ac. Initial acres for each age class within each habitat type are indicated in Table 4.3.

Table 4.1. Average volume (cords) per acre of aspen for different rotation ages and habitat types within the western Upper Peninsula, Michigan. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

		Rotation age				
Soil moisture	Habitat type	40	50	60	70	80
Xeric	PV	12.00	16.12	19.32	21.93	24.13
	QAE	8.25	12.98	16.65	19.65	22.19
	AQV	10.01	15.28	19.36	22.70	25.52
Mesic	TM	12.09	16.23	19.44	22.06	24.28
(dry-mesic)	ATD	7.61	14.67	20.16	24.64	28.43
	AVO	10.85	15.17	18.51	21.25	23.57
	AOC	9.81	14.30	17.78	20.63	23.04
(wet-mesic)	F	10.44	14.87	18.30	21.11	23.49
	TMC	7.98	13.40	17.59	21.02	23.92

Table 4.2. Regression equations to predict volume (cords/acre) yields for aspen on 40-, 50-, 60-, 70-, and 80-year rotations in different habitat types in the western Upper Peninsula, Michigan. Volumes were determined from 2006 Operations Inventory data from the Michigan Department of Natural Resources. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

Habitat type	Regression Equation	R^2
PV	$y = 14.318 * \ln(x) - 36.695$	0.89
QAE	$y = 16.450 * \ln(x) - 47.702$	0.92
AQV	$y = 18.296 * \ln(x) - 52.215$	0.90
TM	$y = 14.378 * \ln(x) - 36.808$	0.82
ATD	$y = 24.572 * \ln(x) - 75.969$	0.98
AVO	$y = 15.015 * \ln(x) - 40.222$	0.89
AOC	$y = 15.622 * \ln(x) - 43.327$	0.91
F	$y = 15.402 * \ln(x) - 41.949$	0.86
TMC	$y = 18.815 * \ln(x) - 56.010$	0.89

Table 4.3. Number of acres of aspen within 8 age classes in 9 different habitat types used to initialize an aspen harvest scheduling simulation model for a 300 mi^2 area in the western Upper Peninsula, Michigan. Data were obtained from 2006 Operations Inventory Data from the Michigan Department of Natural Resources. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

	Habitat type								
Age class	PV	QAE	AQV	TM	ATD	AVO	AOC	F	TMC
0–9	164	1532	2687	2986	81	5039	2212	621	1347
10–19	414	2913	4674	6305	12	11284	4758	2810	2704
20–29	557	3338	5051	3967	66	10207	4358	1390	1948
30–39	428	2185	2642	2224	15	5744	2681	316	1208
40–49	200	277	1051	1194	6	3109	1888	188	241
50–59	25	224	330	703	24	1636	1112	52	286
60–69	42	290	1448	1045	202	2389	1242	168	386
>70	148	1869	3593	1758	376	4281	2696	488	3069
Totals	1978	12628	21476	20182	783	43689	20947	6034	11189

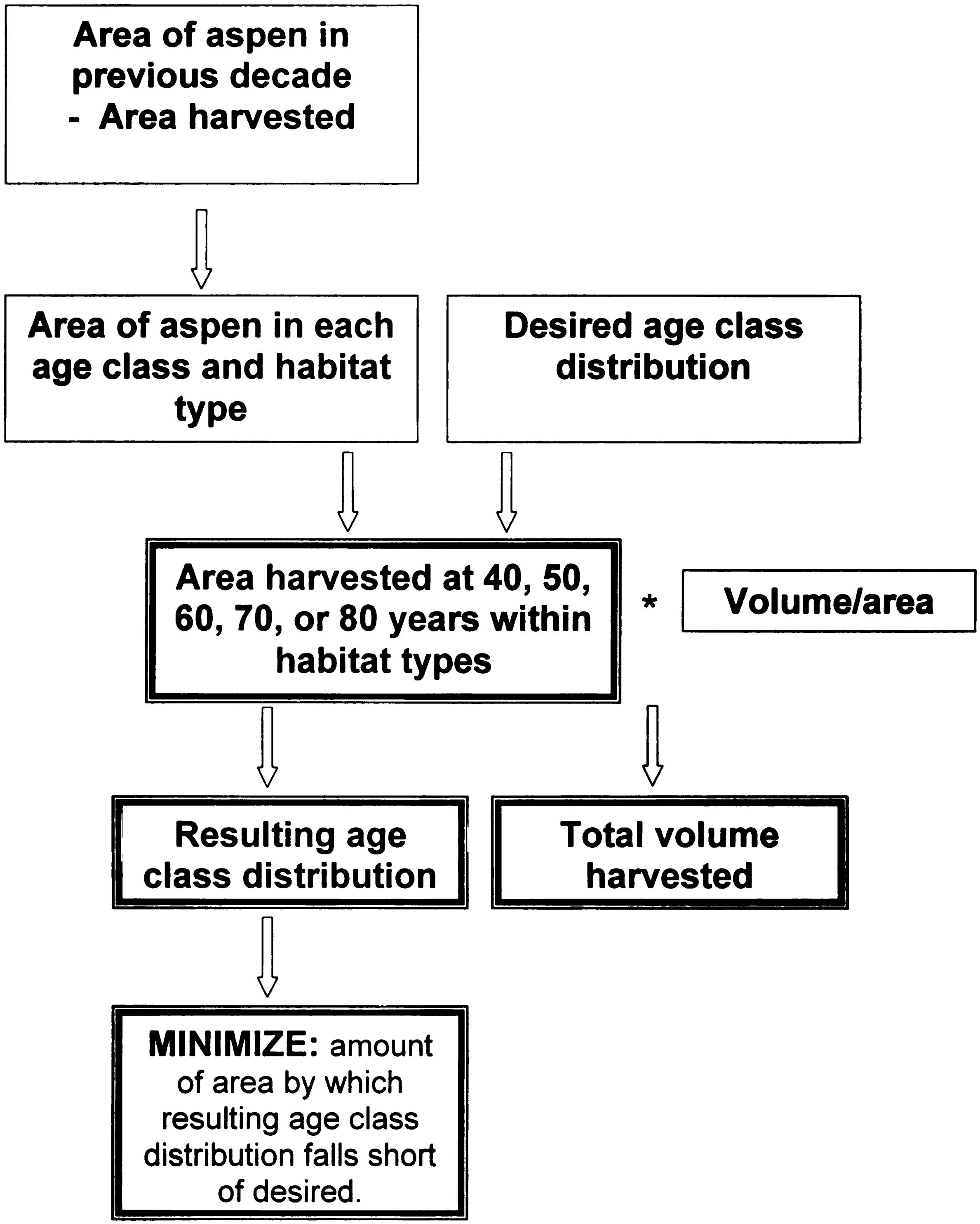


Figure 4.2. Schematic diagram of harvest scheduling model structure. Boxes in bold are model outputs.

I used information from chapters 2 and 3 on the relationship between avian species and aspen age class/habitat type, and ruffed grouse and aspen age class/habitat type to evaluate the effect of simulated timber harvesting schedules on wildlife habitat. In Chapter 2, avian species were grouped into communities based on similar associations with a specific aspen age class and/or habitat type. Communities included species associated with 20–50-year-old aspen within the ATD and AVO habitat types, aspen > 50 years old within the ATD and AVO habitat types, aspen > 50 years old regardless of habitat type, aspen in the 20-year age class within the TM type, aspen > 70 within the TM type, and within the TM habitat type regardless of age. The amount of habitat available for specific communities was assumed to increase or decrease in direct relation to the resulting increase or decrease in the area of their associated age class and/or habitat type. As such, populations of avian species may increase or decrease with changes in the amount of area available within different age classes and habitat types. I cannot, however, assume a linear relationship between changes in population sizes and changes in aspen area because some bird species may obtain life requisites from vegetation types other than aspen. Cavity-nesting birds, for instance, are not specifically associated with aspen.

To evaluate the potential effects of timber harvest on drumming ruffed grouse, I used information on the relationship between preferred drumming habitat and aspen age class/habitat type (see Chapter 3). I assumed that drumming activity (i.e., number of grouse drumming) was directly related to the amount of preferred habitat available (Gullion 1970). Ruffed grouse preferred aspen within the TM, ATD, AVO, and AOC habitat types for drumming (Table 4.4). Habitat types characterized by xeric and hydric soils were generally avoided (see Chapter 3). The following equation quantified expected relative proportional changes in grouse drumming activity:

$$Ck = [\sum_{i=1}^{3} \sum_{j=1}^{4} (Pijk - Pij, k-1) * \hat{w}ij] * \frac{Ajk}{Aj, k-1}$$

Where,

C = expected percent change in ruffed grouse drumming activity.

P = the percent of area.

i = age class 1–3 (young = 0–29 years, medium = 30–49 years, old = 50–79 years old).

j = habitat type 1–4 (ATD, AVO, AOC, TM).

k = time interval (decade).

$\hat{w}$ = selection index (Table 4.4).

A = area.

Table 4.4. Selection indices ($\hat{w}$) for ruffed grouse drumming habitat in 3 habitat types (ATD, AVO, and TM) and 3 aspen age classes in the western Upper Peninsula, Michigan. AOC = *Acer-Osmorhiza-Caulophyllum,* ATD = *Acer-Tsuga-Dryopteris*, AVO = *Acer-Viola-Ozmorhiza*, TM = *Tsuga-Maianthemum*. Aspen age classes included young (< 30 years old), medium (30–49 years old), and old (≥ 50 years old). Data on ruffed grouse habitat selection were collected in the spring of 2005 and 2006 on state lands in Baraga, Dickinson, Iron, and Marquette counties. Selection indices were determined based on methods described by Manly et al. (2002).

		$\hat{w}$		
Soil moisture	Habitat type	young	medium	old
Drier	TM	2.06	1.43	2.28
	ATD	1.14	0.36	0.08
	AVO	1.99	1.03	1.54
Wetter	AOC	2.3	0.85	1.98

The selection index ($\hat{w}$) indicated grouse selection or avoidance of aspen in a given age class and habitat type (Manly et al. 2002). Selection indices > 1.0 indicated selection, and those < 1.0 indicated avoidance. Aspen age classes and habitat types found to be avoided by drumming grouse (i.e., medium and old aspen within the ATD habitat type) were not included to determine C because a decrease in the amount of avoided vegetation classes would not affect grouse populations. An increase in the amount of avoided habitat would be reflected in a subsequent decrease in preferred habitat, which would negatively affect grouse. [Note: Ruffed grouse have cyclic populations. The relationship between the relative proportion of area of preferred habitat availability and grouse drumming activity was based on data collected in 2005–2006. Thus, direct effects of changes in preferred grouse habitat can only reliably be deduced for grouse population sizes in the western Upper Peninsula that are equivalent to the size which occurred at the point in the population cycle in 2005–2006.] This method is useful, however, for predicting increases or decreases in drumming habitat selected by ruffed grouse. Actual changes in drumming activity would likely be confounded by changes in population size due to natural cyclic fluctuations (Gullion 1970).

The product of the difference in the percent of aspen (P_{ij}) between years and the selection index $\hat{w}$ indicated the relative contribution of each aspen age class i and habitat type j to grouse for drumming. In essence, $\hat{w}$ was a weight indicating importance of a specific age class and habitat type for drumming grouse. For instance, if $\hat{w}$ for vegetation class A was 2 and $\hat{w}$ for vegetation class B was 1, a 1% decrease in vegetation class A would likely affect the grouse population twice as much as a 1% decrease in vegetation class B. The sum of the product for each age class and habitat type was multiplied by the ratio of aspen area in each habitat type to the aspen area in each habitat type within the previous decade. This indicated the relative degree of drumming activity for each decade. The underlying assumptions in this model were that preference can be determined from patterns of observed use, and species fitness is higher in highly selected areas (Garshelis 2000).

Simulation descriptions

Three timber harvest scenarios were simulated. The target goal for all scenarios, as specified by the DNR, was an even distribution of aspen area within 8 10-year age classes from 0–79 years. That is, 12.5% of the aspen area was the target goal for each age class. Criteria for feasible solutions included representation of aspen in all habitat types, and sustainable timber harvest. Harvest was considered sustainable once there were no net changes in yield between decades. Wildlife habitat should be maintained, but specific criteria were not indicated.

The first scenario specified that the total area of aspen within the 3 habitat types of interest did not decrease, and all aspen was harvested by 80 years. The second scenario specified non-declining aspen area, and only aspen ≥60 years was harvested. Non-declining aspen area and a 40-year harvest rotation were parameters for the third scenario.

HARVEST simulations

The program HARVEST was designed to assess how the spatial and temporal patterns of age classes and forest composition may change under specific management scenarios (Gustafson 1997). The program requires 4 input maps to simulate harvest activity: forest age, forest type, management area, and stand identification. These maps must be in an ERDAS v7.4+, 8- or 16-bit GIS file. I created these files in ArcInfo by using the GRIDIMAGE command at the Arc: prompt on grid files.

In the forest age map, there were 9 initial 10-year age classes specified only for aspen. Ten vegetation types were specified in the forest age map: aspen (1), birch (2), cedar (3), lowland swamp conifers (4), lowland hardwoods (5), mesic conifers (6), pine (7), oak (8), northern hardwoods (9), non-forested (10). Non-forested areas included grasslands, bogs, and open water. Management units (n = 30) were defined by an intersection of land ownership and 10 habitat types (Table 4.5). Separate management units were identified for public land, industrial forests, and non-industrial private forest because management practices differ among them. The stand identification map was created by passing the age map through the REGIONGROUP clumping algorithm in ArcInfo, which groups contiguous pixels with the same age class values. Initial landscape conditions were identical for each scenario.

Once input maps were rendered in HARVEST, I initiated simulation by selecting the "Execute" option on the Model menu and specified appropriate harvest parameters. The following parameters were used: for all land ownerships, I selected the "Fill Stands" option to avoid partial cutting of stands. Stands were randomly selected for harvest using the "Dispersed" harvesting method. The age of all harvested stands was reset to 1 following harvest. Adjacency constraints and riparian buffers were not enforced.

For MDNR lands, the amount of area to be harvested within aspen stands ≥ 40, within each habitat type, and during each decade was determined from the goal programming harvesting schedule. The amount of area to be harvested on non-industrial private forests was set at 6% of all areas ≥ 40 years (as specified by Gustafson et al. 2007). On commercial lands, minimum age allowed for harvest was 50 years and 100% of aspen ≥ 50 was harvested each decade.

Succession of aspen > 80 years old only occurred on non-industrial private forests and within hydric habitat types on state-owned and commercial forests. Aspen within the PV habitat type succeeded to pine; QAE and AWV succeeded to oak; TM succeeded to mesic conifers; ATD, AVO, AOC, F, and TMC succeeded to northern hardwoods; and aspen within hydric habitat types succeeded to lowland swamp conifers or lowland hardwoods. HARVEST program scripts were saved for each management scenario. (Due to the extensive length of these scripts, they were not included in this document. I can provide them on request).

Simulations in HARVEST are stochastic. That is, the specific outcome of an event is determined by a random number seed. Consequently, repeated simulations result in differences in locations of harvest events. Therefore, each scenario was simulated 5 times.

Landscape metrics

The amount of aspen area within each age class and habitat type resulting from the spatial simulations was calculated for each scenario to evaluate the feasibility of the aspatial harvest scheduling model when applied spatially. Average area of forest edge and interior was also determined to compare landscape effects among scenarios and identify potential implications for edge and edge-sensitive wildlife species. I assumed edge effects penetrated 295 ft (90 m) into the forest (Gustafson et al. 2007). The spatial distribution of habitat for different avian communities, and the spatial distribution of ruffed grouse drumming habitat was assessed for initial landscape conditions, decade 2, decade 5, and decade 10.

Table 4.5. Management unit codes for specific land ownership and habitat types (HT) used as inputs for the HARVEST simulation model. NIPF = non-industrial private forests.

Code for state-owned	Code for NIPF	Code for industrial	HT code	HT
101	201	301	PV	*Pinus-Vaccinium*
102	202	302	QAE	*Quercus-Acer-Epigaea*
103	203	303	AQV	*Acer-Quercus-Vaccinium*
104	204	304	TM	*Tsuga-Maianthemum*
105	205	305	ATD	*Acer-Tsuga-Dryopteris*
106	206	306	AVO	*Acer-Viola-Osmorhiza*
107	207	307	AOC	*Acer-Osmorhiza-Caulophyllum*
108	208	308	F	*Fraxinus*
109	209	309	TMC	*Tsuga-Maianthemum-Coptis*
110	210	310	hydric	

RESULTS

Scenario 1: Harvest all aspen by 80 years

Timber harvest

In the first scenario (i.e., all aspen harvested by 80 years), the harvest schedule produced an even-age class distribution in all habitat types by the eighth decade; however, an even-age class distribution was achieved by the fifth and sixth decades for aspen within the TM and AQV habitat types, respectively (Appendix 1). Results of the spatial harvesting simulations achieved similar results (Figures 4.3–4.5). Spatial constraints such as no partial cutting of stands made it infeasible to achieve exactly a 12.5% distribution of area within each age class, however the resulting distribution was within 1% of the 12.5% goal for each age class in all habitat types by the eighth decade (Figures 4.3–4.5). The total number of acres that fall short of the even-age class distribution in each habitat type declined sharply from > 5,000 ac in the AQV, TM, and AVO habitat types and > 2,000 ac in the QAE, AOC, F, and TMC types to < 500 acres in the fifth decade of the simulated harvest schedule (Figure 4.6). The number of deficient acres was 0 by the eighth simulated decade (Figure 4.6).

The total number of aspen acres harvested remained relatively constant at approximately 17,800 ac after the third decade, but decreased from a harvest of 20,829 ac in the first decade (Figure 4.7a, Table 4.6). Total volume decreased from approximately 197,000 cords harvested in decade 1 to 131,000 cords by the third decade (Figure 4.7b). Volume fluctuated more than total acres because aspen may be harvested in different age classes and habitat types, which may yield different amounts of timber (Table 4.6). Total volume increased to approximately 168,700 by decade 7 and remained stable for the duration of the simulated timeframe (Figure 4.7b, Table 4.7).

Relatively few acres (approximately 4700 ac/decade) were harvested from the xeric habitat types (PV, QAE, AQV) because they were not as prevalent as mesic habitat types in the study area and thus supported less aspen. Harvest remained relatively consistent in those habitat types throughout the 10-decade scheduling simulation (Figure 4.8). Volume harvested from the AQV habitat type, however, declined substantially from 37,500 cords in decade 1 to 16,000 cords in decade 3 (Figure 4.9, Table 4.7), due to the increased number of acres harvested by 40 and 50 years (Table 4.7). Volume increased to roughly 29,000 cords by the sixth decade, where it remained for the duration of the simulation (Figure 4.9, Table 4.7).

The number of acres harvested within the dry-mesic habitat types (TM, ATD, AVO) was relatively consistent throughout the scheduling simulation (Figure 4.8). Initial harvest was 8431 ac, which increased to 8574 ac by the fourth decade and remained at 8150 ac for the remainder of the harvest schedule (Table 4.6). Most (> 5000 ac) of the harvested acres came from the AVO habitat type, whereas the ATD habitat type contributed relatively little aspen (Figure 4.8, Table 4.6), due to its low availability in the study area. Volume harvested from the AVO habitat type was lowest (31,651 cords) in decade 2 due to the increased number of acres harvested by 40 years, but volume increased to approximately 78,000 cords by Decade 5 where it remained relatively consistent for the rest of the simulation. Cordage harvested from the TM habitat type declined from an initial yield of 23,086 cords to 12,382 cords in decade 3, but stabilized at 24,868 cords by decade 5 (Figure 4.9, Table 4.7). Aspen volume from the ATD habitat type was about 4000 cords in the first decade, and then stabilized at 1128 cords by the eighth decade.

Total area harvested within the wet-mesic habitat types (AOC, F, TMC) was approximately 6500 ac initially, and remained at approximately 4700 ac by the fifth decade (Table 4.6). Most (3172 ac) of the acres harvested were from the TMC habitat type initially, but then harvest decreased to 1400 ac, and most harvested aspen came from the AOC habitat type (approximately 2600 ac; Figure 4.8, Table 4.6). Roughly 650 ac were harvested from the F habitat type within each decade. In decade 1, about 62,000 cords were harvested from the wet-mesic habitat types; 44,453 cords were harvested each decade by the seventh simulated time period. The most obvious fluctuations in yield occurred in decades 3 and 5 because of an increase in the amount of acres harvested by 40 years old in those decades (Table 4.6). Most of the yield came from the AOC habitat type, which stabilized at 24,645 cords/decade after decade 6, followed by the TMC habitat type, which stabilized at 13,567 cords/decade by the seventh decade (Figure 4.9, Table 4.7). Cordage from the F habitat type was stabilized at 6241 cords/decade by decade 9 (Figure 4.9, Table 4.7).

Effects on wildlife

Avian communities. The amount of habitat available for 5 of the 6 avian communities increased with the establishment and maintenance of an even-age class distribution for aspen (Figure 4.10). Habitat for avian species using aspen > 50 years old increased the most (from 19% to 37% by decade 4). Habitat availability for avian species using aspen > 50 years old within the ATD and AVO habitat types increased by 12% by decade 4. Habitat for birds using aspen within the TM type increased from 17% to 23% by the second decade; subsequently, there was a 1% increase in habitat availability for birds using aspen > 70 years within the TM habitat type by the fourth decade. A 2% increase occurred in the amount of habitat available for avian communities using 20–50-year-old aspen within the ATD and AVO habitat types by decade 4, although habitat availability initially increased by 12% in the first decade. The only community in which a decrease in habitat availability occurred was the 20-year age class within the TM habitat type, which declined by approximately 2% by decade 3 (Figure 4.10).

Ruffed grouse. Once an even-age class distribution was established (i.e., by decade 8), ruffed grouse drumming activity was not expected to change between successive years (Figure 4.11). Initially, however, to establish an even-age class distribution, the expected percent changes were substantial. For instance, drumming activity was expected to decrease by 15% in the first decade of simulated timber harvest from initial conditions due to a decline in the amount of preferred drumming habitat within the TM, AVO, and AOC habitat types. Expected drumming activity further decreased by 7% in decade 2, but then increased in the next 2 decades by a total of 15%. Although drumming activity was not expected to change between successive years by decade 8, total drumming activity was lower than initial conditions due to a decrease in the amount of younger (< 30 years) age classes of aspen (Figure 4.11).

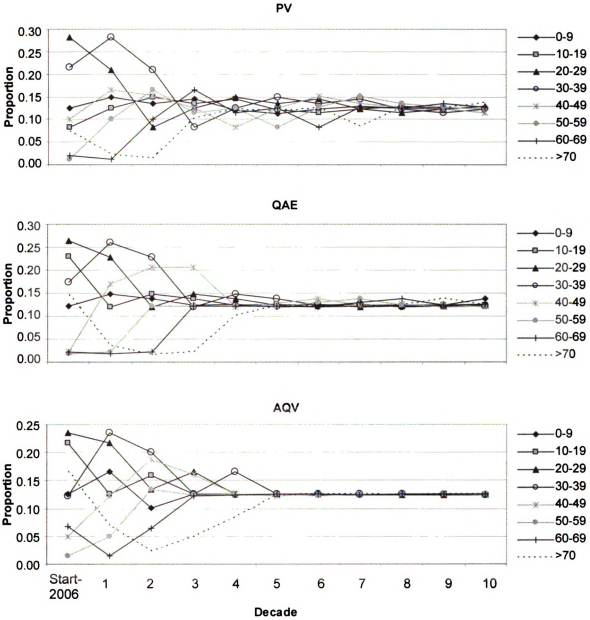


Figure 4.3. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). All aspen was harvested by 80 years old. AQV = *Acer-Quercus-Vaccinium*; *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*.

