Overview of NRCS Conservation Practices to Control and Manage Invasive Plants

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USDA - Natural Resources Conservation Service

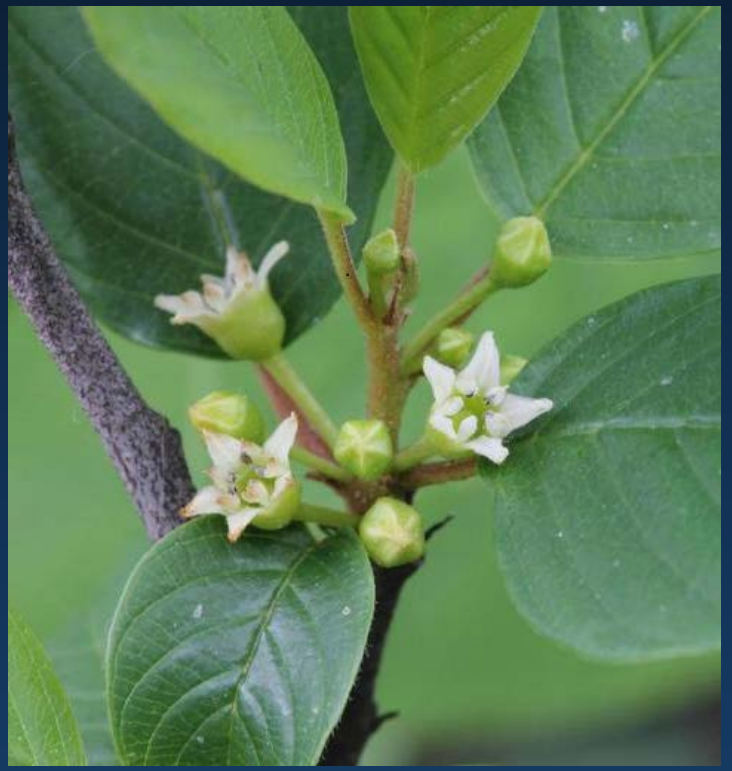
Outline of Today's Discussion

- Planning Considerations and NRCS Policy for Invasive Plants
- Conservation Practices and Conservation Practice Standards
- Conservation Practices to Control Invasive Species
  - Forest Stand Improvement
  - Brush Management
  - Herbaceous Weed Control
  - Prescribed Burning
- Other Conservation Practices to Discourage Invasive Species
  - Conservation Cover
  - Cover Crop
  - Mulching
- Sources of additional information

What Are Invasive Species?

- Definition: An alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health (EO 13112).
  - Includes animals, plants and microorganisms.
  - “Alien” means not native in a particular ecosystem.

- Effects of Invasive Species:
  - A leading cause of population decline and extinction in animals.
  - Increase the severity and frequency of wildfires.
  - Alter nutrient availability and water quality.
  - Interfere with the flow and availability of water and nutrients.
  - Increase erosion.
  - Invasive Species are responsible for $120 billion dollars in damages in the US annually. (Pimental et al. 2005)



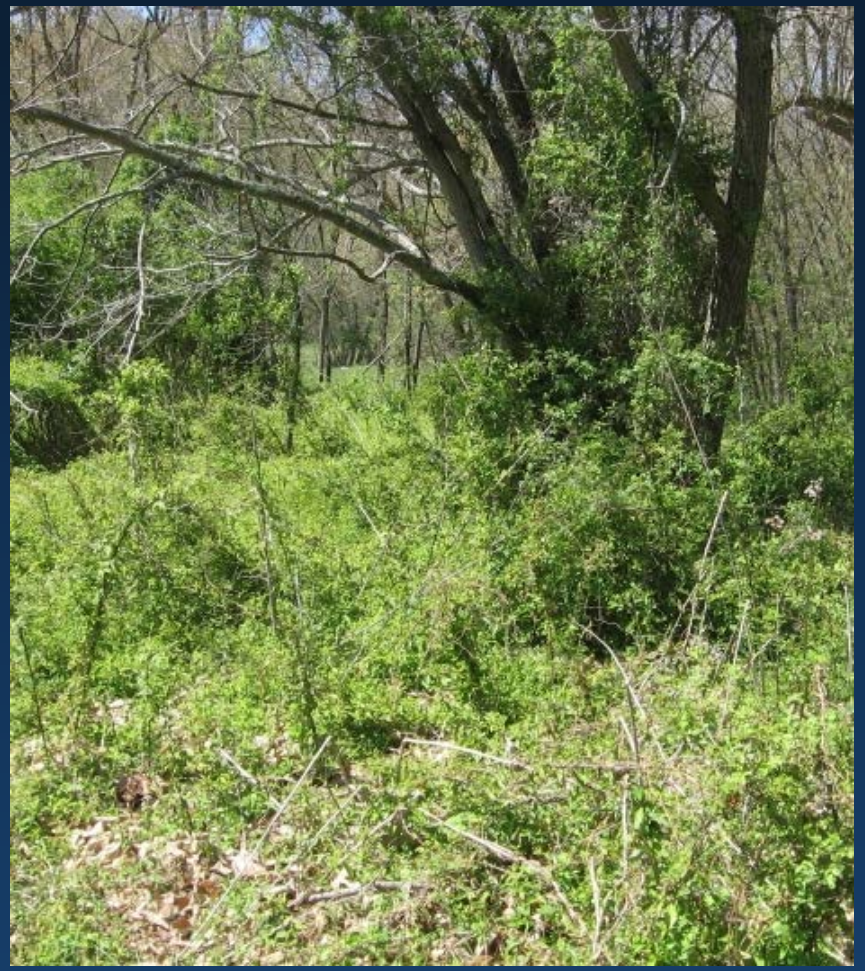
Glossy buckthorn (*Frangula alnus*)

NRCS Invasive Species Policy

- Three primary guidance documents for Invasive Species management:
  - EO 13112, 2/3/1999 – "…to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species causes…"
  - National Invasive Species Management Plan (NISMP), 2001, rev. 8/1/2008 – "…comprehensive 'blueprint' for federal action on Invasive Spp…"
  - GM_190_414 "Invasive Species Policy," 7/2010 – "…provides direction and guidance for agency actions related to…invasive species…"

NRCS Invasive Species Policy

- NRCS Role:
  - Assist with inventories, monitoring, detection, and evaluation efforts on private lands as an integral part of the conservation planning process
  - Inform landowners and managers of the presence of invasive spp. and provide appropriate CTA



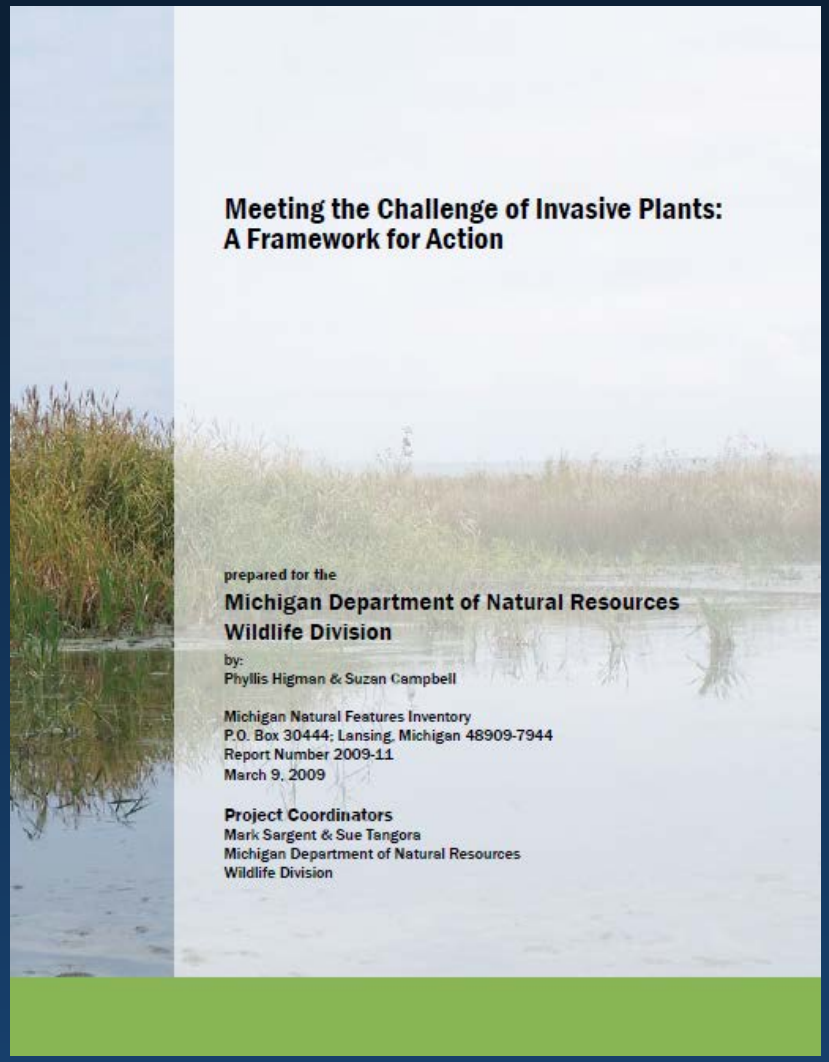
Multiflora rose (*Rosa multiflora*)

NRCS Invasive Species Policy

- The following items, as a minimum, are to be included in the plan:
  - An inventory of invasive species within the conservation management unit being planned
  - A map/aerial photo outlining the affected areas
  - ID of appropriate control and restoration techniques/strategies and their O&M, i.e., planned conservation practices
  - Environmental Evaluation CPA-52
    - Completion of this form is NRCS' responsibilities, not TSP's…
      - However, the Resource Considerations Guide Sheet portion of the CPA-52 is handy for documenting Resource Concerns in a plan.

