Invasive Species Management Plan for the Saginaw Chippewa Indian Tribe

Informed by an Invasive Species Treatment Prioritization Model

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03/31/2021

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Suggested Citation:

Cole-Wick, AA, RA Hackett, HD Enander, CM Wilton, and JG Cohen. 2021. Invasive Species Management Plan for the Saginaw Chippewa Indian Tribe. Michigan Natural Features Inventory, Report No. 2021-03, Lansing, MI.

Cover: Tawas Lake wild rice beds (*Zizania aquatica*.) on Saginaw Chippewa Indian Tribal property in Iosco County, Michigan. Photograph by Ashley Cole-Wick, 2019.

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Introduction

The Saginaw Chippewa Indian Tribe of Michigan is a federally recognized Tribe headquartered on the Isabella Reservation, Isabella County, Michigan. The Tribe continually works towards the conservation, restoration, and protection of its properties comprising various natural and developed areas in three Michigan counties: Isabella, Iosco, and Arenac (Figure 1). These lands contain ecosystems that support wildlife habitat, contain culturally important natural resources, harbor native biodiversity, and provide ecosystem services. To ensure the continuation of these ecosystem functions and services for future generations, long-term, comprehensive conservation planning is needed.

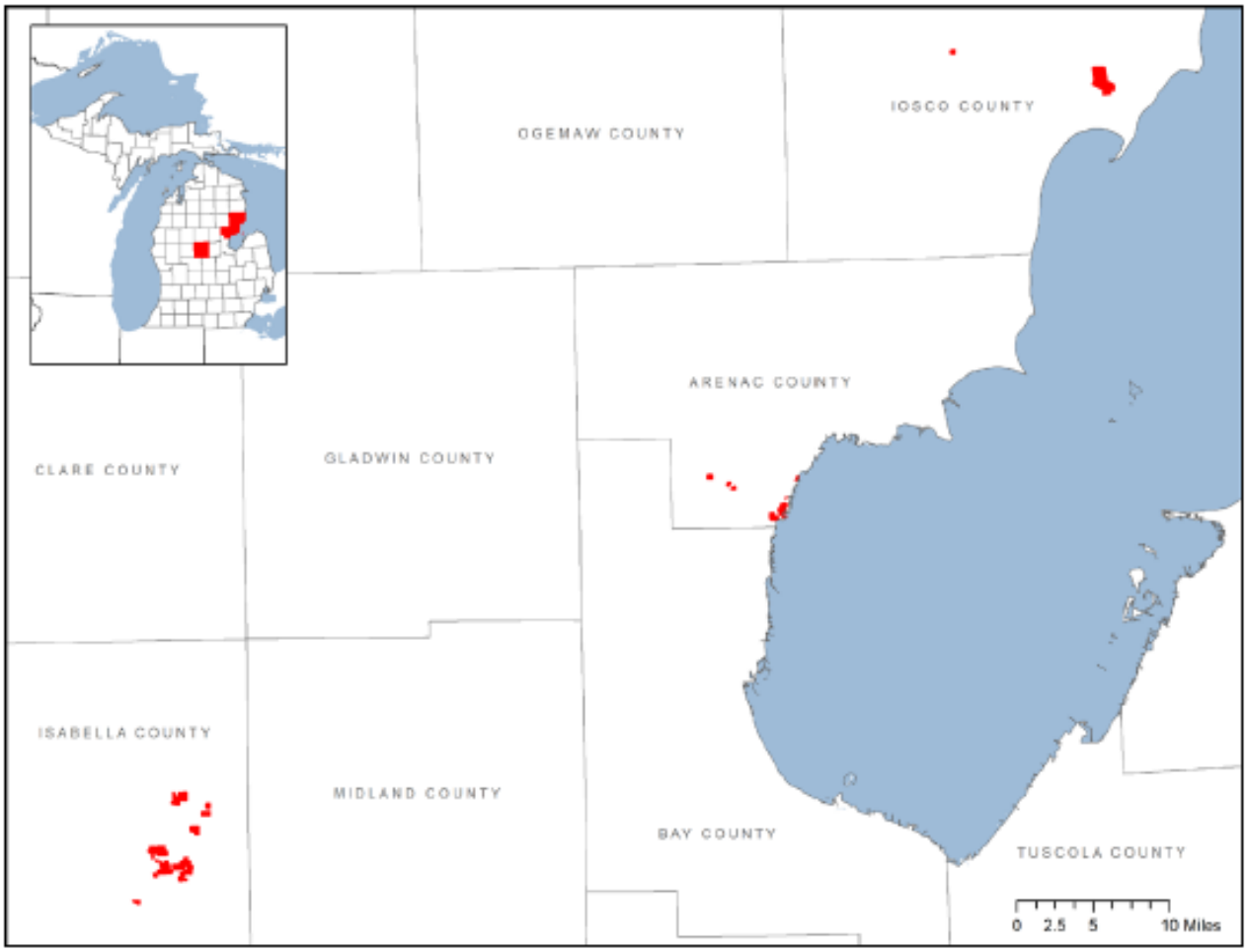

Figure 1. Lands owned and managed by the Saginaw Chippewa Indian Tribe in Michigan, USA.

Conservation planning is an iterative process focused on natural resource management with the following steps: 1) assessment, 2) planning, 3) implementation, 4) analyzing and adapting, and 5) sharing management successes and failures. In 2020, Michigan Natural Features Inventory (MNFI) completed a project that addressed the first two steps of conservation planning by completing a baseline assessment and biological inventory on Saginaw Chippewa Tribal lands in Michigan (Cole-Wick et al. 2020). Through this project, Tribal properties were delineated into stands. Each stand comprised a discrete polygon that represents a relatively homogeneous

area of a similar vegetative covertype, natural community, and land-use history. These stands and aggregation of stands are units that can be the basis of subsequent planning. From this baseline, conservation goals, objectives, monitoring plans, and operational plans may be developed to preserve and restore natural resources.

The 2020 report identified threats to Tribal properties, with invasive species as the leading threat impacting the ecological integrity of natural communities. Invasive plants are non-native species that spread, largely unchecked by ecological processes, and outcompete native species. These aggressive species are a leading threat to biodiversity and ecological integrity across the lands we surveyed, and their impact is exacerbated by the additive effects of other pressures such as deer herbivory, hydrological alterations, habitat fragmentation, disease, and fire suppression. Invasive plants degrade native biodiversity by displacing native species, interrupting food webs, compromising pollination services, changing microclimates, and altering soils, hydrology, and disturbance regimes (Pimental et al. 2005, Ehrenfield 2010).

Development of multifaceted and successful invasive species management plans with finite resources is complicated. Therefore, we have adopted MNFI's Invasive Species Treatment Prioritization Model (Cohen et al. 2019) to inform long-term natural community management focusing on invasive plant species. High-quality and degraded natural areas are susceptible to invasive plant species and present complex decisions about where to invest management resources. The model facilitates the identification of areas to prioritize monitoring, treatment, and containment of invasive plant species. The primary products generated from this model are geospatial stand-level data files attributed with general stand characteristics (e.g., area, natural community) and invasive species treatment priority scores.

Output from this modelling effort can be used to address important conservation planning questions like "Where should invasive species management be prioritized?" In this report we briefly describe the methods and variables used to develop the model. We then provide interpretation of the model to answer the next pressing question "What methods can be used to protect high-quality natural areas?" We offer management recommendations to control infestations of the most pernicious species affecting Tribal Lands by identifying seven "priority areas" for treatment. For each priority area, we describe the characteristics that most contributed to its prioritization and management actions appropriate for the area. In addition to this document, we are also providing Tribal Natural Resource Staff with the spatial results of the Invasive Species Treatment Prioritization Model to be used for future planning endeavors, as well as resources on invasive species treatment (e.g., Table 3 – 1).

Methods

We developed this Invasive Species Treatment Prioritization Model by adapting the methods of recent work completed by MNFI (Cohen et al. 2019). The purpose of the model is to identify stands of the highest priority for invasive species management that have ecosystem integrity, support native biodiversity, are resilient to disturbance, provide ecosystem services, and have a high threat of invasion.

The foundational units of the model are vegetative covertype stands created by MNFI as part of the baseline inventory (Cole-Wick et al. 2020). Each stand is attributed with a Michigan Forest Inventory (MiFI) covertype as well as an MNFI natural community type. For each stand, we generated an intersection with spatial data layers with information on infrastructure (Center for Shared Solutions 2017, MDNR 2018a, MNDNRb), invasive species presence (Chase Stevens pers. comm., Cole-Wick et al. 2020, MISIN 2020), circa 1800 vegetation (Comer et al. 1995), climate resilience (Anderson et al. 2018), and rare species and natural community element occurrences (MNFI 2021). For each stand a suite of thirteen metrics were scored, weighted and summed using GIS-based multicriteria decision analysis, which combines spatially referenced data and multi-attribute criteria in a problem-solving environment (Malczewski 2006, Malczewski et al. 2020; Figure 2). A subset of these metrics (i.e., natural community rarity, natural community richness, natural community resilience, and ecosystem services) are defined by natural community type and the classification of each stand to a natural community type facilitates the scoring for these variables.

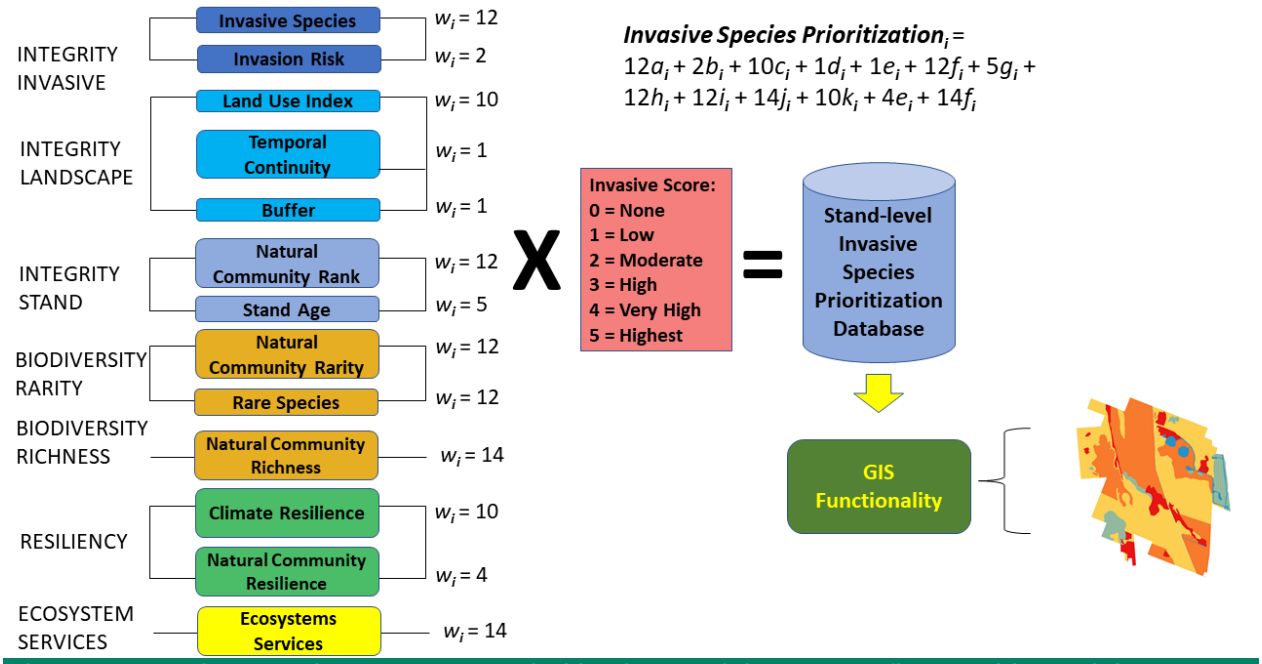

Figure 2. Invasive Species Treatment Prioritization Model summary figure. This model gauges each stand's priority for invasive species treatment based on an array of spatial variables. For each stand, multiple metrics or input variables were evaluated, scored, and weighted to generate an overall priority score. Each metric was binned into one of four factors or categories (i.e., integrity, biodiversity, resiliency, and ecosystem services).