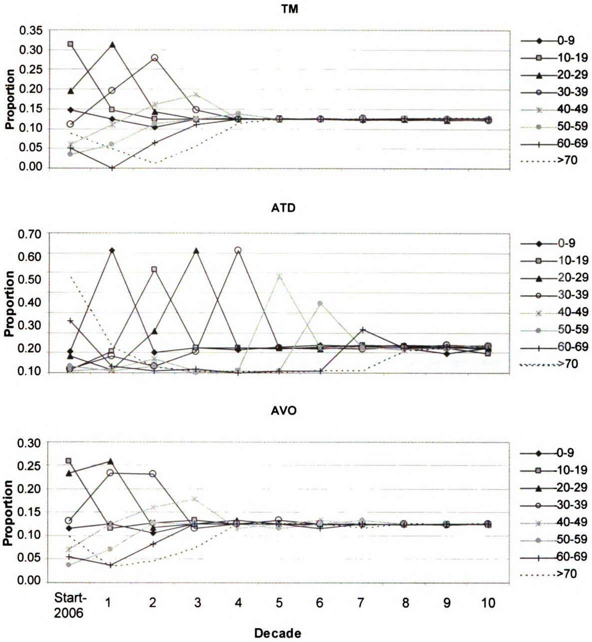


Figure 4.4. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). All aspen was harvested by 80 years old. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

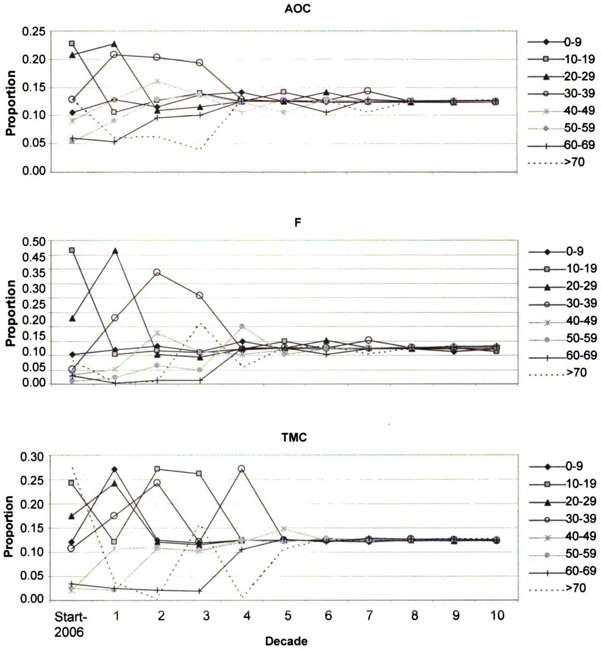


Figure 4.5. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). All aspen was harvested by 80 years old. AOC = *Acer-Osmorhiza-Caulophyllum*; F = *Fraxinus*-spp.; TMC = *Tsuga-Maianthemum-Coptis*.

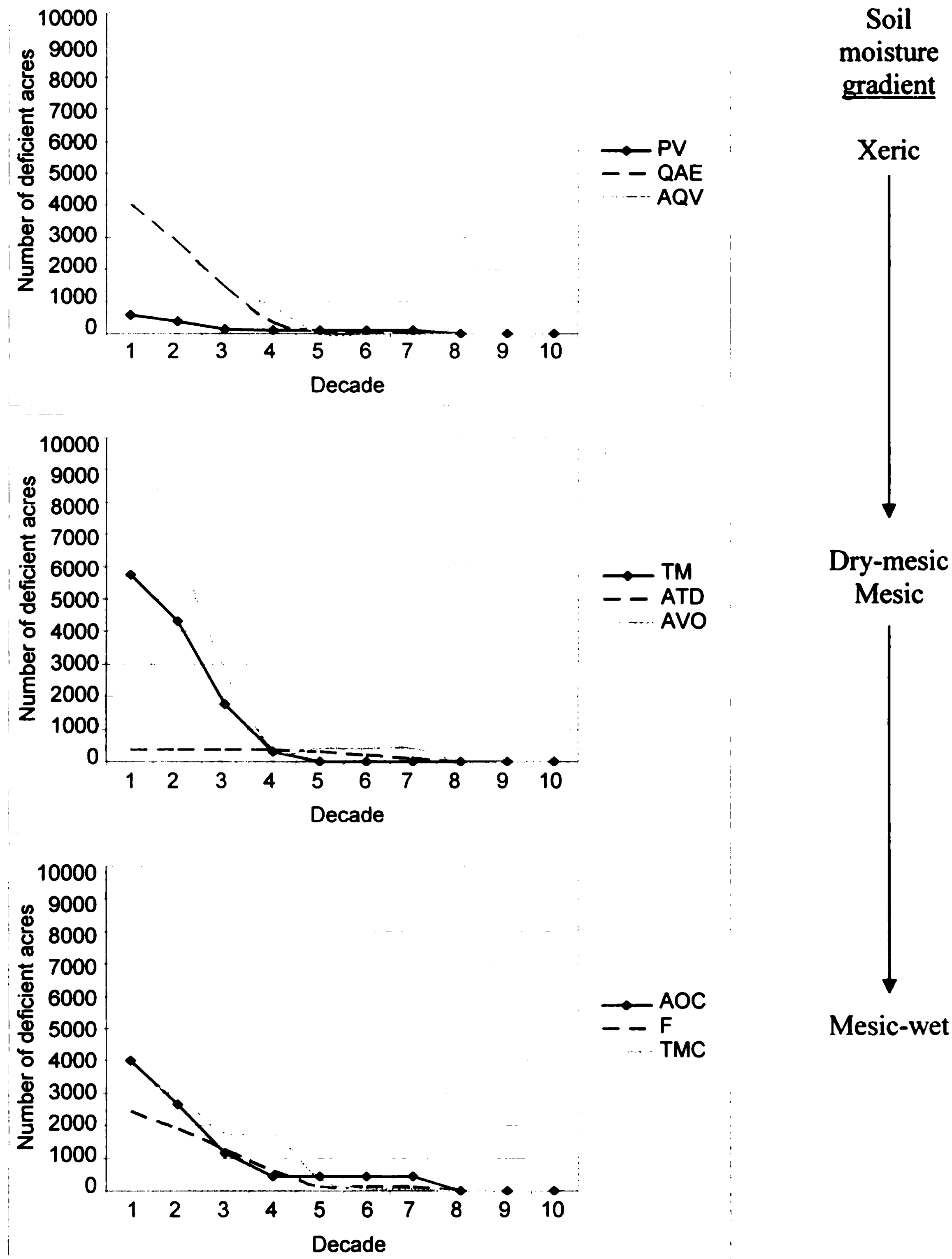
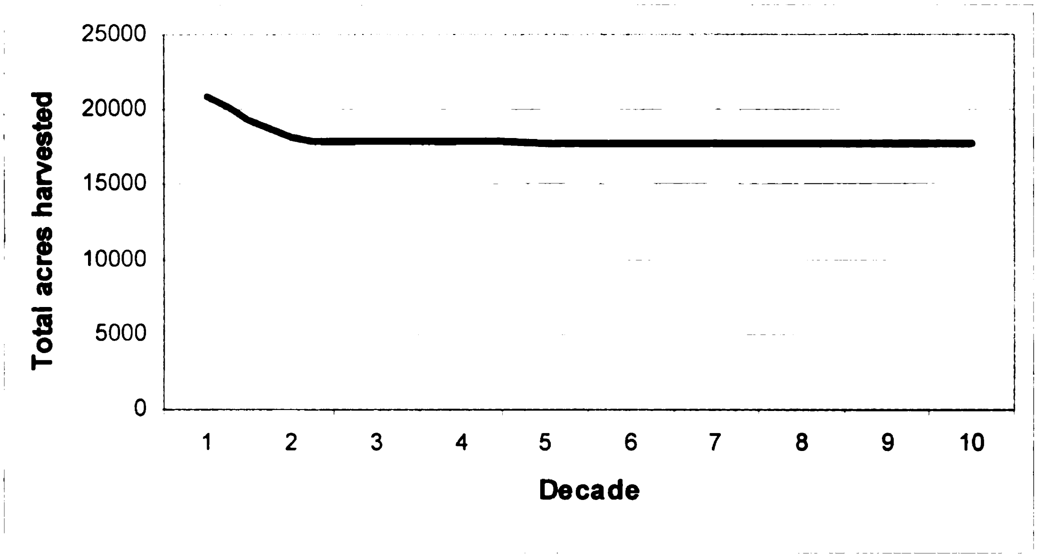


Figure 4.6. Number of deficient acres of aspen needed to establish and maintain an even-age class distribution within different habitat types over 10 decades of simulated harvest in the Upper Peninsula of Michigan. All aspen was harvested by 80 years old. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

A.



B.

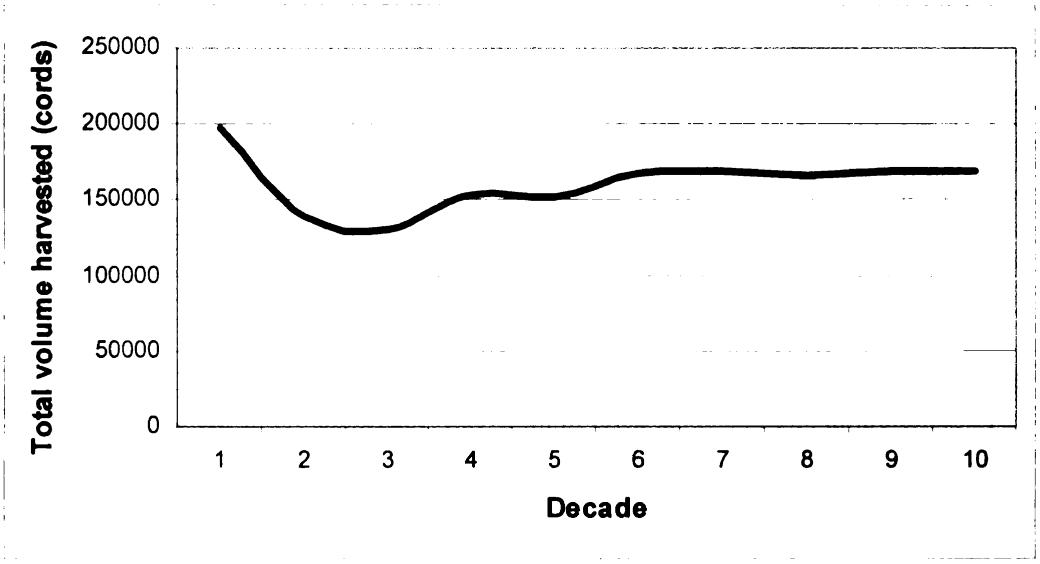


Figure 4.7. Total acres of aspen (A) and total volume (cords; B) harvested in aspen stands in the Upper Peninsula of Michigan over 10 decades of simulated harvest. All aspen was harvested by 80 years old.

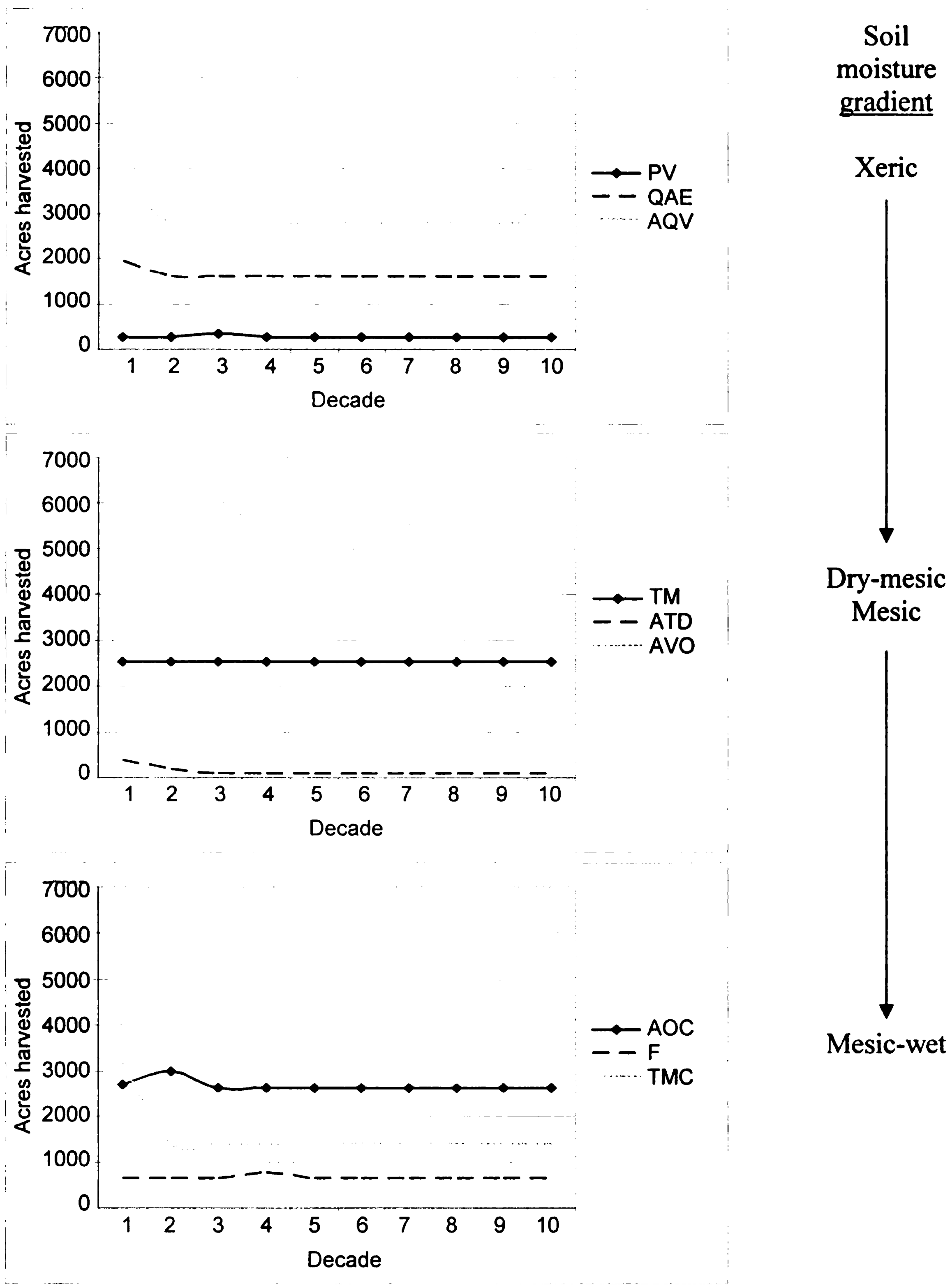


Figure 4.8. Acres of aspen to be harvested in different habitat types over 10 decades of simulated harvest to establish and maintain an even-age class distribution within habitat types in the Upper Peninsula of Michigan. All aspen was harvested by 80 years old. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

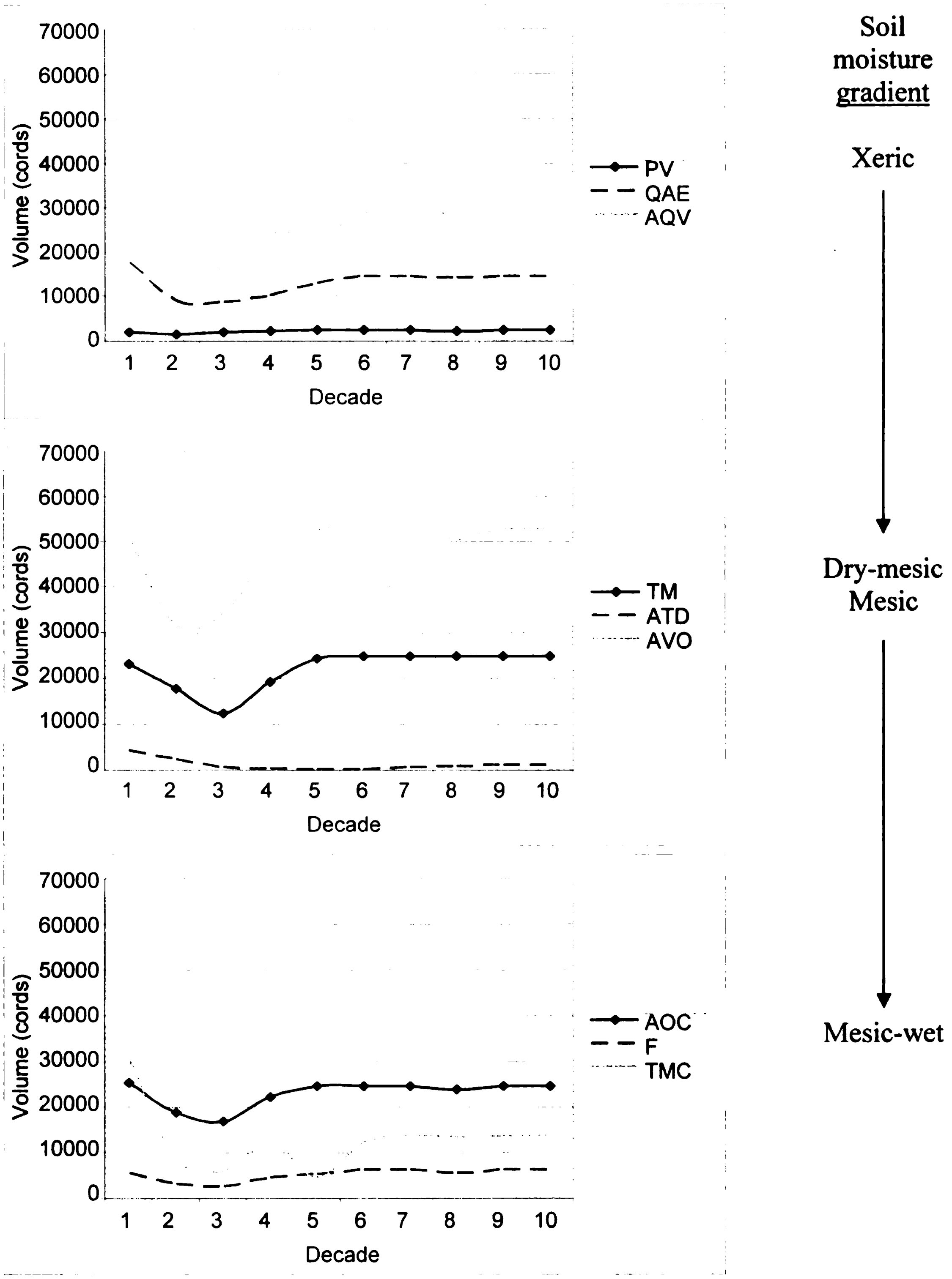


Figure 4.9. Volume (cords) to be harvested in aspen stands in different habitat types over 10 decades of simulated harvest to establish and maintain an even-age class distribution within habitat types in the Upper Peninsula of Michigan. All aspen was harvested by 80 years old. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

Table 4.6. Aspen harvest schedule (number of acres harvested) for state-owned lands within different habitat types in the western Upper Peninsula, Michigan over 10 decades to establish and maintain an even-age class distribution within habitat types. Harvesting strategy was to harvest all aspen by 80 years.

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PV	40	99	254	167	0	0	0	0	35	0	0
	50	0	0	56	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	48	0	0
	70	0	0	0	82	0	0	0	0	0	0
	80	148	42	25	200	247	247	247	164	247	247
Total PV		**247**	**296**	**247**	**282**	**247**	**247**	**247**	**247**	**247**	**247**
QAE	40	0	682	277	0	244	0	0	0	0	0
	50	0	607	1078	1057	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	244	0	0	0	46	0	0
	80	1869	290	224	277	1334	1578	1578	1532	1578	1578
Total QAE		**1869**	**1578**	**1578**	**1578**	**1578**	**1578**	**1578**	**1578**	**1578**	**1578**
AQV	40	0	1236	1224	2	908	0	0	0	0	0
	50	0	0	1130	765	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	866	0	0	0	0	0	0
	80	3593	1448	330	1051	1776	2685	2685	2685	2685	2685
Total AQV		**3593**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**

Table 4.6. (Cont.)

	Harvest	Decade									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
TM	40	0	1445	2523	463	0	0	0	0	0	0
	50	0	0	0	960	0	0	0	0	0	0
	60	703	95	0	0	299	0	0	0	0	0
	70	62	0	0	0	0	0	0	0	0	0
	80	1758	983	0	1099	2224	2523	2523	2523	2523	2523
Total TM		**2523**	**2523**	**2523**	**2523**	**2523**	**2523**	**2523**	**2523**	**2523**	**2523**
ATD	40	0	0	2	73	98	0	0	0	0	0
	50	0	0	66	10	0	98	0	0	0	0
	60	0	0	0	0	0	0	98	0	0	0
	70	105	0	6	15	0	0	0	90	0	0
	80	376	98	24	0	0	0	0	8	98	98
Total ATD		**481**	**98**	**98**	**98**	**98**	**98**	**98**	**98**	**98**	**98**
AVO	40	283	4391	3470	0	0	0	0	0	0	0
	50	0	0	355	2353	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	422	0	0
	70	897	0	0	0	0	0	0	0	0	0
	80	4281	1492	1636	3109	5461	5461	5461	5039	5461	5461
Total AVO		**5461**	**5883**	**5461**	**5461**	**5461**	**5461**	**5461**	**5461**	**5461**	**5461**

Table 4.6. (Cont.)

	Harvest	Decade									
Habitat type	Age Class	1	2	3	4	5	6	7	8	9	10
AOC	40	0	1314	1080	0	0	0	0	329	0	0
	50	0	63	426	1059	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	77	0	0
	80	2696	1242	1112	1888	2618	2618	2618	2212	2618	2618
Total AOC		**2696**	**2618**	**2618**	**2948**	**2618**	**2618**	**2618**	**2618**	**2618**	**2618**
F	40	0	636	754	0	0	0	0	133	0	0
	50	45	0	0	863	0	0	0	0	0	0
	60	52	119	0	0	439	0	0	0	0	0
	70	168	0	0	0	0	0	0	0	0	0
	80	488	0	0	24	316	754	754	621	754	754
Total F		**754**	**754**	**754**	**887**	**754**	**754**	**754**	**754**	**754**	**754**
TMC	40	0	727	1305	0	1399	0	0	0	0	0
	50	0	0	43	0	0	220	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	286	51	1208	0	0	0	51	0	0
	80	3069	386	0	191	0	1178	1399	1347	1399	1399
Total TMC		**3069**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**
TOTALS		**20693**	**17834**	**17363**	**17860**	**17363**	**17363**	**17363**	**17363**	**17363**	**17363**

Table 4.7. Number of cords of aspen harvested on state-owned lands within different habitat types in the western Upper Peninsula, Michigan over 10 decades to establish and maintain an even-age class distribution within habitat types. Harvesting strategy was to harvest all aspen by 80 years.

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PV	40	481	1234	810	0	0	0	0	169	0	0
	50	0	0	366	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	378	0	0
	70	0	0	0	728	0	0	0	0	0	0
	80	1451	408	241	1957	2417	2417	2417	1605	2417	2417
Total PV		**1931**	**1642**	**1417**	**2684**	**2417**	**2417**	**2417**	**2152**	**2417**	**2417**
QAE	40	0	2279	926	0	815	0	0	0	0	0
	50	0	3189	5665	5559	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	1942	0	0	0	369	0	0
	80	16797	2603	2009	2489	11992	14186	14186	13769	14186	14186
Total QAE		**16797**	**8071**	**8600**	**9990**	**12808**	**14186**	**14186**	**14138**	**14186**	**14186**
AQV	40	0	5012	4963	9	3683	0	0	0	0	0
	50	0	0	6994	4736	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	7963	0	0	0	0	0	0
	80	37129	14968	3413	10858	18356	27742	27742	27742	27742	27742
Total AQV		**37129**	**19980**	**15370**	**23566**	**22038**	**27742**	**27742**	**27742**	**27742**	**27742**

Table 4.7. (Cont.)

