Introduction

State forest management and multiple use values

The state forest is managed for many purposes that represent a variety of uses and values. This can be difficult to balance, and even more so when trying to ensure continuity for future generations. These uses and values include forest products such as timber and minerals, wildlife habitat management and hunting, water quality for fish habitat and ecosystem health, recreation including camping, hiking, biking, off-road vehicles and horseback riding, mitigating impacts to rare species, and conserving and protecting places of ecological, cultural and historical importance.

Equitability among these values on the state forest can be difficult to achieve and requires considerable coordination of efforts. This responsibility falls largely across five divisions in the DNR. Forest Resources Division is the land administrator and often takes the lead in making management decisions, especially for silvicultural treatments of forested cover types and managing prescribed burns and wildfire. Wildlife Division works closely with Forest Resources on cover type management, since wildlife habitat and forest management are entwined. These two divisions also work together to manage for and mitigate threats to rare species and special places. Parks and Recreation Division takes the lead on almost all recreation opportunities offered throughout the state forest. Fisheries Division ensures that cover type management and water infrastructure promote habitat for or minimize impacts to aquatic environments or species. Finally, Law Enforcement Division ensures recreationists follow state forest policies and regulations that promote safety and resource protection.

These uses and values are explicitly stated in legislation and other mandates that define the authorities given to the DNR.

DNR legal authority

The Michigan State Constitution (1963) establishes the state's overarching legal framework by delineating the executive, legislative, and judicial branches of government and defining their respective powers. The executive branch is organized through administrative departments, including the Department of Natural Resources, to effectively implement state laws under the supervision of the governor. The Legislature was given the authority to develop laws, and it was specifically entrusted to protect the state's air, water and other natural resources. This serves as the basis for all natural resource laws in Michigan.

All DNR statutory authorities and obligations were consolidated under Public Act 451, the Natural Resources Environmental Protection Act, in 1994 (subsequently amended). This act combined environmental and natural resource laws and allowed for regulation and management of the use and impacts thereof.

Part 525 of this act, Sustainable Forestry on State Forest Lands, gave the DNR management authority over the state forest, in accordance with the principles of sustainable forestry, with the following stipulations:

- Ensuring wildlife areas and parks on state forest lands are managed for their primary purpose.

- Developing a plan to address all the forestry, conservation and wildlife considerations to be updated when necessary or appropriate, including:
    - A stable, long-term, sustainable timber supply.
    - Local and stakeholder interests.
    - Promoting use of state forests for timber and outdoor recreation.
    - A landscape plan that integrates biodiversity considerations.
    - Identification of sensitive areas, or areas that need to be treated to accommodate the needs of wildlife or rare species.
- Establishing regional yearly harvest objectives for all state forest land for a 10-year period, to be reviewed every five years, updated at least once and posted on the DNR website.
- Beginning Oct. 1, 2018, the DNR will prepare for sale a minimum of 90% of the yearly statewide harvest objective.

Part 525 also requires the DNR to seek and maintain third-party certification of state forest management that satisfies sustainable forestry standards.

Forest certification

Section 52505 of Part 525 of the Natural Resources Environmental Protection Act (Public Act 451, as amended) requires the DNR to seek and maintain third-party certification that management of the state forest satisfies the sustainable forestry standards of at least one credible nonprofit, nongovernmental organization certification program. Certification was required by Jan. 1, 2006. The DNR sought forest management certification under two standards:

1. The Regional Forest Stewardship Standard for the Lake States-Central Hardwoods Region (USA), as approved by the Forest Stewardship Council-US Board on Feb. 7, 2002, and accredited by Forest Stewardship Council International on Aug.5, 2002. Initial certification was granted on Dec. 31, 2005. It has since been updated to the current standard, Forest Stewardship Council 2010 Forest Management Standard.

2. The Sustainable Forestry Initiative 2005-2009 Standard as adopted by the Sustainable Forestry Board, Inc. on Jan. 10, 2005. Initial certification was granted on Dec. 14, 2005. The DNR is now certified under Sustainable Forestry Initiative 2022 Forest Management Standard.

Under certification, the DNR must be able to demonstrate that state forest management is sustainable, as assessed by annual third-party audits on a subset of state forest lands. Audits by both certifying bodies are concurrent and evaluate against standards in both certification systems. A recertification audit is conducted every five years in four forest management units and in Lansing. Surveillance audits in three units occur in the intervening years. Internal audits take place annually as well, prior to the third-party audits, in a good faith effort to meet continuous improvement standards. Formal management reviews are conducted in response to audit findings and can lead to policy and procedure revisions. Forest operations are guided by a set of work instructions, internally developed and revised as needed, to assure conformance with the certification standards.

There are some areas that are excluded from forest certification. These include all state parks, state wildlife areas in the lower third of Michigan, and Camp Grayling. Additionally, a few small exclusions exist in the state forest itself.

Administration of the state forest

State forest organization

The state forest, approximately 4 million acres in size, is distributed across the northern Lower and Upper peninsulas. It is administratively organized into a hierarchy of regions, districts and forest management units (Figure 1). FMUs are generally based on groupings of counties. Stand examiners (typically foresters, forest technicians, biologists and wildlife technicians) inventory and manage stands within compartments on state forest land. Compartments are blocks of land typically ranging in size from 1,200 to 11,000 acres, made up of stands that are inventoried at the same time.

The compartments are assigned to a schedule to be inventoried to establish their current condition and treatments are prescribed based on the goals of the management plan toward the desired future conditions. Each compartment is given a year of entry, which is the year they are “entered” to prepare approved treatments. This is based on a 10-year inventory cycle; therefore 10% of the state forest is inventoried every year. This effort is evenly distributed across forest management units annually. Management activities occur at the stand level, the smallest unit on the state forest. Stands are defined geographically by consistency in cover type, age class, basal area, canopy, size and/or stocking density. Cover types are characterized by a predominant species or a group of species that grow in similar conditions.

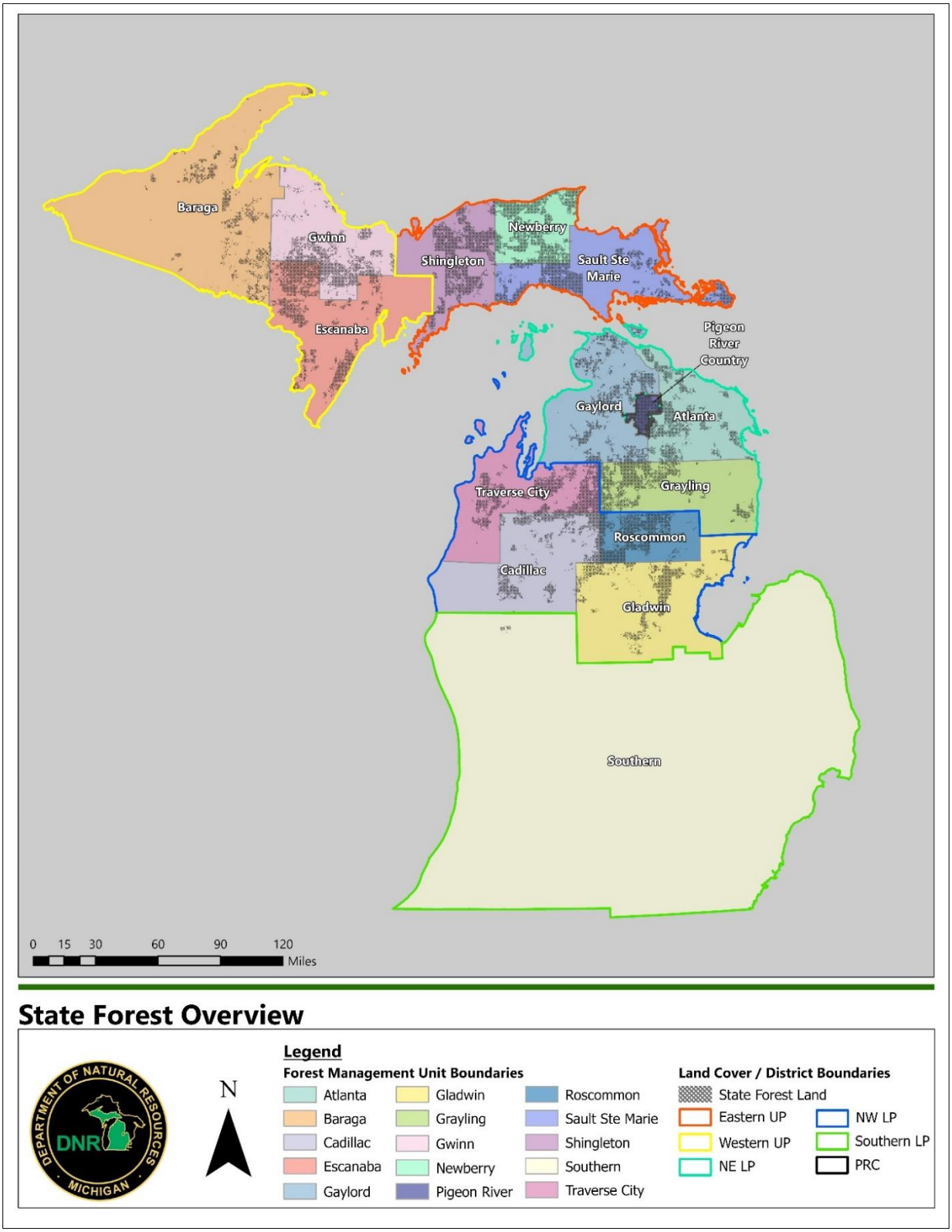

Figure 1. State forest district and forest management unit administrative boundaries.

State forest management approach

Traditional sustained yield management of forests became prominent in the United States in the late 19th century and was generally adopted as the management strategy by the present DNR in the early 20th century. This is a management approach where timber harvest does not exceed forest growth, thereby ensuring a sustained yield of timber in addition to ensuring the perpetuation of the forest. In the current system, the DNR achieves sustained yield forestry primarily through area regulation, because most cover types in the state forest are managed with even-aged management.

Area regulation balances age classes within each cover type so there is a uniform distribution of acres in each age class across the landscape. The oldest age class is typically defined by the rotation age; this also defines the annual acres eligible for harvest. Area regulation can take decades to achieve, but then provides an even flow of timber, and in some cases habitat, each year. Similarly, volume regulation is applied to cover types under an uneven-aged management system and balances the distribution of diameter classes by basal area within a stand. Both are in accordance with part 525 of Public Act 451, which calls for sustainable forest management such that "the harvest objectives for each forest region shall not exceed the sustainable yields." In setting these objectives, the DNR does consider the physical, biological, environmental and recreational objectives mentioned in the act.