Each of the metrics (m_i) in the model had a possible score ranging from 0 to 5, with 0 representing no/lowest priority and 5 representing the highest priority. Each metric was multiplied by an assigned weight (w_i) based on expert opinion. The stand prioritization score was a summation of all thirteen weighed metrics, then rescaled from 0 to 5. To visualize the scoring, the scores were assigned colors on a blue to red color gradient with higher scores corresponding to reds and displayed within a GIS. For the final score, we adjusted some stands to emphasize stands with invasive species present. Stands that did not have any invasive species present had their priority scores reduced by 2 as long as the final score remained greater than zero (Cohen et al. 2019).

We included thirteen metrics in the prioritization model to measure or represent aspects of integrity (I), biodiversity (B), resiliency (R), and ecosystem services (ES; Table 1). Only metrics with customized source data or calculations that differ from Cohen et al. (2019) are described in greater detail below (i.e., invasive species and rare species element occurrence). For detail on the development and scoring of the remaining 11 metrics, please refer to Invasive Species Treatment Prioritization Model (Cohen et al. 2019).

For the invasive species metric, geospatial presence data was compiled from three sources: 2019 surveys conducted by MNFI (Cole-Wick et al. 2020), observations in the Midwest Invasive Species Information Network (MISIN) data repository, and long-term mapping and data collection efforts by Tribal Natural Resources staff (Chase Stevens pers. comm.). Geospatial data fully contained in a single stand was surmised as present. In cases where geospatial data overlapped multiple stands, the species was considered present in the stand if the invasive plant species covered greater than 10% of the stand.

We assigned each invasive plant species a score based on multiple characteristics of the species (e.g., reproductive methods, fertility, habitat restrictions) using the United States Department of Agriculture's Weed Risk Assessment scoring schema (Plant Epidemiology and Risk Analysis Laboratory, 2019; Table 2 - 1). The sum of the invasive species scores per stand were rescaled to 0 to 5 for the model.

The rare species element occurrence (EO) metric was given a ranking of 5 if the stand contained rare species EO records last observed since the year 2000 and a ranking of 1 if the stand contained rare species EO records last observed before the year 2000. We gave a higher ranking to rare species records from the last 21 years, since these records generally have higher geospatial accuracy and there is a greater likelihood that the represented species are still present.

Table 1. Invasive Species Treatment Prioritization Model metrics with weighting, summary description, and source data. Each metric was categorized (Cat.) as a proxy for one of the following: Integrity (I), Biodiversity (B), Resiliency (R), or Ecosystem Services (ES). Model weights for each variable are listed. All metrics used information derived from the baseline ecological assessment of Cole-Wick et al. (2020).

Cat.	Metric (weight)	Description	Additional resource(s)
I	Invasion Risk or Distance to Invasion Vector $(w_1 = 2)$	Distance to nearest physical invasive species vector (e.g., road, powerlines)	• Center for Shared Solutions and Technology Partnerships 2017 • MDNR N.D. a,b • MDNR 2018 a,b
I	Invasive Species $(w_2 = 12)$	Sum of invasive species scores (Table 2 - 1)	• Chase Stevens, pers. comm. • MISIN 2020
I	Unchanged Landcover $(w_3 = 1)$	Percent of stand area with the same covertype as circa 1800 land cover	• Comer et al. 1995 • NOAA 2016
R	Climate Resilience $(w_4 = 10)$	Rank determined by The Nature Conservancy's (TNC) climate resilience model	• Anderson et al. 2018
B	Natural Community Rarity $(w_5 = 12)$	Rank based on community rarity in the state of the natural community type assigned to a stand (Table 2 - 2)	• Cohen et al 2019
R	Natural Community Resilience $(w_6 = 4)$	Rank by expert based on natural community resilience of the natural community type of stand (Table 2 - 2)	• Cohen et al 2019
I	Natural Community EO Rank $(w_8 = 12)$	Greater than 10% of stand intersecting with natural community that was ranked according to size, quality, and landscape of natural community by expert	• MNFI 2020
B	Rare Species EO $(w_9 = 12)$	Rank based on presence and year of last observation of intersecting rare species EO with recent EOs weighted heavier than historic	• MNFI 2020
I	Land Use Index $(w_{10} = 10)$	Proportion of intensive land cover to natural land cover in buffer surrounding stand based on NatureServe's landscape scale ecological integrity metric	• Faber-Langendoen et al. 2016 • Cohen et al. 2019
I	Buffer or Natural Edge $(w_{11} = 1)$	Percentage of perimeter with undeveloped/natural land cover	• Roberts and Cooper 1989
I	Stand Age $(w_{13} = 5)$	Recent tree core(s) of dominate tree species in forested stands	
B	Natural Community Richness $(w_{14} = 14)$	Rank based on average species richness and diversity of the natural community type assigned to a stand (Table 2 - 2)	• Cohen et al 2019
ES	Community Ecosystem Services $(w_{15} = 14)$	Rank by expert based on contribution to provisioning, regulating, supporting, and cultural services (e.g., pollinator habitat, recreation, water filtration) of the natural community type assigned to a stand (Table 2 - 2)	• Cohen et al 2019

Results and Discussion

The Invasive Species Management Prioritization Model can be used to aid in decision-making regarding invasive species management. The model is available for download online through an ArcGIS Online map (Figure 3). The final priority layer is called “SCIT adjusted priority view (v3)”. To view the resulting variables for a particular stand, clicking on the stand will bring up some stand characteristics (e.g., area, covertype), each metric and its score as described in Table 1, and the overall adjusted priority score from 0 to 5.

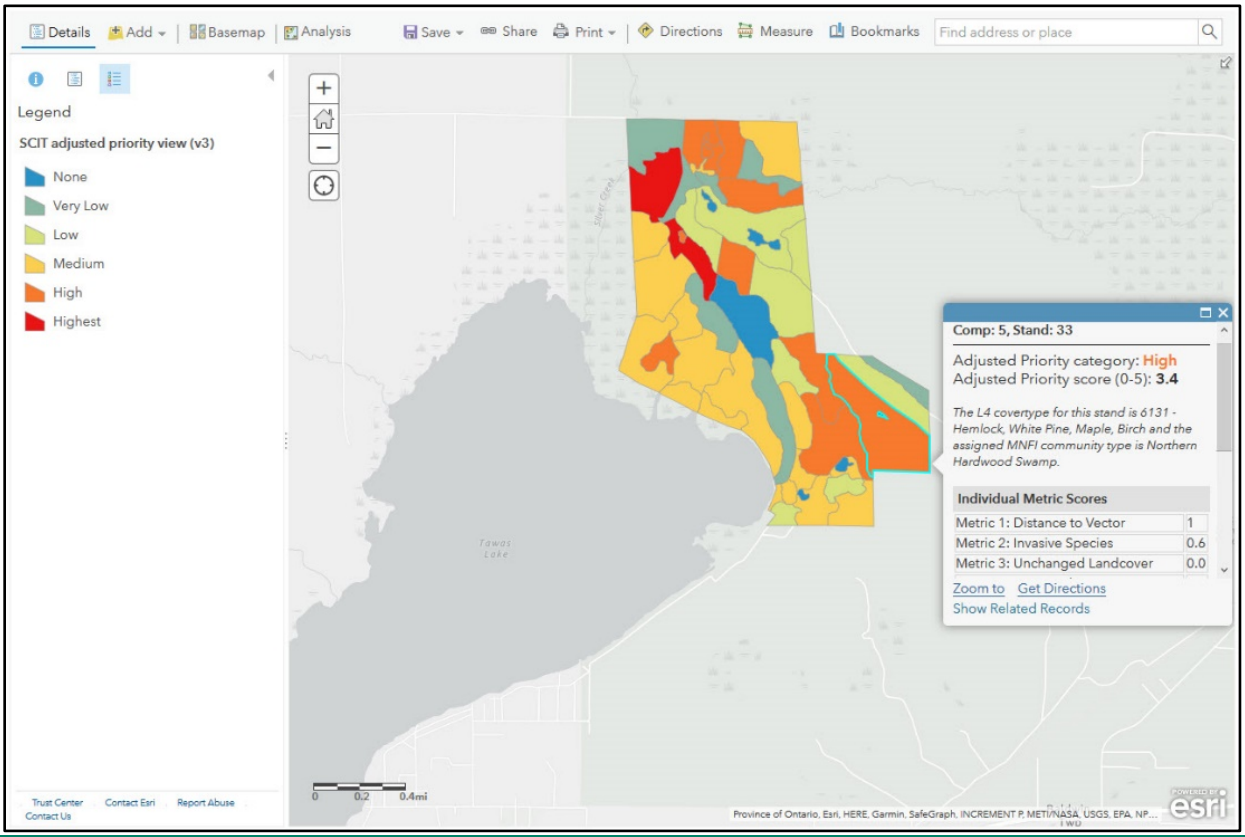

Figure 3. Invasive Species Treatment Prioritization Model results for Tawas Lake as viewed on ArcGIS Online Map Feature.

This model is a tool and should be used as one part of the decision-making process. Interpretation of the model may rely on stand or landscape characteristics that were not quantified across the model. Examples of such characteristics are nearby or bordering EO records (e.g., those that do not overlap the stand but may provide habitat), hydrological interactions, and field-knowledge that may not be captured in stand-level attributes (Cole-Wick et al. 2020). Additionally, stands with very low numbers of invasive species may rank as higher priority in the model because eradication is feasible and simple, whereas stands that have large numbers of invasive species may not rank as highly because containment/control is resource-intensive, or the land is greatly altered from its natural state (e.g., forest to abandoned field).

Our model did not include the Indian Lake parcel (Goedecke Property). This small parcel is surrounded by the Huron Manistee National Forest and we documented no invasive species

during surveys in 2019. We recommend regular monitoring and using Early Detection and Rapid Response (EDRR) at this property if invasive species are documented. Cooperation with the Forest Service to determine and monitor nearby infestations may be beneficial.

Below we present seven priority areas for invasive management, divided by county. These priority areas vary in size and the degree of invasive species present. We present terminology for suggested management actions (Table 2) and summarize management goals and actions for stands in each priority area (Table 3). To assist in implementation of invasive species management, we have included a table describing treatments used to control invasive species present in SCIT lands (Appendix Table 3 – 1).

Table 2. Management terminology used to describe management goals.