Habitat type	Harvest Age Class	Decade 1	2	3	4	5	6	7	8	9	10
TM	40	0	7073	12352	2268	0	0	0	0	0	0
	50	0	0	0	6314	0	0	0	0	0	0
	60	5532	749	0	0	2351	0	0	0	0	0
	70	551	0	0	0	0	0	0	0	0	0
	80	17292	9669	0	10809	21873	24809	24809	24809	24809	24809
Total TM		**23376**	**17490**	**12352**	**19390**	**24224**	**24809**	**24809**	**24809**	**24809**	**24809**
ATD	40	0	0	5	225	302	0	0	0	0	0
	50	0	0	395	59	0	581	0	0	0	0
	60	0	0	0	0	0	0	799	0	0	0
	70	1044	0	55	149	0	0	0	894	0	0
	80	4334	1127	279	0	0	0	0	95	1127	1127
Total ATD		**5378**	**1127**	**734**	**433**	**302**	**581**	**799**	**989**	**1127**	**1127**
AVO	40	1243	19295	15247	0	0	0	0	0	0	0
	50	0	0	2179	14453	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	3164	0	0
	70	7720	0	0	0	0	0	0	0	0	0
	80	40869	14241	15621	29675	52131	52131	52131	48102	52131	52131
Total AVO		**49832**	**33536**	**33047**	**44127**	**52131**	**52131**	**52131**	**51266**	**52131**	**52131**

Table 4.7. (Cont.)

	Harvest	Decade									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AOC	40	0	1314	1080	0	0	0	0	329	0	0
	50	0	63	426	1059	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	77	0	0
	80	2696	1242	1112	1888	2618	2618	2618	2212	2618	2618
Total AOC		**2696**	**2618**	**2618**	**2948**	**2618**	**2618**	**2618**	**2618**	**2618**	**2618**
F	40	0	636	754	0	0	0	0	133	0	0
	50	45	0	0	863	0	0	0	0	0	0
	60	52	119	0	0	439	0	0	0	0	0
	70	168	0	0	0	0	0	0	0	0	0
	80	488	0	0	24	316	754	754	621	754	754
Total F		**754**	**754**	**754**	**887**	**754**	**754**	**754**	**754**	**754**	**754**
TMC	40	0	727	1305	0	1399	0	0	0	0	0
	50	0	0	43	0	0	220	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	286	51	1208	0	0	0	51	0	0
	80	3069	386	0	191	0	1178	1399	1347	1399	1399
Total TMC		**3069**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**	**1399**
TOTALS		**140961**	**86617**	**76291**	**105424**	**118691**	**126638**	**126856**	**125869**	**127184**	**127184**

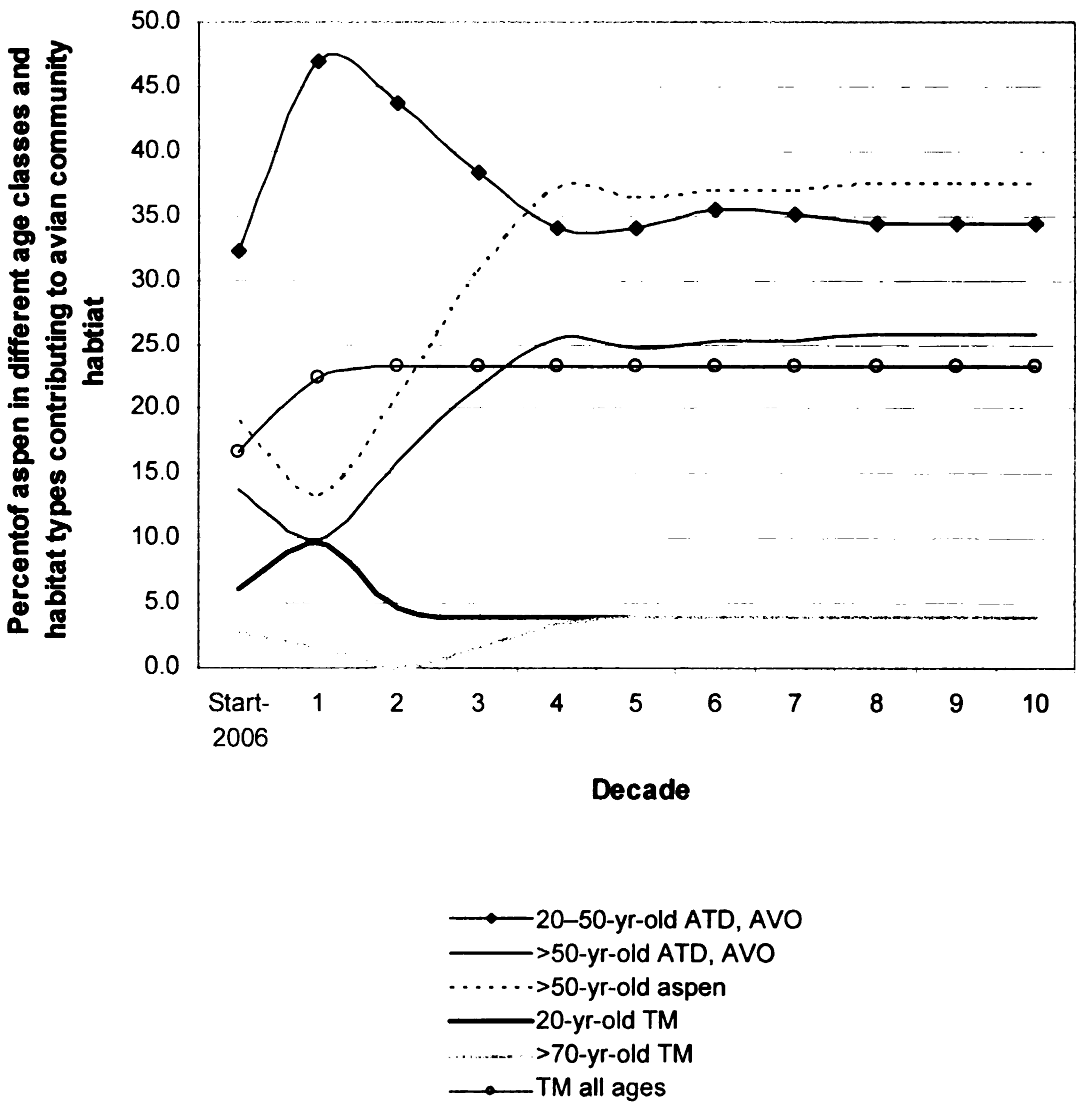


Figure 4.10. Expected percent changes in availability of different ages of aspen and habitat types that contribute to habitat for 6 avian communities using aspen during the breeding season following 10 decades of simulated timber harvest in the Upper Peninsula of Michigan. All aspen was harvested by 80 years old. Percents may sum to > 100 because some communities overlap age classes or habitat types. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*. Avian communities included those associated with 20–50-year-old aspen in the ATD and AVO habitat types, aspen ≥ 50 years within the ATD and AVO types, aspen ≥ 50 years old, aspen in the 20-year age class within the TM habitat type, aspen > 70 in the TM type, and aspen of all ages within the TM habitat type.

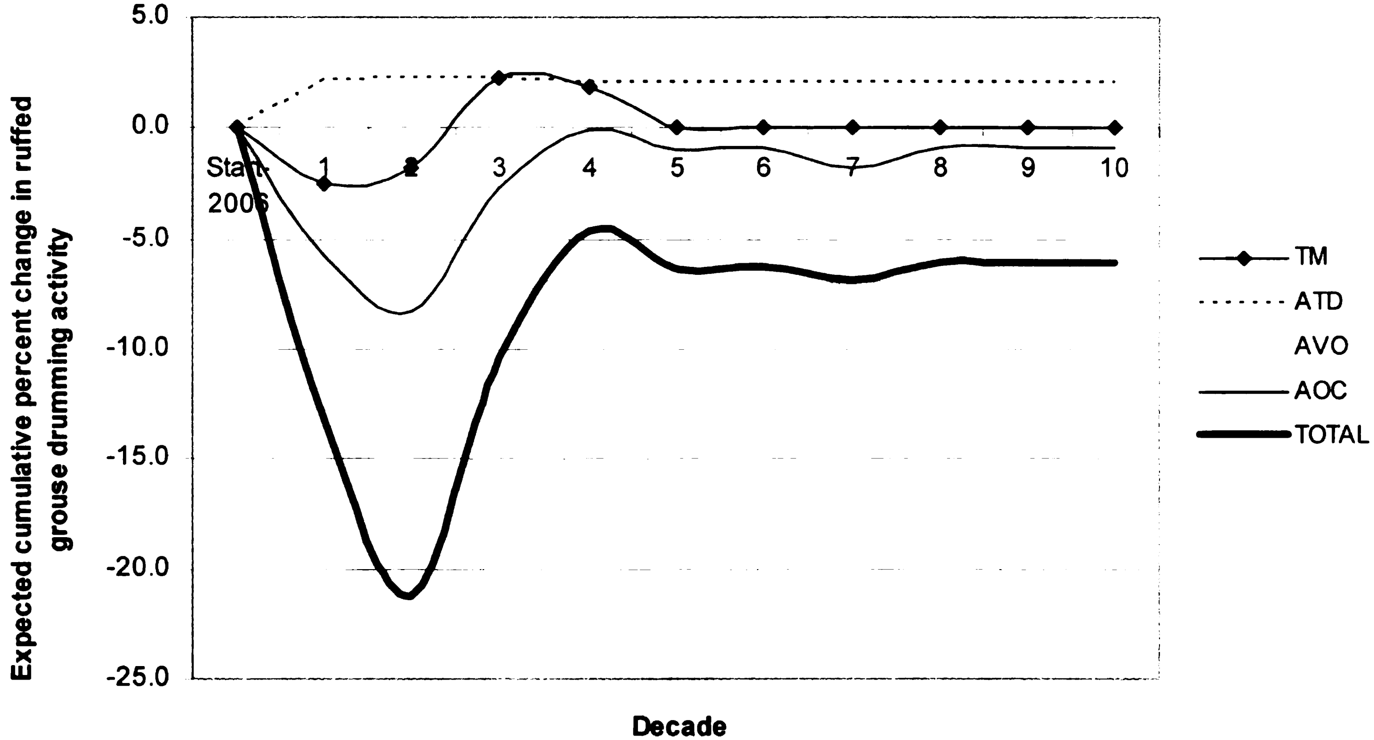


Figure 4.11. Expected changes in ruffed grouse drumming activity (number of drumming grouse) within preferred habitat types and collectively at the end of each of 10 decades following simulated aspen harvest in the Upper Peninsula of Michigan. All aspen was harvested by 80 years old. [Note: these projected trends do not consider natural cyclic fluctuations in grouse populations.] AOC = *Acer-Osmorhiza-Caulophyllum*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Scenario 2: Harvest aspen ≥ 60 years

Timber harvest

In the second scenario (i.e., harvest aspen ≥ 60 years), an even-age class distribution was only achieved in the PV and AQV habitat types by decades 10 and 7, respectively (Figure 4.12). Within the AVO habitat type, resulting area was within ± 1% of an even-age class distribution (Figure 4.13), and within the AOC type, resulting area was within ± 2% (Figure 4.14). The total number of acres that fall short of the even-age class distribution in each habitat type declined to < 700 ac by the eighth decade in all habitat types except for F (Figure 4.15).

The total number of acres harvested remained relatively constant at approximately 18,000 ac/decade by decade 5 (Figure 4.16a, Table 4.8). Harvest decreased from an initial 20,706 ac in the first decade to roughly 16,000 ac in the second decade. Number of acres harvested per decade was similar to the harvest for the first scenario (harvest aspen by 80 years). Similar fluctuations occurred for total volume harvested per decade. Initial volume was approximately 198,700 cords in the first decade, 145,500 cords in decade 2, and between 166,000 and 172,300 cords for decades 6 through 10 (Figure 4.16b, Table 4.9).

Trends in number of acres of aspen harvested were similar to those of scenario 1 for the xeric habitat types (Figure 4.17). Number of acres harvested within the QAE habitat type, however, demonstrated more fluctuation among decades until decade 8 when harvest appeared to stabilize at 1623 ac/decade (Figure 4.17, Table 4.8). Volume harvested from the xeric habitat types decreased from 57,000 cords in the first decade to about 45,000 cords/decade after decade 5 (Table 4.18). Volume harvested within the

QAE and AQV habitat types was lower in decades1–3 when more acres were harvested from aspen in the 60 year age class rather than older aspen (Figure 4.18).

Total acres harvested within the TM habitat type increased to a high of 3223 ac in decade 5 from an initial 2529 ac, and then stabilized at approximately 2500 ac in decades 6 through 8 (Figure 4.17, Table 4.8). Aspen acres harvested within the AVO habitat type remained relatively consistent throughout the 10-decade scheduling simulation (Figure 4.17). The ATD habitat type contributed < 300 ac of aspen after the first decade (Table 4.8), but the harvesting schedule never yielded an even-age class distribution. Fluctuations in volume were not as extreme as they were in Scenario 1 (Figure 4.18), although cordage was higher (Table 4.9). Volume from the AVO habitat type ranged from a low of 42,163 cords in decade 2 to a high of 52,720 cords in decade 5 (Figure 4.18, Table 4.9). Volume from the TM habitat type ranged from a low of 15,315 cords in decade 2 to 24,868 cords in decades 6 through 10 (Figure 4.18, Table 4.9). Aspen volume from the ATD habitat type was less than that harvested in Scenario 1, except in the first decade. Harvest stabilized at 1128 cords by decade 9, but did not achieve an even-age class distribution (Table 4.9).

Total area harvested within the wet-mesic habitat types (AOC, F, TMC) was similar to acres harvested in Scenario 1 (Table 4.9). Although harvested acres were similar within each habitat type as they were in Scenario 1, number of acres fluctuated more during the course of the 10-decade simulated harvested schedule (Figure 4.17). Total volume for these habitat types was also similar to that in Scenario 1 (Table 4.9), but volume did not stabilize within any of the wet-mesic habitat types (Figure 4.18).

Effects on wildlife

Avian communities. The amount of habitat available for 5 of the 6 avian communities also increased in Scenario 2, but later than in Scenario 1 for communities associated with 20–50-year old aspen within the ATD and AVO habitat types, and aspen ≥ 70 years old within the TM type. Habitat for avian species using aspen > 50 years old decreased by 6% in decade 1, but then increased by approximately 25% by decade 4 (Figure 4.19). Habitat availability for avian species using aspen > 50 years old within the ATD and AVO habitat types increased by 13% from initial conditions by decade 4. Habitat for birds using aspen within the TM type increased by 6% in decade 2, but habitat availability for birds associated with old aspen in the TM habitat type did not increase until decade 5. A 5% increase from initial conditions in habitat availability occurred for avian species using 20–50-year old aspen within the ATD and AVO habitat types by decade 4, but this followed a 26% decline from conditions in decades 1 and 2 (Figure 4.19). The only community in which a decrease in habitat availability occurred was associated with the 20-year age class within the TM habitat type, which declined 2% by decade 4 (Figure 4.19).

Ruffed grouse. Expected ruffed grouse drumming activity at the end of the aspen harvesting simulation was approximately 2% higher in Scenario 2 than in Scenario 1. Initially, however, drumming activity was expected to decrease more than in Scenario 1 because the amount of young aspen in the TM and AVO habitat types decreased more under Scenario 2. For instance, activity was expected to decrease by 14% in the first decade and then by an additional 15% in the second decade (Figure 4.20). Changes in expected activity never stabilized, but fluctuated within 1% between successive years after the fourth decade (Figure 4.20). Expected activity within the TM, ATD, and AOC habitat types increased from initial conditions, whereas activity within the AVO type decreased (Figure 4.20).

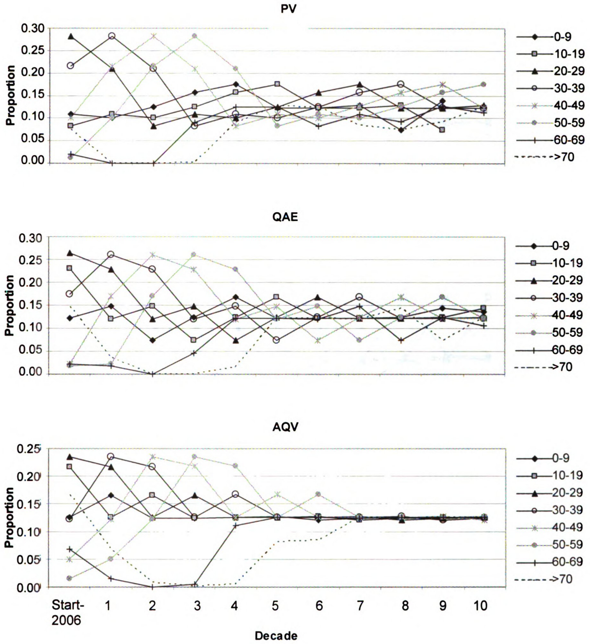


Figure 4.12. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). Only aspen $\geq$ 60 was harvested. AQV = *Acer-Quercus-Vaccinium*; *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*.

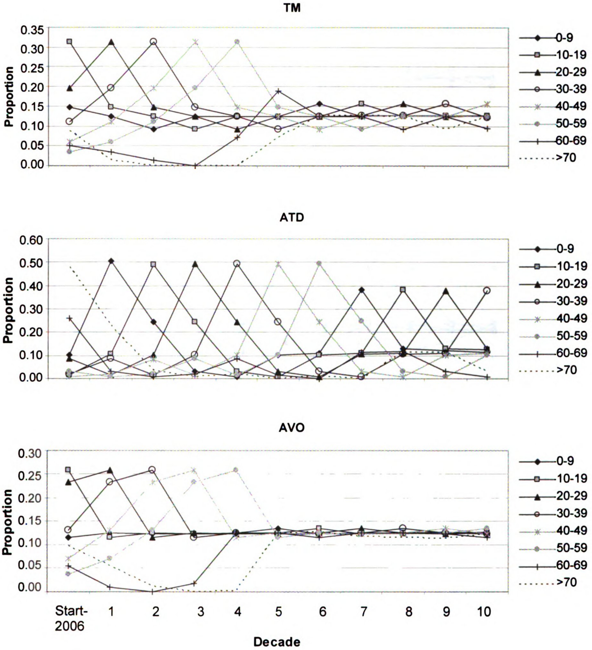


Figure 4.13. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). Only aspen ≥ 60 was harvested. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

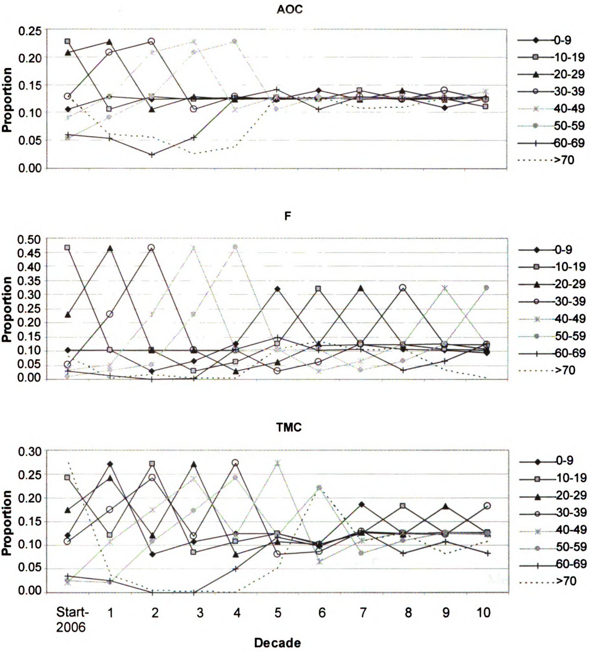


Figure 4.14. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). Only aspen $\geq$ 60 was harvested. AOC = *Acer-Osmorhiza-Caulophyllum*; F = *Fraxinus*-spp.; TMC = *Tsuga-Maianthemum-Coptis*.

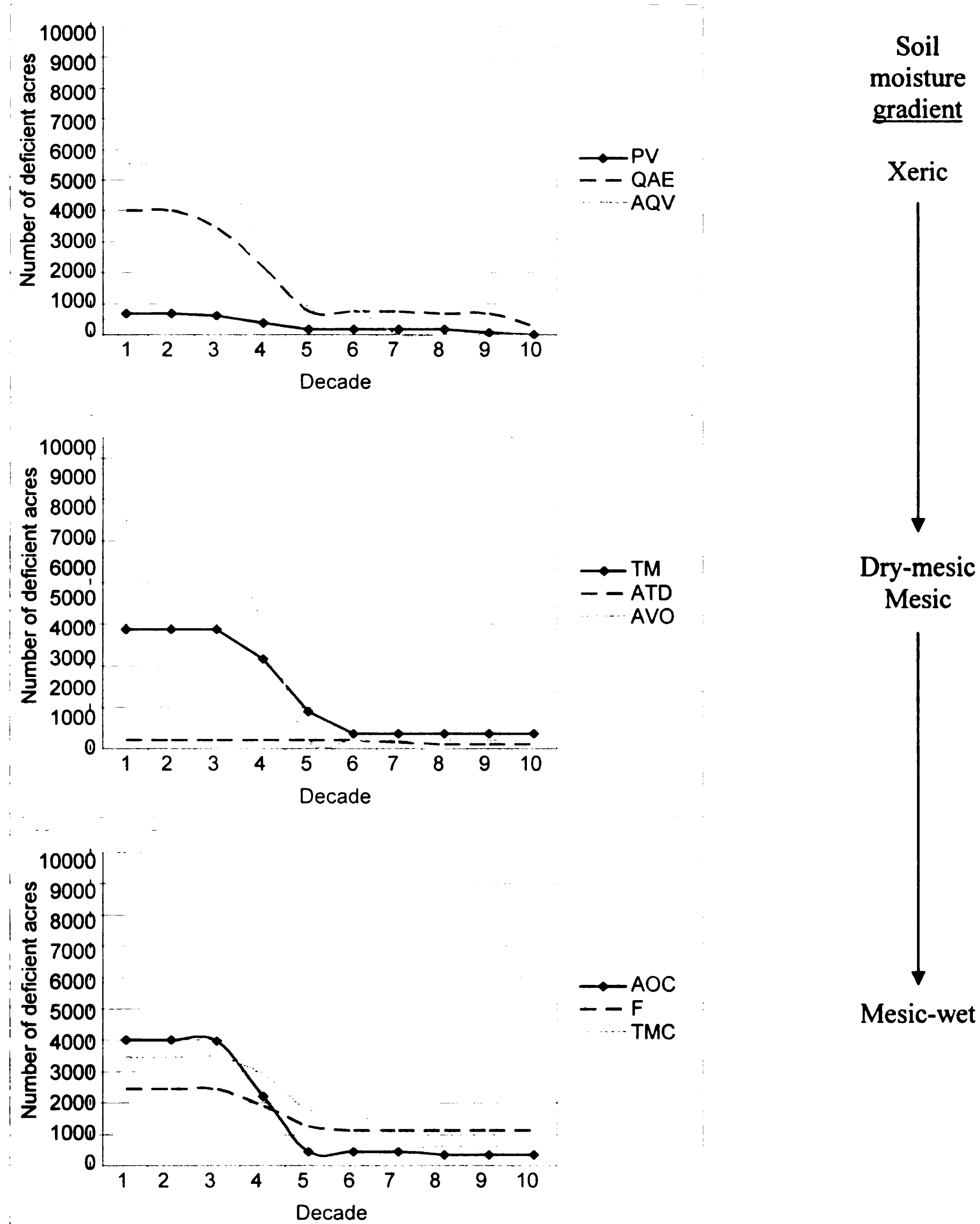


Figure 4.15. Number of deficient acres of aspen needed to establish and maintain an even-age class distribution within different habitat types over 10 decades of simulated harvest in the Upper Peninsula of Michigan. Only aspen ≥ 60 was harvested. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

A.