State forest geographic scales

State forest management planning and activities employ an ecological framework for establishing and tracking forest cover type and habitat objectives for each forest management unit. Based generally on U.S. Forest Service ecologist D.T. Cleland's ecological sections and subsections (McNabb et al. 2009) and using Michigan Natural Features Inventory ecologist (D. Albert 1995) landscape descriptions, the state forest now consists of three ecological regions and 30 management areas (Figure 2). Compared to the 99 management areas based on ecological subsubsections in the 2013 Regional State Forest Management Plans, this current approach better facilitates effective management. It also aligns with the ecological classification system the U.S. Forest Service uses, enabling better coordination between agencies.

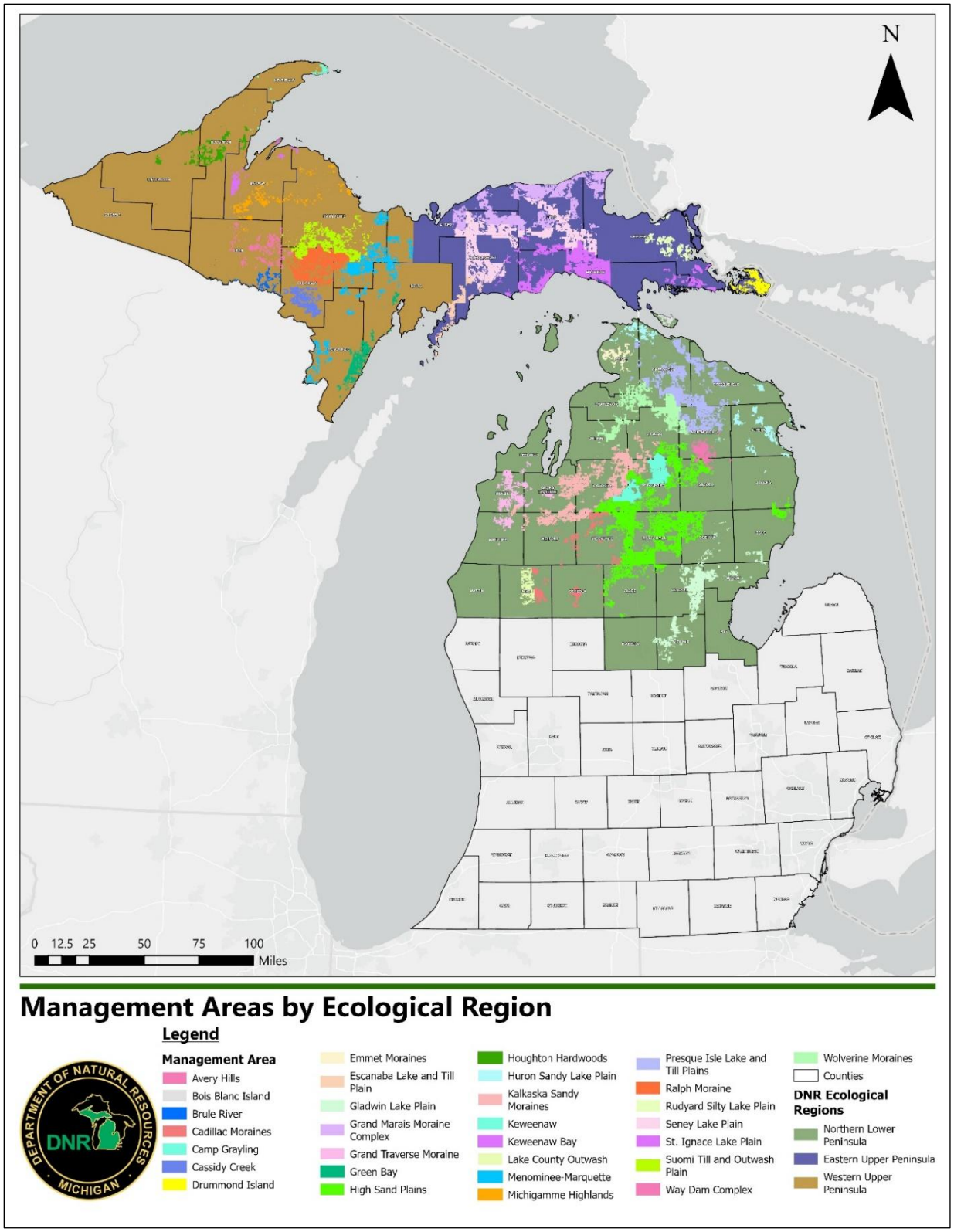

Figure 2. State forest ecoregion and management area boundaries.

The three regions recognize natural ecological boundaries that generally align with Cleland's sections. One such divide occurs in the Upper Peninsula, splitting Alger and Delta counties, which forms the boundary between the eastern and western Upper Peninsula. This is based on the inherent terrain and climate differences; the eastern Upper Peninsula climate is moderated by air flow moving over the Great Lakes, whereas the climate of the western Upper Peninsula is strongly continental, with little moderation by Lake Superior. These give rise to distinctive vegetation communities and management approaches. The northern Lower Peninsula is defined by a horizontal boundary between Bay and Oceana counties, demarcating a climate zone predominantly moderated by Great Lakes influence north of that line.

Management areas are groupings of state forest compartments that synthesize climate, physiography and geologic substrate that form ecosystems with distinctive vegetation and other unique characteristics within the landscape. These management areas form the primary context for cover type evaluation, setting goals, monitoring and tracking harvest targets. This is where strategic concepts from other plans are synthesized with silvicultural criteria and wildlife habitat goals at a landscape scale to provide operational direction.

Special analysis units are new in the 2025-2034 planning period. They are defined geographic areas, each associated with a planning effort different than the state forest at large. These areas are important to distinguish in the forest planning model as differences in rotation ages, desired age-class distributions, cover type transitions, and silvicultural methods would influence forest harvest targets and scheduling. These areas do not fit into any geographic hierarchy as they can be within or across management areas and management units. They include the Pigeon River Country State Forest, the Elk Management Area, the Kirtland's warbler area, deer wintering complexes, and grouse enhanced management sites.

State forest inventory

This management plan provides harvest targets by silvicultural method for each cover type within each management area for the 10-year planning period. Those harvest targets are then distilled into more specific guidance for each forest management unit in each year of the planning period. Stand examiners assess stand level attributes within their assigned compartments to identify stands that are operable for harvest. Because the state forest is recognized as a multiple-use system, silvicultural criteria, wildlife habitat needs, presence of rare and invasive species, occurrence of state and Tribal Historic Preservation Office records, invasive species, soil and water best management practices, effects on recreation and fisheries as well as climate change risks all are considered in cover type treatments. Stand examiners will then propose treatment prescriptions, including harvest, to meet planned management goals.

The DNR uses an interactive spatial database called Michigan Forest Inventory (MiFI), which houses information related to the physical, biological, and social information on each unit of land. It provides information regarding many aspects of forest management such as timber, wildlife, recreation, land use, treatments and reforestation efforts. The MiFI system stores information gathered during inventory to describe the composition of each stand, site factors that may limit management, and treatment prescriptions that support the goals and objectives to reach desired future conditions.

Each year of entry, proposed treatments entered into MiFI are discussed and must be approved by DNR resource divisions through the compartment review process. These include Forest Resources, Wildlife,

and Parks and Recreation, with varying input by Fisheries and Law Enforcement divisions. Staff from each of these divisions consider commercial and non-commercial management prescriptions for forested and non-forested resources. All proposed treatments are made available to the public for a 30-day review culminating in a public open house in each of the forest management units. This process constitutes an integrated management approach to sound management of state forest resources.

Approved treatments are typically prepared during their compartment's year of entry, but they may also be scheduled for preparation in any year of the planning period. Treatments involving each timber sale are implemented by creating a timber sale proposal which is combined with other sales to generate a bid packet. These sales are bid on in a sealed-bid silent auction and awarded to the highest qualified bidder. The DNR then enters into a contract with the purchaser once a 10% down payment and a bond are secured. Timber sale contracts typically span one to three years, often with extensions available upon request.

Prescribed treatments often decrease slightly in size during sale preparations due to a variety of factors that can come into play. For example, if a rare species is found, if a raptor nest is discovered, if access is limited or has changed or if conditions become unfavorable for harvest operations, a stand may become unavailable or the area of harvest may change. The actual harvest acres can differ from the planned harvest acres for any given treatment but generally results in about a 6% decrease from what was planned to the area prepared for harvest.

State forest co-management

FRD and WLD

The origin of the current state forest system is also the origin of the primary co-management relationship between FRD and WLD. Historically, predecessors of today's Forest Resources and Wildlife divisions separately administered and managed lands. Co-management was initiated through merging these lands into a new state forest system, under an agreement described in a 1946 Department of Conservation Commission Memorandum. The agreement was for the then-Forestry Division to be the primary land administrator conducting management activities on this system, but both divisions would have equal management authority, and neither could conduct work without approval from the other. This agreement was mutually beneficial in that the Forestry Division acquired more land, while wildlife biologists were freed from land management activities to focus on wildlife species management.

Recognition of this equal partnership "without one being subordinate to the other" is just as relevant today, as is the importance of collaboration between the two divisions. In 2005, this became DNR policy by jointly charging both divisions "with the responsibility of developing and implementing a comprehensive management plan" (DNR Policy and Procedure 32.22-07). In 2013, FRD and WLD chiefs jointly developed a co-management vision and set of actions and outcomes titled "Securing the Future of Michigan's Forests and Wildlife" to reaffirm their commitment and to set expectations for all staff in both divisions.

This expectation for co-management across both divisions is shared outside of the DNR as well. It is stipulated under part 525 of NREPA, to manage wildlife areas for their primary purpose and to ensure forest treatments sustain quality wildlife habitat. Forest certification standards keep us accountable to our own co-management plans and call for the protection of rare species and their habitats, and the maintenance of ecosystem functions, services and environmental values in forest management. Lastly,

various Tribes, partners, stakeholders and members of the public expect to see evidence of co-management in service of the relationship between forests and wildlife habitat, as substantiated by the number of comments on this topic received during the 2024 draft plan Tribal and public review.

While management of timber and wildlife can have some inherent conflict, they can also be mutually beneficial with similar goals achieved. Of all of the DNR resource management divisions that participate in joint decision-making during compartment review, the Wildlife and Forest Resources divisions are the only two that have equal management authority and responsibility across the entire state forest. As such, both divisions have a unique and important relationship. This State Forest Management Plan attempts to facilitate better collaboration between the two divisions by more fully integrating wildlife habitat needs and goals into strategic and operational direction.