NRCS Invasive Species Policy

- NRCS Role:
  - Ensure that no species is recommended in a conservation plan that is listed on official county, State, or Federal Noxious and/or invasive species lists.
    - Prohibited and Restricted Weeds: eFOTG, Section II, Folder H. (link to MDA webpage)
    - “Meeting the Challenge of Invasive Plants: A Framework for Action, ” MDNR, 2009
    - NRCS-MI “Invasive Plants Species List,” eFOTG, Section II, Folder G



Michigan NRCS Invasive Plant Species List

- **A List Species:** Medium to high threat; mostly isolated occurrences, treat wherever found.
- **B List Species:** Medium to high threat; mostly local - found in some areas but not others; designate areas for eradication, suppression or containment; may choose to control based on specific management goals and situations.
- **C List Species:** Medium to high threat; widespread; no action required; may choose to control based on specific management goals and situations.
- **D List Species:** More information required; may choose to control based on specific management goals and situations.

Michigan NRCS Invasive Plant Species List: Example from Southern Lower Peninsula

A List Species	
amur cork-tree	*Phellodendron amurense*
black jetbead	*Rhodotypos scandens*
European frog-bit	*Hydrocharis morsus-ranae*
giant hogweed	*Heracleum mantegazzianum*
giant knotweed	*Polygonum sachalinensis*
hydrilla	*Hydrilla verticillata*
Japanese stilt grass	*Microstegium vimineum*
kudzu	*Pueraria lobata*
Norway maple	*Acer platanoides*
pale swallowwort	*Vincetoxicum rossicum*
black swallowwort	*Vincetoxicum nigrum*
reed mannagrass	*Glyceria maxima*
water-hyacinth	*Eichhornia crassipes*
B List Species	
baby's breath	*Gypsophila paniculatus*
flowering rush	*Butomus umbellatus*
Japanese knotweed	*Polygonum cuspidatum*
leafy spurge	*Euphorbia esula*
Russian olive	*Elaeagnus angustifolia*
Scotch pine	*Pinus sylvestris*
C List Species	
amur honeysuckle	*Lonicera maackii*
autumn olive	*Elaeagnus umbellata*
Japanese barberry	*Berberis thunbergii*
Bell's honeysuckle	*Lonicera Xbella*
black locust	*Robinia pseudoacacia*
Canada thistle	*Cirsium arvense*
common buckthorn	*Rhamnus cathartica*
curly pondweed	*Potamogeton crispus*
Eurasian water milfoil	*Myriophyllum spicatum*
European fly honeysuckle	*Lonicera xylosteum*
garlic mustard	*Alliaria petiolota*
glossy buckthorn	*Frangula alnus*
Japanese honeysuckle	*Lonicera japonica*
Morrow's honeysuckle	*Lonicera morrowii*
multiflora rose	*Rosa multiflora*
Oriental bittersweet	*Celastrus orbiculata*
purple loosestrife	*Lythrum salicaria*
reed canary grass	*Phalaris arundinacea*
Phragmites, common reed	*Phragmites australis*
Scotch pine	*Pinus sylvestris*
spotted knapweed	*Centaurea maculosa*
Tartarian honeysuckle	*Lonicera tatarica*
tree-of-heaven	*Ailanthus altissima*
variable-leaf watermilfoil	*Myriophyllum heterophyllum*
D List Species	
black alder	*Alnus glutinosa*
European cranberrybush	*Viburnum opulus var. opulus*
lesser naiad	*Najas minor*

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Conservation Practices and Conservation Practice Standards

What are Conservation Practices and Standards?

- A Conservation Practice is an activity or treatment that improves a land unit's resource condition(s) (soil, water, air, plants, animals).
  - Often used in concert with one another, but can be used independently
- A Conservation Practice Standard is a written document that establishes the minimum level of quality in planning, designing, installing, operating, and maintaining conservation practices.
  - Ensures consistency in conservation delivery
  - Meet social, economic, and environmental needs
  - Provide an ecological-based approach to planning
  - Are program neutral

Prescribed Burning (Acre) 338

DEFINITION

Controlled fire applied to predetermined area.

PURPOSES

- Control undesirable vegetation
- Prepare sites for harvesting, planting or seeding
- Control plant disease
- Reduce wildfire hazards
- Improve wildlife habitat
- Improve plant production quantity and/or quality
- Remove slash and debris
- Enhance seed and seedling production
- Facilitate distribution of grazing and browsing animals
- Restore and maintain fire-dependant natural communities

CONDITIONS WHERE PRACTICE APPLIES

All lands as appropriate.

CRITERIA

General Criteria Applicable to All Purposes

Ensure there are adequate procedures, equipment, and number of trained personnel to accomplish the intended purpose.

Comply with all applicable laws and regulations, including the Clean Air Act.

The landowner is responsible for retaining all permits and clearances required by law. Visit the Michigan DNRE web site for burn permit information: http://www.michigan.gov/dnr/0,1607,7-153-30301_30505_44539---,00.html

Time prescribed burning appropriately for soil and site conditions to maintain site productivity and minimize effects on soil erosion and soil properties (structure, soil moisture), and wildlife.

Time prescribed burns based on all of the following: plant growth stage of species being burned, relative humidity, wind conditions, air temperature, and fuel conditions. See Table 1. Refer to "Managing Michigan's Wildlife: A Landowner's Guide," Part V - Grassland Management, Prescribed Burning and the Michigan Prescribed Fire Council's "Prescribed Fire in Michigan – Best Management Practices."

Integrate the expected weather conditions, human and vehicular traffic that may be impeded by heat or smoke, liability, safety and precautions into the timing, location and planned intensity of the burn.

Smoke management is an extremely important safety and health consideration in most prescribed burns. Use burning techniques and timing (based on weather conditions) to minimize the smoke effects on sensitive areas.

Monitor weather parameters that affect fire behavior and smoke effects throughout the burn.

A weather outlook for the period of at least 24 hours following the burn is required prior to conducting a prescribed burn.

Establish firebreaks, including existing barrier such as lakes, roads, etc., around the perimeter of the burn unit prior to conducting the prescribed burn. Firebreaks must meet the NRCS Michigan Firebreak (394) practice standard in the eFOTG.

Prescribed burning in forest land is only permitted to reduce wildfire hazards, for invasive species control, or in fire-dependant natural communities, such as dry southern forest (oak-hickory forest), dry northern forest (mixed pine-oak forest), etc., or to restore such communities. Refer to the Michigan Natural Features Inventory's (MNFI) Natural Communities Abstracts at http://web4.msue.msu.edu/mnfi/communities/index.cfm and Vegetation circa 1800s Maps at http://web4.msue.msu.edu/mnfi/data/veg1800.cfm for more information.

Prescribed burning in forest land will be limited to low- or moderate-intensity surface fires. Fire must be kept away from snags (standing dead trees) and chimney trees (hollow trees) by reducing fuel near such trees and/or increased monitoring and suppression.

Do not conduct prescribed burning on forest land sites where significant "ladder fuels" – shrubs and other mid-level woody vegetation – pose a significant risk of initiating a crown fire.

Parts of a Conservation Practice Standard

- **Definition**
- **Purposes**
- **Condition where Practice Applies**
- **Criteria**
  - General Criteria Applicable to All Purposes – MUST ALWAYS BE MET
  - Additional Criteria for specific purposes or type of installation – MUST BE MET IF APPLICABLE
- **Considerations** – not required, but generally recommended
- **Plans and Specifications** – details the type of information that must be included in a conservation plan
- **Operation and Maintenance** – information on how to keep the practice functioning throughout its lifespan. O&M that is known to be required during planning should be detailed in the conservation plan
- **References** – basis of practice standard, as well as sources of addition information

Forest Stand Improvement (666)

- Definition: The manipulation of species composition, stand structure and stocking by cutting or killing selected trees and understory vegetation.
- Purposes (applicable to Invasive Spp. Control):
  - Increase the quantity and quality of forest products by manipulating stand density and structure
  - Improve forest health by reducing the potential of damage from pests and moisture stress
  - Restore natural plant communities
  - Improve aesthetic and recreation values
  - Improve wildlife habitat
- Generally, the best practice for the removal of tree species, e.g., Norway maple, Scotch pine, European Black Alder
- FY2015 EQIP rates: approx. $202-291/ac. for most typical FSI work

Scotch Pine (*Pinus sylvestris*)

Forest Stand Improvement (666)

- General Criteria Applicable to All Purposes
  - Ensure practice is compatible with harvest-regen strategy (even- or uneven aged)
  - Base decisions on a thorough and current forest inventory
  - Do not cut in oak stands during “oak wilt season”
  - Comply with “Sustainable Soil and Water Quality on Forest Land”
  - Retain 2 large den trees and 2 large snags per acre if possible
- Considerations
  - Use a professional forester to mark and layout practice
  - Arrange cut material into brushpiles
  - Minimize impacts on nesting wildlife

Forest Stand Improvement (666)

- Plans and Specifications
  - Purpose(s) of treatment
  - Map indicating location of practice
  - The harvest-regeneration strategy:
    - Uneven-aged management (e.g., single-tree selection, group selection, coppice selection)
    - Even-aged management (e.g., clear-cut, seed-tree, shelterwood, coppice)
  - Pre-treatment and post-treatment basal area (for even- or uneven-aged stands) or average DBH and spacing/trees per acre (for even-aged stands)
  - Number, species, and size class of trees to be removed
  - The method, timing, and type of equipment to be used
  - Mitigation measures, e.g., slash and debris disposal to mitigate wildfire or pest hazards
  - Operation and Maintenance requirements

Forest Stand Improvement (666) Job Sheet

Table 1. Thinning Guidelines for Even-aged Hardwoods

Existing stand:			Thin the stand to:		
Avg. DBH (in.)	Trees per acre	Avg. spacing between trees (ft.)	Trees / Ac.	Avg. spacing between Trees (ft.)	Basal Area (sq. ft. per acre)
5	≥ 770	≤ 7	681	8	95
6	≥ 535	≤ 9	436	10	87
7	≥ 393	≤ 11	302	12	82
8	≥ 301	≤ 12	258	13	90
9	≥ 238	≤ 14	194	15	85
10	≥ 193	≤ 15	151	17	83
11	≥ 159	≤ 17	134	18	90
12	≥ 134	≤ 18	109	20	86
13	≥ 114	≤ 20	90	22	83
14	≥ 98	≤ 21	82	23	88
15	≥ 86	≤ 23	70	25	86
16	≥ 75	≤ 24	60	27	84
17	≥ 67	≤ 26	56	28	88
18	≥ 59	≤ 27	48	30	85
19	≥ 53	≤ 29	43	32	85
20	≥ 48	≤ 30	40	33	87
21	≥ 44	≤ 32	36	35	87
22	≥ 40	≤ 33	32	37	84
23	≥ 36	≤ 35	30	38	87
24	≥ 33	≤ 36	27	40	85