B.

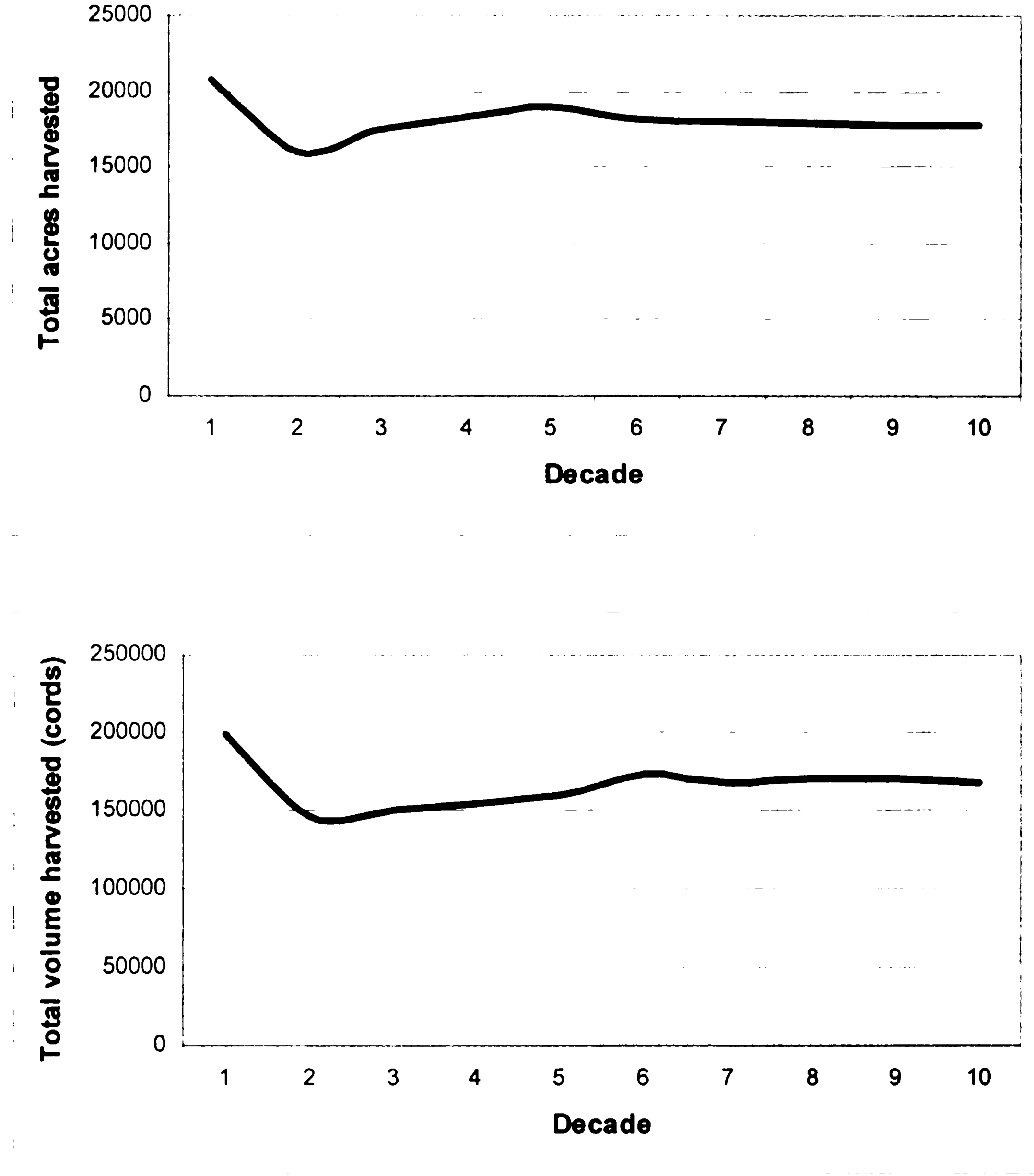


Figure 4.16. Total acres of aspen (A) and total volume (cords; B) harvested in aspen stands in the Upper Peninsula of Michigan over 10 decades of simulated harvest. Only aspen ≥ 60 was harvested.

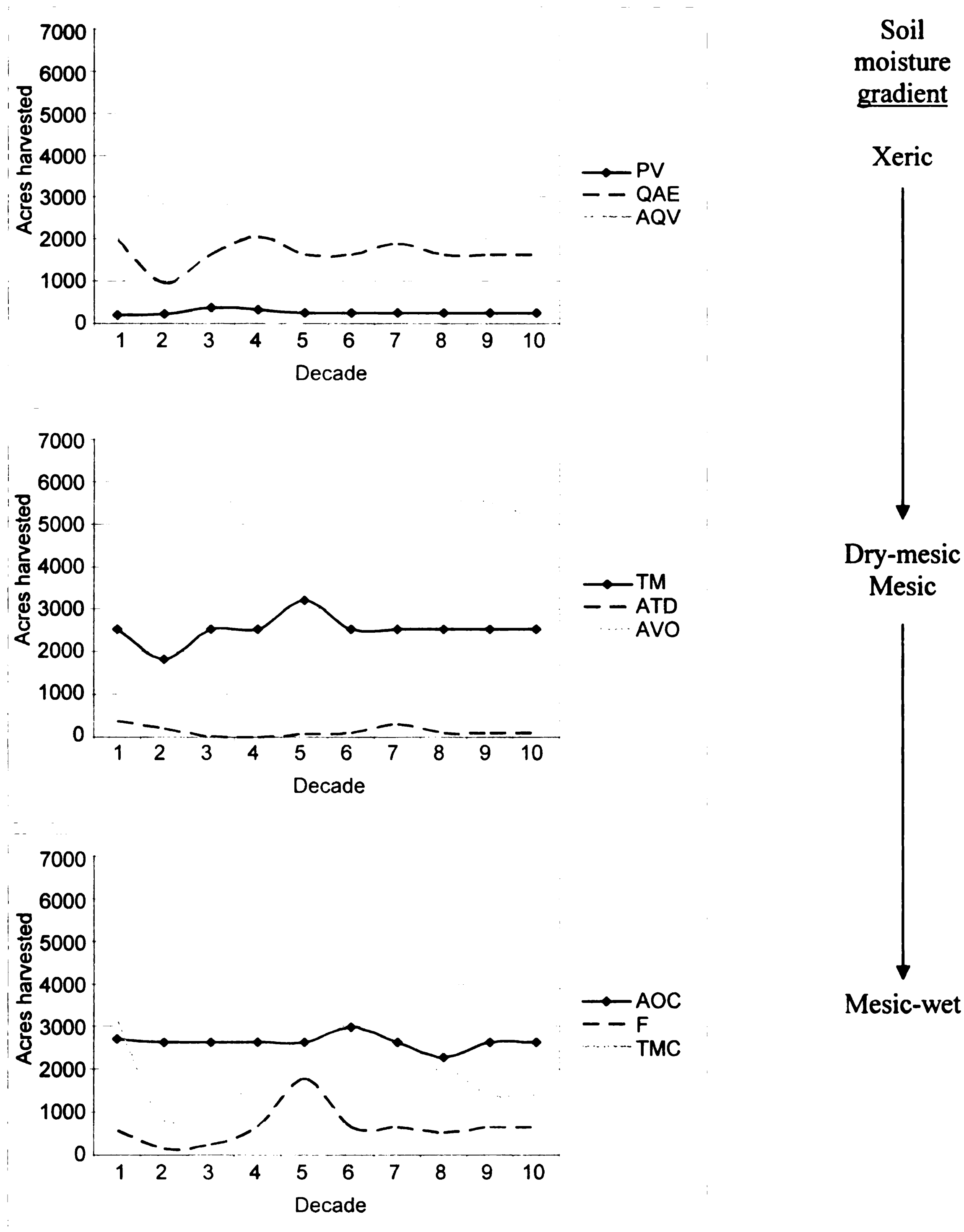


Figure 4.17. Acres of aspen to be harvested in different habitat types over 10 decades of simulated harvest to establish and maintain an even-age class distribution within habitat types in the Upper Peninsula of Michigan. Only aspen ≥ 60 was harvested. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

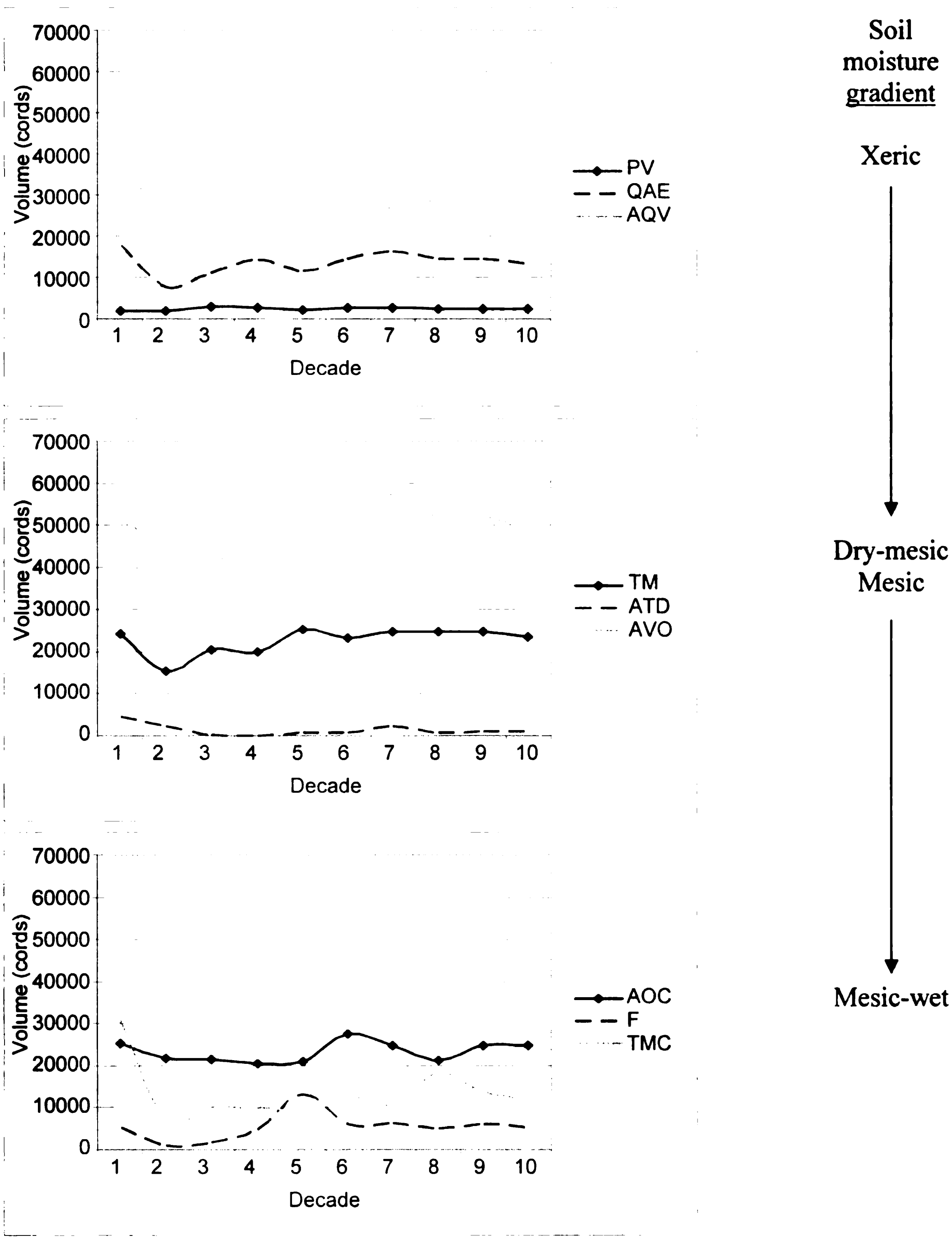


Figure 4.18. Volume (cords) to be harvested in aspen stands in different habitat types over 10 decades of simulated harvest to establish and maintain an even-age class distribution within habitat types in the Upper Peninsula of Michigan. Only aspen ≥ 60 was harvested. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

Table 4.8. Aspen harvest schedule (number of acres harvested) for state-owned lands within different habitat types in the western Upper Peninsula, Michigan over 10 decades to establish and maintain an even-age class distribution within habitat types. Harvesting strategy was to harvest all aspen ≥ 60 years.

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PV	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	25	200	247	310	167	0	0	15	0	63
	70	42	0	0	0	0	0	0	68	0	0
	80	148	0	0	0	181	247	247	164	147	185
Total PV		**215**	**200**	**247**	**310**	**348**	**247**	**247**	**247**	**147**	**247**
QAE	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	277	1578	1760	1335	0	0	0	0	788
	70	0	224	0	363	0	0	0	46	0	0
	80	1869	290	0	0	244	1578	1578	1532	1822	790
Total QAE		**1869**	**790**	**1578**	**2123**	**1578**	**1578**	**1578**	**1578**	**1822**	**1578**
AQV	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	1051	2540	2685	1989	2	908	0	0	0
	70	0	185	0	0	592	908	0	0	0	0
	80	3593	1448	145	0	103	1774	1776	2685	2685	2685
Total AQV		**3593**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**	**2685**

Table 4.8. (Cont.)

Habitat type	Harvest Age Class	Decade 1	2	3	4	5	6	7	8	9	10
TM	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	896	2224	2523	2523	463	0	0	0	644
	70	764	703	299	0	0	1259	0	0	0	0
	80	1758	281	0	0	0	1445	2523	2523	2523	1879
Total TM		**2523**	**1879**	**2523**	**2523**	**2523**	**3167**	**2523**	**2523**	**2523**	**2523**
ATD	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	81	285	98	0	0
	70	7	0	0	0	66	12	0	0	0	0
	80	376	196	24	6	15	0	0	0	98	98
Total ATD		**383**	**196**	**24**	**6**	**81**	**93**	**285**	**98**	**98**	**98**
AVO	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	1143	3109	4968	4746	5823	0	0	0	0	422
	70	36	0	0	715	0	0	0	422	422	0
	80	4281	2353	493	0	61	5461	5461	5039	5039	5039
Total AVO		**5461**	**5461**	**5461**	**5461**	**5883**	**5461**	**5461**	**5461**	**5461**	**5461**

Table 4.8. (Cont.)

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AOC	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	1376	1506	1740	1810	0	0	0	0	0
	70	0	0	0	366	0	329	0	406	0	0
	80	2696	1242	1112	512	808	2618	2618	2212	2289	2618
Total AOC		**2696**	**2618**	**2618**	**2618**	**2618**	**2948**	**2618**	**2618**	**2289**	**2618**
F	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	188	316	754	1937	0	0	0	0	0
	70	168	0	0	0	0	119	0	0	0	368
	80	488	0	52	0	0	636	754	621	656	188
Total F		**656**	**188**	**368**	**754**	**1937**	**754**	**754**	**621**	**656**	**556**
TMC	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	241	1208	1399	1399	0	1619	0	0	486
	70	0	286	0	0	0	849	0	51	0	0
	80	3069	386	0	0	0	550	456	1347	1399	913
Total TMC		**3069**	**913**	**1208**	**1399**	**1399**	**1399**	**2075**	**1399**	**1399**	**1399**
TOTALS		**20465**	**14930**	**16713**	**17878**	**19052**	**18331**	**18227**	**17230**	**17080**	**17165**

Table 4.9. Number of cords of aspen harvested on state-owned lands within different habitat types in the western Upper Peninsula, Michigan over 10 decades to establish and maintain an even-age class distribution within habitat types. Harvesting strategy was to harvest all aspen ≥ 60 years.

	Harvest	Decade									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PV	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	193	1567	1936	2426	1304	0	0	121	0	490
	70	371	0	0	0	0	0	0	601	0	0
	80	1451	0	0	0	1767	2417	2417	1605	1439	1805
Total PV		**2015**	**1567**	**1936**	**2426**	**3071**	**2417**	**2417**	**2327**	**1439**	**2295**
QAE	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	1867	10643	11865	9000	0	0	0	0	5316
	70	0	1779	0	2889	0	0	0	369	0	0
	80	16797	2603	0	0	2190	14186	14186	13769	16380	7101
Total QAE		**16797**	**6249**	**10643**	**14754**	**11190**	**14186**	**14186**	**14138**	**16380**	**12417**
AQV	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	8238	19914	21049	15599	18	7122	0	0	0
	70	0	1705	0	0	5446	8350	0	0	0	0
	80	37129	14968	1496	0	1061	18332	18356	27742	27742	27742
Total AQV		**37129**	**24911**	**21410**	**21049**	**22106**	**26700**	**25478**	**27742**	**27742**	**27742**

Table 4.9. (Cont.)

Habitat type	Harvest Age Class	Decade 1	2	3	4	5	6	7	8	9	10
TM	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	7051	17512	19862	19862	3647	0	0	0	5070
	70	6829	6278	2668	0	0	11248	0	0	0	0
	80	17292	2759	0	0	0	14205	24809	24809	24809	18476
Total TM		**24121**	**16088**	**20179**	**19862**	**19862**	**29100**	**24809**	**24809**	**24809**	**23546**
ATD	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	664	2329	799	0	0
	70	67	0	0	0	663	115	0	0	0	0
	80	4334	2253	279	64	171	0	0	0	1127	1127
Total ATD		**4401**	**2253**	**279**	**64**	**834**	**779**	**2329**	**799**	**1127**	**1127**
AVO	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	8572	23305	37246	35580	43651	0	0	0	0	3164
	70	313	0	0	6156	0	0	0	3633	3633	0
	80	40869	22456	4706	0	579	52131	52131	48102	48102	48102
Total AVO		**49754**	**45762**	**41952**	**41735**	**44230**	**52131**	**52131**	**51735**	**51735**	**51266**

Table 4.9. (Cont.)

	Harvest	Decade									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AOC	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	9909	10846	12529	13034	0	0	0	0	0
	70	0	0	0	3062	0	2750	0	3395	0	0
	80	25153	11592	10379	4778	7543	24433	24433	20641	21361	24433
Total AOC		**25153**	**21501**	**21224**	**20369**	**20577**	**27183**	**24433**	**24036**	**21361**	**24433**
F	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	1395	2339	5590	14358	0	0	0	0	0
	70	1438	0	0	0	0	1015	0	0	0	3146
	80	4645	0	499	0	0	6046	7175	5911	6245	1791
Total F		**6083**	**1395**	**2838**	**5590**	**14358**	**7061**	**7175**	**5911**	**6245**	**4937**
TMC	40	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0
	60	0	1719	8604	9963	9963	0	11534	0	0	3462
	70	0	2433	0	0	0	7225	0	438	0	0
	80	29732	3735	0	0	0	5327	4420	13050	13549	8842
Total TMC		**29732**	**7887**	**8604**	**9963**	**9963**	**12552**	**15954**	**13488**	**13549**	**12303**
TOTALS		**195186**	**127613**	**129064**	**135813**	**146192**	**172110**	**168913**	**164986**	**164387**	**160067**

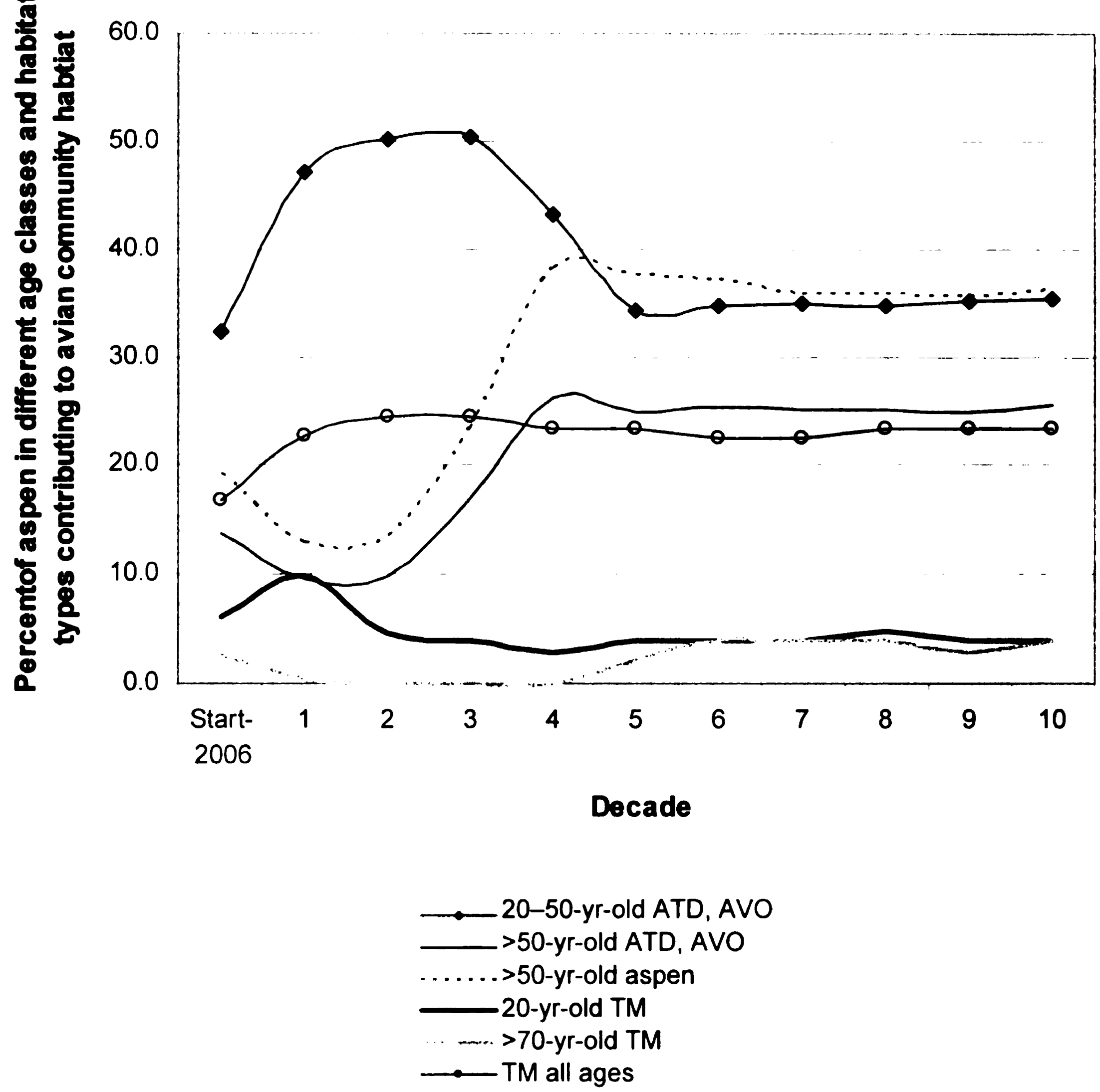


Figure 4.19. Expected changes in availability of different ages of aspen and habitat types that contribute to habitat for 6 avian communities using aspen during the breeding season following 10 decades of simulated timber harvest in the Upper Peninsula of Michigan. Only aspen ≥ 60 years old was harvested. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*. Avian communities included those associated with 20–50-year-old aspen in the ATD and AVO habitat types, aspen ≥ 50 years within the ATD and AVO types, aspen ≥ 50 years old, aspen in the 20-year age class within the TM habitat type, aspen > 70 in the TM type, and aspen of all ages within the TM habitat type.