FRD and other divisions

Parks and Recreation, Fisheries, and Law Enforcement divisions also have co-management relationships with FRD on the state forest, though to differing degrees. Part 525 of NREPA stipulates that Parks and Recreation areas will be managed for their primary purpose, and that outdoor tourism and recreation will be identified and promoted in the forest management plan. PRD has management responsibility for all recreation sites on state forest land, including state forest campgrounds, recreation trails and boating access sites. Staff from both divisions work closely when forest management activities may have an impact on a recreational site or if changes must be made to the recreation system. Likewise, many cold water streams and lakes, and other aquatic habitats important to fish, reptiles and mussels are found throughout the state forest system. Staff from FRD and Fisheries work closely when forest management activities may overlap such areas of interest to minimize negative impacts. Law Enforcement Division spends a lot of time in the state forest monitoring for the safe and sustainable use of this vast and varied public resource.

State forest land acquisition

The state forest was largely established on land acquired by the state due to the non-payment of taxes. During the early 1900s, after the land was stripped of the timber resource, a significant number of landowners stopped paying taxes and let the land revert to the state. Much of this land was then sold by the state, only to have it revert again due to farm failures and lack of timber value. This cycle of selling and reacquiring the land occurred again during the Great Depression of the 1930s. At this point, the state decided to stop this cycle and retain the land; it became the foundation for the state forest system. Although a majority of the state forest exists on land that was acquired through this tax reversion process, there has also been extensive intentional land acquisition using a variety of methods and funding sources.

Additional methods for state forest land acquisition includes transfer of land from the federal government, special legislation enacted by state government, gifts of land from private individuals, land exchanges and land purchases. Of these, land exchanges and land purchases are the most common. Land exchanges are regularly completed with private individuals, conservation partners and units of government. These transactions provide an opportunity to exchange surplus lands that are not contributing significantly to the DNR's mission for lands that consolidate well with existing state forest land, provide a valuable timber resource, and benefit both natural resource protection and public

outdoor recreation. Land purchases are funded through a variety of sources, many of which have specific purposes and requirements.

The funding sources used to acquire land for the state forest include federal, state, license fees and private donations. Federal funding sources, or those with federal implications, include the Forest Legacy Program, revenue generated from the Pittman-Robertson Wildlife Restoration and Dingell-Johnson Sport Fish Restoration acts, and hunting and fishing license fees. The latter three include added protections on acquired lands and are part of the U.S. Fish and Wildlife Service's Office of Conservation Investment.

The Forest Legacy Program, administered by the U.S. Forest Service and funded through the Land and Water Conservation Fund, is a nationally competitive grant program that provides funding to acquire land or rights in land to protect environmentally important forests. Michigan can submit up to three projects for consideration each year. As a result of the Inflation Reduction Act, there is additional funding available through the program that provides opportunities for three new project categories: large landscape level projects, state-tribal partnership projects, and small strategic tracts. This funding is expected to be obligated and fully spent by 2031. More than 4,800 acres have been added to the state forest through this funding source, with an additional 9,100 acres funded and the acquisitions pending. These lands must be managed sustainably as a working forest in perpetuity, though complementary uses such as public recreation are permitted.

Many DNR lands which are Pittman-Robertson or Dingell-Johnson acquired and/or managed are desirable to a variety of recreation users. Recreational use is not prohibited on lands purchased with funds acquired through these acts. However, when it does occur, the intensity and frequency cannot interfere with the primary purpose for which the land was acquired. Acquisition purposes could be for desired fish and wildlife habitat, species management or facilities to support wildlife administration and management. If the Office of Conservation Investment determines that the state is not adequately managing the frequency and intensity of recreation use on these lands and if a satisfactory resolution is not achieved, future funding is jeopardized. Since these funds have been significant, approximately $20 million (Pittman-Robertson) and $13 million (Dingell-Johnson) in 2021, careful management of nonhunting and non-fishing activities is very important.

Other DNR lands were acquired and/or are managed with hunting and fishing license fees. A provision of the Pittman-Robertson (1937) and Dingell-Johnson (1950) acts is that states must assent to only use state license fees for fish and wildlife services. Section 324.2010 of Michigan's Natural Resources and Environmental Protection Act states that the DNR will manage lands acquired with these funds "...through the use of scientific game species management for the primary purpose of managing habitat and thereby enhancing recreational hunting opportunities." Further, it clarifies that fund expenditures and forest treatments on lands acquired with these funds must demonstrate this primary purpose, and that any nongame benefits are a result of the primary purpose.

State funding sources that have contributed significantly to the acquisition of state forest land include the Michigan Natural Resources Trust Fund and the Land Exchange Facilitation Fund. The Natural Resources Trust Fund was established in 1976 and provides grant funding annually through a competitive application process to the DNR and local units of government to support acquisition of important lands and development of outdoor recreation. Lands acquired with the trust fund must be open to the public for recreational purposes.

The Land Exchange Facilitation Fund is managed by the DNR and funded from the proceeds of the sale of land that the state acquired through tax reversion. As surplus lands that are not contributing to the DNR's mission are sold, typically via public auction, proceeds are deposited into the facilitation fund. The DNR then uses a majority of the fund to acquire priority lands to be managed as part of the state forest, state game areas or state parks.

This variety of acquisition methods and funding sources enables the DNR to ensure ownership and management of the appropriate footprint for the state forest.

State Forest Management Plan purpose and scope

The primary purpose of the State Forest Management Plan is to provide strategic and landscape-level operational direction through specific goals and objectives for forest cover type and wildlife habitat management for 2025-2034. This plan replaces the 2008 Michigan State Forest Management Plan and the three 2013 Regional State Forest Management Plans. This plan integrates strategic planning at the forest-wide and regional levels, operational planning at the management area and special analysis unit levels, and tactical planning at the forest compartment level. The plan satisfies the planning requirements of Part 525 of the Natural Resources and Environmental Protection Act (1994 Public Act 451, as amended) and the Forest Stewardship Council and Sustainable Forestry Initiative forest certification standards. Although this plan will not provide specific objectives for other values such as recreation uses, it will consider these values in the context of forest management activities.

The plan also considers strategic direction in the form of goals and objectives from other DNR planning efforts, to better integrate and guide management of state forest land for many uses and values. The plan will help the DNR accomplish its timber and wildlife habitat management goals while taking other forest values into consideration over this 10-year planning period by:

- Effectuating the 10-year harvest schedule and long-term cover type and habitat projections from the preferred Woodstock® model scenario (Remsoft® Corporation, New Brunswick, Canada).
- Using a revised framework of management areas to provide operational-level assessments and management direction.
- Using special analysis units to provide specific management direction for unique resources and values, such as Kirtland's warbler and elk habitat.
- Ensuring all relevant values (and their respective planning direction) receive due consideration and consistent treatment within relevant geographies.
- Ensuring consistency in management direction where resource values cross boundaries of management areas or forest management units.
- Identifying current and future issues, such as climate change, as well as gaps in this plan.
- Identifying relevant management goals and objectives.
- Identifying and resolving issues between opposing objectives.
- Ensuring that forest management is transparent to all forest stakeholders.

Forest management unit staff will implement management direction within this plan for each management area through the compartment review planning process. This begins with the 2027 year of entry.

State forest planning process

No plan is an island

DNR plans provide overarching strategic direction for all divisions and are incorporated by reference in this plan. DNR divisions use a hierarchical planning framework that integrates departmental, divisional and programmatic plans (Figure 3). State forest management touches most DNR divisions as it encompasses wildlife habitat, fish habitat and water quality, cultural and mineral resources, and a multitude of recreation opportunities. These division programs and state forest management converge where forest operations may be influenced or impacted, and vice versa. This plan works within the guidance provided by each division program to inform state forest management decisions.

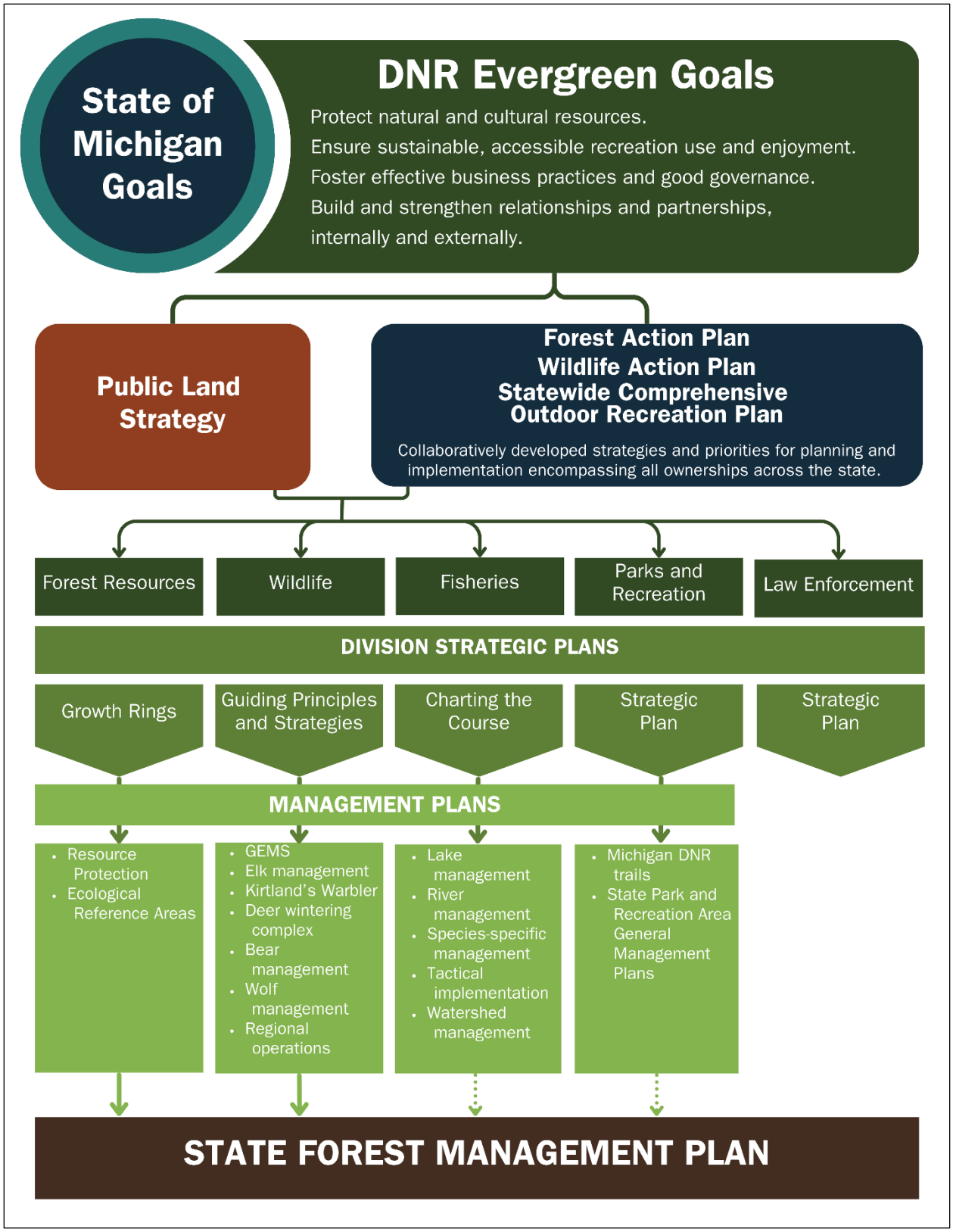

Figure 3. The State Forest Management Plan in relation to other DNR plans.