Term	Description
Early Detection/Rapid Response (EDRR)	Surveillance technique to monitor and treat emerging pest infestations.
Monitoring	On-going surveillance and documentation of infested or non-infested areas for pest populations at a regular frequency.
Eradication	Population is small and isolated enough that complete eradication of all plants and reproductive propagules is possible with little chance of re-introduction.
Elimination/Zero Density	Population is of high enough priority or small enough size to eliminate from a designated area, but re-introduction is likely from surrounding areas or vectors.
Outlier Control	When populations are present as large infestations, the first priority is to eliminate small outlier populations away from the larger infestation.
Perimeter Control	When populations are present as large infestations, once outlier populations have been eliminated, management focus switches to control around the perimeter of the larger infestation moving from the fringes towards the center.
Sustained Control	The species is so widespread that elimination is unlikely due to population size and pressure of continual reintroduction from neighboring areas. Control areas would most likely focus on specific high priority areas impacted from the species with a long-term commitment expected.

Table 3. Management goals for priority areas.

County (acres)	Priority Area	Compartment: Stand	Priority Area (acres)	Primary Management Goal					
				Monitoring / EDRR	Eradication	Elimination	Outlier control	Perimeter Control	Sustained Control
Arenac (345)	1.1 Whites Beach	4: 26-43, 45-47	113.7	X		X	X	X	
Isabella (1606)	2.1. Jordon Creek	1: 16, 19, 30	21.9	X		X	X	X	
	2.2 Little Elk Drive Forests	3: 68, 72, 73, 79	47.1	X		X			X
	2.3 Remus Road Forests	3: 8, 37	92.5	X		X	X		X
Iosco (932)	3.1 Northern Tawas Forests	5: 6, 19, 21	68.8	X		X		X	
	3.2. Southeast Tawas Forests	5: 33, 34, 35	135.6	X		X			
	3.3 Tawas Lake Shoreline	5: 25-28, 39-40	133.3	X		X	X	X	

Arenac County (Compartment 4)

Situated along the shoreline of Lake Huron, Tribal properties in Arenac County comprise several disjunct parcels that were historically wet prairie and Great Lakes marsh along the lakeshore, transitioning into swamp forests further inland. Wetlands along the lake contain diverse vegetative zones including submergent marsh, emergent marsh, wet meadow, and shrub swamp. Fluctuation of Great Lakes water levels is an important influence on these systems. As lake levels change, vegetative zones shift inland or lakeward, which is a natural process. However, with ecosystem fragmentation and lakeshore hardening, these shifts are often no longer possible. Today, the legacy of farming, declining water quality, and invasive species have contributed to the degradation of these ecosystems. The property is the site of several recent and historic observations of rare species and natural communities (Table 4). Due to the large size and ecological importance of Whites Beach, this compartment has one invasive species priority area (Figure 4).

Table 4. Summary of rare species found on Tribal properties in Arenac County from Michigan's Natural Heritage Database. EO ID is a unique identifier assigned to each EO record in the Natural Heritage Database.

Common Name	Scientific Name	Last year observed	EO ID	Status
Bald eagle	*Haliaeetus leucocephalus*	2019	23067	State special concern
Black sandshell	*Ligumia recta*	1932	17673	State endangered
Blanding's turtle	*Emydoidea blandingii*	2017	23697	State special concern
Butler's garter snake	*Thamnophis butleri*	2013	23698	State special concern
Common gallinule	*Gallinula galeata*	2019	23895	State threatened
Least bittern	*Ixobrychus exilis*	2019	23894	State threatened
Marsh wren	*Cistothorus palustris*	2019	17406	State special concern
Great Lakes Marsh		2005	7139	NA

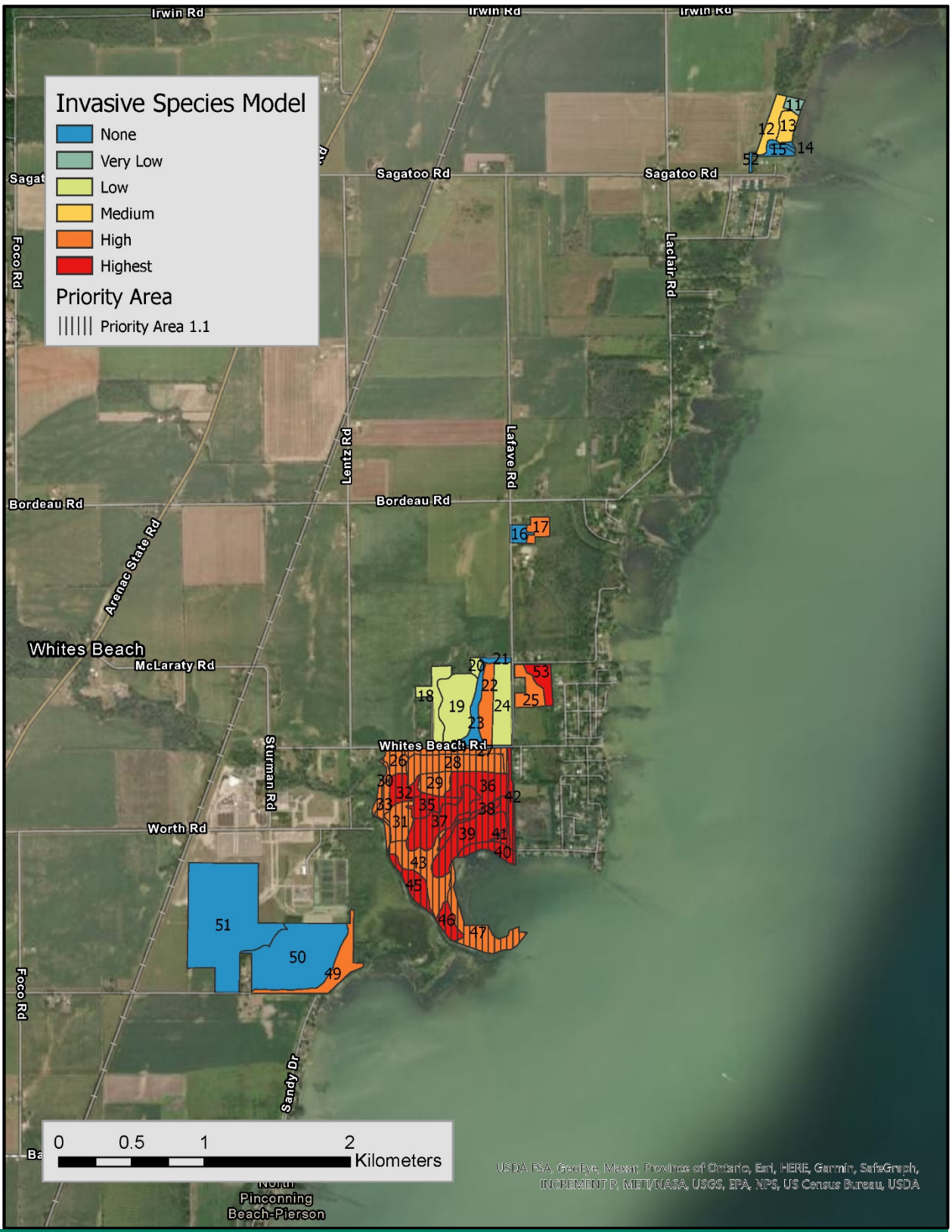

Figure 4. Invasive Species Treatment Prioritization Model results for stands in Arenac County (Compartment 5)

Priority 1.1 Whites Beach (Compartment 4, Stands 26-43, 45-47)

This large priority area comprises all stands bordered by Whites Beach Road to the north, Saganing River to the west, a drainage ditch to the east, and Lake Huron to the south and east (Figure 5). These wetlands provide habitat for a variety of wildlife, including commercially important fish, freshwater mussels, bald eagles, and secretive marsh birds (Table 4). Several stands surveyed in 2019 were recorded as 'open water' (e.g., stands 40, 46, 47). This area was not underwater until recently, as evident by standing dead paper birch and other shrubs, which were under several feet of water. Invasive Phragmites (*Phragmites australis* subsp. *australis*) and invasive cattails (*Typha angustifolia*, *Typha* x *glauca*) occur infrequently in these open water stands as the water levels are currently too high for these species to establish or thrive. Woody vegetation becomes more prominent as the habitat transitions from emergent marsh to lowland shrub and young, low density swamp forest near Whites Beach Road. As the habitat changes, so do the primary invasive species, with autumn olive (*Elaeagnus umbellata*) and honeysuckles (*Lonicera spp.*) replacing Phragmites and cattails. We also observed European frog's-bit in the Saganing River at the border of Tribal property near Worth Road.

Whites Beach stands rank high in the model due to several metrics, including unchanged landcover, rare species, natural edge, natural community rarity, and community ecosystem services.

Actions

- *Outlier control* of Phragmites and cattails (stands 35, 36, 37, 38, 39, 41, 43, 45, 46)
- *Elimination* of new Phragmites and cattails infestations (stands 29, 40, 42, 47)
- *Elimination* of low-density European frog's-bit in aquatic habitat along the Saganing River
- *Perimeter control* of autumn olive and honeysuckle populations starting with smaller infested areas (stand 36) and working toward Whites Beach Road in the north and Saganing River in the west (stands 26, 27, 28, 29, 30, 31, 33, 42)
- *Monitor* currently flooded stands (stands 40, 46, 47) for new infestations as a result of fluctuating Great Lakes levels in 1-to-5-year frequency