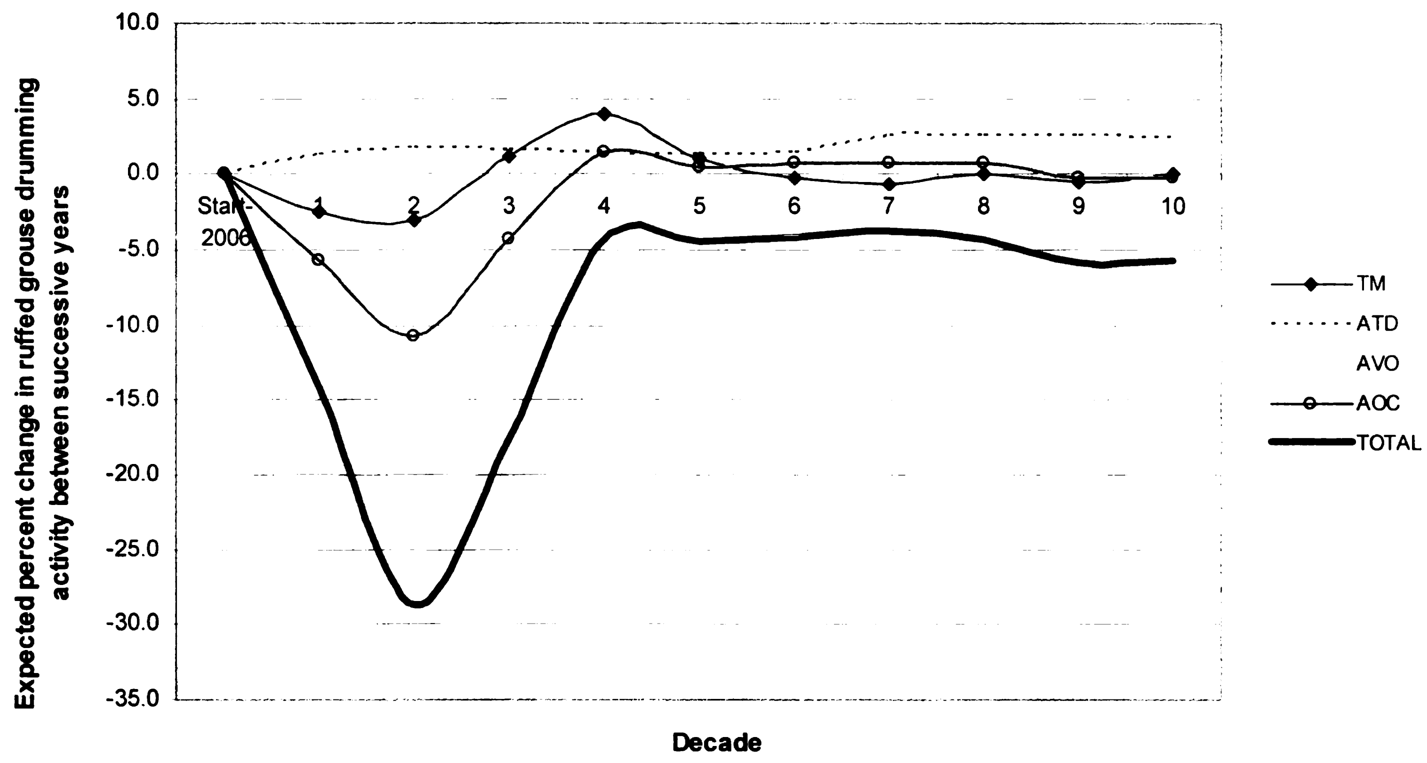


Figure 4.20. Expected changes in ruffed grouse drumming activity (number of grouse drumming) within preferred habitat types and collectively following 10 decades of simulated timber harvest in the Upper Peninsula of Michigan. Only aspen ≥ 60 years old was harvested. [Note: these projected trends do not consider natural cyclic fluctuations in grouse populations.] AOC = *Acer-Osmorhiza-Caulophyllum*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza.*

Scenario 3: Intensive harvest of aspen (60% of all aspen harvested from the 40-year age class)

Timber harvest

In the third scenario, establishing an even-age class distribution under a more intensive management scheme (i.e., harvest most aspen on a 40-year rotation) was not feasible (Figures 4.21–4.23). Representation of aspen in all age classes within all habitat types was not even feasible under this management scenario (Figures 4.21–4.23). The total number of acres that fell short of the even-age class distribution in each habitat type declined after the sixth decade in most habitat types, but was still > 1000 ac by the end of decade 10 in 7 habitat types (Figure 4.24).

The total number of acres harvested fluctuated between roughly 22,000 and 30,000, but exhibited a downward trend over the 10 simulated decades (Figure 4.25a). Total volume harvested per decade also declined over the simulated timeframe. Initial volume was approximately 220,000,700 cords in the first decade, but declined to 127,000 cords in decade 10 (Figure 4.25b, Table 4.10).

The number of acres of aspen harvested was not stable within the xeric habitat types (Figure 4.26). Total number of acres declined over time, except for a peak in harvest in decade 6 in all xeric habitat types (Figure 4.26, Table 4.10). Number of acres harvested declined by 2300 acres within the PV habitat type, 400 ac within the QAE habitat type, and 220 within the AQV type (Table 4.10). Volume harvested from the xeric habitat types exhibited a similar pattern (Figure 4.27).

Total acres harvested within the TM habitat type increased from an initial 3983 ac to a high of 7007 ac in decade 3, but declined in subsequent decades to 2523 ac in decade

10 (Figure 4.26, Table 4.10). Aspen acres harvested within the AVO habitat type increased throughout the simulation with 2 large peaks in decades 3 and 6. Harvest increased by over 7,000 ac from initial conditions in decades 3 and 6 (Figure 4.26). Final harvest was approximately 1700 ac higher than initial harvest (Figure 4.26). The ATD habitat type contributed 391 ac of aspen after the first decade, and declined to 171 ac by decade 10 (Table 4.10). Total volume declined in all dry-mesic habitat types over the simulated timeframe, although fluctuations in yield were evident (Figure 4.27; Table 4.11).

Total area harvested within 2 wet-mesic habitat types (AOC, TMC) also exhibited a downward trend over the duration of the simulation (Figure 4.26, Table 4.10). Harvest from the AOC habitat type declined by approximately 2000 ac, and harvest declined by roughly 3000 ac from the TMC habitat type (Table 4.10). Although harvest from the F habitat type fluctuated, initial and final harvests were the same (804 ac). Total volume for these habitat types also decreased throughout time (Figure 4.27, Table 4.11).

Effects on wildlife

Avian communities. Habitat availability generally was lower for avian communities under Scenario 3 than the other 2 management scenarios. The amount of habitat available for 4 of the 6 avian communities increased in Scenario 3 from initial to final conditions, but was lower than in the other scenarios and exhibited dramatic fluctuations during the simulation (Figure 4.28). Available habitat for avian species using aspen > 50 years old within the ATD and AVO habitat types increased by 6% from initial conditions by decade 4, but then decreased by 16% by decade 6. Habitat availability increased again in subsequent decades and was 5% higher in decade 10 than in initial conditions (Figure 4.28). Habitat availability for avian species using aspen > 50 years old increased by 4% between the first and last decades (Figure 4.28). Habitat for birds using aspen within the TM type decreased by 2% between the first and last decades. Habitat availability for avian communities using old aspen within the TM habitat declined to 0 in decades 4 through 9 (Figure 4.28).

Ruffed grouse. Expected ruffed grouse drumming activity at the end of the aspen harvesting simulation was much higher in decade 3 than in Scenarios 1 and 2, but resulted in lower predictions at the end of decade 10 (Figure 4.29). Changes in expected activity never stabilized and fluctuated drastically, with an overall decline in activity. Expected activity within the TM and ATD habitat types was more stable than in other habitat type (Figure 4.29).

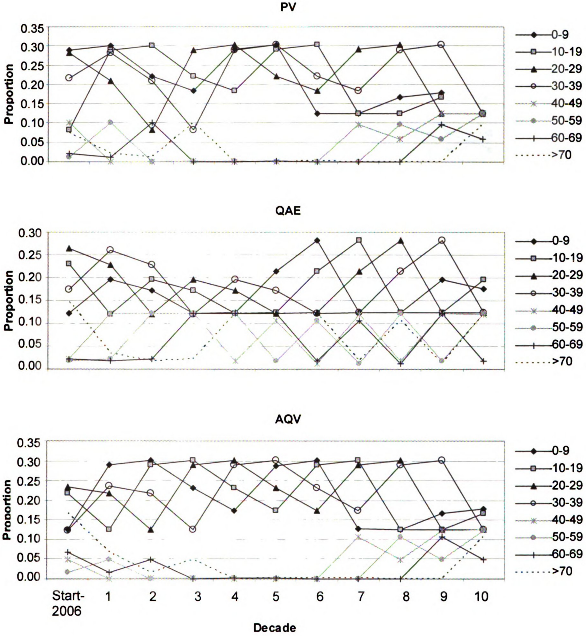


Figure 4.21. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). Most (60%) of the aspen was harvested on a 40-year rotation. AQV = *Acer-Quercus-Vaccinium*; *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea.*

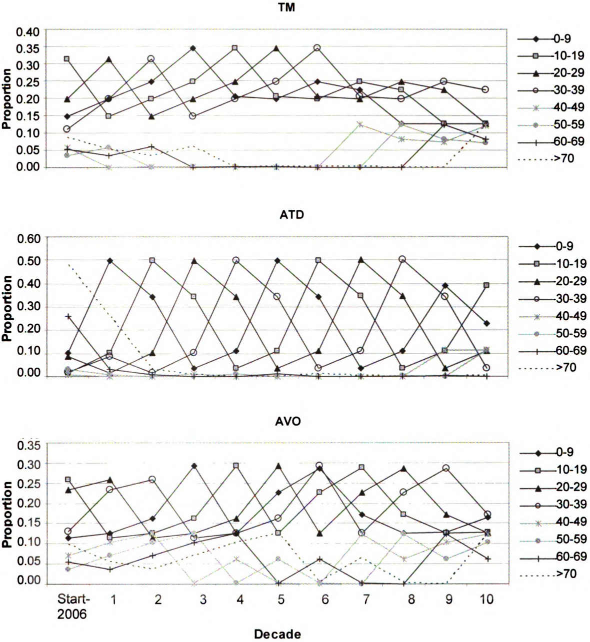


Figure 4.22. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). Most (60%) of the aspen was harvested on a 40-year rotation. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

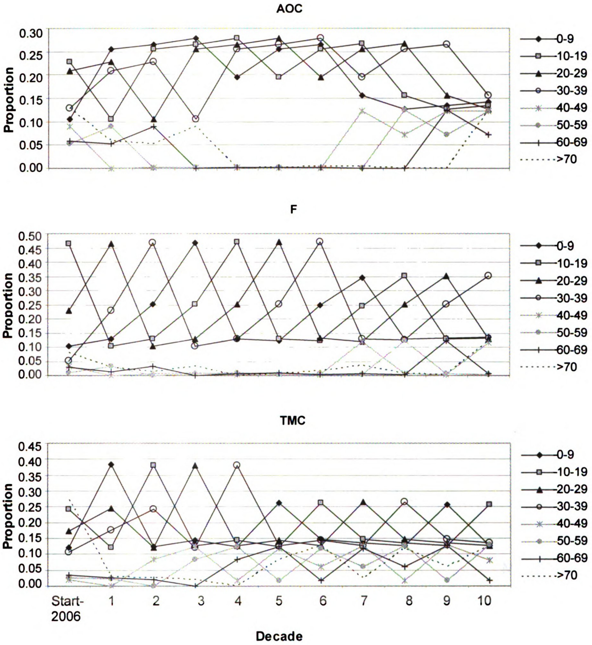


Figure 4.23. Average proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest (n = 5 simulations). Most (60%) of the aspen was harvested on a 40-year rotation. AOC = *Acer-Osmorhiza-Caulophyllum*; F = *Fraxinus*-spp.; TMC = *Tsuga-Maianthemum-Coptis*.

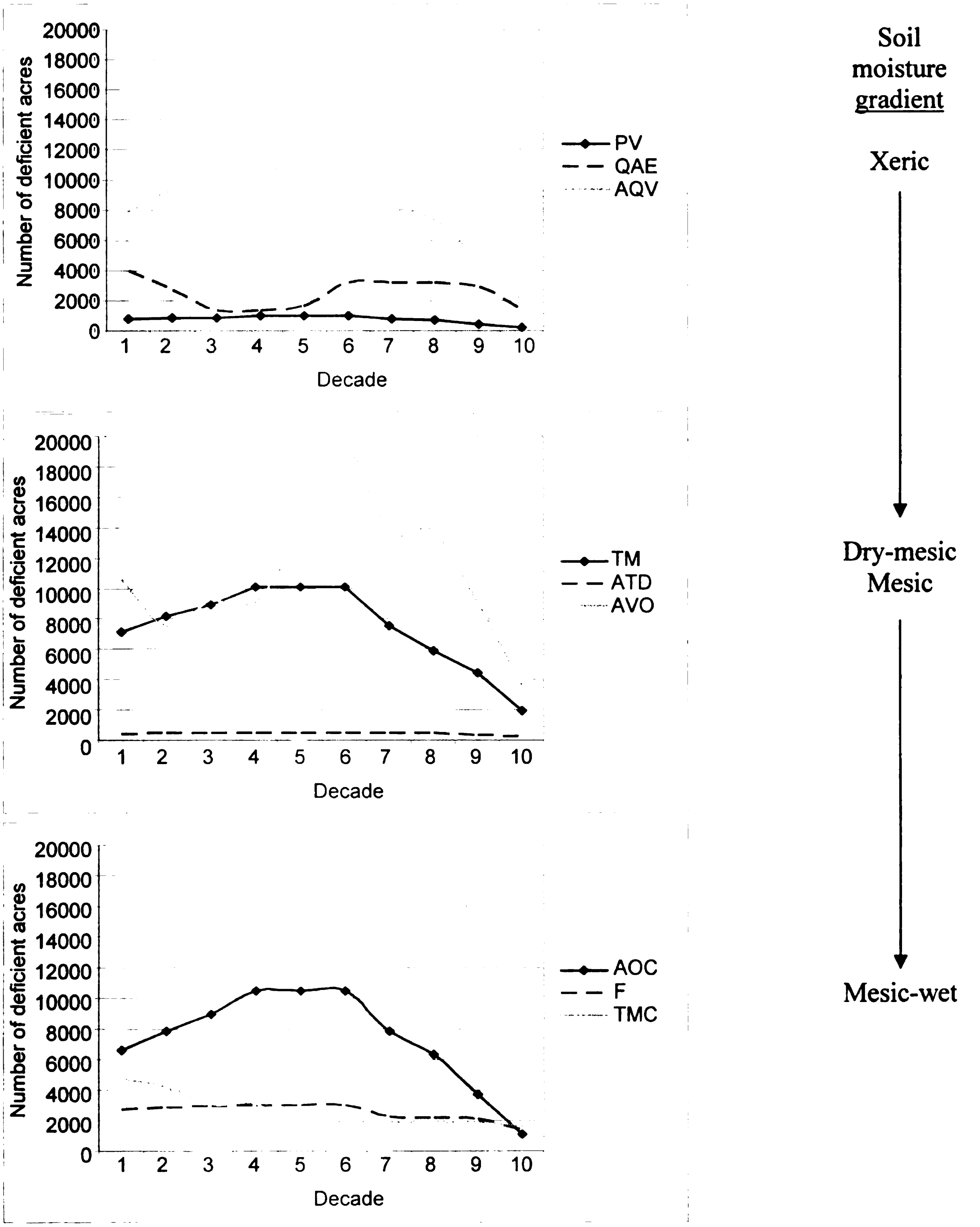
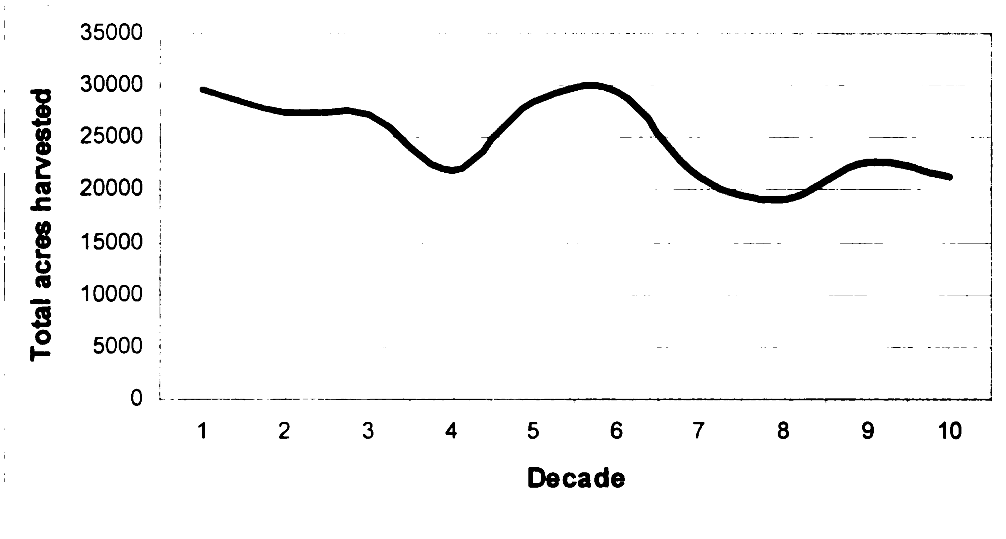


Figure 4.24. Number of deficient acres of aspen needed to establish and maintain an even-age class distribution within different habitat types over 10 decades of simulated harvest in the Upper Peninsula of Michigan. Most (60%) of the aspen was harvested on a 40-year rotation. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

A.



B.

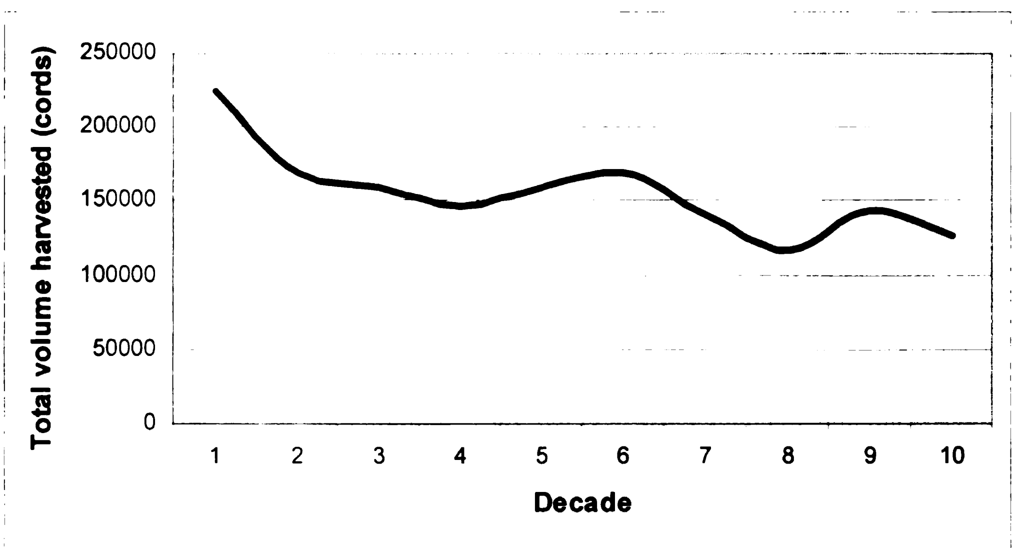


Figure 4.25. Total acres of aspen (A) and total volume (cords; B) harvested in aspen stands in the Upper Peninsula of Michigan over 10 decades of simulated harvest. Most (60%) of the aspen was harvested on a 40-year rotation.

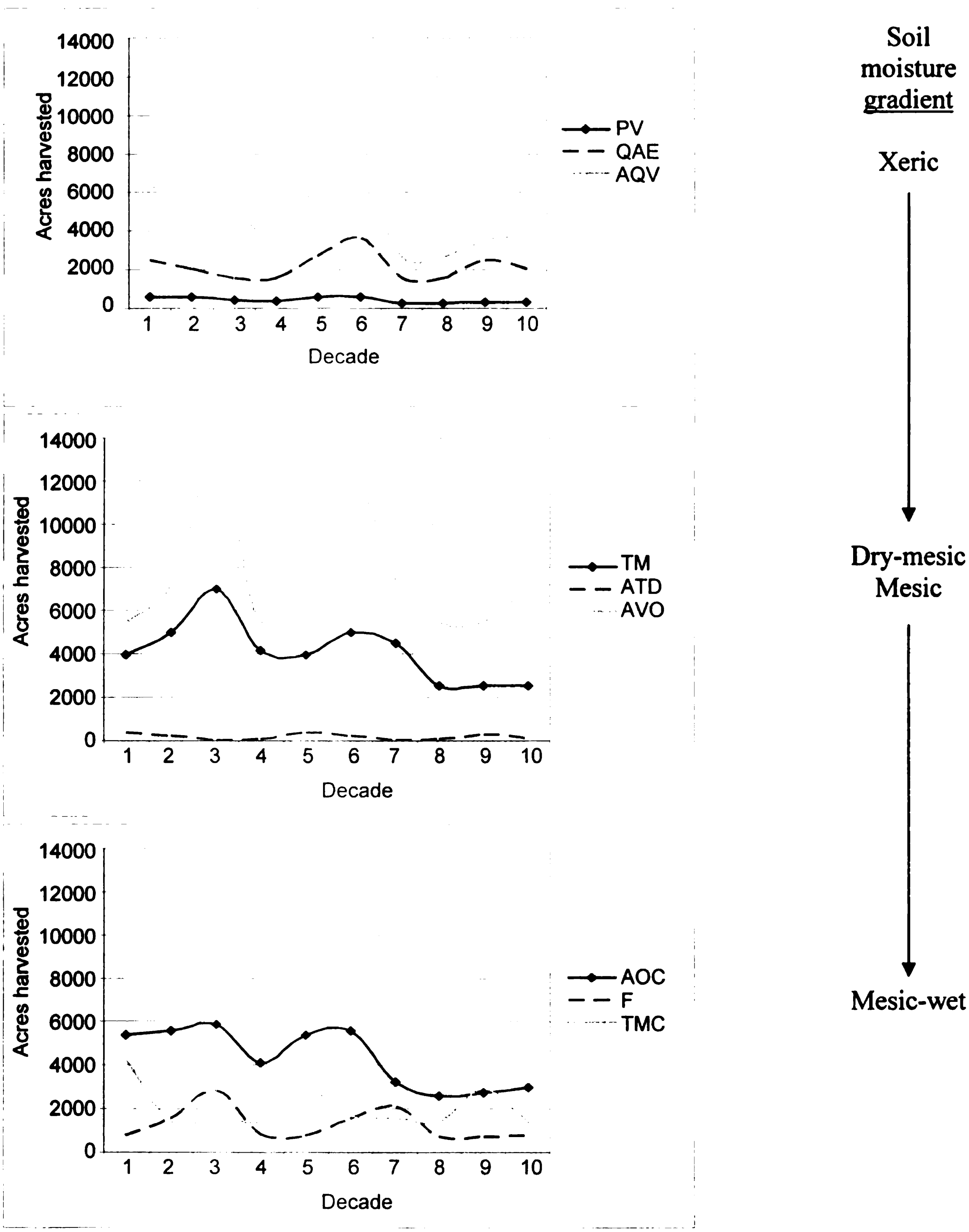


Figure 4.26. Acres of aspen to be harvested in different habitat types over 10 decades of simulated harvest to establish and maintain an even-age class distribution within habitat types in the Upper Peninsula of Michigan. Most (60%) of the aspen was harvested on a 40-year rotation. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