Table 2. Thinning Guidelines for Even-aged Conifers

Existing stand:			Thin the stand to:		
Avg. DBH (in.)	Trees per acre	Avg. spacing between trees (ft.)	Trees / Ac.	Avg. spacing between Trees (ft.)	Basal Area (sq. ft. per acre)
5	≥ 538	≤ 9	360	11	50
6	≥ 436	≤ 10	302	12	60
7	≥ 360	≤ 11	258	13	70
8	≥ 302	≤ 12	222	14	78
9	≥ 258	≤ 13	194	15	85
10	≥ 222	≤ 14	170	16	94
11	≥ 194	≤ 15	151	17	101
12	≥ 170	≤ 16	134	18	106
13	≥ 151	≤ 17	121	19	111
14	≥ 134	≤ 18	109	20	117
15	≥ 121	≤ 19	99	21	122
16	≥ 109	≤ 20	90	22	126
17	≥ 99	≤ 21	82	23	130
18	≥ 90	≤ 22	76	24	134
19	≥ 82	≤ 23	70	25	138
20	≥ 76	≤ 24	64	26	140
21	≥ 70	≤ 25	60	27	145
22	≥ 64	≤ 26	56	28	148
23	≥ 60	≤ 27	52	29	150
24	≥ 56	≤ 28	48	30	151

Forest Stand Improvement (666) Job Sheet

GENERAL INFORMATION:

Client name*:	Joe Landowner	Tract no.:		Field no. *:	3
Specifications date:				Planned implementation date*:	1/15/2016
Total stand Acres:				Total acres of practice planned*:	8.0
Map of site* – attach a sketch, map, or aerial photo indicating the location of area to be treated with FSI.					

PURPOSES (check all that apply)*:

☒	Increase the quantity and quality of forest products by manipulating stand density and structure
☐	Harvest forest products
☐	Initiate forest stand regeneration
☐	Development of renewable energy systems
☐	Reduce wildfire hazard
☐	Improve forest health by reducing the potential of damage from pests and moisture stress
☒	Restore natural plant communities
☐	Achieve or maintain a desired native understory plant community for special forest products, grazing, and browsing
☐	Improve aesthetic and recreation values
☒	Improve wildlife habitat
☐	Alter water yield
☐	Increase carbon storage in selected trees

STAND INFORMATION:

Forest Cover Type/Dominant Spp. *:	Mixed Oak-Hickory		
Dominant Soil Types:		Site Index:	(S.I. Spp.:)
Silvicultural (Harvest/Regeneration) System (complete applicable section below):			
☒ Uneven-aged System*		☐ Even-aged System*	
Basal Area:	120 sq. ft./ac. *	Avg. DBH*:	Trees per Ac. *:
Type of Intermediate FSI Treatment*:	☒ Single tree selection ☐ Group selection ☐ Other:	Type of Intermediate FSI Treatment*:	☐ Single tree selection ☐ Row thinning ☐ Other:
Type of Harvest FSI Treatment*:	☐ Single tree selection ☐ Group selection ☐ Other:	Type of Harvest FSI Treatment*:	☐ Shelterwood ☐ Seed Tree ☐ Clearcut ☐ Other:

FOREST STAND IMPROVEMENT IMPLEMENTATION DETAILS:

Diameter class*[1/]:	Existing (pre-treatment)*: ☐ Trees/Ac. or ☒ B.A. (ft²/ac.)	Removals*: Trees/Ac. or B.A/	Species	Residual (post-treatment)*: Trees/Ac. or B.A.
saplings	5	0		5
pole	30	8	Norway Maple	22
sawlogs	85	22	Norway Maple	63
Total Trees/Ac.:		*		
Total BA:	120*	30*		90*

[1/] Specify Diameter in two-inch classes, e.g., 6 = 5.0 – 6.9", or by timber size class, e.g., saplings, poletimber, sawtimber.

Additional information, including equipment to be used, and O&M details, necessary to install and maintain practice*:	Cut trees and apply a herbicide (labelled for stump application) to the cut stumps within 30 minutes. Monitor the site monthly during the growing season for 2 years, and treat any Norway maple stump sprouts or seedlings with an approriately labelled herbicide. Install according to the general criteria, all applicable additional criteria, and as detailed in this specification sheet.

Brush Management (314)

- Definition: The management or removal of woody (non-herbaceous or succulent) plants including those which are invasive and noxious.
- Purposes (applicable to Invasive Spp. Control):
  - Create the desired plant community consistent with the ecological site.
  - Restore or release desired vegetative cover to protect soils, control erosion, reduce sediment, improve water quality or enhance stream flow.
  - Maintain, modify, or enhance fish and wildlife habitat.
  - Improve forage accessibility, quality and quantity for livestock and wildlife.
- Generally, the best practice for the control of shrub species, e.g., autumn olive, Asian honeysuckles, glossy and common buckthorn
- FY2015 EQIP rates: approx. $52-303/ac.

autumn olive (*Elaeagnus umbellata)*

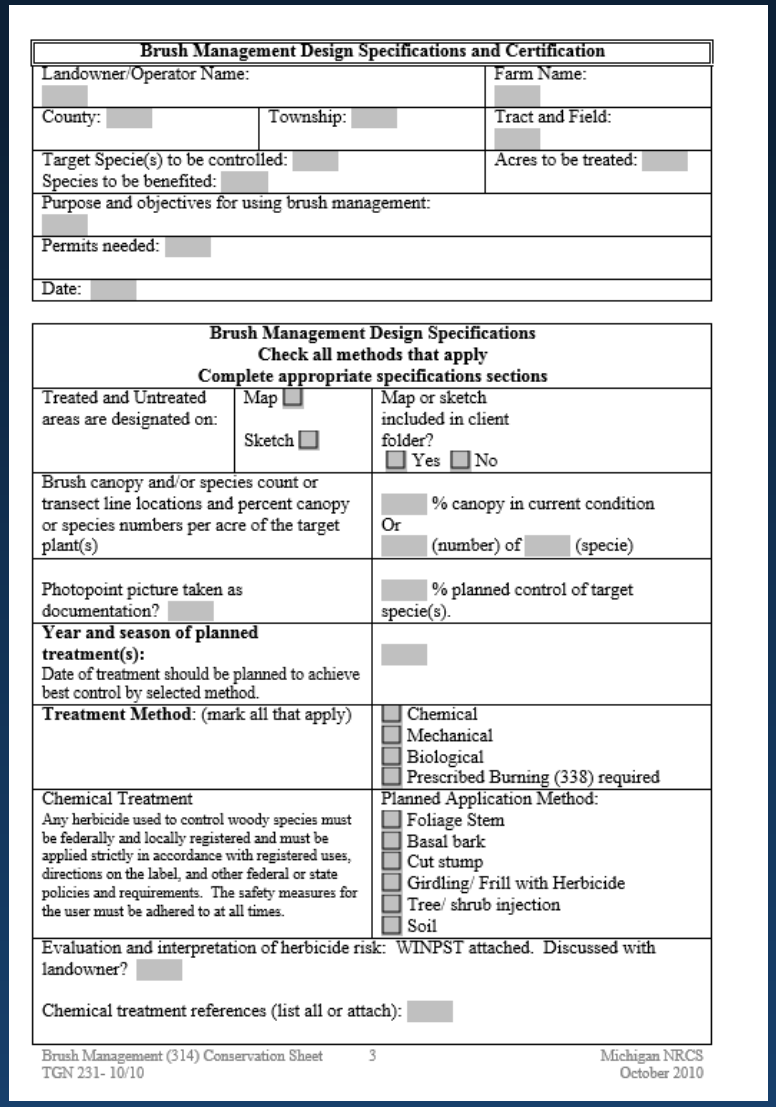
Brush Management (314)

- General Criteria Applicable for All Purposes:
  - Accomplish by mechanical, chemical or biological methods alone or in combination.
  - To manipulate tree species composition, structure or stocking, use Forest Stand Improvement (666)
  - NRCS will not develop biological or chemical treatment recommendations except for biological control utilizing grazing animals

Brush Management (314)

- Plans and Specifications
  - Goals and objectives clearly stated.
  - Pre- and post-treatment cover or density of the target plant(s)
  - Maps, drawings, and/or narratives detailing or identifying treatment areas and pattern
  - Monitoring plan
  - Mechanical Treatment Specifications
    - Types of equipment
    - Dates of treatment
    - Operating instructions (if applicable)
    - Techniques or procedures to be followed
  - Note: additional required documentation in CPS for chemical and biological treatments.