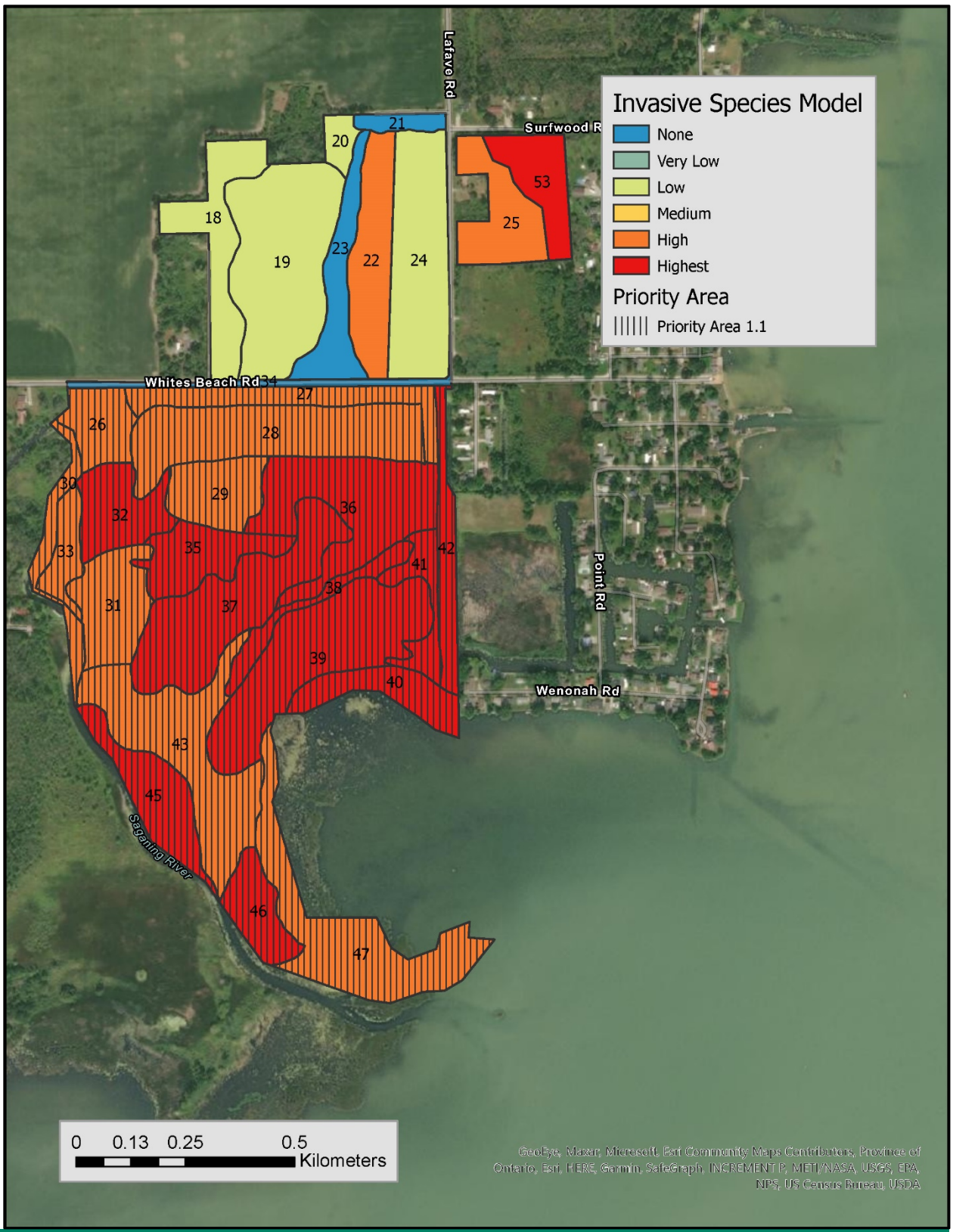

Figure 5. Invasive Species Treatment Prioritization Model results focusing on priority area 1.1 in Arenac County.

Isabella County (Compartments 1-3)

Historically, much of what is now Isabella County was mesic southern forest, mesic northern forest, hardwood-conifer swamp, and rich conifer swamp (Comer et al. 1995). Much of the conifer component of these forests was significantly reduced due to logging practices in recent centuries, resulting in hardwood-dominated swamp forests with some remaining conifer component. No herbaceous-dominated habitats rank as high priority on the model because no prairies and barrens habitat has been documented here, therefore it is assumed that most herbaceous-dominated open areas are not natural, but rather land that was cleared for development, forestry, or agriculture. Tribal lands and nearby properties contain several recent and one historic observations of rare species (Table 5).

Tribal properties in Isabella County comprise several disjunct parcels located throughout the city of Mount Pleasant and Chippewa, Denver, and Union Townships. The parcels were grouped into three compartments, with one invasive species priority area in Compartment 1 and two in Compartment 3 (Figure 6).

Table 5. Summary of rare species found on Tribal properties in Isabella County from Michigan's Natural Heritage Database. EO ID is a unique identifier assigned to each EO record the Database.

Common Name	Scientific Name	Last year observed	EO ID	Status
Slippershell	*Alasmidonta viridis*	2019	23690	State threatened
Slippershell	*Alasmidonta viridis*	2019	23689	State threatened
Slippershell	*Alasmidonta viridis*	2019	23691	State threatened
Rainbow	*Villosa iris*	2019	23694	State special concern
Rainbow	*Villosa iris*	2019	23693	State special concern
Rainbow	*Villosa iris*	2019	23692	State special concern
Ellipse	*Venustaconcha ellipsiformis*	2019	23695	State special concern
Dickcissel	*Spiza americana*	2007	16589	State special concern
Northern flying squirrel	*Glaucomys sabrinus*	1965	22856	State special concern

Priority 2.1 Jordon Creek (Compartment 1: Stands 16, 19, 30)

This priority area comprises floodplain forest and mesic southern forest along Jordon Creek, which is characterized by numerous canopy gaps created by ash (*Fraxinus* sp.) die-off. The canopy is primarily cottonwood (*Populus deltoides*) with some remaining live ash. The canopy also contains aspen as well as culturally important species like basswood (*Tilia americana;* Figure 7). Canopy gaps created by ash die-off are often filled with ruderal native species such as boxelder (*Acer negundo*) and hawthorn species (*Crataegus spp*.). Invasive multiflora rose (*Rosa multiflora*) is the primary treatment priority here, with lower abundance of autumn olive, purple loosestrife (*Lythrum salicaria*), and invasive glossy and common buckthorns (*Frangula alnus, Rhamnus cathartica,* respectively).

These stands rank high in the model based on the presence of rare species, natural community rarity, natural edge, and ecosystem services. A 2019 survey recorded eight species of mussels in Jordon Creek, including the state threatened slippershell (*Alasmidonta viridis*), and two species of special concern, rainbow (*Villosa iris*) and ellipse (*Venustaconcha ellipsiformis*; Table

5; Cole-Wick et al. 2020). Excessive sedimentation can impact native mussel populations and the fish hosts they rely on for reproduction. Given the relationship between fish and mussel species, protection of fishes in the Jordon Creek is critical for the continued survival of these rare mussels. To maintain high-quality habitat for these listed species in Jordan Creek, invasive species management in adjacent stands should minimize erosion and runoff.

Actions:

- *Eliminate* low density multiflora rose along Jordon Creek (stands 19, 30)
- *Outlier control to perimeter control* of medium density multiflora rose (stand 16)
- *Outlier control to perimeter control* of autumn olive, buckthorn (stands 16, 19, 30)
- *Outlier control* of invasive species autumn olive, common buckthorn, honeysuckle, multiflora rose populations in adjacent stands (14, 15, 18, 22, 23, 24) as a preventative measure in priority area
- *Monitor* and protect stream water quality, thus rare mussel species and host fish, from disturbance, sediment, runoff, and invasive species. Management may extend beyond borders of the priority area. When disturbance occurs near creek, actively revegetate

Priority 2.2 Little Elk Drive Forests (Compartment 3: Stands 68, 72, 73, 79)

This priority area of woodlands is located east of Tomah Road on either side of East Little Elk Drive (Figure 8). These stands differ in composition, but they share similar invasive species threats, and are located near each other, although they are not contiguous. Stands 73 and 79 are high-quality mesic southern forest with abundant spring ephemeral plants and culturally important species [e.g., bloodroot (*Sanguinaria canadensis*)]. Within both of these stands, invasions are limited mostly to the stand margins. Stand 68 is floodplain forest with abundant maple (*Acer* spp.) and swamp white oak (*Quercus bicolor*) along with beech (*Fagus grandifolia*) and elm (*Ulmus* spp.). This site also contains culturally important species, as well as a variety of established paths throughout, which has facilitated the dumping of trash along the streams. Stand 68 is degraded on the boundaries but improves towards the center. Stand 72 was historically beech-maple forest but today presents as degraded oak-pine barren, and improvement of this stand will help to buffer nearby high-quality forest (stand 73) from invasions. These stands rank high in the model based on community biodiversity, ecosystem services, natural community resilience, and land use index.

Actions:

- *Elimination* of low-density or small infestations of autumn olive, honeysuckles, buckthorns, and black locust (*Robina pseudoacacia*) in stand interior (stands 73, 79)
- *Elimination* of invasive species in stand borders where infestations threaten high-quality interior with a focus on multiflora rose, autumn olive, buckthorns, and honeysuckles (stand 73)
- *Sustained control* of white sweet clover (*Melilotus albus*; stands 68, 72) and garlic mustard (*Alliaria petiolata*, stand 68)
- *Monitor* stand borders for new infestations [e.g., autumn olive, common buckthorn, glossy buckthorn, honeysuckle, multiflora rose, Scotch pine (*Pinus sylvestris*)] from *adjacent* stands (75, 76)
- *Manage* deer population with hunting to improve forest understory where culturally important plants are presen

Priority 2.3 Remus Road Forests (Compartment 3: Stands 8, 37)

This priority area contains high-quality forested stands in Mount Pleasant located near Remus and Leaton Roads (Figure 8). This area is mostly mesic-southern forest with some component of dry-mesic southern forest. Stand 8 is a maturing second-growth forest. Stand 37 is a large forest with excellent oak (*Quercus* spp.) and ash regeneration, interspersed with speciose vernal pools. Stands in this priority area contain few invasive species, restricted mostly to the margins.

Stands 8 and 37 ranked high in the model due to land use index, natural community biodiversity, and ecosystem services. While several other stands were scored similarly by the model, we selected these stands because they have the highest potential for restoration. Other medium scoring stands were more degraded and heavily invaded by invasive shrub species (e.g., buckthorns) These stands would require a more expensive restoration endeavor, however, by exploring the stand attributes in the model, land managers can easily expand priority areas using this data-driven approach.

Actions:

- *Elimination* of multiflora rose, honeysuckles, and autumn olive infestations in the forest interior (stands 8, 37)
- *Outlier control to perimeter control to elimination* along stand margins (stands 8, 37)
- *Monitor* for new infestations in 1-to-5-year frequency (stands 8, 37)
- *Sustained control* of autumn olive, common buckthorn, honeysuckles, multiflora rose, St. John's-Wort (*Hypericum perfoliatum*), and sweet clover (*Melilotus* spp.) in adjacent stands (7, 10, 33, 36, 38) near priority area boundaries
- *Manage* deer population with hunting to improve forest understory where culturally important plants are present