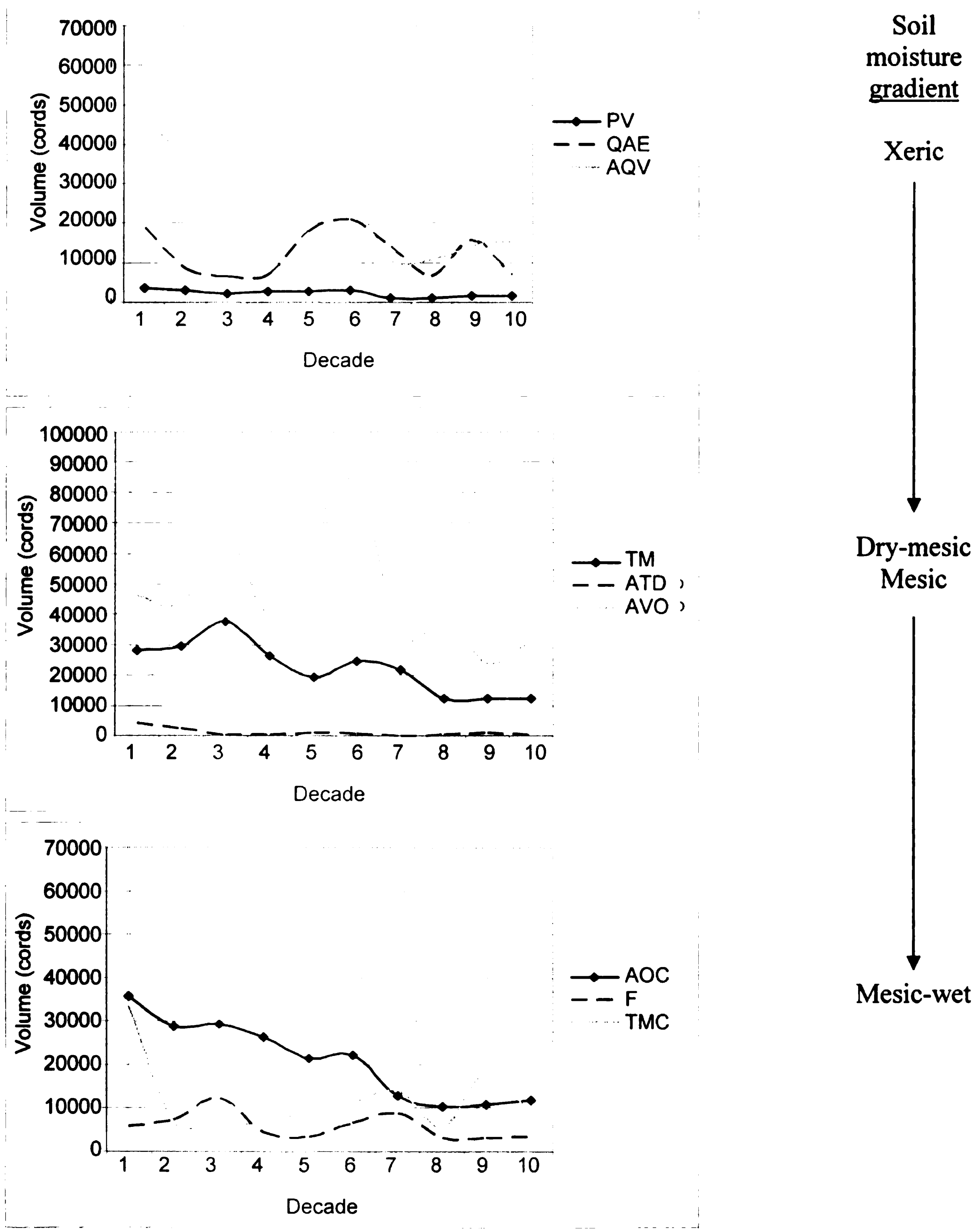


Figure 4.27. Volume (cords) to be harvested in aspen stands in different habitat types over 10 decades of simulated harvest to establish and maintain an even-age class distribution within habitat types in the Upper Peninsula of Michigan. Most (60%) of the aspen was harvested on a 40-year rotation. AOC = *Acer-Osmorhiza-Caulophyllum*; AQV = *Acer-Quercus-Vaccinium*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; F = *Fraxinus*-spp.; PV = *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*; TM = *Tsuga-Maianthemum*; TMC = *Tsuga-Maianthemum-Coptis*.

Table 4.10. Aspen harvest schedule (number of acres harvested) for state-owned lands within different habitat types in the western Upper Peninsula, Michigan over 10 decades to establish and maintain an even-age class distribution within habitat types. Harvesting strategy was to harvest 60% of all aspen on a 40 year rotation. Total aspen area did not decrease.

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PV	40	428	557	414	164	577	599	247	247	329	352
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	148	42	25	200	0	0	0	0	0	0
Total PV		**577**	**599**	**439**	**364**	**577**	**599**	**247**	**247**	**329**	**352**
QAE	40	607	1760	1355	1302	1149	2049	20	1348	1149	2049
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	1869	290	224	277	1578	1578	1558	230	1327	0
Total QAE		**2476**	**2049**	**1578**	**1578**	**2727**	**3628**	**1578**	**1578**	**2476**	**2049**
AQV	40	2642	5051	4674	2687	6235	6499	2685	2685	3551	3815
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	3593	1448	330	1051	0	0	0	0	0	0
Total AQV		**6235**	**6499**	**5004**	**3738**	**6235**	**6499**	**2685**	**2685**	**3551**	**3815**

Table 4.10. (Cont.)

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
TM	40	2224	3967	6305	2986	3983	5012	4485	2523	2523	2523
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	1758	1045	703	1194	0	0	0	0	0	0
Total TM		**3983**	**5012**	**7007**	**4180**	**3983**	**5012**	**4485**	**2523**	**2523**	**2523**
ATD	40	15	66	12	81	391	269	36	87	293	171
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	376	202	24	6	0	0	0	0	0	0
Total ATD		**391**	**269**	**36**	**87**	**391**	**269**	**36**	**87**	**293**	**171**
AVO	40	1180	4766	11284	2353	5461	7155	7459	2775	5461	7135
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	4281	2389	1636	3109	4564	5441	0	2687	0	0
Total AVO		**5461**	**7155**	**12920**	**5461**	**10025**	**12596**	**7459**	**5461**	**5461**	**7135**

Table 4.10. (Cont.)

	Harvest	Decade									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AOC	40	2681	4358	4758	2212	5376	5600	3251	2618	2758	2982
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	2696	1242	1112	1888	0	0	0	0	0	0
Total AOC		**5376**	**5600**	**5870**	**4100**	**5376**	**5600**	**3251**	**2618**	**2758**	**2982**
F	40	316	1390	2810	621	804	1558	2108	754	754	804
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	488	168	52	188	0	0	0	0	0	0
Total F		**804**	**1558**	**2862**	**810**	**804**	**1558**	**2108**	**754**	**754**	**804**
TMC	40	1208	1013	1305	1157	2878	742	192	1209	1480	742
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	3069	386	286	241	0	935	1399	190	1399	657
Total TMC		**4277**	**1399**	**1591**	**1399**	**2878**	**1677**	**1591**	**1399**	**2878**	**1399**
TOTALS		**29580**	**30141**	**37308**	**21717**	**32997**	**37439**	**23440**	**17352**	**21024**	**21229**

Table 4.11. Number of cords of aspen harvested on state-owned lands within different habitat types in the western Upper Peninsula, Michigan over 10 decades to establish and maintain an even-age class distribution within habitat types. Harvesting strategy was to harvest 60% of all aspen on a 40-year rotation. Total aspen area did not decrease.

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PV	40	2081	2709	2012	798	2803	2912	1202	1202	1601	1710
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	1451	408	241	1957	0	0	0	0	0	0
Total PV		**3532**	**3117**	**2253**	**2755**	**2803**	**2912**	**1202**	**1202**	**1601**	**1710**
QAE	40	2027	5879	4526	4348	3837	6846	67	4503	3837	6846
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	16797	2603	2009	2489	14186	14186	14005	2072	11927	0
Total QAE		**18824**	**8482**	**6536**	**6837**	**18023**	**21032**	**14072**	**6575**	**15764**	**6846**
AQV	40	10713	20478	18950	10894	25280	26351	10884	10884	14396	15467
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	37129	14968	3413	10858	0	0	0	0	0	0
Total AQV		**47843**	**35447**	**22363**	**21751**	**25280**	**26351**	**10884**	**10884**	**14396**	**15467**

Table 4.11. (Cont.)

	Harvest	**Decade**									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
TM	40	10890	19425	30869	14620	19500	24541	21958	12352	12352	12352
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	17292	10275	6910	11744	0	0	0	0	0	0
Total TM		**28183**	**29700**	**37779**	**26364**	**19500**	**24541**	**21958**	**12352**	**12352**	**12352**
ATD	40	46	205	36	251	1206	829	110	268	904	527
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	4334	2331	279	64	0	0	0	0	0	0
Total ATD		**4380**	**2536**	**314**	**315**	**1206**	**829**	**110**	**268**	**904**	**527**
AVO	40	5184	20942	49579	10336	23995	31438	32774	12191	23995	31349
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	40869	22804	15621	29675	43569	51938	0	25646	0	0
Total AVO		**46053**	**43745**	**65200**	**40011**	**67564**	**83376**	**32774**	**37837**	**23995**	**31349**

Table 4.11. (Cont.)

	Harvest	Decade									
Habitat type	Age Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AOC	40	10651	17315	18901	8788	21360	22250	12917	10402	10957	11847
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	25153	11592	10379	17620	0	0	0	0	0	0
Total AOC		**35804**	**28906**	**29280**	**26408**	**21360**	**22250**	**12917**	**10402**	**10957**	**11847**
F	40	1334	5877	11882	2627	3399	6588	8915	3189	3189	3399
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	4645	1600	499	1791	0	0	0	0	0	0
Total F		**5979**	**7477**	**12381**	**4418**	**3399**	**6588**	**8915**	**3189**	**3189**	**3399**
TMC	40	3903	3274	4217	3740	9301	2396	621	3906	4782	2396
	50	0	0	0	0	0	0	0	0	0	0
	60	0	0	0	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0	0	0	0
	80	29732	3735	2769	2338	0	9062	13549	1839	13549	6365
Total TMC		**33635**	**7009**	**6985**	**6078**	**9301**	**11458**	**14170**	**5745**	**18331**	**8761**
TOTALS		**224232**	**166419**	**183091**	**134936**	**168436**	**199337**	**117002**	**88455**	**101490**	**92258**

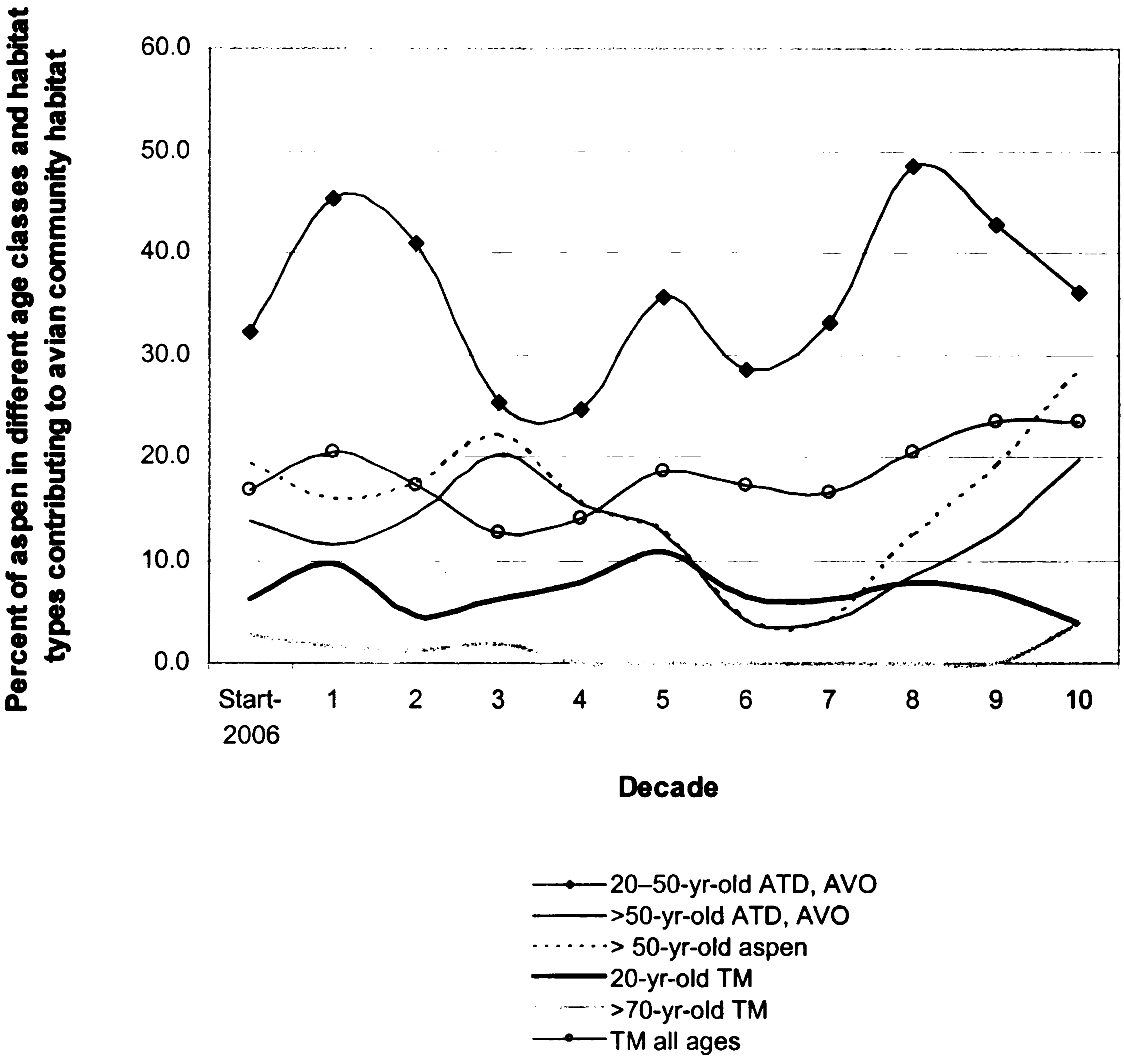


Figure 4.28. Expected changes in availability of different ages of aspen and habitat types that contribute to habitat for 6 avian communities using aspen during the breeding season following 10 decades of simulated timber harvest in the Upper Peninsula of Michigan. Most (60%) of the aspen was harvested on a 40-year rotation. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*. Avian communities included those associated with 20–50-year-old aspen in the ATD and AVO habitat types, aspen ≥ 50 years within the ATD and AVO types, aspen ≥ 50 years old, aspen in the 20-year age class within the TM habitat type, aspen > 70 in the TM type, and aspen of all ages within the TM habitat type.

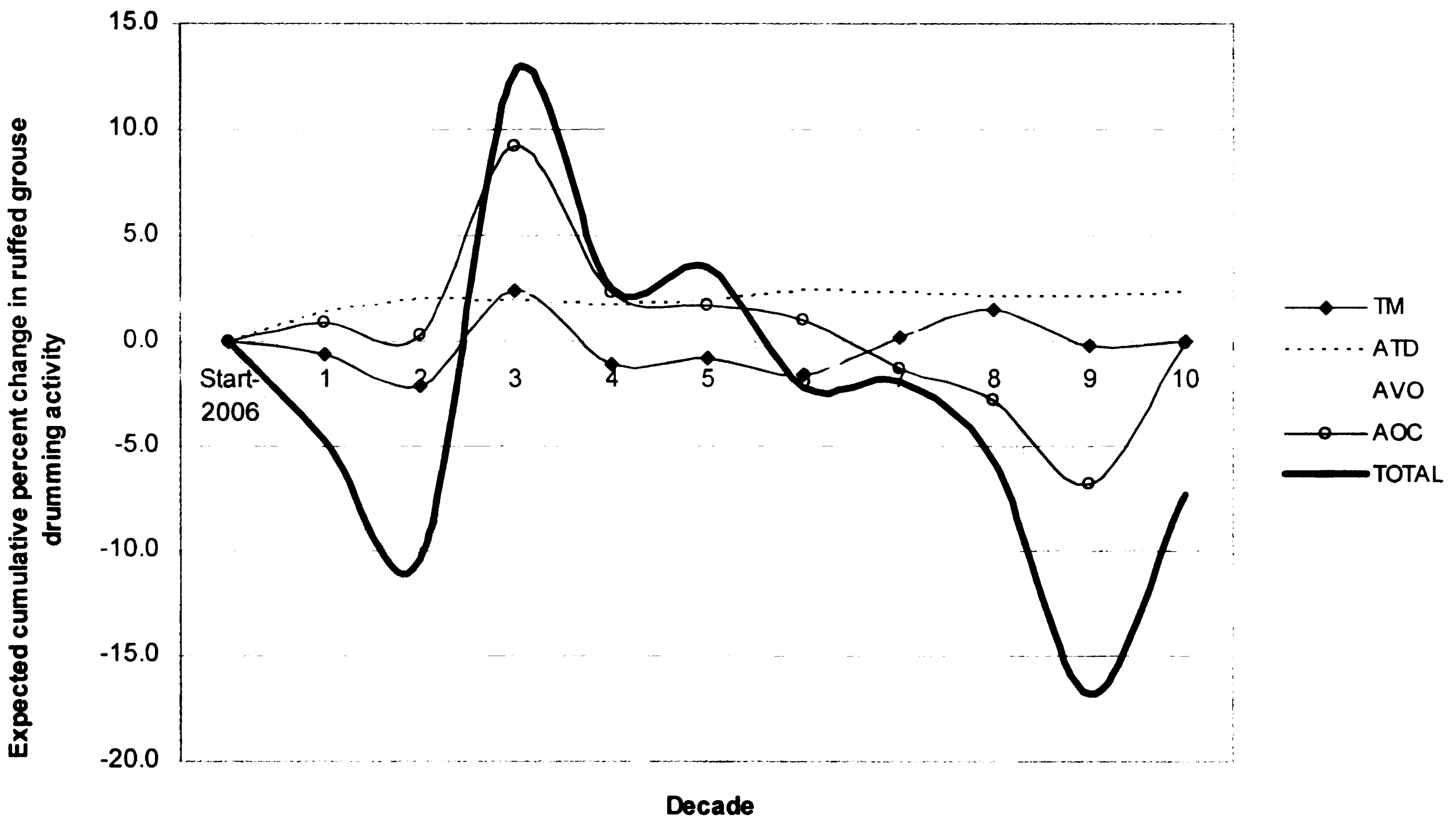


Figure 4.29. Expected changes in ruffed grouse drumming activity (number of drumming grouse) within preferred habitat types and collectively following 10 decades of simulated timber harvest in the Upper Peninsula of Michigan. Most (60%) of the aspen was harvested on a 40-year rotation. [Note: these projected trends do not consider natural cyclic fluctuations in grouse populations.] AOC = *Acer-Osmorhiza-Caulophyllum*; ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

Landscape metrics

The amount of area classified as forest interior slightly increased from 411,889 ac to > 416,000 ac by decade 10 under scenarios 1 and 2, but remained similar to initial conditions under scenario 3 (Figure 4.30). The amount of forest interior under scenario 3 was always lower than that under scenarios 1 and 2 throughout the simulated timeframe (Figure 4.30). Fluctuations in the amount of forest interior between years differed among all scenarios, except in scenarios 1 and 2 after decade 8 when an even-age class distribution was achieved. The largest difference in the amount of interior area was observed in decade 3 between scenario 2 (418,384 ac) and scenario 3 (381,449 ac; Figure 4.31). The amount of edge declined under all management scenarios throught the simulation (Figure 4.30).

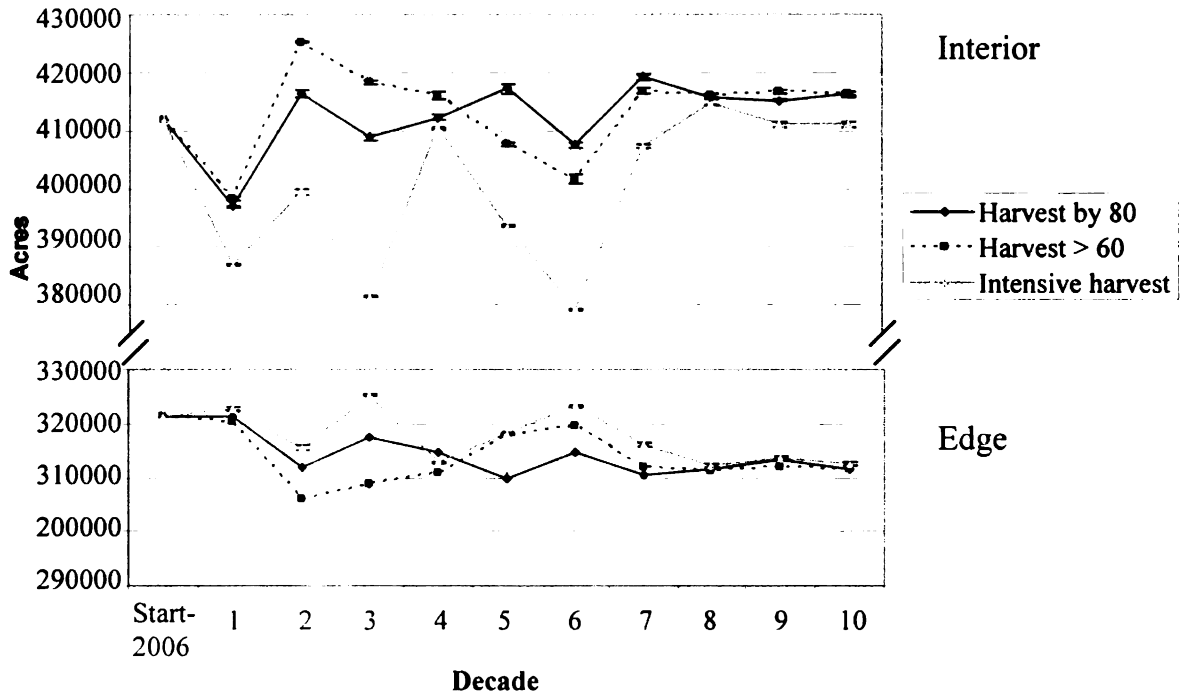


Figure 4.30. Amount of forested area classified as interior and edge after 10 decades of simulated aspen harvest in the western Upper Peninsula, Michigan under 3 management scenarios: harvest all aspen by 80 years, harvest aspen > 60 years, and a more intensive harvest where 60% of all aspen harvested was in the 40-year age class. Edge area was defined as area within 295 feet (90 m) of a forest edge.

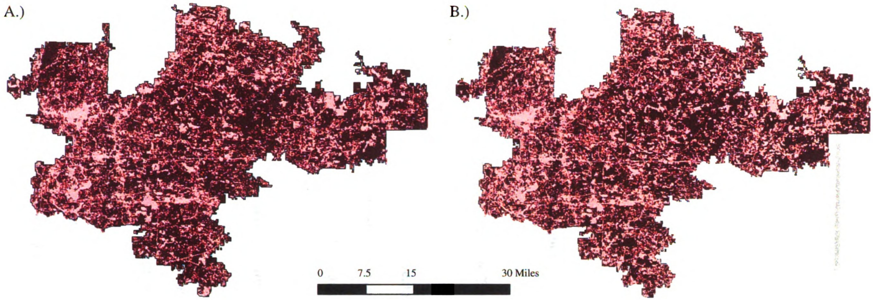


Figure 4.31. Maps of forest interior (dark shades) and edge (light shades) in a 300 mi^2 area in the western Upper Peninsula, Michigan during decade 3 of a 10-decade simulated aspen harvest where all aspen > 60 years old was harvested (A; more interior), and where ≥ 60% of the aspen harvested was from the 40-year age class (B; less interior). Edge was considered any area within 295 ft (90 m) of a forest edge.