Planning approach

To satisfy statutory, policy, and departmental and division plan obligations and to facilitate sustainable co-management of the state forest, three primary approaches were identified:

- Developing a new forest planning model to guide management decisions and harvest operations.
- Integrating featured species habitat and landscape habitat conditions into the model and plan.
- Identifying climate change risks and applying mitigation strategies into forest management operations as described below.

State Forest Management Plan model design

Introduction

The 2013 Regional State Forest Management Plans used a Microsoft Excel® based model to generate 10-year harvest goals, which were then formulated into annual harvest goals for each forest management unit. Substantial limitations were recognized in using this approach as Excel® is limited in power and capacity to address the complexity and size of state forest management. It also lacks the inherent ability to design and project management scenarios into the future, which is an important function to evaluate management decisions, and didn't allow for the ability to define and track wildlife habitat over time.

For this plan update, the DNR invested in the Remsoft Woodstock Optimization Studio®, an industry-standard modeling platform. It is a suite of software applications that work together to allow users to build custom models representing different forest management strategies. Woodstock® is a linear programming model that strives to find an optimal solution (e.g., maximum or minimum) given a set of parameters represented as goals and constraints.

The DNR invested in training several staff and hired a consultant, Mason Bruce & Girard (Portland, Oregon), to help build components of the DNR's State Forest Management Plan model. The model was used to evaluate current forest cover type management strategies, assess new options and outcomes, solve management challenges, integrate wildlife habitat goals and tracking, and ultimately, determine a preferred scenario that adds confidence in harvest sustainability while achieving desired future conditions in terms of landscape-level forest composition and wildlife habitat.

Representing the land base in the model

The Woodstock® model makes use of a custom-built shape file (mapped polygons) containing important attributes of the state forest relevant to forest management including stand-level characteristics like cover type, age, and stocking, administrative and planning boundaries. These attributes become themes in the model's landscape section and are an integral part of the area section the model evaluates while executing a scenario (see Appendix G for more details). This made it possible to delineate regions, management areas, special analysis units, districts and forest management units to allow for different management approaches in each, and to produce outputs at different scales.

Representing area regulation in the model

The basic premise of any DNR model scenario is for it to represent the area regulation (area control) approach to forest management. This approach calls for setting specific age class and basal area class goals and regulating harvests to meet those goals in each planning period. The DNR uses 10-year

planning periods along with 10-year age classes for even-aged management. This makes it relatively straightforward to create desired age class levels in each applicable cover type. Harvesting and regenerating a specific amount of a given cover type over 10 years will result in establishment of a decade age class. That process is then repeated during each future planning period, resulting in establishing desired age class distribution over time.

In uneven-aged management, area regulation is accomplished with different harvesting techniques that change stand densities rather than resetting stand ages. A desired basal area distribution is defined by setting basal area-class goals that focus on maintaining stands in a condition that sustains optimal growth and stand structure. For example, the northern hardwood cover type is typically managed in a bell-shaped curve of basal area ranging from 70 square feet of basal area per acre on the low end to 120 square feet of basal area per acre on the high end. Stands are harvested when they reach the desired density and thinned to the lower density, allowing for more growth on the remaining trees. There are many variations of this general thinning approach that favor different diameter distributions or other management goals like regeneration and recruitment. Similarly, group selection is an uneven-aged approach to area regulation within a stand through small clear-cut patches harvested each decade. Variations of this system are based on patch size, re-entry period and cycle completion period. It's important to represent the basic principle of each in the model.

Forest inventory data in the model

To make the DNR's State Forest Management Plan model most useful, it needed to be built from the best representation of the current forest inventory. Given that there are approximately five years of treatments already prescribed and approved at various stages of implementation or completion, this made representing the current condition in the model a challenge. A decision was made to advance the inventory forward five years (see Appendix G) to represent what it would likely look like near the beginning of the next 10-year period when this plan is implemented. This method, however, likely resulted in an artificially inflated 0-9 age class, especially in the planted red pine cover type, when in reality some of those acres will not enter the 0-9 age class until the next planning period because of the time it takes for initial and follow-up treatments. To prepare for this plan update, the DNR completed a wall-to-wall assessment of the state forest to document each stand's management "availability" status in MiFI. A stand is deemed unavailable for commercial harvest if there are identified operability issues that prevent it. This comprehensive effort defined the manageable land base for the state forest and thereby defined the acres that were eligible for treatment in the model.

Projecting forest growth in the model

Growth and yield tables are the backbone of the Woodstock model, as these are used to "grow" cover types across periods (10-year intervals). These are based on representative tree size (height and diameter), age and site data collected to calculate cover type growth rates. Without this function, it wouldn't be possible to assess management scenarios to evaluate outcomes over time.

Though the DNR doesn't collect volumetric data to create these tables for the model, the U.S. Forest Service does in its Forest Inventory and Analysis program. This program is based on a network of sample plots across the U.S. to monitor forests by area and ownership, forest growth, removals, health, stand-level characteristics such as snags and downed wood, and other ecological and wildlife habitat attributes. Only Inventory and Analysis program plots on state forest land in Michigan were used to represent characteristics of various strata (unique combinations of cover type, age class and basal area

class) from the DNR's MiFI data. It was important to distinguish the state forest land plots from those located on private land because much of the state forest is comprised of land that was less productive in terms of soil nutrients and moisture availability. This resulted in failed farming attempts and the land ultimately reverting to the state because of delinquent tax payments. One limitation that evolved because of this approach was that fewer data points existed in each stratum resulting in growth and yield tables that are relatively coarse and only represent an average condition of each stratum across the state forest, negating the opportunity to add any geographic specificity.

Evaluation of model capabilities and usefulness

A pilot area was identified in the early stages of development to test the efficacy of the Woodstock® model in representing state forest management. Two management areas were chosen in the northern Lower Peninsula: Wolverine Moraines and Presque Isle Lake and Till Plain.

These areas both had high diversity in cover types and silvicultural methods, and they include the Pigeon River Country State Forest and Elk Management Area with established habitat objectives in associated management plans. These goals would provide a good opportunity to test if they could be directly incorporated into the model as goals or hard constraints.

Forest composition and structure goals in conjunction with habitat-related goals (where applicable) were set for each management area and drove the resulting harvest outputs and schedule in the model. Because harvests are implemented through the management units, which are aligned with county and not management area boundaries, the pilot area offered an ideal scenario to test implementation of the harvest schedule derived from goals in each management unit. The pilot area consisted of the entire Pigeon River Country management unit, as well as parts of the Gaylord and Atlanta units.

The pilot model testing quickly identified numerous challenges that needed to be overcome through modeling strategies and different approaches. The relatively small landscape offered quick solve times during the execution model, enabling a fast turnaround to analyze the results after a change was made. After several months of testing, it was determined that the Woodstock Optimization Studio® was an excellent tool for the DNR to determine a midterm (10 years) harvest schedule that would contribute to and enable long-term sustainable management eventually resulting in desired future conditions.

DNR preferred management scenario and 10-year harvest projection

One of the first decisions in building a model was to resolve whether it would help determine the management approach or improve efficiencies in the current approach. Once the latter was decided, how to combine the objective function, which defines what the model is trying to accomplish, with the goals and constraints that provide control for any given scenario needed to be determined. This is key to adapting a model to function as a surrogate for actual management on the state forest.

A set of desired future conditions was needed to establish a model scenario. The top five cover types in each management area were identified by acreage and data from the previous 10 years were summarized for conversion rates, silvicultural methods and age class distributions. Featured species were identified for each management area and associated with their habitat cover types. Meetings with foresters and biologists were held to discuss past trends and to get a consensus on future management direction. These discussions generated specific data for model inputs by cover type including the distribution of silvicultural methods by type, conversion rates between cover types, rotation ages, individual age-class goals and an overall cover type population trend. For cover types that were not in

the top five by acreage in each management area, standard silvicultural criteria were applied in the model. This formed the basis for the current DNR preferred model scenario, with some subsequent adjustments for a shift in natural pine (removal of clearcut as a viable silvicultural method) and Kirtland's warbler (use of mastication and biomass) management.

After running several scenarios with different objective functions, DNR staff chose the scenario with an objective function to maximize harvest using goals and constraints to ensure sustainable levels of cover type and wildlife habitat management. This model scenario incorporates staff input on cover type management by management area, specific cover type and habitat goals within special analysis units from area-specific plans, and featured species wildlife habitat. This scenario was vetted through forestry and wildlife staff.

This management scenario projected an approximate 50,000-acre, 10-year prescribed harvest target. This is lower than previous targets for several reasons. The last decade was characterized by a compensatory management approach, which called for higher than typical or sustainable restart acres across many even-aged cover types to build the 0-9 age class and reduce the older age classes. This was done to make room for the surplus of acres in the 30-and 40-year-old classes that would soon be reaching economic maturity in coming decades. In addition, extensive salvage cutting due to beech bark disease and emerald ash borer temporarily increased harvest acres. These circumstances emphasize the need for a planning model that can illustrate the impacts of management decisions over time. This 10-year harvest planning goal meets the statutory obligation of sustainable forest management.

Multiple use and the model

The DNR's primary intended use of the Woodstock® model was to determine a preferred management scenario that struck a balance between maximizing timber harvest and meeting forest sustainability mandates, integrating wildlife habitat goals where possible, and ensuring ecological values were sustained. Wildlife habitat values were defined by a set of featured species chosen to represent a range of forest and habitat conditions, and habitat variables for the model were identified and integrated (see below).

Ecological values on the state forest are largely represented by the conservation area network, which includes state forest lands that have some special conservation designation. These lands were not explicitly represented in the model since they were not eligible for treatment in the model. Any management or restoration actions will be specific to each designated area.

It was not possible to include other state forest values, such as rare species, non-forested habitat, recreation, water and soil quality, forest health and minerals extraction in the model. This is also not a climate change model, and it was not possible to include climate change-related parameters. This underscores the important difference between the model informing this plan update and the plan itself. The model is primarily limited to predictable and foreseeable cover-type management influences and changes over time. The plan itself more comprehensively addresses all values on the state forest. It is also suggestive of the need for model scenario runs throughout implementation during the planning period due to unforeseen events including wildfires, insect or disease outbreaks, wildlife habitat goal changes, or climate change impacts that may affect annual harvest plans.