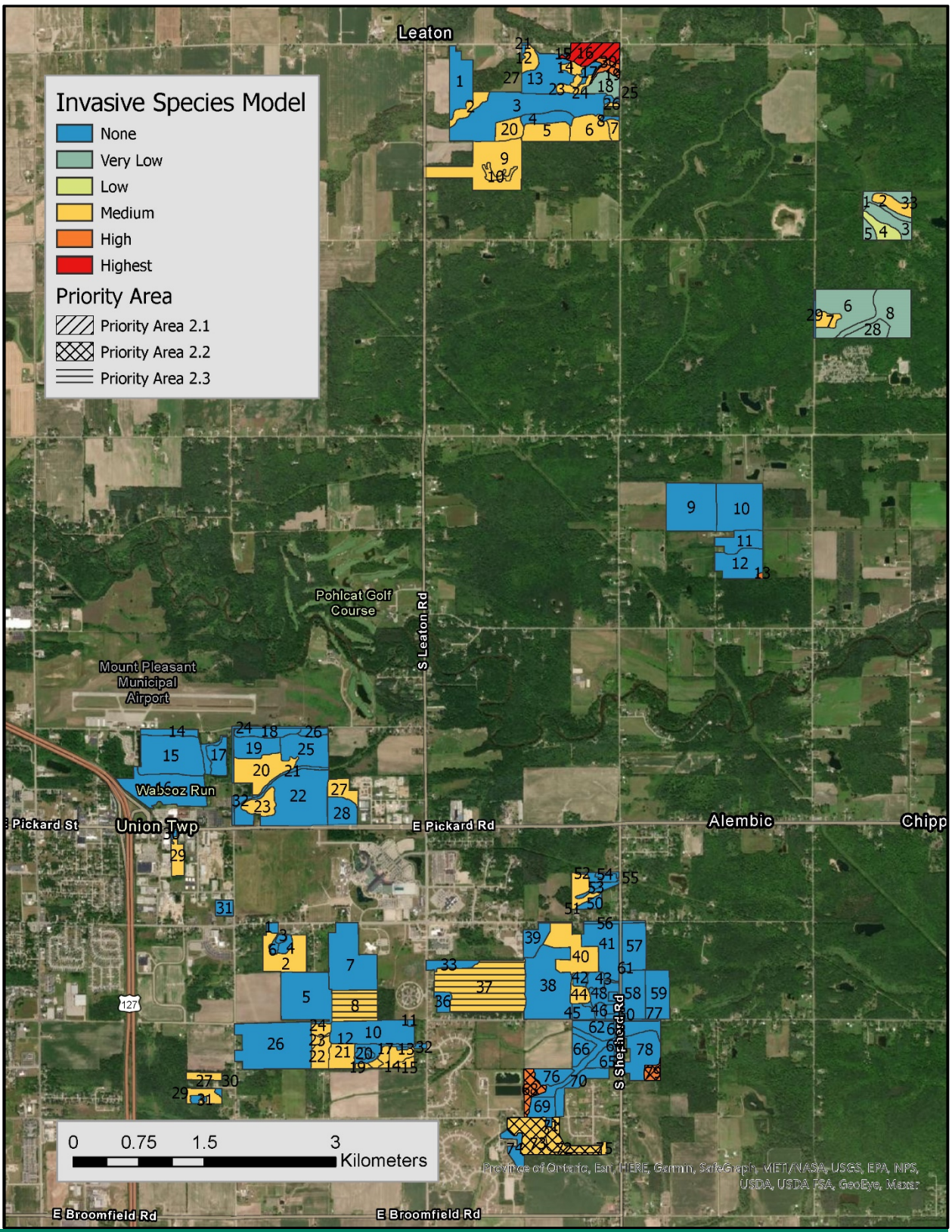

Figure 6. Invasive Species Treatment Prioritization Model results for stands in Isabella County (Compartments 1-3)

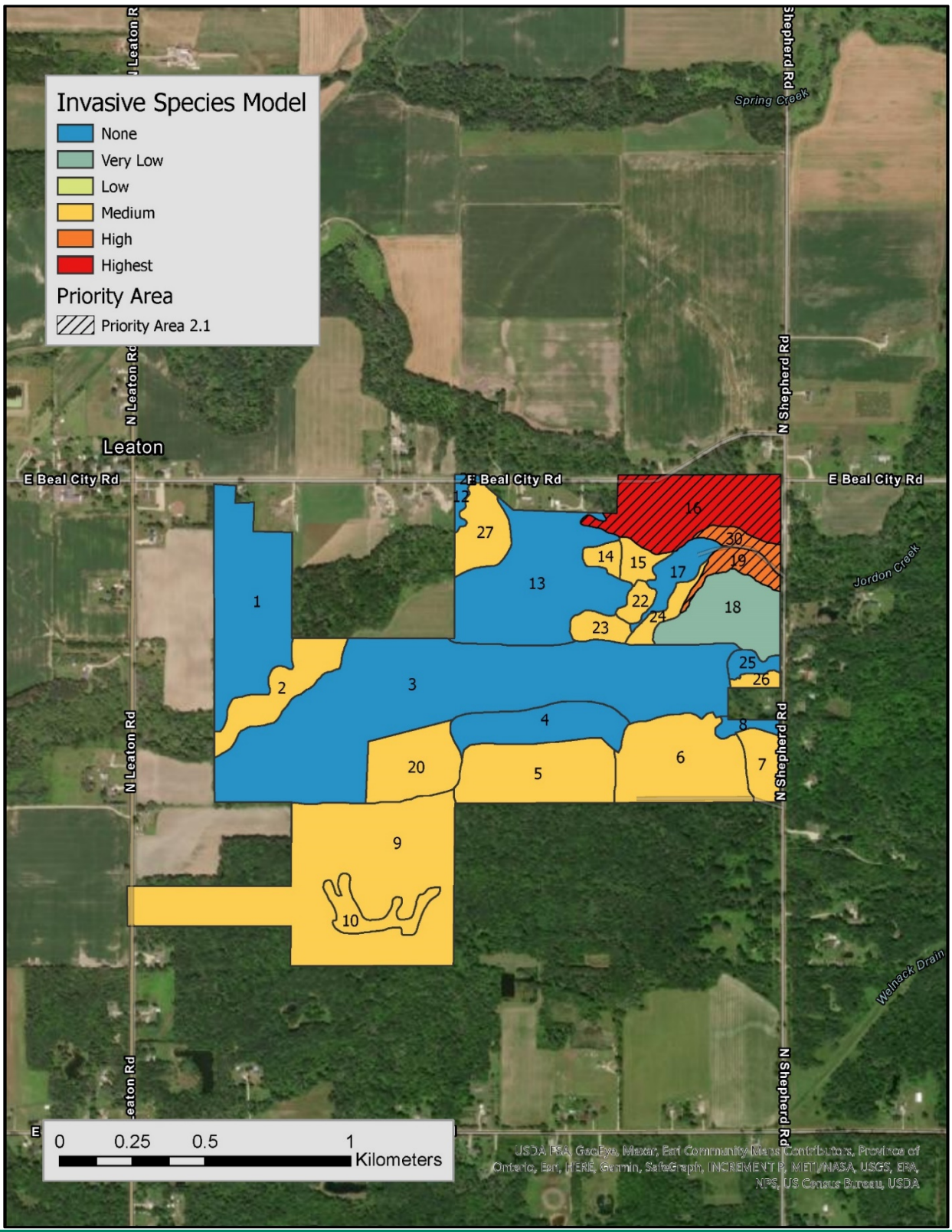

Figure 7. Invasive Species Treatment Prioritization Model results focusing on priority area 2.1 in Isabella County (Compartments 1-3)

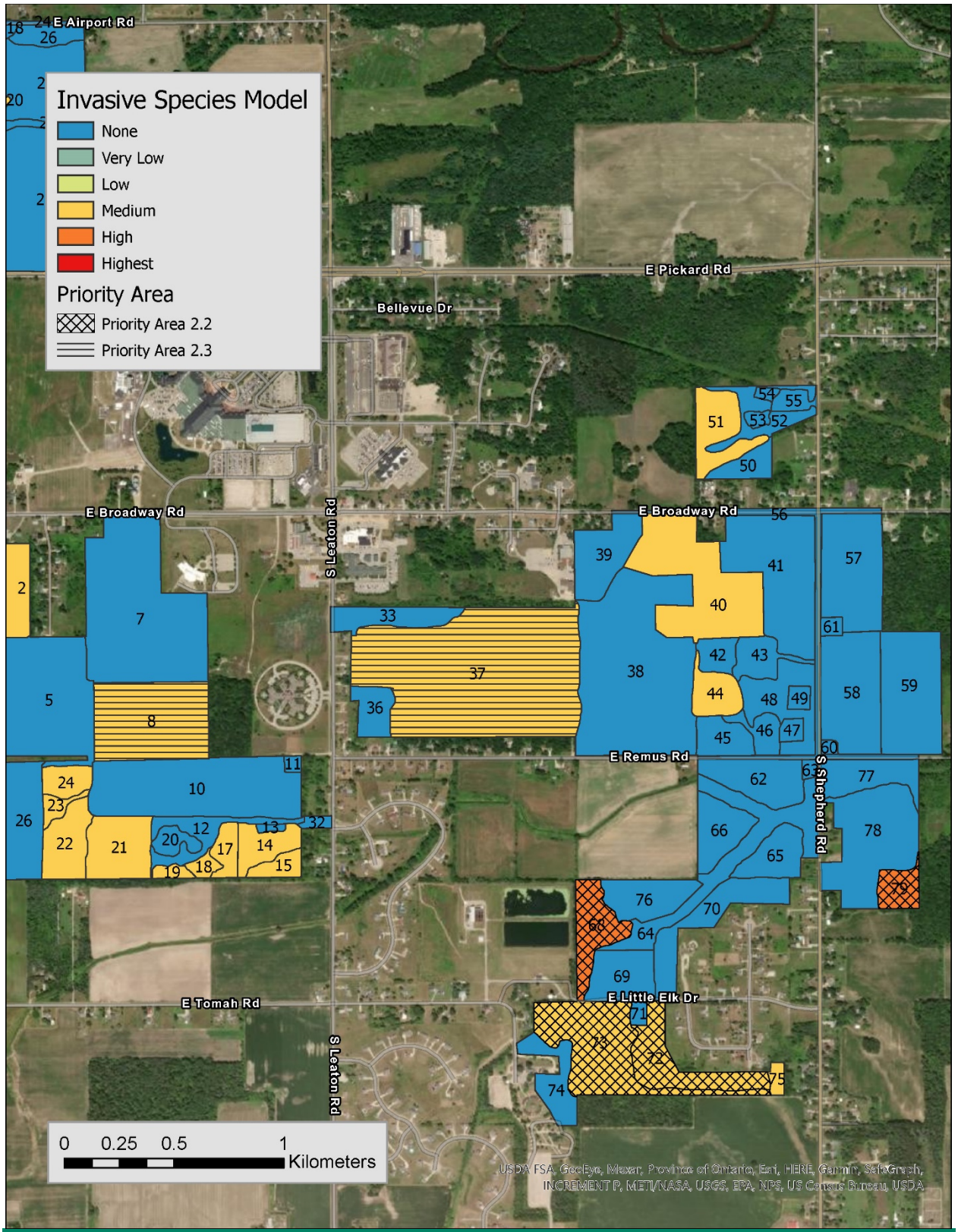

Figure 8. Invasive Species Treatment Prioritization Model results focusing on priority areas 2.2 and 2.3 in Isabella County (Compartments 1-3)

Iosco County (Compartment 5)

Located along Tawas Lake, the 902-acre Amesbury property historically contained a mix of pine-dominated dry northern forest, hardwood-conifer swamp, conifer swamp dominated by cedar (*Thuja occidentalis*), northern shrub thicket, and emergent marsh. In the 1930s the jack pine-red pine forests and cedar swamps were still largely forested. This property is notable due to its lakefront on Tawas Lake, which contains one of the largest extant wild rice beds in Michigan's Lower Peninsula and for recent observations of other rare species (Table 6). Tawas Lake is currently experiencing high lake levels, which may result in changes in invasive species abundance. As lake levels fluctuate in the future, management goals and actions may need to be adjusted accordingly. Tawas Lake has three invasive species priority areas (Figure 9).

Table 6. Summary of rare species found on Tribal properties in Iosco County from Michigan's Natural Heritage Database. EO ID is a unique identifier assigned to each EO record the Database.