Brush Management (314) Job Sheet



Brush Management Design Specifications and Certification

Landowner/Operator Name:		Farm Name:
County:	Township:	Tract and Field:
Target Specie(s) to be controlled: Species to be benefited:		Acres to be treated:
Purpose and objectives for using brush management:		
Permits needed:		
Date:		

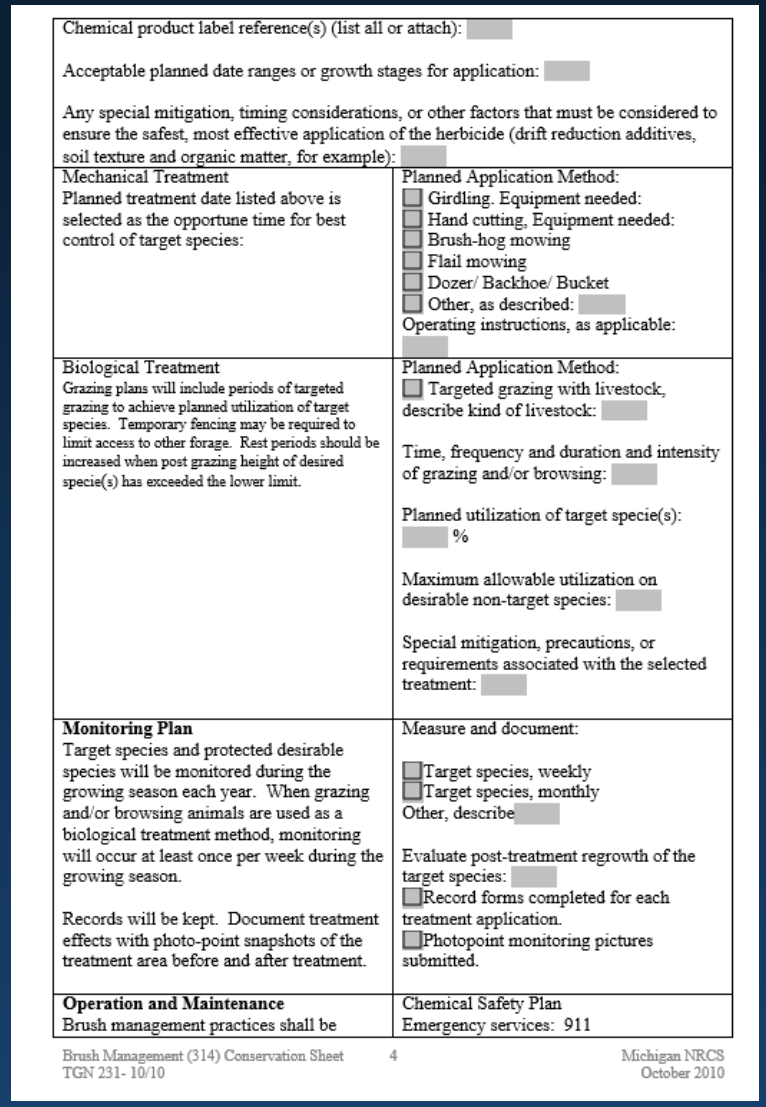
Brush Management Design Specifications
Check all methods that apply
Complete appropriate specifications sections

Treated and Untreated areas are designated on:	Map ☐ Sketch ☐	Map or sketch included in client folder? ☐ Yes ☐ No
Brush canopy and/or species count or transect line locations and percent canopy or species numbers per acre of the target plant(s)		% canopy in current condition Or (number) of (specie)
Photopoint picture taken as documentation?		% planned control of target specie(s).
Year and season of planned treatment(s): Date of treatment should be planned to achieve best control by selected method.		
Treatment Method: (mark all that apply)		☐ Chemical ☐ Mechanical ☐ Biological ☐ Prescribed Burning (338) required
Chemical Treatment Any herbicide used to control woody species must be federally and locally registered and must be applied strictly in accordance with registered uses, directions on the label, and other federal or state policies and requirements. The safety measures for the user must be adhered to at all times.		Planned Application Method: ☐ Foliage Stem ☐ Basal bark ☐ Cut stump ☐ Girdling/ Frill with Herbicide ☐ Tree/ shrub injection ☐ Soil

Evaluation and interpretation of herbicide risk: WINPST attached. Discussed with landowner?

Chemical treatment references (list all or attach):

Brush Management (314) Conservation Sheet 3 Michigan NRCS
TGN 231- 10/10 October 2010



Chemical product label reference(s) (list all or attach):

Acceptable planned date ranges or growth stages for application:

Any special mitigation, timing considerations, or other factors that must be considered to ensure the safest, most effective application of the herbicide (drift reduction additives, soil texture and organic matter, for example):

Mechanical Treatment Planned treatment date listed above is selected as the opportune time for best control of target species:	Planned Application Method: ☐ Girdling. Equipment needed: ☐ Hand cutting, Equipment needed: ☐ Brush-hog mowing ☐ Flail mowing ☐ Dozer/ Backhoe/ Bucket ☐ Other, as described: Operating instructions, as applicable:
Biological Treatment Grazing plans will include periods of targeted grazing to achieve planned utilization of target species. Temporary fencing may be required to limit access to other forage. Rest periods should be increased when post grazing height of desired specie(s) has exceeded the lower limit.	Planned Application Method: ☐ Targeted grazing with livestock, describe kind of livestock: Time, frequency and duration and intensity of grazing and/or browsing: Planned utilization of target specie(s): % Maximum allowable utilization on desirable non-target species: Special mitigation, precautions, or requirements associated with the selected treatment:
Monitoring Plan Target species and protected desirable species will be monitored during the growing season each year. When grazing and/or browsing animals are used as a biological treatment method, monitoring will occur at least once per week during the growing season. Records will be kept. Document treatment effects with photo-point snapshots of the treatment area before and after treatment.	Measure and document: ☐ Target species, weekly ☐ Target species, monthly Other, describe Evaluate post-treatment regrowth of the target species: ☐ Record forms completed for each treatment application. ☐ Photopoint monitoring pictures submitted.
Operation and Maintenance Brush management practices shall be	Chemical Safety Plan Emergency services: 911

Brush Management (314) Conservation Sheet 4 Michigan NRCS
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Herbaceous Weed Control (315)

- Definition: The removal or control of herbaceous weeds including invasive, noxious and prohibited plants.
- Purposes (applicable to Invasive Spp. Control):
  - Restore or release native or create desired plant communities and wildlife habitats consistent with the ecological site.
- Generally, the best practice for the control of non-woody plants, e.g., garlic mustard, periwinkle, spotted knapweed
- FY2015 EQIP rates: $28-110/ac.

Garlic Mustard (*Alliaria petiolata*), Washtenaw Co.

Herbaceous Weed Control (315)

- General Criteria Applicable to All Purposes
  - Accomplish by mechanical, chemical or biological methods alone or in combination.
  - NRCS will not develop biological or chemical treatment recommendations except for biological control utilizing grazing animals
  - For weed control using natural or artificial mulch, refer to Mulching (484)
  - Manage or dispose of treated weeds in a manner that will prevent spreading to new sites.

Herbaceous Weed Control (315)

- Plans and Specifications
  - Goals and objectives clearly stated.
  - Plan map and soil map for the site
  - Pre- and post-treatment cover or density of the target plant(s)
  - Maps, drawings, and/or narratives detailing or identifying treatment areas and pattern
  - Monitoring plan
  - Mechanical Treatment Specifications
    - Types of equipment
    - Dates of treatment
    - Operating instructions (if applicable)
    - Techniques or procedures to be followed

  - Note: additional required documentation in CPS for chemical and biological treatments.

Herbaceous Weed Control (315) Job Sheet

Herbaceous Weed Control Design Specifications and Certification

Landowner/Operator Name:		Farm Name:
County:	Township:	Tract and Field:
Target Species to be controlled: Species to be benefited:		Acres to be treated:
Purpose and objectives for using herbaceous weed control:		
Permits needed:		

Herbaceous Weed Control Design Specifications
Complete the specifications below for all treatment methods that apply.

Treated and Untreated areas are designated on:	Map ☐ Sketch ☐	Map or sketch included in client folder? ☐ Yes ☐ No
Pre-treatment Cover Weed canopy and/or species count or transect line locations		% canopy in current condition Or (number) of (specie)
Describe current herbaceous weed community:		% **planned** control of target specie(s).
Year and season of planned treatment(s): Date of treatment should be planned to achieve best control by selected method. Treatments will be conducted during periods of the year when weed species are most vulnerable and will promote restoration of the native or desired plant communities.		
Describe desired plant community: Desirable species present, expected herbaceous weed decrease		
Treatment Method: (mark all that apply)		☐ Chemical ☐ Mechanical ☐ Biological
Chemical Treatment Any herbicide used to control weed species must be federally and locally registered and must be applied strictly in accordance with registered uses,		Planned Application Method: ☐ Foliage and Stem Spraying ☐ Soil

directions on the label, and other federal or state policies and requirements. The safety measures for the user must be adhered to at all times.	
Chemical Treatment specifications: Evaluation and interpretation of herbicide risk: WINPST attached. Discussed with landowner? Chemical treatment references (list all or attach): Chemical product label reference(s) (list all or attach): Acceptable **planned** date ranges or growth stages for application: **Planned** application rate and product selected by client: **Records** will be kept to document treatment date, growth stage and rates for each product used. Photopoint pictures will be taken before and after treatment. Any special mitigation, timing considerations, or other factors that must be considered to ensure the safest, most effective application of the herbicide (drift reduction additives, soil texture and organic matter, for example):	
Mechanical Treatment Planned treatment date listed above is selected as the opportune time for best control of target species. **Records** will be kept to document treatment dates. Photopoint pictures will be taken before and after treatment.	Planned Application Method: ☐ Hand cutting, Equipment needed: ☐ Mower or Brush-hog mowing ☐ Flail mowing ☐ Mulching, requires Mulching (484) ☐ Fabrics and/or Plastics ☐ Other, as described: Operating instructions, as applicable:
Biological Treatment Grazing plans will include periods of targeted grazing to achieve planned utilization of target species. Temporary fencing may be required to limit access to other forage. Rest periods should be increased when post grazing height of desired specie(s) has exceeded the lower limit. **Records** will document grazing activities. Photopoint location pictures will be taken before and after grazing treatment.	Planned Application Method: ☐ Targeted grazing with livestock, describe kind of livestock: Time, frequency and duration and intensity of grazing and/or browsing: Planned utilization of target specie(s): % Maximum allowable utilization on desirable non-target species: % Special mitigation, precautions, or requirements associated with the selected treatment:
Monitoring Plan	Measure and document:

Target species and protected desirable species will be monitored during the growing season each year. Length of evaluation periods will depend on the weed species being monitored, proximity of propagules (seeds, roots, plant materials), transport of seeds by wind or animals and methods and materials used. When grazing and/or browsing animals are used as a biological treatment method, monitoring will occur at least once per week during the growing season. **Records** will be kept. **Document treatment effects with photo-point snapshots of the treatment area before and after treatment.**	☐ Target species, weekly ☐ Target species, monthly Other, describe Evaluate post-treatment regrowth of the target species: ☐ Record forms completed for each treatment application. ☐ Photopoint location monitoring pictures submitted.
Operation and Maintenance Herbaceous weed control practices shall be applied using approved materials and procedures. Operations will comply with all local, state and federal laws and ordinances. Evaluation of practice success is an on-going operation. Success is determined by evaluating the regrowth or reoccurrence of the target species after sufficient time has passed for the treatment to be effective. Spot treatment of individual plants or areas needing re-treatment should be completed as needed while vegetation is small and most vulnerable to treatment effects.	Chemical Safety Plan Emergency services: 911 Local hospital emergency number: Local police or sheriff: Ambulance: In case of emergency, notify: Name: Phone numbers: National Pesticide Information Center 1-800-858-7384 National Chemical Transportation Emergency Center (CHEMTRAC) 1-800-424-9300 Follow label requirements for mixing/loading setbacks from wells, intermittent streams and rivers, natural or impounded ponds and lakes, and reservoirs. Post signs, according to label directions and/or federal, state, tribal or local laws, around fields that have been treated. Follow restricted entry intervals. Dispose of herbicides and herbicide containers in accordance with label directions and adhere to federal, state, tribal, and local regulations. **Read and follow label directions and maintain appropriate Material Safety Data**

Prescribed Burning (338)

- Definition: Controlled fire applied to predetermined area.
- Purposes (applicable to Invasive Spp. Control):
  - Control undesirable vegetation
  - Improve wildlife habitat
  - Improve plant production quantity and/or quality
  - Restore and maintain fire-dependant natural communities
- Would be used in lieu of Brush Management (314) or Herbaceous Weed Control, if fire is used
- Typically, Firebreak (394) needs to be scheduled in plan with this practice
- FY2015 EQIP rates: $8-121/ac.