DISCUSSION

Several concepts and techniques were integrated and synthesized in this chapter to demonstrate a process for identifying the effects of aspen management practices on wildlife and timber resources. For instance, the habitat-type classification system was used to predict vegetation development and successional change of aspen, and was linked with wildlife community and species associated with different successional stages of aspen in various habitat types. Then, availability and spatial and temporal distribution of aspen was manipulated through spatial simulations of harvest schedules developed through goal programming methods to establish and maintain an even-age class distribution of aspen within habitat types under 3 different management scenarios that MDNR managers and planners were most interested in to maintain forest and wildlife resources over time. The results of the analysis revealed the spatial feasibility of implementing harvest schedules, and the most pronounced effects of forest management on wildlife and timber under each scenario and throughout space and time.

Feasibility of implementing harvest schedules developed from goal programming methods

Timber harvesting schedules are obviously important to identify the best strategies for meeting specific objectives. Linear programming has typically been used to develop harvesting schedules that maximize values of a specific goal such as volume or revenue, or minimize costs, but may present problems when trying to find solutions to multiple goals. Goal programming was derived from linear programming methods to find solutions that minimize deviations from meeting specified goals (Buongiorno and Gilless 2003).

Foresters have developed harvest scheduling plans using tools such as Spectrum (USDA Forest Service 1995) and FORPLAN (Johnson et al. 1996). Although those tools are useful for constructing linear-based programming models that can help evaluate alternative management strategies, they may be complicated to use. Excel Solver is a Microsoft Excel Add-in tool that can easily be used within a spreadsheet framework for constructing linear-based programming models. Solver has not typically been used to solve goal programming problems, but it has been shown to produce solutions consistent with other optimization software with the advantage of being easily displayed in a spreadsheet (Steiguer 2000). The Solver Add-in tool limits the size of the problems that can be solved by the maximum number of decision variables (n = 200) and constraints (n = 100) that can be specified. I had 1350 decision variables (i.e., number of acres harvested in 5 age classes, 9 habitat types, and 10 decades); thus I used Premium Solver, which allows up to 2000 decision variables.

Gustafson et al. (2006) demonstrated a process of linking linear programming models and spatial simulation models to predict spatial and temporal effects of forest management. In this chapter, I used a similar procedure and determined that the harvest schedule from the goal-programming model was spatially feasible, and that HARVEST allowed assessment of the variability associated with implementing the harvest schedule. This procedure can easily and cost-effectively be adopted by managers and planners who are interested in evaluating consequences of alternative management strategies.

Spatial and temporal differences in availability and distribution of forest resources

The most obvious effect of the forest management scenarios was the change in spatial and temporal availability and distribution of forest resources. Under all management scenarios, representation of area in 50–70-year-old aspen increased throughout space and time (Appendix 1). In management scenario 1 (i.e., harvest of all aspen by 80 years) and scenario 2 (i.e., harvest of all aspen ≥ 60 years), representation of aspen in the 50- and 60-year age classes reached 12.5% by the fifth decade in most habitat types. Management strategies under scenarios 1 and 2 were sustainable over the long-term. In the intensive aspen management scenario 3, however, representation of aspen ≥ 40 years old decreased and in some instances, became non-existent by decade 3 or 4. To maintain any harvest and have representation of aspen in all age classes under this management scenario, the amount of aspen in age classes < 40 would have to be greater than 12.5%, and the amount of aspen in age classes > 40 would have to be less than 12.5%.

In management scenarios 1 and 2, representation of younger aspen age classes (< 30) decreased to allow for increased representation in older age classes; however, in scenario 3, representation of young aspen generally increased throughout time, except in decade 10. The main differences between scenarios 1 and 2 included the infeasibility of establishing a relatively even distribution of aspen area within all age classes of 6 habitat types under scenario 2, and the length of time required to establish a relatively even-age class distribution in habitat types where it was feasible (i.e., 5–8 decades under scenario 1, and 7–10 decades under scenario 2).

Comparison of effects of harvesting strategies on wildlife

Changes in resource availability under scenarios 1 and 2 were expected to benefit 5 of 6 avian communities associated with the ATD, AVO, and TM habitat types, whereas under scenario 3 habitat availability increased for only 4 communities and the magnitude of the increases were lower (Figures 4.10, 4.19, 4,28). Scenarios 1 and 2 benefited avian communities more than scenario 3 because the establishment of an even-age class distribution increases diversity (i.e., one age class does not dominate the area). Under scenario 3, representation of some age classes within habitat types was lost. Thus, the amount of potential habitat area for avian species was also lost, unless the avian species could attain life requisites from other vegetation types available in the landscape. The association between avian communities and other vegetation types should be further investigated.

For ruffed grouse, populations would likely benefit from conditions produced in decades 3–5 under scenario 3 when the availability of young aspen increased; however, overall availability of selected drumming habitat will likely decline by decade 5 under scenarios 1 and 2. These results demonstrate some of the trade-offs that managers may face when implementing activities to achieve an even-age class distribution within the aspen vegetation type.

Evaluation of the spatial and temporal consequences of the different scenarios revealed areas that may be maintained for different avian communities or for habitat management for specific species. For instance, ruffed grouse is a popular game bird and has exhibited declines in population numbers due to declines the availability of aspen (Rusch et al. 2000). Across the study area landscape, total aspen availability declined by approximately 18% (i.e., 1.8% per decade) over the simulated timeframe due to successional conversions in hydric habitat types and in other habitat types on non-industrial private forests. Thus, most of the aspen declined on non-industrial private forests (Figure 4.32). This decline is less than trends in aspen decline observed in Michigan between 1980 and 1993 (i.e., 1% per year; Cleland et al. 2001), but declines were probably not evenly distributed throughout the state. Although total aspen area on state lands remained relatively constant under all scenarios, ruffed grouse and other species that depend on aspen may exhibit population declines because of aspen declines on adjacent land-ownerships. Thus, to meet stakeholder demands for ruffed grouse management on public lands, it may be beneficial to identify areas that might be most effective in benefitting ruffed grouse populations.

Under all 3 management scenarios, an area in the central part of the study area consistently produced sites that were considered highly selected by ruffed grouse (Appendix 2) because they were located in habitat types that support aspen types providing the necessary structure and composition for drumming (see Chapter 3). If maintaining ruffed grouse habitat is a management priority for the MDNR, areas with high potential for providing habitat should be considered for management. Perhaps more intensive management could occur on those sites to increase representation of aspen age classes selected by ruffed grouse.

Similarly, habitat availability for other species of concern can also be monitored and evaluated. For instance, the golden-winged warbler, pine siskin, red-headed woodpecker, and wood thrush are listed on the Audubon Society's Watch List as sensitive species (Brewer et al. 2001, Audubon Society 2002). These species were associated with aspen in the 50 year age class of ATD and AVO habitat types, 70-year class within the TM habitat type, 50-year age class in all habitat types, and 20-year class within the TM habitat type, respectively (see Chapter 2). Areas potentially providing habitat for the golden-winged warbler and the red-headed woodpecker are currently scattered throughout the study area and increase throughout time (Appendix 3). Areas potentially providing habitat for the pine siskin and wood thrush are located in the central part of the study area. Potential habitat for the pine siskin increased, while habitat decreased for the wood thrush throughout the simulation due to a decrease in the amount of aspen in the 20-year age class within the TM habitat type (Appendix 3).

Adaptive management

The results of this project can effectively be incorporated into an adaptive management framework with the recognition that adopted management approaches are working hypotheses and, therefore, should be continually monitored and evaluated (Lindenmayer and Franklin 2002) to assess the actual effectiveness and sustainability of the management program. Hypotheses are what we consider to be the most likely explanation of a particular event (Ratti and Garton 1996). The hypotheses generated from this project included: 1) it is feasible to establish and maintain an even-age class distribution within the aspen vegetation type under scenarios 1 and 2; 2) the harvesting schedule developed is spatially feasible given actual harvesting constraints such as not partially cutting existing stands; 3) the association between avian communities and different aspen age classes and/or habitat types is true; 4) ruffed grouse habitat selection relationships reflect how grouse are actually selecting drumming habitat; and 4) grouse populations will respond to changes in habitat availability according to the model developed. Although evidence from this research project supports the stated relationships (with some ecological assumptions), there will always be some unpredictability and uncertainty in managed ecosystems that may cause slightly different outcomes (Davis et al. 2001) such as natural disturbances or changes in land ownership. Therefore, continued research is necessary to test these hypotheses. The success of management for sustainability will depend on continuing strategic research to build on current forest management strategies that are likely to achieve sustainability, such as harvesting aspen by 80 years old or harvesting all aspen > 60 years old, and establishing representation of aspen in several age classes and habitat types.

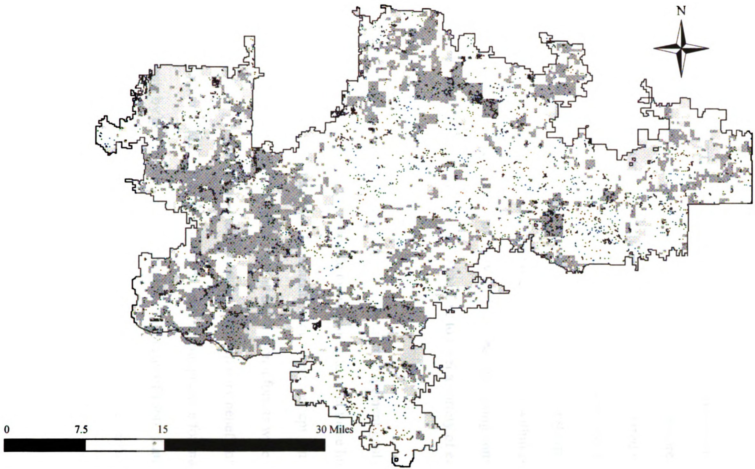


Figure 4.32. Areas (indicated in black) where aspen is expected to be lost due to succession in the next 10 decades in a 300 mi^2 area in the western Upper Peninsula. White areas indicate state land, light gray areas are commercial forest land, and dark gray areas are non-industrial private forests.

CHAPTER 5

MANAGEMENT IMPLICATIONS

In forest management, current structure, composition, spatial arrangement, and availability of forest types in a given area is a consequence of all the preceding management actions occurring in that area. This is essentially referred to as cumulative effects of management. Cumulative effects of management should not be ignored because they explain the pattern, availability, and structure of forest types occurring in the landscape, the richness, diversity, and occurrence of species within communities, and the habitat conditions and viability of individual species. Assessing cumulative effects of management is critical for developing future plans to meet a variety of ecological, social, and economic objectives.

Within many state and federal agencies, forest management goals have shifted from timber production toward sustainable management to meet those broad objectives (Kessler et al. 1992). Sustainable management is not a new concept. In fact, in the early part of the 20th century, Gifford Pinchot wrote that national forests were to be managed for the permanent good of all people and not for the temporary benefit of individuals or companies (Davis et al. 2001). This concept was put into practice for management of national forests by the Multiple Use-Sustainable Yield Act of 1960. Later state agencies began to adopt this concept and by the 1980s and early 1990s, the public had an increased awareness of the impacts of land use activities on wildlife. Thus, state and federal agencies and some private landowners began to develop plans to manage forests as naturally functioning ecosystems to meet human and wildlife demands for forest resources (Davis et al. 2001).

In the early 1990s, the MDNR undertook the task of initiating ecosystem management on state forest lands (Begalle 1991, as cited in Hanaburgh 2001), and in 2004, the Sustainable Forestry Act was signed by the Governor requiring that the MDNR shall seek and maintain forest certification. This research can be used, in part, to fulfill requirements for forest certification through the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI). In 2005, the MDNR's Forest Certification Implementation Team evaluated current plans and identified several shortcomings of meeting standards of the FSC and SFI. Areas needing emphasis included assessment of cover-type and wildlife habitat representation, strategic and long-term landscape-level planning, and development of programs to promote biodiversity conservation (Forest Certification Implementation Team 2005). Several aspects of this research project can help address those shortcomings or emphasis areas.

In Chapter 1, structural and compositional characteristics of different age classes within aspen vegetation types were linked with an ecological classification system (i.e., habitat types) to understand potential spatial and temporal distributions of vegetation characteristics within the western Upper Peninsula landscape. I identified specific aspen age classes within habitat types that are currently not well represented in the landscape, thus potentially decreasing habitat availability for wildlife species or communities of species. For instance, 7% of all aspen is between 50 and 60 years old, and 50–60-year-old aspen within the ATD habitat type is virtually nonexistent.

Results of this project provided evidence that all aspen stands are not equivalent in terms of structure, composition, value to wildlife, and timber potential. The different abiotic conditions (e.g., soil moisture, texture, and nutrient regimes) associated with different habitat types are the underlying factors contributing to the variations in vegetation physiognomy associated with aspen vegetation types observed throughout the western region of the Upper Peninsula. Thus, aspen should not be managed as one vegetation type; habitat types should be considered in management.

If aspen is not viewed as a diverse resource and is managed the same regardless of habitat type, plans for providing wildlife habitat may not be valid. For instance, in Chapter 2, results suggested that although several avian species use aspen, specific community associations were evident when habitat types were considered. If managers planned to provide aspen in a landscape, habitat requirements for some species may not be accounted for because life requisites occur in aspen associated with a particular habitat type. The pine siskin, for example, was not observed in aspen stands without a conifer component (see Chapter 2). The golden-winged warbler was not observed in aspen stands with a conifer component (see Chapter 2).

It should be noted that the associations between various wildlife species and communities reported in this document were based on the availability and spatial arrangement of vegetation types that occurred in 2004–2006. These associations may change under different management scenarios if the availability or arrangement of vegetation types change. For example, suppose bird species X was observed in a particular habitat type and aspen age class only because its preferred vegetation type, was limiting or not available in the landscape. Once that preferred vegetation type becomes available, its community association could change. Therefore, wildlife associations within various vegetation age classes and habitat types should be monitored throughout time and as vegetation distribution and availability changes.

In Chapter 2, I identified avian community associations with specific aspen age classes and/or habitat types and described threshold conditions for vegetation structure and composition that were important for determining species presence. Because presence of avian species is now associated with aspen age and habitat type, managers can predict future changes in habitat availability for avian species or communities under different management activities that may change representation of aspen within specific age classes and habitat types. Increasing the representation of aspen in the 50-year age class in all habitat types will benefit avian communities.

Results of Chapter 3 demonstrated that ruffed grouse respond differently to the various ecological conditions that support aspen, and thus aspen age classes and habitat types are important factors in grouse selection of drumming sites. Knowledge of this information will help managers identify and maintain areas highly selected by ruffed grouse and understand how grouse may respond to forest management activities or successional changes that may alter representation or spatial arrangement of highly selected vegetation types. For instance, grouse populations may likely increase if managers increased the amount of young (< 30-year-old) aspen within the TM, ATD, AVO, and AOC habitat types, the amount of aspen represented in all age classes within the TM type, or old aspen in the TM, AVO, and AOC habitat types .

In Chapter 4, I integrated information from Chapters 1–3 to evaluate spatial and temporal outcomes of meeting specific MDNR forest management goals to maintain wildlife habitat and timber production. The timber harvest scheduling model and results of the spatial simulations can help managers develop strategic long-term and landscape-level planning and predict spatial and temporal effects on long-term sustained timber yield, wildlife habitat availability, and potential wildlife population responses (e.g., for ruffed grouse). The modeling process has great value for evaluating trade-offs between maintaining habitat for individual wildlife species, communities, and timber yield under alternative scenarios (Table 5.1). For example, to maintain sustainable timber harvest, an even-age class distribution should be established, but a trade-off is a decrease in the amount of highly selected ruffed grouse drumming habitat. Scenario 1 (i.e., harvest all aspen by 80 years) appeared the best of the 3 scenarios described to provide a diversity of vegetation conditions for avian species and sustain timber. The process described in Chapter 4 should be used to evaluate consequences of other management scenarios that are also being considered. Further research should also quantify the magnitude of differences in trade-offs among alternative scenarios.

The MDNR has adopted the practice of ecosystem management and forest certification because they are based on the premise that functioning, sustainable ecosystems will consequently conserve biodiversity (Grumbine 1994). While this project specifically evaluated responses of avian communities and ruffed grouse to vegetation differences within aspen age classes and habitat types, mechanisms illustrated in this project can be expanded to address specific measures of biodiversity conservation. For instance, an important aspect of biodiversity conservation is maintaining adequate ecological representation of cover types (Haufler et al. 1996). The MDNR's goal of establishing and maintaining an even-age class distribution of aspen within all represented habitat types is a start. Results of this project indicated this is a feasible goal, but it will take many decades (> 5) to establish an even-age class within all most habitat types. Identification of performance measures such as presence of sensitive species, species richness, species diversity, and landscape diversity can be used to monitor how well the plan to establish and maintain an even age class distribution of aspen is achieving biodiversity objectives. The maps resulting from timber harvest simulations can be used to evaluate representation of habitat for other wildlife species over time because they reveal changes in spatial arrangement and availability of forest types, which are important landscape-level variables for evaluating wildlife habitat. The modeling process can be used to simulate effects of other management scenarios in different forest types as well.

The cumulative effects of management decisions are what determine how well long-term forest management goals are being met. As the public becomes more aware of environmental issues, and consequently desires agencies to become more accountable for sustainable management on public lands, it becomes increasingly important to be able to predict long-term outcomes of forest management decisions. Although there are limitations in use of any model because of uncertainty and variability in data or assumptions made, the modeling approach used in this project provides significant benefits. It provides evidence that aspen should not be managed as a single forest type, and it provides quantitative answers to questions such as how much aspen to cut, where can it be cut, and what are the effects on timber production and wildlife at multiple levels of biological organization. With increasing demands on natural resources, answers to such questions are essential for agencies and other landowners to sustain timber and wildlife resources for current and future generations.

Table 5.1. Comparison of consequences of different aspen management strategies simulated for a 300 mi^2 area in the western Upper Peninsula, Michigan. Strategies included: harvest all aspen by 80 years, harvest all aspen > 60 years, and intensively harvest aspen (i.e., > 60% of volume harvested on a 40-year rotation).

Metric	Timeline	Harvest by 80 Consequence	Harvest > 60 Consequence	Intensive Consequence
Habitat diversity for avian communities	Decade 2	-3%	-13%	-8%
	Decade 5	10%	7%	-5%
	Decade 10	10%	10%	-9%
Amount of highly selected ruffed grouse drumming habitat	Decade 2	-21%	-29%	-10%
	Decade 5	-6%	-4%	4%
	Decade 10	-6%	-6%	-7%
Amount of young aspen (< 30)	Decade 2	-32%	-38%	-8%
	Decade 5	-36%	-36%	10%
	Decade 10	-36%	-38%	-29%
Amount of med-aged aspen (30-49)	Decade 2	122%	160%	71%
	Decade 5	41%	38%	28%
	Decade 10	41%	43%	57%
Amount of old aspen (> 50)	Decade 2	13%	-33%	-37%
	Decade 5	61%	67%	-53%
	Decade 10	61%	70%	30%
Timber volume	Decade 2	-30%	-26%	-24%
	Decade 5	-23%	-14%	-29%
	Decade 10	-14%	-16%	-44%
Amount harvested	Decade 2	-14%	-16%	-7%
	Decade 5	-14%	-12%	-4%
	Decade 10	-14%	-14%	-28%
Interior forest	Decade 2	2%	3%	-4%
	Decade 5	2%	-1%	-12%
	Decade 10	2%	2%	0%
Edge	Decade 2	-2%	-1%	-3%
	Decade 5	0%	0%	-3%
	Decade 10	-2%	-2%	-3%

APPENDIX 1

The following figures display the proportion of area within 8 aspen age classes in 9 different habitat types resulting from harvest schedules from 3 different aspen management scenarios. The first scenario was to harvest all aspen by 80 years. Scenario 2 was to harvest only aspen > 60 years old, and the third scenario was to harvest aspen intensively (i.e., 60% of harvest came from aspen in the 40-year age class). The goal for all scenarios was to establish and maintain an even age class distribution of aspen in all habitat types.

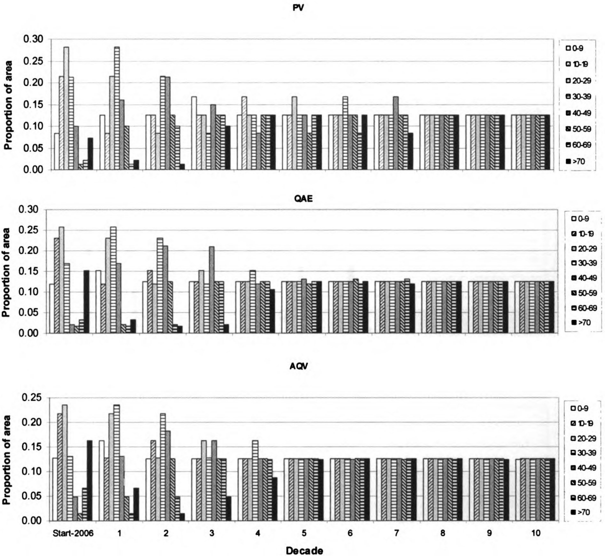


Figure A.1. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. All aspen was harvested by 80 years old. AQV = *Acer-Quercus-Vaccinium*; *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea.*

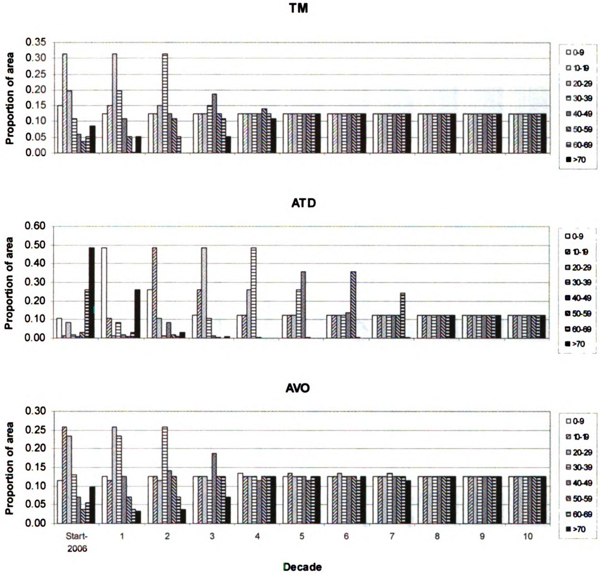


Figure A.2. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. All aspen was harvested by 80 years old. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

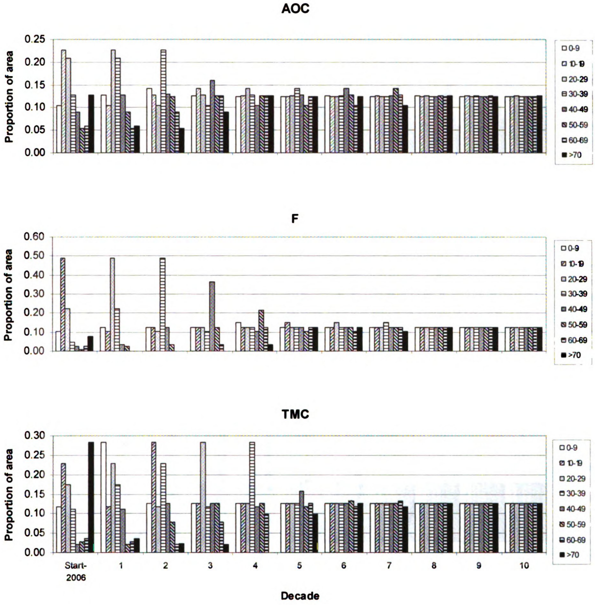


Figure A.3. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. All aspen was harvested by 80 years old. AOC = *Acer-Osmorhiza-Caulophyllum*; F = *Fraxinus*-spp.; TMC = *Tsuga-Maianthemum-Coptis*.