Modifications to the model due to the 2025 Ice Storm

The ice storm that began on the evening of Friday, March 28, 2025, and lasted for the next 60 hours, until the early morning hours of Monday, March 31, left its mark on the forests of the northern Lower Peninsula. Approximately 790,000 acres of forested stands on DNR-managed lands in the eastern Lower Peninsula district were affected by ice accumulation at varying levels of severity. Over the course of the ice storm, some areas of northern Michigan were coated in up to 1 inch of ice.

Nearly 100 % of the trees snapped in half or tipped over in the most severely affected areas. This level of damage was most common in homogenous stands of 50- to 60-year-old planted red pine. Moderately damaged stands suffered from many snapped trees; those that didn't snap had numerous broken branches. Lighter damage was characterized by several trees within a stand having broken branches, but most trees not snapped or toppled.

The impacts from the ice storm were of sufficient magnitude to necessitate a modification of this plan. This final release includes modifications that incorporate the damage caused from the ice storm, the associated timber salvage efforts and the modified timber harvest projections where a loss in stem density may negate the need for treatment in this planning period (aside from potential salvage harvest of prioritized stands).

Two treatment types were added to the model to capture ongoing and projected future salvage efforts. The salvage clearcut represents harvests that will likely occur on stands where regenerating the stand is the best path forward. Salvage thinning was created to represent a partial harvest of damaged stands where there will still be a healthy, viable mature stand to manage in the future.

An action was also created in the model that represents severe damage of stands that are not eligible for harvest. Examples would include stands that were too young (sub-merchantable) or unavailable due to other constraints identified in the site conditions layer (too wet, too steep, no access, etc.). These stands have had their age projected to reset to the 0-9 age class and are shown to begin natural regeneration in this planning period.

The growth of highly impacted cover-types was also slowed by 25% for the 10-year period by applying a reduction factor to several variables of existing development types in growth and yield curves in the eastern Lower Peninsula. This change was implemented to represent the impact the ice storm is expected to have on remaining trees in stands as they recover from the damage by healing open wounds and re-growing branches.

Changes were also made to the model in response to feedback that resulted from the first release in 2024. The selection harvest projection in the northern Lower Peninsula was determined to be above achievable levels, which was likely caused by inaccurate assumptions about the distribution of actual basal area values across more coarse inventory data ranges. Essentially, there were more acres of northern hardwood forecasted to be ready for a selection harvest than what was deemed possible based on several years of testing the implementation of the model. This resulted in a reduction in selection harvest from what was projected in the first release by about 25% in most northern Lower Peninsula management areas. This reduction was nearly offset, however, by the projected need for northern hardwood salvage harvest across the management areas impacted by the ice storm. Many stands that would have otherwise gone untreated in this planning period will likely receive some sort of partial harvest, likely driven by the need to salvage damaged sawlog trees and improve the overall

health of the stand. Total salvage harvest projections as well as projections for each impacted cover type can be viewed in section 3.1 - Forested Cover Types.

Featured species and landscape habitat conditions

Featured species are target species identified by the DNR Wildlife Division as a focus for landscape-level habitat planning and management. This approach began in 2013 with an intention to review and revise the list every three years. The state forest plan update coincided with the 2019 featured species review. Given the new opportunity to integrate wildlife habitat needs into the Woodstock® planning model, it was determined that a list revision was warranted to maximize this potential. Thus, most of the forest-related featured species chosen for the update in the northern Lower and Upper peninsulas are those that may be negatively affected by normal forest management practices, and species whose habitat requirements have an impact on normal forest operations at a large scale. They were also primarily species that would be relatively straightforward to monitor, should the opportunity arise. This was done intentionally to ensure featured species habitat goals and monitoring could be incorporated in the model. This is pivotal, because for the first time, wildlife habitat treatment acres will be integrated into planned forest harvest acres.

A few forest-related featured species that were generalists or that responded to natural disturbances were chosen for the northern Lower and Upper peninsulas as well. These species couldn't be added to the model, but all featured species are included in this plan. In total, 18 forest-related featured species were chosen and went out for public review with this plan in 2024, 14 of which were incorporated into the model. In response to multiple comments on the lack of herptiles on the list and concern for moose, both wood turtle and moose were added to the plan as featured species but could not be added to the model at this planning stage. The new list of 20 featured species may look slightly different from previous lists but still includes highly valued game species and species of conservation concern.

The featured species also represent landscape habitat conditions, key elements of wildlife habitat that are often overlooked or underrepresented in typical forestry practices. Due to staffing capacity, they had not been previously implemented. Most landscape habitat conditions originated from field staff and species specialists identifying management issues over time. They were updated in conjunction with the state forest plan update to reflect tree harvest-related attributes trackable through the model and MiFI over time.

Any given landscape habitat condition has multiple featured species associated with it, and any given featured species may represent multiple landscape habitat conditions (Table 1). This, in large part, is because landscape habitat conditions are fairly broad, and associated featured species may represent differences in habitat needs within that landscape habitat condition (e.g., mature forest with open understory versus mature forest with dense understory). Young forest doesn't necessarily meet the typical landscape habitat condition criteria described above, but was included given its importance to many wildlife species. The landscape habitat conditions are:

- Young forest
- Mature forest (structural components of both closed canopy and canopy gap forests)
- Large patch or block size (area sensitivity)
- Mast (oak, hickory, beech, cherry, etc.), as a cover type and within stand component
- Mesic conifer, as a cover type and within stand component

- Big trees
- Upland openings
- Natural disturbance

Table 1. Featured species and the landscape habitat conditions they are associated with.

Featured Species	Associated Landscape Habitat Conditions
American marten	Mature forest, area sensitive, large trees, mesic conifer
American woodcock	Young forest, openings
Black bear	Mast
Black-backed woodpecker	Natural disturbance
Blackburnian warbler	Mature forest, area sensitive, large trees, mesic conifer, closed canopy
Black-throated blue warbler	Mature forest, area sensitive, large trees, closed canopy
Cerulean warbler	Mature forest, area sensitive, large trees, canopy gaps
Elk	Young forest, mast, openings
Golden-winged warbler	Young forest, openings
Kirtland's warbler	Young forest, area sensitive
Moose	Young forest, mature forest, big trees
Red crossbill	Mature conifer forest, large trees
Ruffed grouse	Young forest
Sharp-tailed grouse	Large openings
Snowshoe hare	Young forest
Spruce grouse	Mature conifer forest, canopy gaps
White-tailed deer	Mature forest in wintering complexes, mast
Wild turkey	Mast, openings
Wood thrush	Mature forest, closed canopy
Wood turtle	Openings

Featured species habitat modeling and non-model featured species

Forest inventory data is primarily used to determine whether a stand of trees requires treatment from a silvicultural perspective. Important habitat components for wildlife species are not directly measured in standard forest inventory protocols. A spreadsheet was created to align life requisites for a particular featured species to the information that field foresters collect. The resulting wildlife habitat diversity matrix created a set of forest inventory habitat attributes for each featured species that was used to define habitat for each featured species in the model. The featured species habitat in the model represents either limiting factors or priority habitats for each species. It would add too much complexity to the model to attempt to describe the entire suite of habitats for each featured species.

Of the 20 featured species, six are not addressed in the model. Black-backed woodpecker moves around the landscape where disease and insect outbreaks occur. Without substantially limiting factors, and without any important habitat impacts to or from forest management, black bear was deemed unsuitable for the model. For sharp-tailed grouse and wild turkey, openings were identified as limiting factors, but it was determined early in the modeling process that openings were not going to be addressed for this planning period. Both wood turtle and moose were added too late in the planning process.

The 14 species in the model are tied to specific, consistent and limiting forested habitat attributes that could be represented by a set of forest inventory data. For each of these 14 species, the model tracked featured species habitat over time as one of the outputs. For each species, this is an aggregate of the cover types, age classes, basal area ranges, stocking, etc., resulting in an acreage total for any of the geographic scales in the model. This new capability enables prior assessment of the impacts that management decisions may have on featured species habitat through scenario exercises. Under the preferred DNR model scenario, featured species habitat looks relatively abundant and stable over the 15 periods, or 150 years of the model run (Figure 4).

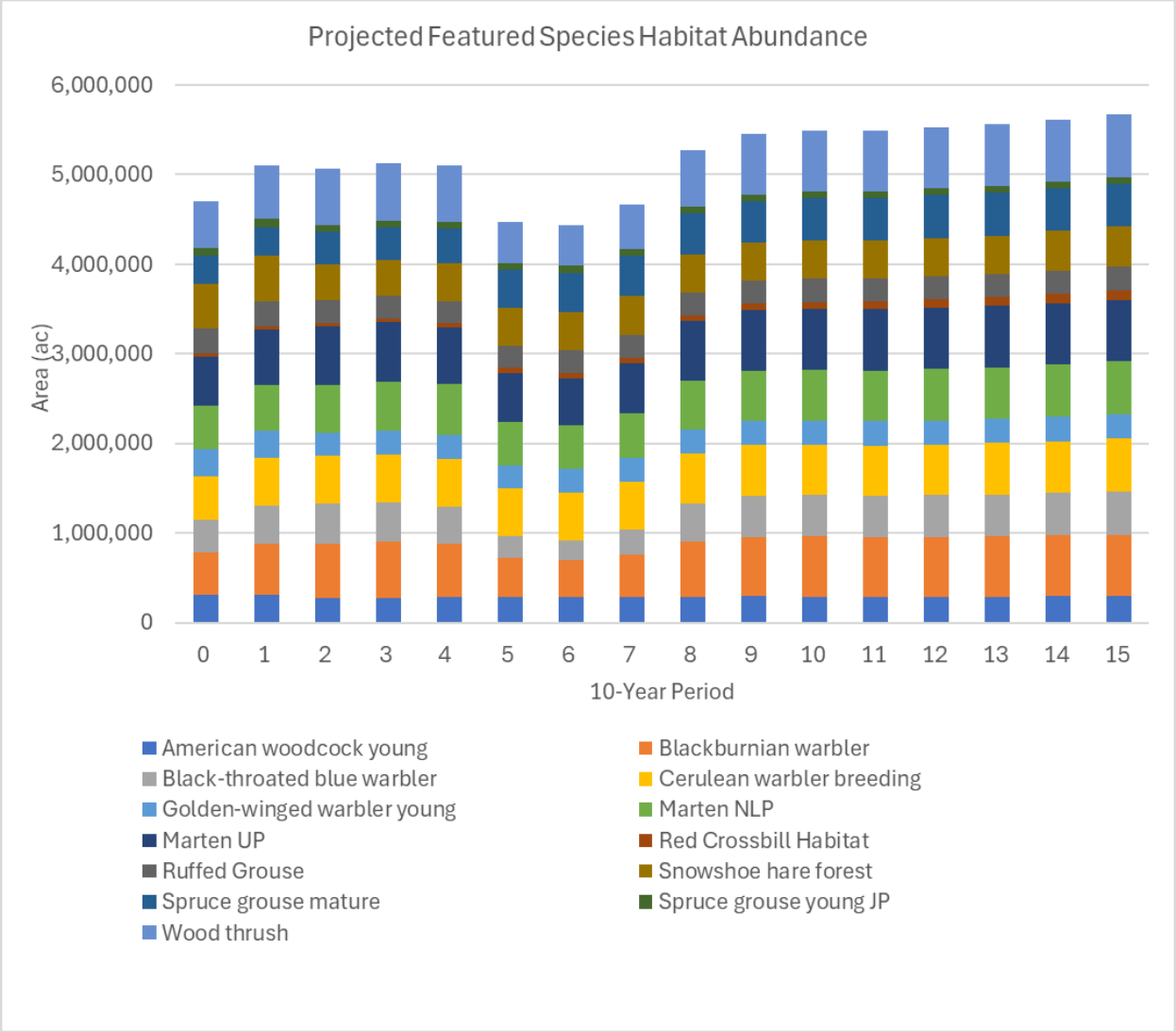

Figure 4. Model outputs for featured species habitat over 15 periods (150 years).