Prescribed Burning (338)

- General Criteria Applicable to All Purposes
  - Minimize the smoke effects on sensitive areas
  - Prescribed burning in forest land will be limited to low- or moderate-intensity surface fires.
  - Do not conduct prescribed burning on forest land sites where significant “ladder fuels” pose a significant risk of initiating a crown fire.
  - To prevent subsurface fires, do not burn sites with organic soils, e.g., muck, and peat, except when soils are frozen or saturated.
  - Prescribed burns will only be conducted in accordance with a prescribed burn plan. These plans
  - May be developed by landowners, consultants, or other qualified individuals. NRCS employees may not author a burn plan.
  - Prescribed burn plans must be provided to NRCS for review and certification.
  - Prescribed burn plans should also be provided to the local fire department
  - Prescribed burn plans are valid only for the area planned and for the burning season planned.

Prescribed Burning (338)

- Plans and Specifications (Burn Plan requirements)
  - Location and description of the burn area and firebreaks
  - Resource management and prescribed burn objectives
  - Dates and times targeted for burn
  - An aerial photo indicating wind direction, fire lanes, contingency (back-up) fire lanes, firing sequence, and hazards such as roads, buildings, power lines, natural gas pipelines, etc.
  - Description of pre-burn vegetation cover
  - Required weather conditions for prescribed burn, including temperature, wind speed, wind direction and relative humidity ☐Checklist of parties to notify, and when to notify them
  - Pre-burn preparation
  - Post burn evaluation and management criteria
  - Description of the burning method to be used, including ignition method and firing sequence ☐ Job assignments and descriptions of responsibilities for all persons assisting with the fire patrol, containment, mop-up, and suppression of the burn
  - Required equipment checklist
  - Smoke impacts and location of smoke-sensitive and other affected areas, including a forecast trajectory of smoke plume for the appropriate downwind distance
  - Contingency plan to suppress an escaped burn
  - Approval signatures (client and plan author)

When to use Prescribed Burning?

- If you are not experienced with prescribed burning, consult an expert before including the practice in a plan!
  - See Michigan Prescribed Fire Council's Burn Consultants list: http://firecouncil.org/mpfc-resources/
- Consult the Fire Effects Information System website for species-specific fire effects information:
  - http://feis-crs.org/beta/

Tree/Shrub Establishment (612)

- Definitions: Establishing woody plants by planting seedlings or cuttings, direct seeding, or natural regeneration.
- Purposes (applicable to Invasive Spp. Control):
  - forest products such as timber, pulpwood, etc.
  - wildlife habitat
  - long-term erosion control and improvement of water quality
  - enhancing aesthetics
- Use to enhance woody species diversity on a site, often with 314 or 315
- FY2015 EQIP Rates: $0.31-4.45/ea.

Conservation Cover (327)

- Definition: Establishing and maintaining permanent vegetative cover
- Purposes (applicable to Invasive Spp. Control):
  - Reduce soil erosion and sedimentation
  - Improve water quality
  - Improve air quality
  - Improve soil quality
  - Enhance wildlife habitat.
  - Enhance pollinator habitat
  - Manage plant pests
- Used for a wide variety of grass and forb planting applications
- FY2015 EQIP rates: $92-$510/ac

NRCS Natural Resources Conservation Service

POLLINATOR BIOLOGY AND HABITAT

Michigan Biology Technical Note No. 20 *April 2013 (rev 3/2014)*

Introduction

This technical note provides information on how to plan for, protect, and create habitat for pollinators in agricultural settings. Pollinators are an integral part of our environment and our agricultural systems; they are important in 35% of global crop production. Animal pollinators include bees, butterflies, moths, wasps, flies, beetles, ants, bats, and hummingbirds. This technical note focuses on native bees, the most important pollinators in temperate North America, but also addresses the habitat needs of butterflies and, to a lesser degree, other beneficial insects.

Common Eastern bumble bee (*Bombus impatiens*) on giant yellow hyssop (*Agatache nepetoides*).

Worldwide, there are an estimated 20,000 species of bees, with approximately 4,000 species native to the United States. The non-native European honey bee (*Apis mellifera*) is the most important managed crop pollinator in the United States. However, the number of honey bee colonies is in decline because of disease and other factors, making native pollinators even more important to the future of agriculture. Native bees provide free pollination services, and are often specialized for foraging on particular flowers, such as squash, berries, or orchard crops. This specialization results in more efficient pollination and the production of larger and more abundant fruit from certain crops. Native bees contribute at least $3 billion worth of crop pollination annually to the U.S. economy, which is likely a conservative estimate. A 2012 study in California, for example, found that native bees there are likely responsible for between $900 million and $2.4 billion in crop production. This suggests that the role of wild native bees may be much greater than earlier estimates.

Undeveloped areas on and close to farms can serve as long-term refugia for native wild pollinators. Protecting, enhancing or providing habitat is the best way to conserve native pollinators and, at the same time, provide pollen and nectar resources that support local honey bees; on farms with sufficient natural habitat, native pollinators can provide all of the pollination for some crops.

Habitat enhancement for native pollinators on farms, especially with native plants, provides multiple benefits. In addition to supporting pollinators, native plant habitat will attract beneficial insects that are predators or parasitoids of crop pests and lessen the need for pesticides on your farm. Pollinator habitat can also provide habitat for other wildlife, such as birds, serve as windbreaks, help stabilize the soil, and improve water quality.

Pollinators have two basic habitat needs: a diversity of flowering native or naturalized plants, and egg-laying or nesting sites. The NRCS can assist landowners with providing adequate pollinator habitat by, for example, suggesting locally appropriate plants and offering advice on how to provide nesting or egg-laying habitat.

This document provides a three step approach to pollinator conservation: (1) advice on recognizing existing pollinator habitat, (2) steps to protect pollinators and existing habitat, and (3) methods to further enhance or restore habitat for pollinators.

Conservation Cover (327)

Table 1a. Seeding Dates

COOL SEASON GRASSES & LEGUMES -	*WARM SEASON GRASSES & LEGUMES*
***Upper Peninsula**:*	
• *May 1 - June 1 or July10 - August 1*	*May 15 - June 15*
North 1/2 of Lower Peninsula (N. of US10)	
• *April 20 - June 1 or July 15 - August 1.*	*May 15 - June 15*
South 1/2 of Lower Peninsula (S. of US 10)	
• *April 10 - May 20 or July 20 - August 15*	*May 5 - June 15*

DORMANT SEEDING DATES - **Statewide** After *November 1 or when soil temperature at a 2-inch depth is below 50 degrees Fahrenheit.*

Conservation Cover (327)

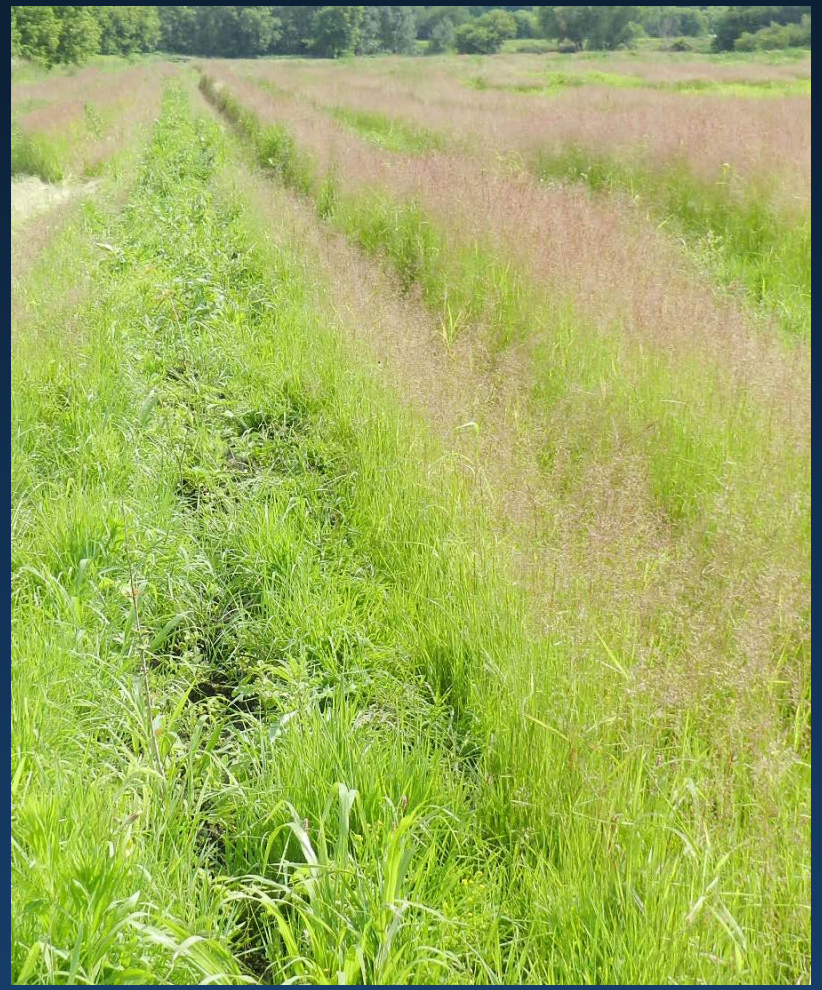
Table 2. Grasses and Legumes Mixtures (lbs/ac)

Mixtures 1/	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Legumes																		
Alfalfa 2/	6								6	6	6	3	6		6			
Alsike Clover		4					4											
Birdsfoot Trefoil 3/						3												
Ladino Clover				1	2			1				3						
Red Clover			5	3										3				
Cool season grasses																		
Int. Wheatgrass															8			
Kentucky bluegrass						5		2				2.5	2					
Orchardgrass				3			4			3				3				
Red top	6	2												3				
Smooth Bromegrass	2		8		8				6				6					
Timothy								4			4	2.5		3				
Warm season grasses																		
Big bluestem																	3	2*
Indian grass																	3	2
Little bluestem																	2	2
Switchgrass 4/																5	2	2
Wildflowers/forbs																	0.5	0.5
Total lbs./ac/mixture	14	6	13	7	10	8	8	7	12	9	10	11	14	12	14	5	10**	8.5

1/ use long-term winter hardy varieties. 2/ Trefoil needs to be inoculated with rhizobia bacteria @ 2 times the normal rate. 3/ See Michigan DNR publication. *Substitute Switchgrass for Indian grass on hydric soils. **Any combination that adds up to a total of 10 (or lower) total pounds/ac.