Common Name	Scientific Name	Last year observed	EO ID	Status
Red-shouldered hawk	*Buteo lineatus*	2019	23688	State threatened
Bald eagle	*Haliaeetus leucocephalus*	2017	11330	State special concern
American bittern	*Botaurus lentiginosus*	2019	18569	State special concern
Common loon	*Gavia immer*	2019	23318	State threatened
Marsh wren	*Cistothorus palustris*	2019	23317	State special concern
Eastern massasauga	*Sistrurus catenatus*	1999	14202	Federally threatened, state special concern
Blanding's turtle	*Emydoidea blandingii*	2010	6156	State special concern
Wild rice	*Zizania aquatica*	2019	23318	State threatened

Priority 3.1 Northern Tawas Forests (Stands 6, 19, 21)

This priority area is represented by two stands of high-quality rich conifer swamps (stands 6, 19) along with one hardwood-conifer swamp (stand 21; Figure 9). Although not detected in the most recent surveys, Blanding's turtle and eastern massasauga rattlesnake (*Sistrurus catenatus*), and possibly other rare herptiles with low detectability, are likely extant. Stands 6 and 19 represent some of the highest-quality forests on the property. Stand 21 scores lower on the model than stands 6 and 19 but active invasive species management will improve this habitat. Stand 6 represents an exemplary occurrence of rich conifer swamp. Very little effort can ensure that this stand remains high quality while the forest continues to mature. Several small patches of Japanese barberry (*Berberis thunbergii*) and reed canary grass (*Phalaris arundinacea*) persist in the stand 6 as the only serious invasive plant threats.

These stands score high on the model because of unchanged landcover, natural community richness, ecosystem services, and the presence of rare species (Table 6).

Actions:

- *Elimination* of interior Japanese barberry and reed canary grass infestations (stands 6, 19)
- *Perimeter control* of Phragmites (stand 21)
- *Monitor* forest interior for new invasions (stands 6, 19)
- *Monitor* adjacent stands for new infestations with 1-to-3-year frequency (stands 7, 8)

- *Perimeter control* of Phragmites in stands adjacent to 8 and 21 (stands 2, 18, 23)
- *Manage* deer population with hunting to increase regeneration of cedar and other forest understory species

Priority 3.2 Southeast Tawas Forests (Stands 33, 34, 35)

These stands remain relatively intact, as they were historically recorded as cedar swamp and today support swamp forests comprising both conifers and hardwoods (Figure 9). There is also an upland mesic northern forest component, primarily towards the north and east near Kunze Road. These stands contain bald eagle nests that are likely still active (Table 6). The two-track that leads from Kunze Road to Tawas Lake through stands 33 and 34 is a high-risk vector for invasive species, such as Phragmites.

These stands ranked high in the model due to the presence of rare species and natural edge, with lesser contributions from natural community rarity, natural community resilience, and ecosystem services.

Actions:

- *Eliminate* low density infestations of Japanese barberry, honeysuckles, Phragmites (stands 33, 34, 35)
- *Monitor* for new infestations along two-track between Kunze Road and Tawas Lake
- *Manage* deer population with hunting to increase regeneration of cedar and other forest understory species

Priority 3.3 Tawas Lake Shoreline (Stands 25-28, 39-40)

This priority area comprises the western and southwestern portion of the property along Lake Tawas (Figure 9). These stands transition from open water to emergent wetland, then to northern shrub thickets. Several rare and culturally important species (e.g., wild rice) are present in these stands and in the adjacent lake (Table 6). An active vector for invasive species in this area is a two-track running parallel to the lake.

The model ranked most of these stands with medium priority scores. However, because of the cultural value of Tawas Lake (not a metric in the model), the ecosystem service value of the wetlands, and the presence of numerous rare species we have identified this area as a high priority (Table 6). Stand 28 ranks higher as this was classified as northern wet meadow, a rarer community type than northern shrub thicket. The lower ranking for the remainder is likely due to the commonality and typically lower biodiversity of the northern shrub thicket communities that presently comprise much of the shoreline.

Actions:

- *Eliminate* invasive Phragmites and cattails along the shoreline where wild rice occurs (stands 26, 27, 39, 40)
- *Outlier control to perimeter control* of Phragmites infestation along the two-track leading from Kunze Road to Tawas Lake
- *Monitor* Tawas Lake shoreline for new infestations as lake levels fluctuate in 1-to-5-year frequency

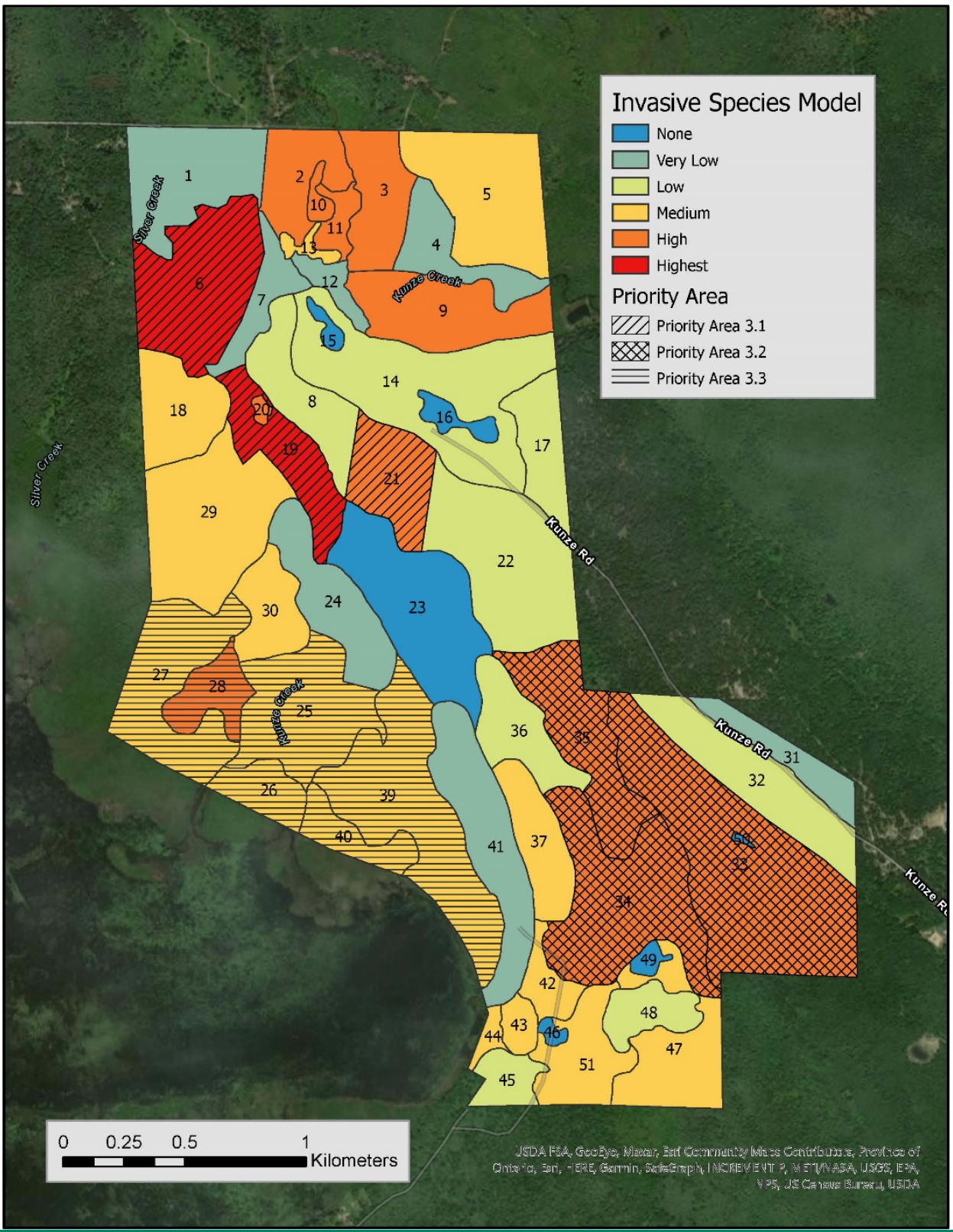

Figure 9. Invasive Species Treatment Prioritization Model results for stands in Iosco County (Compartment 5)

Conclusion

Invasive species management is critical for promoting wildlife habitat, sustaining culturally important natural resources and native biodiversity, and enhancing ecosystem services. In this report we demonstrated the application of the Invasive Species Treatment Prioritization Model to inform invasive species management on natural areas owned and managed by the Saginaw Chippewa Indian Tribe in Michigan. This model provides a framework to identify high priority stands for management based on ecosystem integrity, biodiversity, resilience, ecosystem services, and threat of invasion. The model is a tool we have developed not to provide definitive answers, but instead to foster informed discussion about allocation of finite resources. We used the model to identify seven priority areas for invasive species management. For each priority area, we detailed invasive species management goals and actions. Tribal natural resource managers can combine their knowledge of sites with these recommendations at their discretion to make future decisions about land management beyond the priority areas we identified.

This model, as all models, has its limitations. At the time of this report, we selected thirteen variables to describe and quantify ecosystem characteristics in relation to the goal of developing long-term, comprehensive conservation planning for invasive species to ensure the continuation of ecosystem services for future generations. We believe these variables were the best fit for the model that could be derived from the information available at this time.

This model framework could be used to prioritize other management actions. For instance, without the invasive species data the model can provide information to inform where to focus other management actions (e.g., deer management, fire management, habitat creation). The model currently provides useful information about where to focus EDRR at a stand-level that may be isolated from identified priority areas.

This modelling framework can be adjusted to incorporate additional factors, as they become available, for the analyzing and adapting process of conservation planning. Future iterations of the model could incorporate a hydrological importance factor or a variable related to culturally important plants, whereby stands with hydrological resources or culturally valuable species would receive increased scores. Upon a change of management goal, organizational vision, newly available or developed data, or an improved resolution of data, this model may be revised in the future to best meet the needs of the Tribe.

Acknowledgments

This project was made possible with funds provided by the Saginaw Chippewa Indian Tribe. We thank everyone from the Tribe, and in particular the Tribal Natural Resource staff who provided information for this project: Chase Stevens and Carey Pauquette. We also thank the Michigan Department of Natural Resources for use of their Michigan Forest Inventory protocol and database and supporting the initial development of the Invasive Species Treatment Prioritization Model. Administrative support was provided by Ashley Adkins, Sarah Carter, Debra Richardson, and Tyler Tulloch.

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Appendices

Appendix 1. Definition of Terms and Abbreviations

Table 1 - 1. Additional definitions of terms and abbreviations used in report.

Term	Description
Element Occurrence (EO)	A presence record of a listed species or natural community in a Natural Heritage Database
Metric	A measurement proxy calculated or attributed to a characteristic
Natural Community	An assemblage of interacting plants, animals, and other organisms that repeatedly occur under similar environmental conditions across the landscape and is predominantly structured by natural processes rather than modern anthropogenic disturbances, such as timber harvest, alterations to hydrology, and fire suppression. Historically, indigenous peoples were an integral part of Michigan's natural communities with many natural community types being maintained by native management practices such as prescribed fi re.
Natural Heritage Database	A repository of records documenting location, status, and characteristics of rare plant populations, animal populations, and natural communities in a designated region
Stand	Polygons representing a relatively homogeneous area of a similar covertype and age

Appendix 2: Additional Metric Scoring Data

These rankings were developed in Cohen et al. (2019). Additional species added for this project are denoted with an *.