There are limitations on how to interpret the model outputs. As with any model, real complexities must be simplified, data gaps exist, and difficult decisions are made to create the best representation of state forest condition and management in the model. When all factors are accounted for, model outputs may be several steps removed from what is on the ground. Therefore, when tracking featured species habitat

over time in the model, it is best to put it into context as potential habitat. This potential can then be evaluated through the continuously updated MiFI inventory and verified with the help of field staff. The value of these habitat outputs lies in evaluating how much habitat (potential) is on the landscape for each featured species for the first time, and in monitoring trends over time.

Of the 14 featured species in the model, four have habitat management plans and geographically defined habitat management areas. Because of this, special analysis units were created in the model for Kirtland's warbler essential habitat, the elk management area, deer wintering complexes over 15,000 acres and grouse enhanced management sites. Each of these species habitat plan goals were added to the model so that model harvest outputs for each SAU ensure that these habitat goals are achieved. Because analysis units occur both within and across management areas, the goals are weighted higher than goals for the associated management area(s). This ensures SAU goals are met first, and then those are integrated into the management area goals as part of the solution. By doing this, the DNR has integrated wildlife habitat goals into planned forest harvest goals for the first time. For these four species, both habitat goals within SAUs and forest matrix habitat outside of them can be monitored in the model.

Not all landscape habitat conditions could be addressed in the model, aside from young and mature forest. Natural disturbances are not possible to predict; mast and within-stand mesic conifers, as well as big trees and mature forest understory, are at too fine of a scale; non-forested openings will remain static in the model this planning period; and large contiguous patches require geospatial capabilities the model does not have. For most of the landscape habitat conditions and the six species not included in the model, tracking will be done as needed through MiFI and other tools.

Forest diversity matrix

Featured species habitat exists in a broader landscape matrix that influences both habitat potential and featured species presence. The forest diversity matrix is an attempt to describe the forested landscape at a coarse scale in a way that will be useful to inform landscape habitat conditions and featured species habitat goals and track potential habitat availability as defined by the model.

The forest diversity matrix is defined by the following inventory data:

- Forest age grouping or category: young forest (0-19); intermediate forest (20-39); mid-aged forest (40-79); mature forest (80+)
- Shade tolerance versus shade intolerance
- Upland versus lowland
- Available versus unavailable (for management, as defined by site conditions)

Understanding the abundance and distribution of these broad forest matrix categories allows for high-level assessment of management potential and provides landscape context to cover type management decisions within management areas. It also is a starting point to identify broadscale habitat needs and potential. Because landscape habitat conditions represent more specific habitat requirements of featured species, they can be used to dial down analysis into evaluating, setting and monitoring featured species habitat goals.

The current condition of the state forest matrix is predominantly older age classes (mid-aged and mature) and is dominated by upland cover types available for harvest management (Figure 5). Lands

unavailable for management are largely older, lowland and shade-tolerant forest types. Available, shade-intolerant forest types dominate in the young and intermediate forests, which is likely driven by aspen and jack pine.

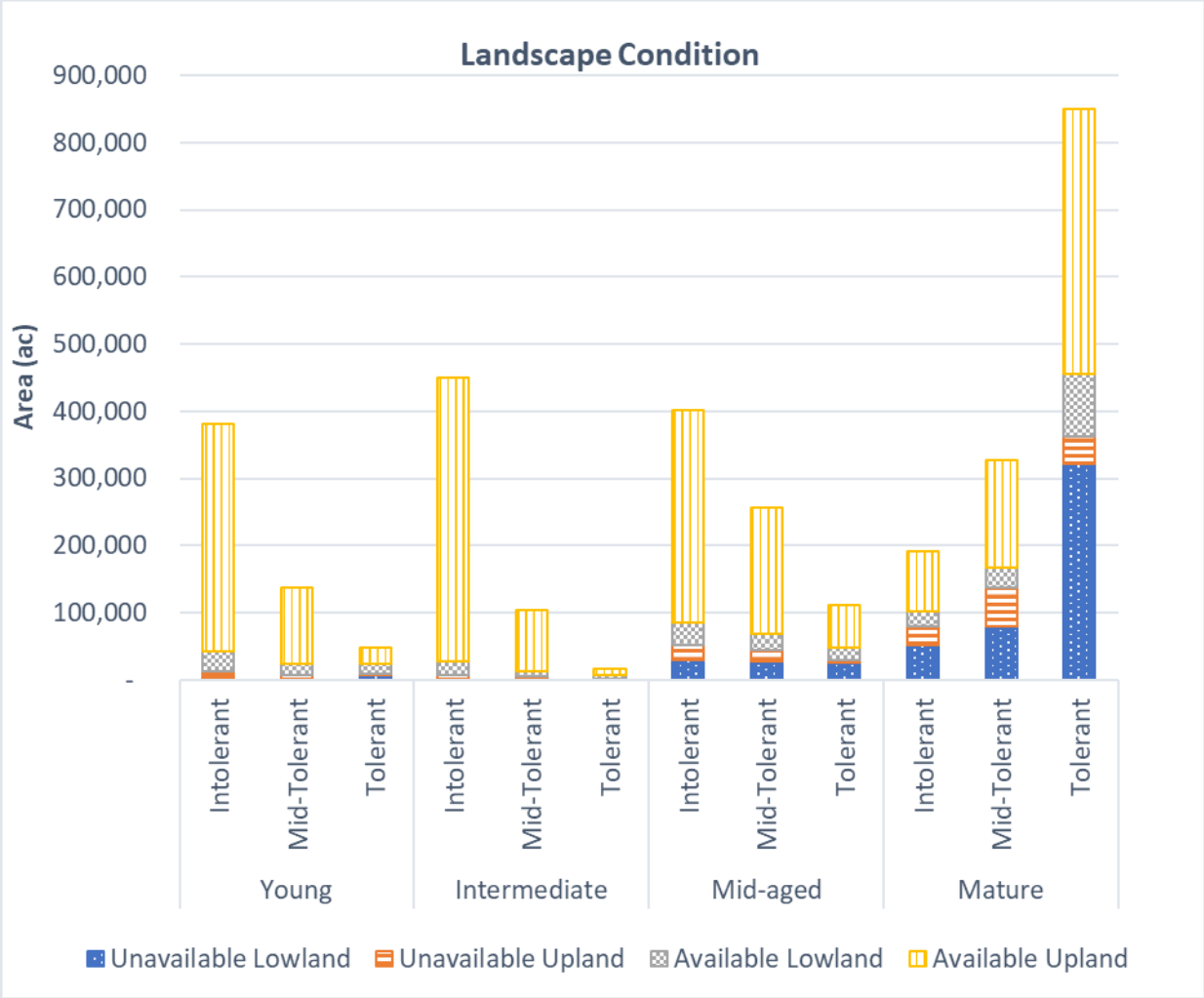

Figure 5. Forest diversity matrix showing management availability, age category, landscape position and shade tolerance by number of acres statewide.

Implementing the featured species approach

Featured species have geographic boundaries that vary in scale. Some that were chosen are specific to the northern Lower Peninsula (e.g., cerulean warbler) or Upper Peninsula (e.g., sharp-tailed grouse). Others have geographic priority areas within regions based on range-wide conservation plans (golden-winged warbler (Roth et al. 2019), American woodcock (WMI 2010). Based on differences in range, geographic prioritization, habitat potential and species occurrence, and with wildlife biologist and species specialist input, the 20 featured species were assigned to relevant management areas where habitat management will be focused. Each management area has a list of featured species to help prioritize management. There is plenty of opportunity to manage for each of these species that occupy

different habitat niches. Management area-level habitat models can provide a starting point for biologists to determine how much, where and which methods to manage for each species in conjunction with Forest Resources Division counterparts.

One of the main priorities of this state forest plan update was to integrate wildlife habitat planning and implementation as much as possible. At the statewide and regional scales, desired future conditions, objectives and management actions were developed for each featured species and landscape habitat condition. These should be used to guide featured species management and inform decisions at the management area and forest management unit levels.

The management area section of the plan includes geographically specific forest diversity matrix and landscape habitat conditions data and integrates current and future conditions for featured species habitat from the model and MiFI. Harvest goals for the 10-year planning period are described for each cover type, and featured species habitat conditions and considerations are included where applicable. It will be up to forest management unit staff to determine specific prescriptions to achieve habitat conditions at the stand level.

The special analysis unit section of the plan describes the 10-year timber harvest goals and silvicultural methods from the model outputs that achieve the desired habitat goals. Again, staff from each management unit will need to determine where and how to apply these harvest targets.

Management guidance has been stepped down through multiple geographic scales to help field staff implement goals for featured species habitat and landscape habitat conditions. Other tools will be developed to bridge remaining gaps during the planning period to support plan implementation. This includes landscape assessments of large contiguous patches of habitat for area sensitive species and habitat guidance documents for each featured species that will include prescription specifications at the stand scale.

Despite an emphasis on featured species in the model and this plan, the DNR has statutory and forest certification obligations to other species. A combination of forest certification work instructions, species-specific guidelines and best management practices provide guidance on managing for species outside of featured species. These include forest raptors, bald eagles, turtles and bats. In-stand retention guidelines and some water-quality best management practices guide on-the-ground management, mitigating forest harvest activities on wildlife. Lastly, at the stand level, rare species reviews are conducted to avoid impacts to these important plants and animals, following state and federal laws.

The intent is to benefit the broadest suite of wildlife species whose needs are not being fully met by current forest management practices. The general approach on state forest land is to ensure representative cover types, age classes and structural conditions across the landscape to maintain the broadest diversity of wildlife. The list of 20 featured species was chosen to represent those cover types, age classes and structural conditions across the state forest. Ensuring this occurs is a matter of implementing the model and this plan, and monitoring habitat over time via the model and MiFI. This will be described in more detail in the monitoring section of the plan (Section 6).