Cover Crop (340)

- Definition: Cover crops include grasses, legumes, and forbs, established for seasonal cover and other conservation purposes.
- Purposes (applicable to Invasive Spp. Control):
  - Reduce erosion from wind and water
  - Increase biodiversity
  - Suppress weeds
  - Reduce pest pressure
  - Encourage Pollination
- Commonly used with Tree/Shrub Establishment (612) and other practices
- FY2015 EQIP rates: $45-61/ac.



Mulching (484)

- Definition: Applying plant residues or other suitable materials produced off site, to the land surface.
- Purposes (applicable to Invasive Spp. Control):
  - Conserve soil moisture
  - Provide erosion control
  - Facilitate the establishment of vegetative cover
  - Improve soil health
- Can be used to place natural mulch or fabric weed barriers.
- FY2015 EQIP rates: $1.58/ea. or $0.09/sq. ft.

Additional Invasive Species Management Resources

Fire Effects Information System (Garlic Mustard example) http://feis-crs.org/beta/

Alliaria petiolata

- INTRODUCTORY
- DISTRIBUTION AND OCCURRENCE
- BOTANICAL AND ECOLOGICAL CHARACTERISTICS
- FIRE ECOLOGY
- FIRE EFFECTS
- MANAGEMENT CONSIDERATIONS
- REFERENCES

INTRODUCTORY

- AUTHORSHIP AND CITATION
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- SYNONYMS
- NRCS PLANT CODE
- COMMON NAMES
- TAXONOMY
- LIFE FORM
- FEDERAL LEGAL STATUS
- OTHER STATUS

AUTHORSHIP AND CITATION:
Munger, Gregory T. 2001. Alliaria petiolata. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2015, September 23].

FEIS ABBREVIATION:
ALLPET

SYNONYMS:
Alliaria officinalis Andrz. ex Bieb. [6,31,68,73]

NRCS PLANT CODE [78]:
ALPE4

COMMON NAMES:
garlic mustard

TAXONOMY:
The scientific name of garlic mustard is *Alliaria petiolata* (Bieb.) Cavara Grande (Brassicaceae) [26,27,32,48,61,82,86,89].

DISTRIBUTION AND OCCURRENCE

SPECIES: Alliaria petiolata

GENERAL DISTRIBUTION:
Native to Europe [6,15,26,48,68,73,82,87] and Asia [48,82,87], garlic mustard occurs in northern Europe from England across Scandinavia to the western areas of the former Soviet Union, and south to Italy [55]. It was 1st reported in the North America in 1868 on Long Island, New York [50], and has since established throughout much of the Northeast and Midwest. Garlic mustard can be found in Canada from southern Ontario east into the St. Lawrence Valley in Quebec [15,27], as well as around Victoria, British Columbia [15]. In the United States it is established and invasive in deciduous woodlands and disturbed areas from northern New England west to eastern North Dakota, and south to eastern Oklahoma and South Carolina [6,14,17,23,27,32,33,48,55,57,60,61,65,68,73,77,82,89]. Occurrences of garlic mustard have also been recorded in Utah, eastern Colorado, and around Portland, Oregon, Seattle, Washington, and Juneau, Alaska [31,56,75,77,86,87]. The PLANTS database provides a map of garlic mustard's distribution in the United States.

HABITAT TYPES AND PLANT COMMUNITIES:
In the eastern U.S., garlic mustard occurs in the understory of a variety deciduous forests and woodlands. It is rarely reported as being associated with conifers, although Cavers and others [15] state 7 of 37 tree and shrub species found growing over garlic mustard in eastern Canada were coniferous. While not intended as an exhaustive or definitive list, the following are specific examples of communities in which garlic mustard has been found.

Oak savanna/eastern prairie: In northern Illinois prairie and savanna remnants, garlic mustard is an important herb layer species in areas with greater relative shade. Associated herbs include rue anemone (*Thalictrum thalictroides*), broadleaf enchanter's nightshade (*Circaea lutetiana*), starry false lily-of-the-valley (*Maianthemum stellatum*), jumpseed (*Polygonum virginianum*), Atlantic camas (*Camassia schilloides*), spotted geranium (*Geranium maculatum*), and avens (*Geum* spp.) [11]. Garlic mustard was present along the fringes of a white oak-northern red oak (*Quercus alba-Q. rubra*) savanna in northern Illinois [29].

Xeric upland eastern deciduous forest: Garlic mustard is present in black oak (*Q. velutina*)-dominated sand forest in central Illinois, especially in disturbed areas, and along nearby shaded roadsides. Herbaceous associates at 1 site included hog peanut (*Amphicarpa bracteata*), lambsquarters (*Chenopodium album*) , broadleaf enchanter's nightshade, white snakeroot (*Ageratina altissima*), licorice bedstraw (*Galium circaezans*), beggarslice (*Hackelia virginiana*), Carolina leaf-flower (*Phyllanthus caroliniensis*), and feathery false lily-of-the-valley (*Maianthemum racemosum*) [54].

Mesic upland eastern deciduous forest:
Northeast - Garlic mustard occurs in upland oak-hickory (*Quercus-Carya* spp.) forest in New Jersey [14], and was present in the herb layer of a sugar maple (*Acer saccharum*)-dominated stand in southwestern Vermont, along with jewelweed (*Impatiens capensis*), ladyfern (*Athyrium filix-femina*), intermediate wood fern (*Dryopteris intermedia*), Christmas fern (*Polystichum acrostichoides*), Canadian white violet (*Viola canadensis*), Jack-in-the-pulpit (*Arisaema triphyllum*), and rosy sedge (*Carex rosea*) [90].

Midwest - In southwestern Ohio it is found under sugar maple, white oak, northern red oak, American elm (*Ulmus americana*), and hickory, along with herbaceous associates cutleaf toothwort (*Cardamine concatenata*), stickywilly (*Galium aparine*), Virginia springbeauty (*Claytonia virginica*), toadshade (*Trillium sessile*), Jack-in-the-pulpit, mayapple (*Podophyllum peltatum*), Clayton's sweetroot (*Osmorhiza claytonii*), downy yellow violet (*Viola pubescens*), and touch-me-not (*Impatiens* spp.) [19]. In west-central Ohio, garlic mustard is associated with sugar maple, American beech (*Fagus grandifolia*), hickories, oaks, and slippery elm (*Ulmus rubra*). Herbaceous associates include toadshade, wild blue phlox (*Phlox divaricata*), running strawberry bush (*Euonymus obovata*), common periwinkle (*Vinca minor*), white panicle aster (*Symphyotrichum lanceolatum*), whiteflower leafcup (*Polymnia canadensis*) , wild leek (*Allium tricoccum*), Adam-and-Eve (*Aplectrum hyemale*), and goldenrod (*Solidago* spp.) [24].

In central Indiana native forest remnants in a rural agricultural matrix, garlic mustard occurred across the field-forest ecotone, from open areas into the forest interior. Dominant overstory species were sugar maple and American beech at some sites; other sites also included American basswood (*Tilia americana*), white ash, and several oak and hickory species [12]. Garlic mustard is listed as an understory associate in several sugar maple-basswood and sugar maple-basswood-white ash habitat types in southern Wisconsin. Common ground flora for these similar habitat types include broadleaf enchanter's nightshade, feathery false lily-of-the-valley, spotted geranium (*Geranium maculatum*), white avens (*Geum canadense*), mayapple, Jack-in-the-pulpit, whip-poor-will flower (*Trillium cernuum*), American lopseed (*Phryma leptostachya*), riverbank grape (*Vitis riparia*), Clayton's sweetroot, pointedleaf tick trefoil (*Desmodium glutinosum*), rattlesnake fern (*Botrychium virgianum*), Maryland sanicle (*Sanicula marilandica*), bloodroot (*Sanguinaria canadensis*), blue cohosh (*Caulophyllum thalictroides*), early meadow-rue (*Thalictrum dioicum*), Shawnee salad (*Hydrophyllum virginianum*), bristly greenbrier (*Smilax tamnoides*), sharplobe hepatica (*Hepatica nobilis*), and Canadian woodnettle (*Laportea canadensis*) [36].

Garlic mustard was invasive in the herb layer of a northern Illinois mesic upland white oak forest, with additional herbaceous layer components consisting of cutleaf toothwort (*Cardamine concatenata*), snow trillium (*Trillium grandiflorum*), bloody butcher (*Trillium recurvatum*), dogtooth violet (*Erythronium americanum*), Shawnee salad, wild leek, rock polypody (*Polypodium virginianum*), mayapple, and whip-poor-will flower [30], and was abundant in a northern Illinois dry-mesic forest with a white oak and black oak overstory [49]. Another northern Illinois location mentioning the presence of garlic mustard included a forested site dominated by a slippery elm, white oak and white ash overstory and nodding wakerobin (*Trillium flexipes*), bloody butcher, spotted geranium and feathery false lily-of-the-valley in the herb layer, as well as a sugar maple, white ash, white oak forest with a variety of herbaceous spring ephemerals [53]. Also in northern Illinois, a large population of garlic mustard was found in a white oak-northern red oak-black walnut (*Juglans nigra*) woodland with a native herbaceous layer of broadleaf enchanter's nightshade, Jack-in-the-pulpit, stickywilly, and spotted geranium [67].