Table 2 - 1. List of invasive plant species and their score calculated using the United States Department of Agriculture's Weed Risk Assessment scoring schema (Plant Epidemiology and Risk Analysis Laboratory, 2019). Most scores were developed for Cohen et al. (2019) and used to calculate the Invasive Species metric (Table 1)

Scientific name	Common name	Score
Acer platanoides	Norway maple	2
Achyranthes japonica	Japanese chaff flower	4
Aegopodium podagraria	Bishop's goutweed	3
Ailanthus altissima	Tree of heaven	5
Alliaria petiolata	Garlic mustard	5
Alnus glutinosa	Black/European alder	3
Amorpha fruticosa	False indigo	4
Ampelopsis brevipedunculata	Turquoise berry	2
Arctium minus	Common burdock	3
Barbarea vulgaris	Garden yellowrocket	3
Berberis spp.	Barberry	4
Berberis thunbergii	Japanese barberry	4
Berberis vulgaris	Common barberry	3
Berteroa incana	Hoary alyssum	3
Buddleja davidii	Butterfly Bush	3
Butomus umbellatus	Flowering Rush	3
Campsis radicans	Trumpet vine	1
Cardamine impatiens	Narrow-leaved bitter cress	4
Carex kobomugi	Asiatic sand sedge	3
Celastrus orbiculatus	Oriental bittersweet	5
Centaurea jacea	Brown knapweed	4
Centaurea stoebe	Spotted knapweed	5
Cirsium arvense	Canada thistle	5
Cirsium palustre	European swamp thistle	4
Cirsium vulgare	Bull thistle	4
Conium maculatum	Poison hemlock	4
Convolvulus arvensis	Field bindweed	5
Cynanchum louiseae	Louise's swallow-wort	4
Cynanchum rossicum	European swallow-wort	4
Cynoglossum officinale	Hound's-tongue	4
Daucus carota	Wild carrot, Queen-Anne's-lace	3
Dioscorea oppositifolia	Chinese yam	3
Dipsacus laciniatus	Cut-leaf teasel	4
Elaeagnus umbellata	Autumn olive	4
Euonymus alatus	Wahoo/burning bush (Invasive)	2
Euonymus europaeus	Spindle tree	2
Euonymus fortunei	Wintercreeper	3
Euphorbia esula	Leafy spurge	5
Fallopia japonica	Japanese knotweed	4
Fallopia sachalinensis	Giant knotweed	4
Frangula alnus	Glossy buckthorn	5
Galeopsis tetrahit	Hemp-nettle	2
Galium odoratum	Sweet woodruff	1
Glechoma hederacea	Ground-ivy, creeping Charlie	2
Glyceria maxima	Reed manna grass	4
Gypsophila paniculata	Baby's breath	3
Heracleum mantegazzianum	Giant hogweed	3
Hesperis matronalis	Dame's rocket	4
Hydrocharis morsus-ranae	European frog-bit	3
Hypericum perforatum	Common St. John's-wort	5
Impatiens glandulifera	Himalayan balsam	3

Scientific name	Common name	Score
Iris pseudacorus	Pale yellow iris	3
Lespedeza bicolor	Shrubby lespedeza	3
Lespedeza thunbergii	Japanese bush clover	3
Leucanthemum vulgare	Ox-eye daisy	3
Leymus arenarius	Lymegrass	2
Ligustrum obtusifolium	Border privet	2
Ligustrum spp.	Privet (spp.)	2
Ligustrum vulgare	Common privet	2
Lonicera maackii	Amur honeysuckle	3
Lonicera morrowii	Morrow honeysuckle	3
Lonicera spp.	Lonicera species	3
Lonicera tatarica	Smooth Tartarian honeysuckle	3
Lonicera x bella	Hybrid honeysuckle	3
Lonicera xylosteum	European fly honeysuckle	3
Lotus corniculatus	Bird's-foot trefoil	4
Lupinus polyphyllus	Bigleaf lupine	3
Lysimachia nummularia	Moneywort	3
Lythrum salicaria	Purple loosestrife	5
Melilotus alba	White sweet clover	5
Melilotus albus	White sweet clover	5
Melilotus officinalis	Yellow sweet clover	5
Microstegium vimineum	Japanese stiltgrass	5
*Myriophyllum spicatum**	Eurasian water-milfoil	3
*Nitellopsis obtusa**	Starry stonewort	4
Pastinaca sativa	Wild parsnip	2
Persicaria perfoliata	Mile-a-minute weed	4
Petasites hybridus	Butterbur	
Phalaris arundinacea	Reed canary grass	5
Phleum pratense	Timothy	5
Phragmites australis subsp. australis	Phragmites (exotic)	4
Pinus sylvestris	Scotch pine	2
Poa compressa	Canada bluegrass	4
Poa pratensis	Kentucky bluegrass	3
Poa spp.	Poa species	4
Populus alba	White poplar	2
Populus nigra	Lombardy poplar	2
Potentilla recta	Sulphur cinquefoil	3
Prunella vulgaris	Self-heal, heal-all	2
Prunus avium	Sweet cherry	2
Pueraria lobata	Kudzu	3
Pueraria montana	Kudzu	3
Ranunculus repens	creeping buttercup	4
Rhamnus cathartica	Common buckthorn	4
Rhamnus frangula	Glossy buckthorn	5
Rhamnus utilis	Chinese buckthorn	3
Rhodotypos scandens	Jetbead	2
Robinia hispida	Bristly locust	2
Robinia pseudoacacia	Black locust	3
Rosa multiflora	Multiflora rose	4
Rumex acetosella	Sheep sorrel	5
Salix fragilis	Crack willow	2
Salix x rubens	Hybrid crack willow	2
Saponaria officinalis	Bouncing bet, soapwort	1
*Securigera varia**	Crown vetch	4
Senecio jacobaea	stinking willie	4
Solanum dulcamara	Bittersweet nightshade	2
Tamarix parviflora	Tamarisk	3
Taraxacum officinale	Common dandelion	3
Torilis japonica	Hedge-parsley	2
Trifolium pratense	Red clover	3
Trifolium repens	White clover	3
Typha angustifolia	Narrow-leaved cattail	5
Typha x glauca	Cattail	5
Ulmus pumila	Siberian Elm	2
Verbascum thapsus	Common mullein	2
Vincetoxicum nigrum	Black swallow-wort	4
Vincetoxicum rossicum	Pale swallow-wort	4

Table 2 - 2. Scoring for natural community metrics developed by Cohen et al. (2019). All Michigan natural community types are listed with their assocaited global and state ranks (G-rank and S-rank,) assigned by NatureServe and MNFI to rank the rarity and vulnerability of natural community types. See Table 1 for descriptions of Natural Community Rarity, Resilience, Richness, and Ecosystem Services metrics.

Natural Community Type	G-RANK	S-RANK	Natural Com-munity Rarity	Natural Commun-ity Resilience	Natural Community Richness	Natural Community Ecosystem Services
Alvar	G2?	S1	5	2	4	2
Bog	G3G5	S4	2	4	2	3.5
Boreal Forest	GU	S3	3	4	2	3.5
Bur Oak Plains	G1	SX	5	0	0	0
Cave	G4?	S1	4	5	1	1
Clay Bluff	GNR	S2	4	1	1	1
Coastal Fen	G1G2	S2	4	2.5	3	3
Coastal Plain Marsh	G2	S2	4	1	5	3
Dry Northern Forest	G3?	S3	3	3	2	3
Dry Sand Prairie	G3	S2	4	2	3	2.5
Dry Southern Forest	G4	S3	3	2	3	3
Dry-mesic Northern Forest	G4	S3	3	3	3	3
Dry-mesic Prairie	G3	S1	4	1	4	2
Dry-mesic Southern Forest	G4	S3	3	2	3	3.5
Emergent Marsh	GU	S4	2	2	1	2.5
Floodplain Forest	G3?	S3	3	2	5	5
Granite Bedrock Glade	G3G5	S2	4	2.5	2	2
Granite Bedrock Lakeshore	G4G5	S2	4	3	1	1
Granite Cliff	G4G5	S2	4	5	1	0.5
Granite Lakeshore Cliff	GU	S1	5	5	1	0.5
Great Lakes Barrens	G3	S2	4	2	2	2.5
Great Lakes Marsh	G2	S3	3	1.5	4	5
Hardwood-Conifer Swamp	G4	S3	3	3	4	3
Hillside Prairie	G3	S1	4	1	3	2.5
Inland Salt Marsh	G1	S1	5	2	1	1
Interdunal Wetland	G2?	S2	4	3	2	1.5
Intermittent Wetland	G2	S3	3	3	2	2
Inundated Shrub Swamp	G4	S3	3	4	1	1.5
Lakeplain Oak Openings	G2?	S1	5	1	3	3
Lakeplain Wet Prairie	G2	S1	5	1	4	4
Lakeplain Wet-mesic Prairie	G1?	S1	5	1	5	4
Limestone Bedrock Glade	G2G4	S2	4	2	2	2
Limestone Bedrock Lakeshore	G3	S2	4	2.5	1	1
Limestone Cliff	G4G5	S2	4	5	1	1
Limestone Cobble Shore	G2G3	S3	3	2.5	1	1
Limestone Lakeshore Cliff	G4G5	S1	4	5	1	1
Mesic Northern Forest	G4	S3	3	3	4	3
Mesic Prairie	G2	S1	5	1	5	2

Natural Community Type	G-RANK	S-RANK	Natural Community Rarity	Natural Community Resilience	Natural Community Richness	Natural Community Ecosystem Services
Mesic Sand Prairie	G2	S1	5	1	4	2
Mesic Southern Forest	G2G3	S3	3	2	4	3
Muskeg	G4G5	S3	3	4	2	4
Northern Bald	GU	S1	5	2.5	2	1
Northern Fen	G3	S3	3	3	4	3.5
Northern Hardwood Swamp	G4	S3	3	3	2	3
Northern Shrub Thicket	G4	S5	1	3	1	2.5
Northern Wet Meadow	G4	S4	2	2	2	2.5
Oak Barrens	G2?	S1	5	2	3	3
Oak Openings	G1	S1	5	1	4	3
Oak-Pine Barrens	G3	S2	4	2	4	3
Open Dunes	G3	S3	3	2	4	4
Patterned Fen	GU	S2	4	3	4	4
Pine Barrens	G3	S2	4	2	4	3
Poor Conifer Swamp	G4	S4	2	4	2	3.5
Poor Fen	G3	S3	3	4	3	4
Prairie Fen	G3	S3	3	2	5	4.5
Rich Conifer Swamp	G4	S3	3	3	5	3.5
Rich Tamarack Swamp	G4	S3	3	2	4	3.5
Sand and Gravel Beach	G3?	S3	3	3	1	1
Sandstone Bedrock Lakeshore	G4G5	S2	4	3	1	1
Sandstone Cliff	G4G5	S2	4	5	1	0.5
Sandstone Cobble Shore	G2G3	S2	4	3	1	1.5
Sandstone Lakeshore Cliff	G3	S2	4	5	1	1.5
Sinkhole	G3G5	S2	4	5	1	1
Southern Hardwood Swamp	G3	S3	3	3	3	3
Southern Shrub-carr	GU	S4	2	2	3	3
Southern Wet Meadow	G4?	S3	3	1.5	3	3
Submergent Marsh	GU	S4	2	2	1	1.5
Volcanic Bedrock Glade	GU	S2	4	2.5	2	1.5
Volcanic Bedrock Lakeshore	G4G5	S2	4	3	1	1
Volcanic Cliff	G4G5	S2	4	5	1	0.5
Volcanic Cobble Shore	G4G5	S3	3	3	1	1
Volcanic Lakeshore Cliff	GU	S1	5	5	1	1
Wet Prairie	G3	S1	4	1	4	2.5
Wet-mesic Flatwoods	G2G3	S2	4	2	3	3
Wet-mesic Prairie	G2	S1	5	1	4	2.5
Wet-mesic Sand Prairie	G2G3	S2	4	1	4	2.5
Wooded Dune and Swale Complex	G3	S3	3	3	5	5

Appendix 3. Invasive Plant Species Treatment and Timing

We have compiled treatment and timing information for the known invasive species present on SCIT lands at the time of this report. This table is meant as a quick guide to facilitate site specific species management plans.