Climate change

The earth's climate, like a forest ecosystem, is dynamic. It changes constantly, but at a pace that is not always obvious. Change itself is not a problem; it is when change is unexpected that problems arise. This

might be because managers assume the climate is static or changing slowly enough to be treated like it is static. For example, managers might assume an unchanging climate and engineer culverts based on the average precipitation for the last 30 years rather than the trend of rapidly increasing heavy precipitation events. Similarly, forest plants and wildlife evolved and shifted ranges to match the climate over thousands or millions of years. The current rapid changes in climate require species to shift range, evolve in place, grow with reduced vigor or health, or be extirpated locally. Change requires adaptation.

The key challenge to forest management in the 21st century is managing for change at the right pace and the right place. The climate in Michigan is changing, and state forest managers need to anticipate those changes so that they are neither underreacting nor overreacting.

Climate is one of the fundamental drivers of forest health and species composition. Climate change amplifies threats such as forest pests and disease, and it challenges operations such as harvest over frozen ground (Angel et al. 2018). Climate change complicates most aspects of forest management. For these reasons, climate change considerations have been integrated throughout this plan. For example, climate change has been integrated into management priorities (e.g., desired future conditions, objectives and management actions) at the state forest-wide and regional scales using resources published by the Northern Institute of Applied Climate Science. Many of these were coauthored by Michigan DNR staff members (e.g., Handler et al. 2014, Janowiak et al. 2014b, Handler et al. 2022a, Handler et al. 2022b) or refined based on input from DNR staff at workshops or during review (Swanston et al. 2016). At the management area scale, field staff were surveyed to identify management areas that might be prone to certain climate change risks.

Climate change impacts in Michigan

The state forest system in Michigan is unusually vulnerable to climate change for two reasons:

- Michigan's climate, like others at high latitudes in the northern hemisphere, is changing faster than the global average. The average temperature in Michigan has risen almost 3 degrees Fahrenheit since the beginning of the 20th century; most of that warming was concentrated in the winter and spring. The frequency of extreme precipitation events (greater than 2 inches in 24 hours) has also increased; the number of extreme precipitation events for 2010-2014 and for 2015-2020 were the highest on record (Frankson et al. 2022). Both trends are projected to continue for the duration of this plan (Hayhoe et al. 2018).
- Climate vulnerability is highest along the southern edge of the geographic range of a given species (Hampe and Petit 2005), and several of Michigan's most common tree species occur at the southern edge of their geographic ranges. Of the 10 most common tree species on state forest land by area of occupancy, eight occur at or near the southern edge of their range in Michigan.

These vulnerabilities express themselves in many ways (Vose et al. 2018, Handler et al. 2022a). For example, increased temperatures have cascading effects on growing season length, snowfall and snow hardness. These in turn affect timing and persistence of frozen ground, risk of forest insect and pathogen outbreaks, impacts to vegetation from concentrated wildlife foraging, and the ability of wildlife to avoid predators, find food, or stay warm or cool. Changes in precipitation amount and seasonality affect soil moisture, humidity, streamflow and stream temperatures. These in turn affect stress, growth and often survival of organisms from fish to invertebrates to trees. Operations and

infrastructure also are impacted as less predictable frozen ground and increased flooding events affect access, erosion and maintenance costs. This is just a sampling of the ways that climate change continues to complicate forest management.

Adapting to change

Climate adaptation is what managers do in response to recent climate trends and to anticipate future changes. It can be as simple as replacing a blown-out undersized culvert with a larger one or as complicated as conducting planting trials and using climate projections to select the optimal source material for future nursery stock. Adaptation planning involves assessing how vulnerable resources are to climate change in the context of stated goals. After vulnerabilities are estimated, goals are revisited or management actions are adjusted. A great deal of scientific literature, including several good syntheses (Foden et al. 2019, Thurman et al. 2022), now exist to guide assessments of vulnerability. Planning frameworks and decision support tools now exist to structure how goals are reconsidered (Schuurman et al. 2020, Lynch et al. 2021) and how to adjust management actions (Janowiak et al. 2014a, Swanston et al. 2016, Handler et al. 2022b).

Several statewide or regional assessments of climate vulnerability exist for Michigan. These include The Forest Ecosystem Vulnerability Assessment and Synthesis reports for the northern Lower Peninsula and eastern Upper Peninsula (Handler et al. 2014) and for the western Upper Peninsula and northern Wisconsin (Janowiak et al. 2014b). They synthesize three forest modeling approaches to give a good overview of Michigan-specific forest vulnerability. The Michigan Forest Action Plan (Michigan DNR 2020) and the forest chapter of the Midwest section of the National Climate Assessment also contain good summaries of climate change and forest vulnerability. Hoving et al. (2013) conducted an analysis of 400 fish and wildlife species in Michigan, including all featured species used in state forest management planning. Species-specific vulnerability assessments exist for tree species as well, including aspen (Worrall et al. 2013), white pine (Joyce and Rehfeldt 2013) and sugar maple (Reinmann et al. 2019). The state forest management planning process leaned heavily on the assessment and synthesis reports but used information from the other literature as well.

Once goals are set, managers will need to choose strategies and actions that are likely to succeed in current and future climates. One tool used by many forest managers in the Michigan DNR is the Adaptation Workbook (Swanston et al. 2016). It provides a structured process to incorporate climate change considerations into a project or decision, and to document the thought process in logical steps. The Adaptation Workbook can be used in conjunction with several menus of adaptation options specific to contexts such as forestry, wildlife management or watershed management.

This process was applied to this plan once development of the desired future condition, objectives and actions for each of the management priorities in Section 3 was complete. That was followed by a review of predicted climate change impacts for northern Michigan based on Northern Institute of Applied Climate Science tools and these were used to create tables specific to each management priority. Based on these identified vulnerabilities, the adaptation menus were used to modify the desired future condition, objectives and/or actions of a management priority to incorporate some operational adaptations. Finally, these adaptations and the reason for them are briefly explained.

Forest carbon

Forest management can also be a part of the solution when it comes to climate change. Growing forests remove carbon dioxide from the atmosphere (climate change mitigation) through photosynthesis. Forest resources in Michigan, including managed forests, forested wetlands and urban forests, currently store large amounts of carbon. There are often win-win opportunities where climate adaptation and mitigation can work together. Typically, actions that keep forests healthy and prevent large-scale disturbances fulfill both goals (Handler et al. 2022a).

Carbon in forest ecosystems can be accounted for in pools and in fluxes. Soil carbon and live trees are two examples of carbon pools. Much of the carbon stored in forest ecosystems in Michigan occurs in soils. Some forest types have significantly less soil carbon (e.g., jack pine forests), and some have significantly more (e.g., forested wetlands). Soils lose carbon very quickly when disturbed or when soil moisture changes; it can take centuries to rebuild soil carbon stocks. Forest practices that reduce erosion and protect healthy soils are key parts of any strategy to conserve forest carbon (Handler et al. 2022a).

The other large forest carbon pool in Michigan is live tree biomass. Management that promotes forest health and greater productivity promotes carbon storage. Forest harvest and lengthening harvest rotations can increase long-term carbon storage. In forests with relatively low disturbance risk from pests, disease or climate-related mortality, lengthening rotations can increase carbon storage. In forests with greater climate risks, harvest can be a strategy to continue storing the carbon in forest products, especially if those forest products are durable goods such as building materials or furniture.

Individual birds and animals store relatively little carbon in their bodies compared to trees, but their presence can significantly alter carbon cycles in ways that increase or decrease carbon sequestration rates (Schmitz et al. 2023). For example, reduction of herbivores through predation can affect forest regeneration and thus increase carbon storage. Similarly, squirrels and birds transport seeds, increasing the density of trees in forest landscapes.

Much of the state forest system in Michigan sequesters significant amounts of carbon as it is currently managed. The Michigan DNR was the first state forest in the country to sell forest carbon credits in a carbon market. The DNR uses revenue from those carbon credits to invest in climate-friendly forest management projects. This creates a virtuous feedback loop that results in more and healthier natural resources while contributing to global efforts to combat climate change.

Climate change is a challenge. In some ways, it makes reaching our goals of forest sustainability harder. Managers will need to be intentional about adapting to a changing climate while capitalizing on opportunities to sequester carbon from the atmosphere and store it in forest soils, live biomass and durable forest products. Despite the difficulties and complications, Michigan is a leader in both climate adaptation and carbon storage. As an agency, the DNR is determined to meet the climate challenge while managing Michigan's state forest system with science, stakeholder engagement and creativity.

Forest sustainability planning framework

A framework was needed to incorporate the planning components into a comprehensive and cohesive structure for all aspects of state forest management. The DNR manages approximately 4.6 million surface acres of land and more than 6 million acres of subsurface mineral rights in trust for Michigan

residents. To ensure sustainable management of these rich and varied natural resources, as stipulated in part 525 of the Natural Resources and Environmental Protection Act (Public Act 451, as amended), a system was needed to balance the ecological, social and economic capacity of the forest.

Because deciding how to define and operate sustainable forest management has been a challenge, an international group of scientists initiated what is now known as the Montreal Process in 1994 (Montreal-Process.org). This established a set of criteria and indicators representing a large range of forest values. It provides a globally common approach and language to facilitate discussion, partnership and assessment.

The seven criteria of the Montreal Process represent the essential components of sustainable forest management. These are:

- Conservation of biological diversity
- Maintenance of productive capacity of forest ecosystems
- Maintenance of forest ecosystem health and vitality
- Conservation and maintenance of soil and water resources
- Maintenance of forest contribution to carbon global cycles
- Maintenance and enhancement of long-term multiple socio-economic benefits
- Legal, institutional and economic framework for forest conservation and sustainable management

Associated with each of these criteria is a set of indicators (54 in all) to assess progress toward meeting them. Monitoring these criteria over time provides information that allows an organization (or country) to assess its progress toward sustainable forest management.

Until now, the DNR has defined sustainable forest management through area regulation and conformance with Sustainable Forestry Initiative and Forest Stewardship Council standards. This plan outlines a monitoring framework similar to the Montreal Process. Through it, monitoring over time will assess progress toward sustainable forest management. This framework includes area regulation and certification standards.

State forest guiding principles

The Montreal Process criteria were used as a basis to develop seven sustainable state forest management principles:

- Principle 1. The state forest is managed to conserve or enhance biological diversity.
- Principle 2. The state forest is managed for net positive growth.
- Principle 3. The state forest is managed to promote ecosystem health and vitality.
- Principle 4. The state forest is managed to conserve and protect soil and aquatic resources.
- Principle 5. The state forest is managed to provide opportunities for social and economic benefits.
- Principle 6. The state forest is managed to respond to a changing climate.
- Principle 7. The state forest is managed to steward significant cultural resources.