Garlic mustard, Virginia creeper (*Parthenocissus quinquefolia*), and wild grape (*Vitis vulpina*) are common in the understory of a northern Kentucky hardwood forest dominated by white ash (*Fraxinus americana*), black locust (*Robinia pseudoacacia*), and American elm [39]. Another Kentucky forest with an overstory of sugar maple and white ash is dominated by garlic mustard in the herb layer. Downy yellow violet, stickywilly, wild blue phlox, Virginia creeper, Canadian wildginger (*Asarum canadense*), Virginia springbeauty, mayapple, common chickweed (*Stellaria media*), largeleaf waterleaf (*Hydrophyllum macrophyllum*), nodding fescue (*Festuca subverticillata*), bleeding heart (*Dicentra* spp.), and sedge (*Carex* spp.) are associated herbs [41].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Alliaria petiolata

GENERAL BOTANICAL CHARACTERISTICS:
Garlic mustard is an established, cool-season, monocarpic, taprooted, herbaceous biennial [6,15,26,31,49,61] or occasional winter annual [15,31,61]. The common name is derived from the scent of garlic, which is noticeably exuded by its aboveground plant parts, especially foliage [15,31,73,82,86].

Seedlings develop into rosettes 0.8-4 inches (2-10 cm) in diameter during the 1st growing season. Mature plants produce erect flowering stems up to 4.13 feet (1.25 m) high [15]. Each rosette usually produces a single flowering stem, although multiple stems from a single rosette occur occasionally [41]. Flowers are borne in racemes, with fully expanded corollas 0.12-0.48 inches (3-12 mm) across [6,15,17,26,27,61,68,73,74,82,86]. Average plant biomass is quite variable within a habitat, between habitats, or between generations within the same habitat, and is strongly influenced by light. Plants grown under higher irradiance levels typically produce greater biomass per plant [3].

Seeds are produced in pods (siliques) up to 6 inches (15 cm) in length [15,27,31,74,82]. Fully developed siliques typically contain 12-19 seeds, and the number of siliques per plant can vary greatly from 1 to more than 200 [74]. Seeds are oblong to nearly cylindrical [15,61] and about 0.12 inch (3 mm) long [27,31,61].

RAUNKIAER [62] LIFE FORM:
Hemicryptophyte
Therophyte

REGENERATION PROCESSES:
Pollination: Garlic mustard is capable of self-pollinization, as well as cross-fertilization [3,15,17]: both seem equivalent in effectiveness. Self-pollination often takes place before flowers open [3], although variation in this ability may exist between populations [3,17]. Cross-pollination has been observed to occur via generalist insect pollinators, providing a high likelihood of pollination wherever garlic mustard occurs [3,15,17].

Seed production: Because a large percentage of flowers typically set fruit, and most ovules develop seeds, garlic mustard is a prodigious seed producer [17]. Seed production varies between and within sites and between years, but under shaded, moist (apparently favorable) conditions, dense stands may produce > 100,000 seeds/m^2 [14,15]. Seed production in Ohio ranged from 165 to 868 seeds/plant, depending on habitat and population density [74]. The number of seeds per silique in a southern Ontario study varied from 6 to 22 with an average of 16. The number of siliques varied greatly, from 1 or 2 on small plants to up to 150 per plant [15]. Seed production in several states was:

Estimated Seed Production (seeds/m^2)	Location
15,000	Central Illinois [3]
19,060 - 38,025	Ohio [74]
19,800 - 107,580	Southern Ontario [15]
30,689 - 45,018	New Jersey [14]
10,000	Northern Illinois [49]

Seed dispersal: In forested areas, garlic mustard is typically 1st seen along trails and streams, and can quickly spread via seeds throughout the forest within a few generations [7]. Seeds generally fall within a few meters of the plant [50,74], and may be ballistically dispelled from siliques [49]. Wind dispersal is doubtful. Seeds stick together when damp and adhere readily to small soil clusters [15]. Seed dispersal rates may accelerate along river corridors [46,50], although there are conflicting reports regarding the ability of seeds to float [15,74]. Humans may also spread seeds. Garlic mustard often invades natural areas along roads and trails, purportedly via seed transport on muddy boots or pant cuffs. Seed dispersal may also be facilitated by roadside mowing, as well as on mud-encrusted automobile tires [50]. Animals, especially white-tailed deer, may promote seed dispersal and spread of garlic mustard. Deer are thought to provide an important seed dispersal vector over short distances by transporting seeds in their fur, although this has not been tested as of this writing [3,15]. Foraging deer may create microsite disturbances favorable to garlic mustard dispersal by mixing mineral soil and garlic mustard seeds [49].

Germination: Seeds of garlic mustard require cold stratification before they can germinate, with 1 season's overwintering usually sufficient to break dormancy at most North American locations [7]. An additional year of dormancy was reportedly required prior to germination in southern Ontario [15], and this lengthier dormancy period may be required in other northern locations [55,70]. Germination often occurs in early spring and can occur at temperatures approaching 32 degrees Fahrenheit (0 °C) [7,63]. Low-temperature germination is ecologically important because garlic mustard seedlings incur a competitive advantage by being the 1st germinants of the season [7,45].

Seed banking: Garlic mustard produces small but potentially important seed banks. Seed viability has been shown to drop off substantially after the 1st growing season following stratification, indicating seed banks of garlic mustard are relatively short lived [7,63]. In a study of garlic mustard seed biology, roughly 88% of seeds that germinated did so during the 1st spring following production [7]. In a study comparing garlic mustard populations from contrasting habitats in New Jersey, 3 out of 4 populations were found to maintain a seed bank. The 4th population was located in a seasonal floodplain where flooding actions were thought to either remove the seedbank or produce a patchy distribution that was difficult to sample [14].

A small percentage of seeds may remain viable for 4-6 years [7,15,63]. Because garlic mustard is a prodigious seed producer, elimination of a single season's crop may not suffice to eradicate the species from an area because germination and survival of only a few individuals in subsequent years may quickly lead to repopulation at or near previous levels [7].

Seedling establishment/growth: Garlic mustard seedlings emerge in early spring, just before or simultaneous with germination of native spring ephemerals [49]. They establish during periods of relatively high light availability in the forest understory prior to canopy leaf-out, typically with reduced interspecific competition and drought potential [7,15,45]. Greatest mortality rates occur in spring during the seedling stage [15]. Seedling mortality can vary substantially, often depending on moisture availability [14]. Initial seedling density may be very high (20,000 seedlings/m^2) [49,74]. In reports where natural spring seedling densities were approximately 3,100 to 5,600/m^2, only about 1% to 16% survived to produce flowers the following year [14,15]. Two consecutive cohorts retained similar numbers of mature flowering plants during their 2nd spring, despite having initial seedling densities differing by more than 100% [3].

Asexual regeneration: Garlic mustard spreads exclusively by seeds, with no reports of vegetative reproduction [15,74].

SITE CHARACTERISTICS:
Garlic mustard has a wide tolerance of environmental conditions for growth and reproduction, including moisture regimes ranging from periodically flooded areas to dry sand forest [15,42], light environments ranging from open fields to shaded forest interior [12,14], and a range of various soil characteristics including texture [14,15,57], nutrient level [14], organic matter content [14,15], and pH [4,14]. It is apparently not found on acid soils in Indiana, Kentucky, Massachusetts, or the Canadian Shield region [15], and is absent from undrained peat and muck soils [49].

Garlic mustard may be less competitive in areas with low soil pH, as evidenced by an experiment demonstrating a significant positive correlation ($r = 0.98$; $p < 0.001$) between plant dry weight and soil pH. This has been hypothesized as a contributing factor in the limited colonization of garlic mustard in the southern third of Illinois, where soils are more acidic than in the more heavily colonized central and northern sections of the state [4]. Inhibition of garlic mustard by acidic soils may explain its apparent absence from conifer-dominated communities [66].

Garlic mustard appears to favor shaded sites [50], and is often found in dense groups of nearly pure stands, sometimes covering large areas, particularly under moist shaded conditions such as mature eastern deciduous woodlands. In drier or more open areas plants increase allocation to fruit production, perhaps in response to observed declines in seed weight, seed germination, and seedling survivorship [14,46]. While biomass production may be greatest under full sun [15], and garlic mustard plants can also be found under dense shade, they are most commonly found in woodland understories with partial shade and are probably less invasive under extreme conditions of light or shade [49]. Nuzzo [50] describes typical habitat in Illinois as mesic upland or floodplain forest, usually shaded, and often associated with some type of disturbance. Despite its apparent affinity for moist shaded environments, garlic mustard is not tolerant of growing season inundation, which may limit its ability to invade wetland communities [49].

Most populations of garlic mustard appear to be connected to some form of disturbance [14,49]. Garlic mustard is often associated with anthropogenic disturbance such as trails, roads, or railroads [49,50], and less commonly, in farm fields and gardens [50]. Garlic mustard is sometimes linked to naturally disturbed habitats such as floodplains and riverbanks, where the combination of flooding as a dispersal agent and moist, shaded conditions may promote invasion [46]. Garlic mustard was invasive in relatively undisturbed woodlands in central Illinois. Establishment was thought to occur where small-scale anthropogenic and natural disturbance removed competing vegetation, such as areas browsed by white-tailed deer [3].

Experiments examining mechanisms that link disturbance and garlic mustard occurrence and spread are scarce. One study showed that disturbance of soil in a young hardwood forest in northern Kentucky resulted in lowered garlic mustard densities compared to undisturbed plots [39]. An experiment in a southwestern Ohio deciduous forest examined the effects of small-scale litter disturbance on garlic mustard invasiveness. There were no differences ($p = 0.7184$) in garlic mustard germination, rosette survival, growth, or reproduction among total litter removal, partial litter removal, and control treatments, indicating forest floor disturbance alone may not be a prerequisite for invasion [46].