Table 3 - 1. Possible treatments of invasive species detected on SCIT property . These are general guidelines compiled by MNFI for the purpose of this report. Direction on the pesticide label should always be followed and the State Department of Environment, Great Lakes, and Energy and Department of Natural Resources should be consulted for up-to-date regulations, restrictions, permitting, and application information.

Species Name	Treatment Method	Notes	Winter			Spring			Summer			Fall		
			D	J	F	M	A	M	J	J	A	S	O	N
Trees														
Black locust (*Robina pseudoacacia*)	Chemical & Mechanical: cut-stump [1,2,3,4]	Monitor for resprout	■	■	■			■	■	■	■	■	■	■
	Chemical: foliar spray [1,5]	Used for resprouts after cut-stump treatment						■	■			■	■	
	Chemical: basal bark [1,6]	Stems less than 6" diameter Do not use when snow or water are on ground or stems Monitor for resprout						■	■	■	■	■	■	■
	Chemical: girdle/frill [1,4]	For larger trees	■	■	■			■	■	■	■	■	■	■
	Chemical: injection [4]	For larger trees	■	■	■			■	■	■	■	■	■	■
	Biological: grazing	Can be toxic to cattle, sheep, horses Saplings only Multi-year						■	■	■	■	■		
Shrubs														
Autumn olive (*Elaeagnus umbellata)*	Chemical & Mechanical: cut-stump [1,2,3,4]	Monitor for resprout	■	■	■			■	■	■	■	■	■	■
	Chemical: foliar [1,4]	Used for resprouts after cut-stump treatment						■	■			■	■	■
	Chemical: basal bark [1]	Stems less than 6" diameter Do not use when snow or water are on ground or stems Monitor for resprout						■	■	■	■	■	■	■
	Chemical: Injection [4]	For larger trees	■	■	■			■	■	■	■	■	■	■
	Mechanical: pulling/digging	Young plants only					■	■	■					
	Biological: grazing	Multi-year						■	■	■	■	■		

[1] Triclopyr ester with penetrating oil (not approved for wetland use)
[2] Triclopyr ester + 3% Imazapyr and penetrating oil (not approved for wetland use)
[3] Triclopyr amine
[4] Triclopyr amine with aminopyralid
[5] Triclopyr amine with non-ionic surfactant
[6] Triclopyr ester with aminopyralid and penetrating oil

Species Name	Treatment Method	Notes	Winter			Spring			Summer			Fall		
			D	J	F	M	A	M	J	J	A	S	O	N
Buckthorns: Glossy buckthorn (*Frangula alnus*) Common buckthorn (*Rhamnus cathartica*)	Chemical & Mechanical: cut-stump [1,2,3]	Treat cuts immediately	■	■	■			■	■	■	■	■	■	■
	Chemical: basal bark [2]	Do not use when snow or water are on ground or stems; stems > 0.25 inch and < 6 inches in diameter							■	■	■	■	■	■
	Chemical: foliar [5, 7]							■	■	■	■	■	■	■
	Chemical: injection [3]		■	■	■			■	■	■	■	■	■	■
	Mechanical: pulling	Less than 0.5 in in diameter					■	■	■					
	Mechanical: girdling	Reduces resprouting by 40-50%					■	■	■					
	Biological: *Chondrostereum purpureum* (fungal plant pathogen)	Ongoing research No products registered for use in Michigan Applied to girdled cut						■	■					
Honeysuckles: (*Lonicera* spp., *L. maackii, Lonicera x bella*)	Chemical & Mechanical: cut stump [1,3,8]		■	■	■			■	■	■	■	■	■	■
	Chemical: foliar [1,3,9]											■	■	■
	Chemical: basal bark [1,2,7]	Do not use when snow or water on ground or stems stems > 0.25 in and < 6 in in diameter							■	■	■	■	■	■
	Mechanical: hand pulling	Stem less than 0.5 in. Monitor for resprout										■	■	■
	Mechanical: Girdling	Combine with herbicide					■	■	■					
	Fire: prescribed burn	Not effective for large shrubs Repeated every 1-2 years				■	■	■						
	Biological: grazing						■	■	■	■	■	■		
Japanese barberry (*Berberis thunbergii*)	Mechanical: hand pulling		■	■	■	■	■	■	■	■	■	■	■	■
	Mechanical & Chemical: cut stump		■	■	■			■	■	■	■	■	■	■
	Chemical: foliar [3,9]	Better when paired with early season mechanical or fire control				■	■	■					■	
	Fire: Propane torch	Pre- and multiple post-leaf out treatment					■	■		■				
Multiflora rose (*Rosa multiflora*)	Mechanical & Chemical: cut stem [1,3,8]	Thorny brambles make this treatment more difficult than usual	■	■	■			■	■	■	■	■	■	■
	Mechanical: pulling	Small plants/populations only					■	■	■					
	Mechanical: mowing	Restricts spread Multiple times per year (3-6x) Susceptible to flat tires						■	■	■	■	■	■	
	Chemical: foliar [9]	Most effective after flowering							■	■	■	■	■	

[7] Triclopyr ester with vegetable oil-based multi-purpose adjuvant (not approved for wetland use)
[8] Glyphosate
[9] Bentazon

Species Name	Treatment Method	Notes	Winter			Spring			Summer			Fall		
			D	J	F	M	A	M	J	J	A	S	O	N
Multiflora rose (*Rosa multiflora*)	Biological: grafting of rose rosette disease (virus via mites)	Ongoing research Possible non-target effects on cultivated *Rosa* sp. less than 100 m away												
	Biological: grazing	Sheep and goats												
Herbaceous - terrestrial														
Canada thistle (*Cirsium arvense*)	Prevention: competition and shading	Susceptible to shading and crowding												
	Chemical: foliar [8]	Must susceptible during bud stage, before flowering												
	Mechanical & Chemical: pull/cut and foliar	Cut or pull several times during growing season Chemical spot treatment in fall												
Garlic mustard (*Alliaria peiolata*)	Mechanical: hand pull/clip	Pull prior to seed set												
	Chemical: foliar [8,9]													
	Fire: mid-intensity burn													
Spotted knapweed (*Centaurea stoebe*)	Mechanical: Shading													
	Mechanical: hand pull													
	Mechanical: mowing													
	Chemical: foliar [10, 11, 12, 13]	Some effective herbicides persist in environment Herbicides can be used individually or combined												
	Chemical: fertilizer	Must have native grasses present to compete Integrate with other treatments												
	Fire: propane torch	Small infestations only Best on young seedlings and rosettes												
	Biological: Grazing	Sheep and goats will eat if grazing area is restricted (fenced). Viable seeds in manure can spread 7-14 days after ingestion												
	Biological: weevils (*Larinus minutus, L. obusus, Cyphocleonus achates*)	No measurable impacts on spotted knapweed populations in Michigan three years after release												
	Biological: moth (*Agapeta zoegana*)	Best for areas abundance in knapweed, but not yet monoculture. More successful in combination with plantings No Michigan specific studies in establishment found												

[10] Clopyralid
[11] Dicamba
[12] picloram
[13] 2,4-D

Species Name	Treatment Method	Notes	Winter			Spring			Summer			Fall		
			D	J	F	M	A	M	J	J	A	S	O	N
Sweet clover (*Melilotus* spp., *M. albus*, *M. officinalis*)	Mechanical: hand pulling	Prior to seed set Multi-year treatment Integrations with chemical treatment method improve effectiveness												
	Mechanical: mowing	Prior to seed set Results mixed Multi-year treatment Integrations with chemical treatment method improve effectiveness												
	Chemical: foliar [13, 14, 15, 16, 17]	Integrations with mechanical treatment method improve effectiveness												
	Fire: prescribed burn	2nd-year plants survive better than 1st-year plants Best when actively growing												
	Fire: propane torch													
Herbaceous – Aquatic/Wetland														
Cattail (*Typha angustifolia*)	Mechanical: mowing	Twice per growing season: before flowers reach maturity and 1 month later Cutting below waterline is more effective Remove litter if possible												
	Chemical: foliar [8,12,13, 18, 19]													
Eurasian water-milfoil (*Myriophyllum spicatum*)	Chemical: submerged-use [17, 20, 21, 22, 23,]													
	Mechanical: harvesting, weed roller	Repeat visit in single season required Can exacerbate invasion if fragments are not collected properly												
	Mechanical: driver assisted suction	Works best in small areas near docks and piers												
	Physical: benthic barriers	Works best in small areas near docks and piers where non-target effects are minimized												

[14] Chlorsulfuron
[15] 2,4-DB
[16] Clopyralid
[17] Triclopyr
[18] Impazapyr
[19] Imazamox
[20] Chelated copper
[21] Diquat
[22] Flumioxazin
[23] Granular 2,4-D

Species Name	Treatment Method	Notes	Winter			Spring			Summer			Fall		
			D	J	F	M	A	M	J	J	A	S	O	N
Eurasian water-milfoil (*Myriophyllum spicatum*)	Biological: predator insect introduction	Research ongoing												
European frog-bit (*Hydrocharis morsus-ranae*)	Mechanical: hand removal	Time prior to mid-summer turion development Annual spring removal efforts												
	Chemical & Mechanical: treatment and hand pulling [24, 25, 26]	Time hand removal prior to mid-summer turion development Efficacy research on chemical treatments is ongoing												
	Physical: shading													
Non-native Phragmites (*Phragmites australis* subsp. *australis*)	Chemical & Mechanical: foliar [8,18] and mowing	Spray, then mow 2 weeks or more after treatment Cutting below waterline is more effective Remove litter if possible Herbicides can be used individually or combined Mow and remove when ground is frozen to avoid soil disruption												
	Chemical & Fire: foliar [8,18] and prescribed burn	Spray, then burn the following year Herbicides can be used individually or combined												
	Mechanical: tarping	For small sites only												
Purple loosestrife (*Lythrum salicaria*)	Chemical: foliar [8,17]													
	Biological: *Galerucella* beetles; *Hylobius transversovittatus* weevil, *Nanophyes marmoratus* weevil	Successful suppression, not eradication												
Reed canary grass (*Phalaris arundinacea*)	Chemical: foliar [8]	Fall more effective than spring												
	Mechanical: mowing	Alone not successful long-term treatment Prior to flowering												
Starry stonewort (*Nitellopsis obtusa*)	Chemical: submerged-use [27]	Efficacy of copper-based algaecides is in question												
	Mechanical: driver assisted suction	Repeated visits necessary												

[24] Diquat
[25] Flumioxazin
[26] Endothall
[27] Copper-based algaecide – sometimes combined with flumioxazin or endothall

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