Establishing the framework

Once the seven state forest principles were developed, the Montreal Process indicators were used to develop a set of goals and strategies associated with each principle that, taken together, achieve the guiding principles. Management priorities were then identified for each strategy. Realistic, achievable metrics that measure progress toward sustainable state forest management were identified for each management priority.

This plan encompasses three geographic scales (state forest, region, management area/special analysis unit), and four planning scales (principle, goal, strategy, management priority). To move the needle on any given management priority at the statewide or regional level, a desired future condition needed to be established. Then, a set of objectives for each was established to set interim, short-term goals toward the desired future condition. Finally, management actions were identified to meet those objectives. These planning components are all part of the state forest sustainability framework, and are defined as:

> **Principle**: The fundamental standard, serving as the basis for action, by which the state forest is administered.
>
> **Goal**: Aspirational, broad outcome statement of a state or aspect of the state forest system that adheres to a principle. The combined goals should encompass all aspects of all the principles.
>
> **Strategy**: Approach taken to achieve a goal.
>
> **Management priority**: The state forest resource or attribute that is being managed.
>
> **Desired future condition**: A narrative statement that describes the condition of a state forest resource that land managers set to achieve over a long period of time in a distinct geographic area.
>
> **Objective**: SMART (specific, measurable, achievable, relevant, timebound), mid-range targets toward achieving the desired future conditions.
>
> **Management action**: The specific tasks or steps required to achieve the objective.

The state forest sustainability framework differs from the Montreal Process to better adapt the framework to state forest management and scope of operations. The state forest is part of a vast landscape of different ownerships, land covers and land uses. Sustainable management of the state forest is not the same thing as sustainable management of Michigan's forests as a whole. The DNR recognizes that things such as soil and water quality can be influenced by external factors. The DNR also recognizes some inherent limitations in operations, capacity and administrative resources to enact all the criteria and indicators of the Montreal Process. The DNR is also subject to various statutes, mandates, policies and procedures.

Ultimately, this is a state forest management plan, and while multiple-use values are incorporated, it is not within the scope of this plan to influence changes outside of forestry activities. The sustainable forest management framework outlined in this plan reflects a good-faith effort to apply the tenets of the Montreal Process criteria and indicator framework to feasible activity on the state forest. By monitoring the state forest sustainability framework and associated metrics detailed in this plan, the DNR intends to assess progress toward sustainable state forest management over time.

Planning framework

Principle 1. The state forest is managed to conserve or enhance biological diversity.

Goal 1. Conserve or enhance ecosystem diversity.

- Strategy 1. Maintain a consistent land base that ensures continuity in management of forest ecosystems over time.
    - Management priority:
        - State forest area
- Strategy 2. Conserve or enhance forest composition, structure and terrestrial habitats through management.
    - Management priorities:
        - State forest cover types
        - Featured species habitat
        - Landscape habitat conditions:
            - Big trees
            - Mast
            - Mature forest understory
            - Mesic conifers
            - Natural disturbance
            - Nonforested openings
        - Forest and habitat age categories:
            - Young forest
            - Mid-successional forest
            - Mature forest
        - Horizontal and vertical structure
        - Patch size, arrangement and connectivity
        - Stand size
- Strategy 3. Contribute to the conservation of aquatic habitat through management of forested habitats.
    - Management priorities:
        - Riparian and lacustrine habitat.
        - Wetland habitat.
        - Vernal pools and seeps.
- Strategy 4. Conserve a range of biodiversity values on the state forest through special area designations.
    - Management priority:
        - Conservation Area Network.

Goal 2. Conserve or enhance species diversity.

- Strategy 1. Manage species of conservation concern to ensure their continued presence on the landscape.
    - Management priority:
        - Rare species
- Strategy 2. Maintain or enhance native forest species diversity.

    - Management priority:
        - Tree species

Goal 3. Conserve or enhance genetic diversity.

- Strategy 1. Manage tree species within the bounds of seed zones and manage habitat to promote viable unique populations.
    - Management priorities:
        - Seed zones
        - Unique populations

Principle 2. The state forest is managed for net positive growth.

Goal 1. Ensure long-term forest productivity to conserve forest resources.

- Strategy 1. Manage the state forest using silvicultural practices that ensure desired management outcomes.
    - Management priority:
        - Forest regeneration

Goal 2. Manage the state forest to maintain or enhance tree productivity.

- Strategy 1. Ensure forest growth rates exceed the rate of forest product removals.
    - Management priority:
        - Tree growth, mortality and removals

Principle 3. The state forest is managed to promote ecosystem health and vitality.

Goal 1. Protect forests from wildfire, pests, diseases and other damaging agents.

- Strategy 1. Manage disturbances to allow for natural ecosystem function while mitigating negative impacts.
    - Management priorities:
        - Non-native insects and diseases
        - Native insects and diseases
        - Invasive plants and animals
        - Herbivory
        - Wildfire

Principle 4: The state forest is managed to conserve and protect soil and aquatic resources.

Goal 1. Conserve and protect palustrine, lacustrine, riverine, riparian and aquatic resources.

- Strategy 1. Protect water quality in streams, lakes and other water bodies.
    - Management priorities:
        - Streamside damage
        - Riparian trails
        - Riparian roads
        - Stream crossings
        - Riparian area cover-type composition.
- Strategy 2. Protect water quantity in streams, lakes and other bodies of water.

    - Management priority:
        - Watershed vegetation cover

Goal 2. Conserve and protect soil resources.

- Strategy 1. Manage sites to ensure soil quality.
    - Management priorities:
        - Successive rotations
- Strategy 2. Manage sites to prevent soil erosion and compaction.
    - Management priorities:
        - Forestry and recreation impacts
        - Damaged sites

Principle 5. The state forest is managed to provide opportunities for social and economic benefits.

Goal 1. Provide public access for social opportunities on the state forest.

- Strategy 1. Maintain infrastructure to ensure public access.
    - Management priorities:
        - State forest roads
        - Boating access sites
        - Nonmotorized areas
- Strategy 2. Provide for and manage recreation activities to benefit residents and visitors and to promote tourism.
    - Management priorities:
        - Motorized recreation trails
        - Nonmotorized recreation trails
        - Dispersed recreation
        - Areas managed for hunting
        - State forest campgrounds
- Strategy 3. Protect state forest lands from overuse and misuse.
    - Management priorities:
        - Boundary maintenance.
        - Use permits

Goal 2. Ensure external engagement in state forest management.

- Strategy 1. Engage with tribal governments to ensure recognition of tribal rights and uses and to inform forest management through Indigenous knowledge.
    - Management priority:
        - Tribal consultation
- Strategy 2. Provide opportunities for public and stakeholder engagement in state forest management.
    - Management priorities:
        - Public review and input

        - Public observations and input
        - Outreach, engagement and education
- Strategy 3. Engage with partners to address forest management issues.
    - Management priority:
        - Collaborative partnerships

Goal 3. Provide a variety of economic opportunities.

- Strategy 1. Manage for a variety of forest products.
    - Management priorities:
        - Timber harvest volume
        - Fuelwood
        - Carbon offset credits
- Strategy 2. Provide opportunities for energy development consistent with forest conservation.
    - Management priorities:
        - Oil and natural gas.
        - Renewable energy.
- Strategy 3. Provide opportunities for mining consistent with forest conservation.
    - Management priorities:
        - Metallic minerals
        - Nonmetallic minerals
        - Sand and gravel

Principle 6. The state forest is managed to respond to a changing climate.

Goal 1. Manage the state forest through integration of adaptation and mitigation strategies.

- Strategy 1. Identify adaptation approaches and integrate these into relevant management priorities.
    - Management priority:
        - All applicable management priorities
- Strategy 2. Identify portions of the state forest that can act as a carbon sink.
    - Management priorities:
        - Carbon capture utilization and sequestration

Principle 7: The state forest is managed to steward significant cultural resources.

Goal 1. Protect the range of cultural and spiritual needs and values found on the state forest.

- Strategy 1. Acknowledge and respect tribal rights and customary uses.
    - Management priority:
        - Culturally significant natural and cultural resources
- Strategy 2. Steward cultural heritage sites worthy of preservation.
    - Management priority:
        - Heritage sites

Plan organization

The sustainable forest planning framework established a planning hierarchy that ensured the guiding state forest principles developed were stepped down through goals and strategies into operational management priorities. However, it is not the most intuitive way to organize a plan, especially one that needs to address multiple geographic scales. For example, discussion of wetlands occurs both in terms of habitat (Principle 1) and water quality and quantity (Principle 4). Likewise, different aspects of forest cover type management are addressed through principles 1, 2 and 5. All of those need to be addressed at the state forestwide, regional and management area scales. Organizing a plan by the seven state forest principles would likely result in some redundancy, cause confusion in finding information of interest, lack relevant context and result in unnecessary complexity in the plan document.

To make it as user-friendly as possible, the State Forest Management Plan is organized by topic. For example, all wetland-related management priorities are grouped under Aquatic Resources. All cover type-related management priorities are grouped under Forest and Wildlife Habitat Management. The table of contents differs substantially from the sustainable forest planning framework, but those links are maintained within each management priority write-up. The plan is organized as follows:

- **Section 1 – Introduction.** Covers the purpose of, need for and scope of the plan. Provides context by describing state forest administration and associated legal mandates. Describes the approach used to develop the plan and how it is organized.
- **Section 2 – State Forest History.** Context for both the establishment of current forest communities and Michigan's ownership of the state forest are provided through a description of events from the last major glacial episode through the 20th century.
- **Section 3 – State Forestwide and Regional Planning.** Management priorities are grouped by relevant theme and describe the current condition, future direction and strategic guidance required to achieve it at the regional and state forestwide scales. These priorities require careful consideration. They guide how the state forest is managed with other DNR divisions, stakeholders and Michigan residents.
- **Section 4 – Management Areas.** Plans for each management area including descriptions of geographically specific current conditions and desired future conditions for featured species, landscape habitat conditions, the forest diversity matrix and cover types. Summations of current and projected acres for major cover types are provided from the model, and 10-year timber harvest goals are established. Additional management priorities relevant to cover type management are included, which will help inform co-management decisions.
- **Section 5 – Special Analysis Units.** Establishes unique 10-year management goals, model outputs and management activities specific to a defined geographic area. These special analysis units have a corresponding planning/guidance document supporting the information presented in the State Forest Management Plan.
- **Sections 6 – Implementation**. Describes quantitative, landscape-level operational direction that informs decision-making during the compartment review at the forest management unit level. Annual cover type and featured species habitat goals are stepped down from the 10-year model goals. Guidelines are established for when to revisit the model scenario within the planning period based on unforeseen events or new or updated information.

- **Section 7 – Monitoring.** Explains how the metrics identified at the state forestwide and regional scales will be monitored over the planning period; can be used as an assessment of state forest sustainability. Cover type and featured species habitat goals from the management area and special analysis units will be assessed in relation to 10-year model goals.