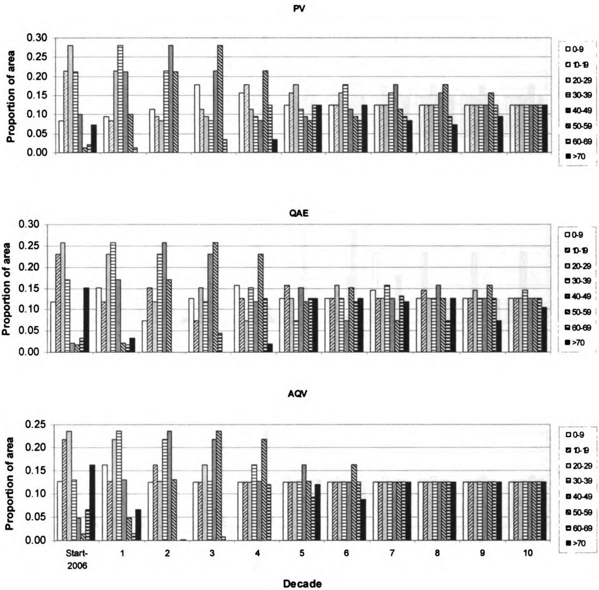


Figure A.4. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. Only aspen ≥ 60 was harvested. AQV = *Acer-Quercus-Vaccinium*; *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*.

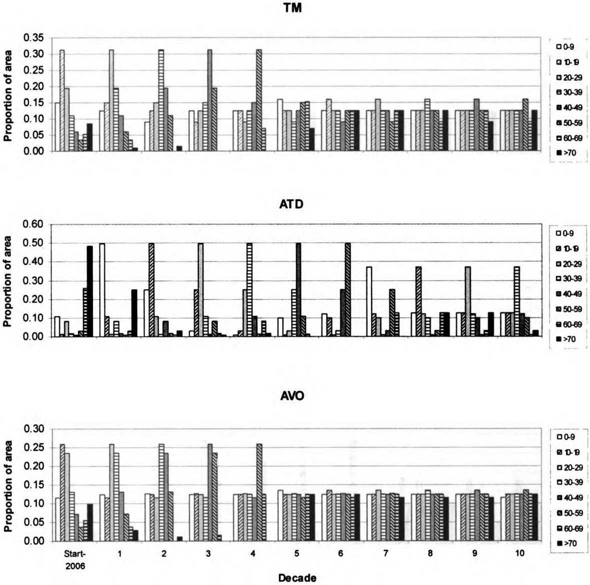


Figure A.5. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. Only aspen ≥ 60 was harvested. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

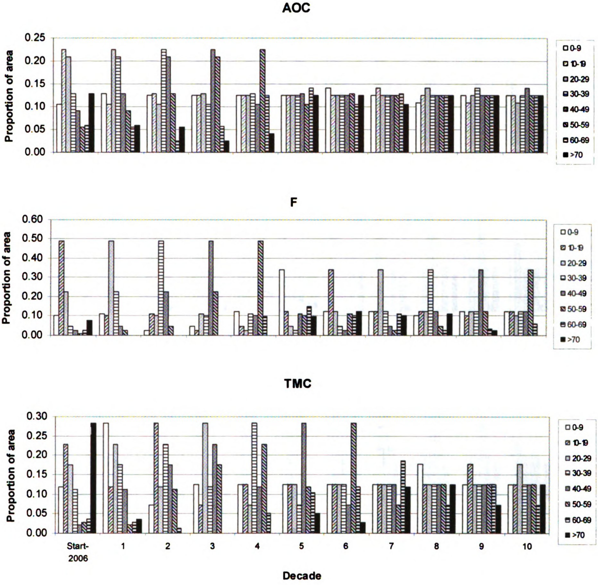


Figure A.6. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. Only aspen ≥ 60 was harvested. AOC = *Acer-Osmorhiza-Caulophyllum*; F = *Fraxinus*-spp.; TMC = *Tsuga-Maianthemum-Coptis*.

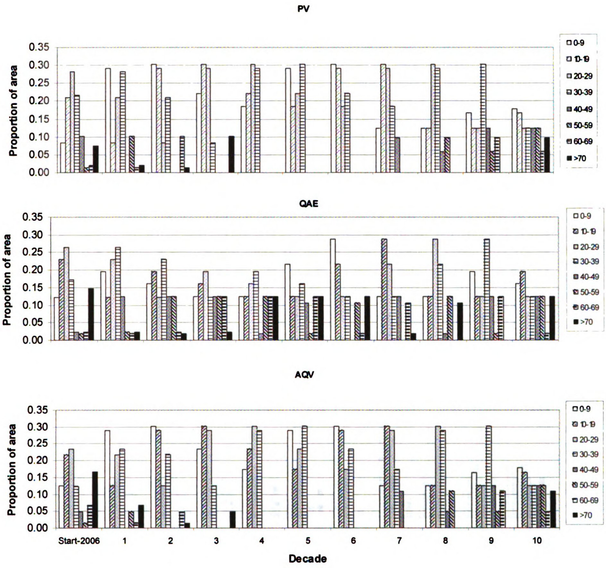


Figure A.7. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. Most (60%) of the aspen was harvested on a 40-year rotation. AQV = *Acer-Quercus-Vaccinium*; *Pinus-Vaccinium*-spp.; QAE = *Quercus-Acer-Epigaea*.

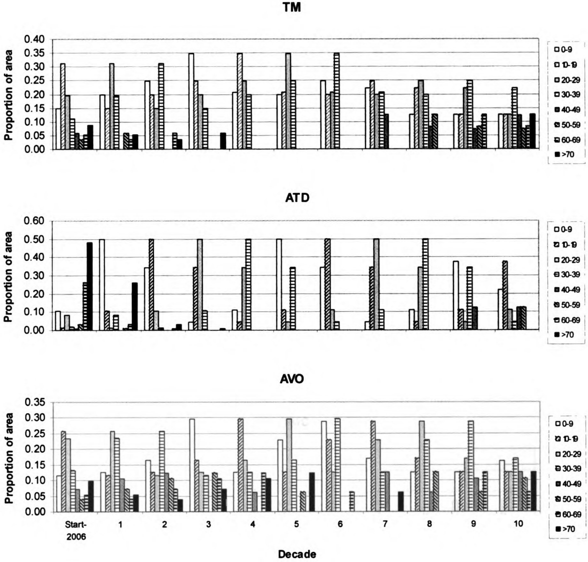


Figure A.8. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. Most (60%) of the aspen was harvested on a 40-year rotation. ATD = *Acer-Tsuga-Dryopteris*; AVO = *Acer-Viola-Osmorhiza*; TM = *Tsuga-Maianthemum*.

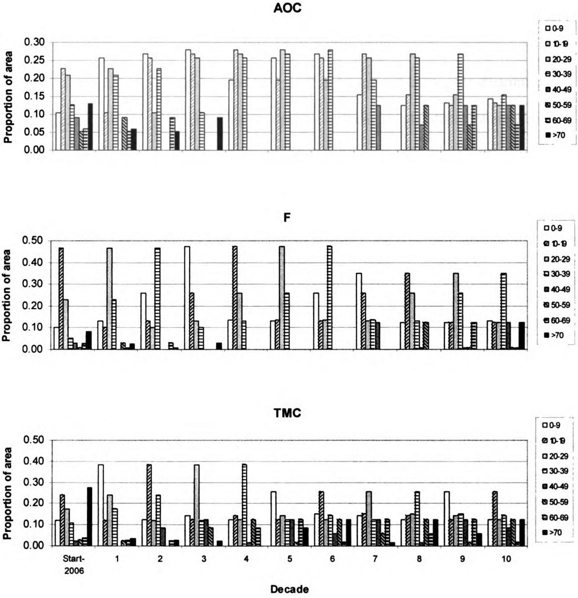
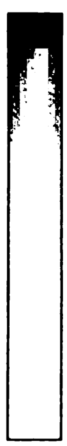


Figure A.9. Proportion of aspen within different habitat types in the Upper Peninsula of Michigan at the beginning of 10 decades following simulated aspen harvest. Most (60%) of the aspen was harvested on a 40-year rotation. AOC = *Acer-Osmorhiza-Caulophyllum*; F = *Fraxinus*-spp.; TMC = *Tsuga-Maianthemum-Coptis.*

APPENDIX 2

The following appendix shows the spatial and temporal changes in distribution of highly selected and avoided ruffed grouse drumming habitat under different simulated management scenarios for a 300 mi^2 area in the western Upper Peninsula, Michigan. Harvest was simulated for 10 decades. Selection values > 1 indicate selection, 1 = neither selection or avoidance, and < 1 indicates avoidance.

For all figures, the following key applies:

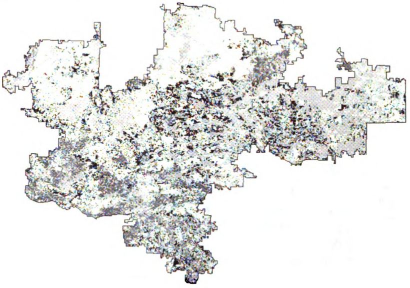


Highly selected
(2.30)

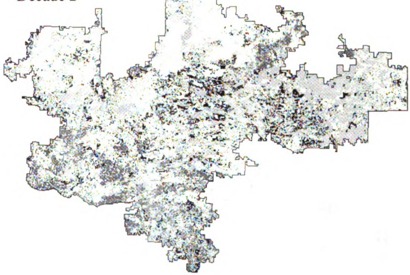
Neutral
1.00

Avoided
0.00

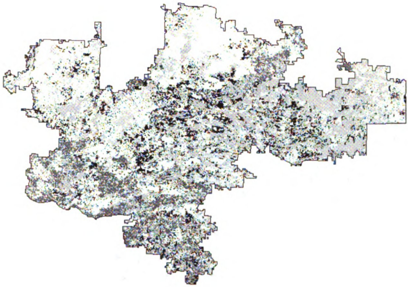
Initial conditions



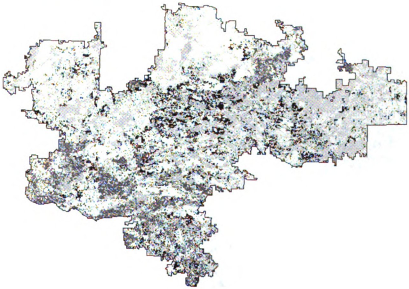
Scenario 1: harvest all aspen by 80 years
Decade 2



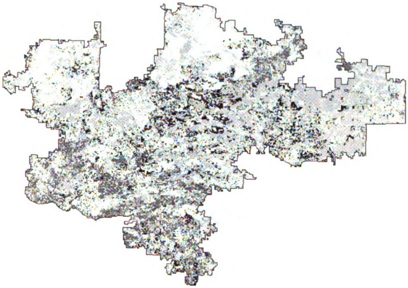
Scenario 1: harvest all aspen by 80 years
Decade 5



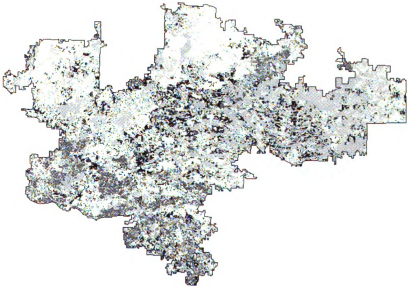
Scenario 1: harvest all aspen by 80 years
Decade 10



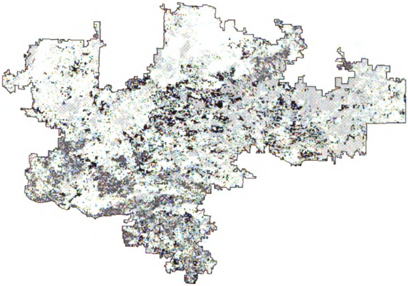
Scenario 2: harvest all aspen > 60 years
Decade 2



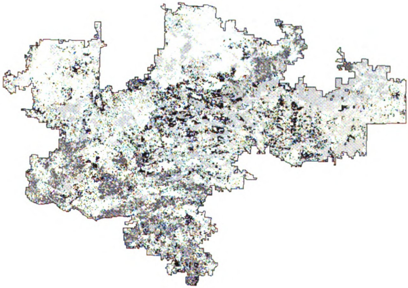
Scenario 2: harvest all aspen > 60 years
Decade 5



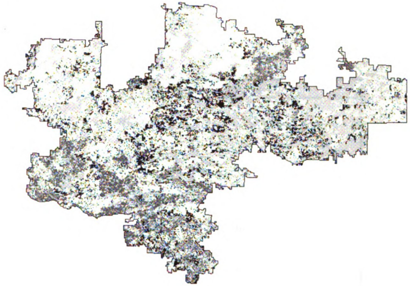
Scenario 2: harvest all aspen > 60 years
Decade 10



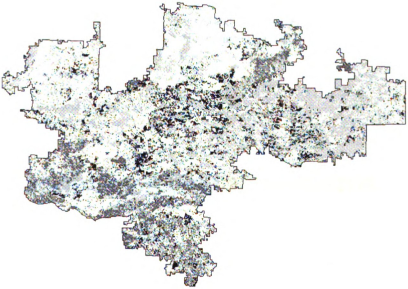
Scenario 3: intensive aspen management. At least 60% harvested from 40-year age class.
Decade 2



Scenario 3: intensive aspen management. At least 60% harvested from 40-year age class.
Decade 5



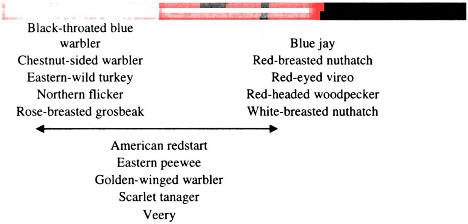
Scenario 3: intensive aspen management. At least 60% harvested from 40-year age class.
Decade 10

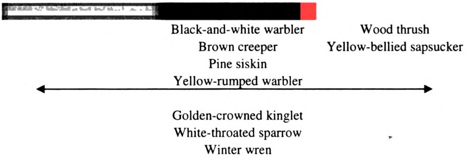


APPENDIX 3

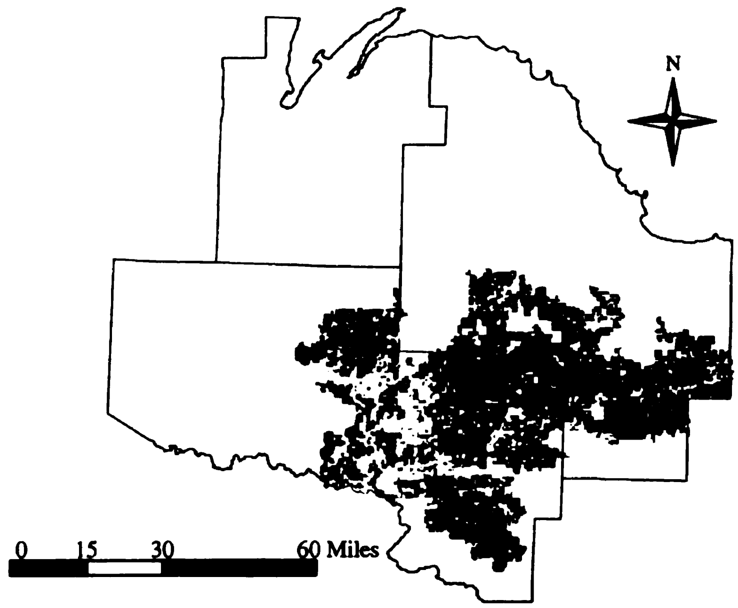
The following appendix shows the spatial and temporal changes in avian habitat distribution under different simulated management scenarios for a 300 mi^2 area in the western Upper Peninsula, Michigan. Harvest was simulated for 10 decades. For all maps, the following color scheme applies:

Color code	Community association
	aspen in the 20–50-year age class in ATD and AVO
	aspen in the 50-year age class
	old (> 60 years) aspen in ATD and AVO
	aspen in the 50-year age class within TM
	old (> 70) aspen in within TM
	aspen in the 20-year age class within TM



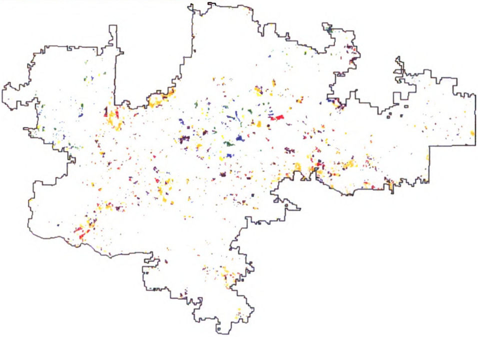


Location of study area within Baraga, Dickinson, Iron, and Marquette Counties.

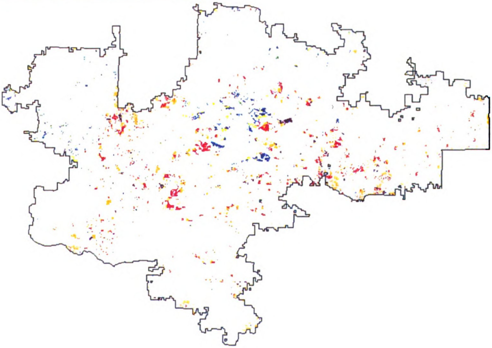


Scenario 1: Harvest all aspen by 80 years old to establish and maintain an even age class distribution.

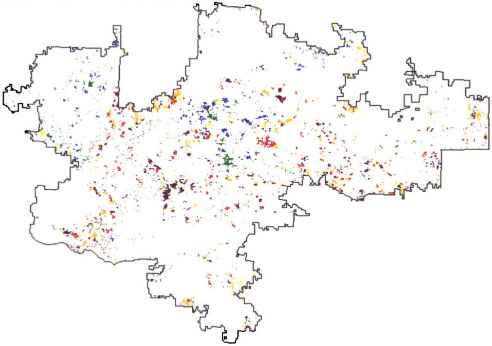
A) Initial conditions



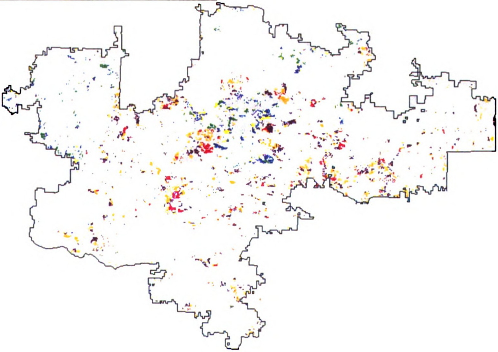
B) Decade 2



C) Decade 5

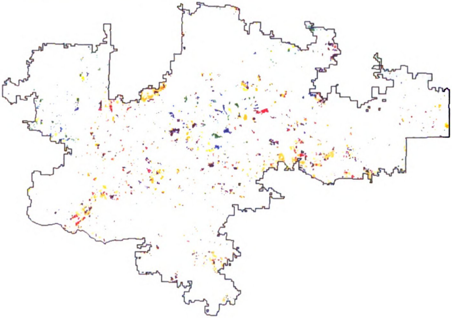


D) Decade 10

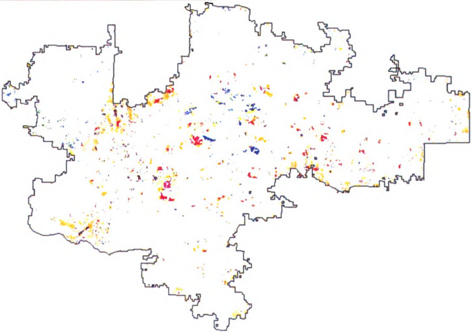


Scenario 2: Harvest all aspen > 60 years old to establish and maintain an even age-class distribution.

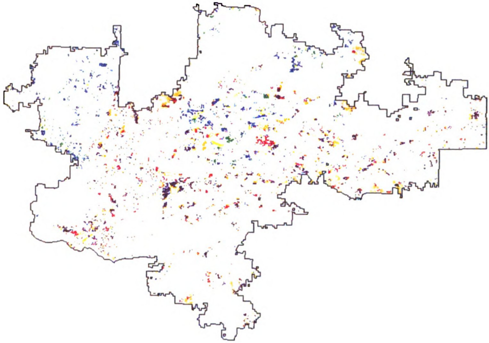
E) Initial conditions



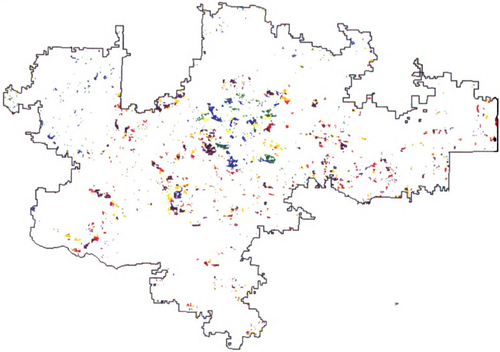
F) Decade 2



G) Decade 5

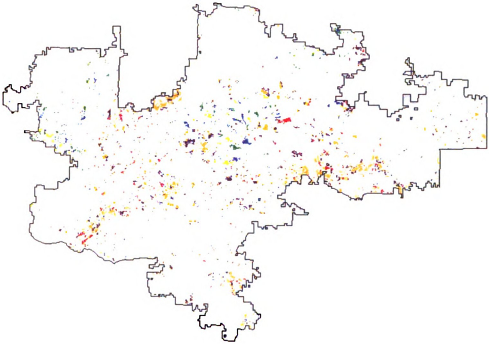


H) Decade 10

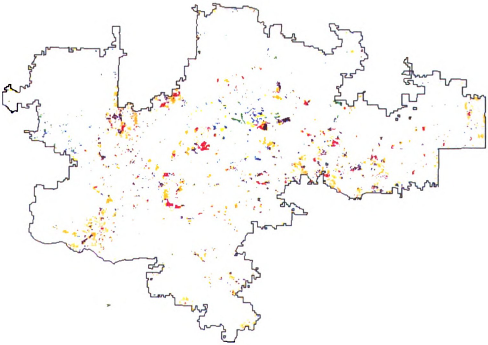


Scenario 3: Harvest 60% of the aspen from the 40-year age class.

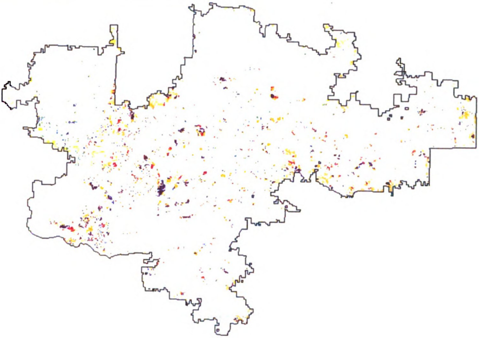
I) Initial conditions



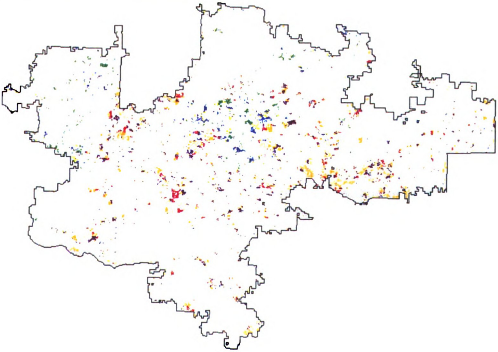
J) Decade 2



K) Decade 5



L) Decade 10



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