FIRE ECOLOGY

SPECIES: Alliaria petiolata

FIRE ECOLOGY OR ADAPTATIONS:

Fire Adaptations: Although garlic mustard plants are readily top-killed when exposed to fire, they may ultimately survive by sprouting from the root crown [54]. Ecological conditions that permit sprouting are not well understood and it is unclear to what extent resprouted plants are capable of producing viable seed (see Fire Effects section of this summary).

At the population level, garlic mustard may be adapted to perpetuate itself in mixed-severity or low-severity surface fire regimes, although this has not been quantified. Even though individual plants may be killed by fire, postfire conditions may be favorable for rapid population expansion because of increases in the area of disturbed habitat and, depending on the extant community, temporary reductions in interspecific competition. Additionally, garlic mustard seed banks may facilitate rapid recolonization of disturbed areas [14]. For example, 3 consecutive years of prescribed burning in a central Illinois black oak forest, which were described as "hot and fast" with flame lengths to 4 feet (1.2 m), failed to eradicate garlic mustard populations. This was attributable, in part, to the protection afforded a small number of plants by refugia such as the lee of a downed log or an area of damp litter [54]. The ability of individual plants to escape mortality will depend upon fire severity and the heterogeneity of the fire landscape.

Fuels: Although it has been demonstrated that fire can top-kill garlic mustard (see Immediate Fire Effect on Plant), it is also apparent that garlic mustard plants can be difficult to ignite. Nuzzo [49] noted that low fuel loads, coupled with abundant green garlic mustard plants, "which on occasion literally extinguished fires", made it difficult to achieve prescribed fire objectives.

Fire Regimes: Garlic mustard may be found within understory surface, stand-replacement, mixed-severity fire, and nonfire regimes [13]. Because garlic mustard has become established only relatively recently in most areas in North America, and because natural fire regimes have been substantially altered in many of these areas, predicting the response of garlic mustard to any particular fire regime is speculative. In some areas colonized by garlic mustard, estimated mean fire return intervals may be longer than the time in which garlic mustard has been present. As natural areas and preserve managers reintroduce fire into locations where natural and anthropogenic fire has been suppressed in recent times, the response of this and many other species may become better understood. Those who intend to reintroduce fire where it has been absent for a substantial period are encouraged to plan and implement research and monitoring programs and share their findings.

Fire return intervals of some of the plant communities in which garlic mustard occurs are summarized below. Find further fire regime information for the plant communities in which this species may occur by entering the species name in the FEIS home page under "Find Fire Regimes".

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
maple-beech-birch	*Acer-Fagus-Betula*	> 1000
silver maple-American elm	*A. saccharinum-Ulmus americana*	< 35 to 200
sugar maple	*A. saccharinum*	> 1000
sugar maple-basswood	*A. saccharinum-Tilia americana*	> 1000 [83]
bluestem prairie	*Andropogon gerardii* var. *gerardii-Schizachyrium scoparium*	< 10 [37,58]
sugarberry-America elm-green ash	*Celtis laevigata-U. americana- Fraxinus pennsylvanica*	< 35 to 200
beech-sugar maple	*Fagus* spp.-*A. saccharum*	> 1000
black ash	*Fraxinus nigra*	< 35 to 200 [83]
tamarack	*Larix laricina*	35-200 [58]
yellow-poplar	*Liriodendron tulipifera*	< 35
eastern white pine-northern red oak-red maple	*Pinus strobus-Quercus rubra-A. rubrum*	35-200
Virginia pine-oak	*P. virginiana-Quercus* spp.	10 to < 35
sycamore-sweetgum-American elm	*Platanus occidentalis-Liquidambar styraciflua-U. americana*	< 35 to 200 [83]
eastern cottonwood	*Populus deltoides*	< 35 to 200 [58]
aspen-birch	*P. tremuloides-Betula papyrifera*	35-200 [21,83]

FIRE EFFECTS

SPECIES: Alliaria petiolata

IMMEDIATE FIRE EFFECT ON PLANT:
Garlic mustard is often top-killed when exposed to fire. A prescribed burn in the understory of a northern Illinois hardwood forest apparently removed all aboveground garlic mustard biomass [30]. Prescribed burns in a central Illinois black oak forest conducted both in the fall and in mid-spring removed nearly all garlic mustard rosettes [54]. Although there was no immediate postfire survey of plants mentioned in the article, Luken and Shea [41] suggest garlic mustard "plants are readily killed by mid-intensity dormant season fires". Emergent seedlings may also be killed by fire [54].

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
It has been suggested that dense stands of garlic mustard may be able to resist low-severity fire, such that "abundant green garlic mustard plants...may literally extinguish fires" [49], but detailed descriptions of the direct effects of fire on garlic mustard plants (or vice versa) are scarce. Such observations may be confounded by the inherently patchy nature of mixed-severity fire regimes in many eastern deciduous forests where garlic mustard may commonly be found. For more information see the Fire Ecology section of this summary.

PLANT RESPONSE TO FIRE:
Garlic mustard has at least some ability to sprout from the root crown following damage by fire. By excavating charred rosettes, Nuzzo and others [54] found that adult plants resprouted from adventitious buds on the root crown located just below the soil surface following a mid-spring burn. In a northern Illinois oak woodland, garlic mustard reportedly resprouted several weeks following complete top removal by a prescribed fire conducted in late March [30]. Repeated fall burning (2-3 annual burns) did not reduce abundance or relative importance of garlic mustard in an eastern mesophytic forest understory in Kentucky [41].

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
There is some indication that garlic mustard is capable of sprouting following fire, but several questions remain. To what extent is postfire sprouting in garlic mustard influenced by fire severity? What, if any, physiological conditions promote or constrain postfire root crown sprouting? To what extent are resprouting plants successful at producing seed?

Nuzzo and others [54] reported that a fall burn in a central Illinois black oak forest removed 79% of the litter layer, and very few adult garlic mustard plants were encountered in these plots the following spring. Conversely, many garlic mustard plants resprouted following a mid-spring burn at the same site that resulted in removal of only 32% of the litter layer. Spring burn plots retained a damp 0.4- to 0.8-inch (1-2 cm) layer of litter which seems to have protected the root crowns of top-killed plants, fostering survival via sprouting of multiple secondary shoots from adventitious buds located just below the soil surface [54].

Hintz [30] conducted a late-March prescribed burn in a mesic upland oak-hickory forest in northern Illinois. Garlic mustard established following the fire, although it is unclear whether these were sprouting burned plants or new spring seedlings. The burn was conducted near the time when seedling emergence might be expected, leaving some question as to which life-cycle stage was observed to be "sprouting". There is reference to "very little" garlic mustard producing seed that summer, intimating that at least some adult plants were present both prior to and after the fire.

Luken and Shea [41] conducted a prescribed fire experiment in a northern Kentucky mesic deciduous forest in which they showed that garlic mustard plants could be removed by a fall burn. Yet it was also apparent from this experiment that populations can persist following even repeated burns. Garlic mustard remained the dominant species in the herb layer of both burned and unburned plots through 3 seasons of fall burning, and beyond. The authors proposed 3 possible explanations. First, persistence of individual garlic mustard plants immediately following fire may result from the patchy nature of many understory or mixed-severity burns. Under such conditions some extant plants may escape damage, and because of its ability to self-pollinate [3,15,17], the survival of a single plant may be sufficient to perpetuate a population. Second, the data of Luken and Shea [41] showed that burning resulted in higher densities of flowering stems compared with control plots. They speculated this as being due to either resprouting or release from competition. No observations of sprouting were reported. Third, even if all plants are killed, the existing seed bank may remain viable for several years [7,14], requiring subsequent annual burns to completely eradicate the population.

The Research Paper by Bowles and others 2007 provides information on postfire responses of several plant species, including garlic mustard, that was not available when this species review was originally written.

FIRE MANAGEMENT CONSIDERATIONS:
Control of invasive garlic mustard populations using prescribed fire, especially as a single management tool, appears to be difficult. Some temporary control is likely, but difficulties sustaining long-term control are confounded by a) the patchiness of understory and mixed-severity fires, b) the biennial nature of the species, c) the moderately persistent seed bank, and d) garlic mustard's propensity for rapid population increase (see Regeneration Processes) [41,54,67].

It may be possible to substantially diminish the number of individuals in a garlic mustard population with repeated burn treatments. But prescribed burning, especially during the growing season, could actually increase the relative importance of garlic mustard [3,41,54]. A prescribed burn conducted in May in a northern Illinois dry-mesic upland deciduous forest effectively reduced cover of garlic mustard, from a pre-burn 29.4% cover to 2.3% cover, postfire year 1. But May burning also damaged the native forb community, where total stem density of major herbs and small shrubs was reduced by 32% and average number of species per plot was reduced by 35%, postfire year 1. Although native plants subsequently showed gradual recovery, these effects were detectable for 3 years, most notably for Jack-in-the-pulpit and stickywilly. Garlic mustard recovery was more rapid. Within three years following burning garlic mustard had rebounded to 17.3% cover compared with a pre-burn level of 29.4% [67].

Dormant-season burns, while less likely to have negative effects on indigenous flora, also appear to be less effective at killing garlic mustard rosettes. After 3 years following a March prescribed burn at the above location, both garlic mustard and native herb cover had returned to approximate pre-burn levels [67].

It has been suggested that a narrow window of time exists during early spring in some areas and in some years, during which garlic mustard may be more effectively controlled by fire without damaging native plants. This hypothesis remains untested as of this writing [67]. Also, spring burns may increase seedling survival. Fires of insufficient severity may spare a sizable fraction of seedlings protected by the unburned portion of the litter layer. Additionally, a spring burn timed too early may permit survival of garlic mustard seedlings that germinate after treatment. In addition to greater initial seedling survival, removal of a portion of the litter layer may also provide a more favorable environment for growth and development of garlic mustard rosettes [54].

Apparently not all fires are equally effective at top-killing garlic mustard. The effectiveness of prescribed spring and fall burn treatments in reducing garlic mustard populations in an oak -dominated dry-mesic upland forest in northern Illinois was directly related to fire "intensity". "Low-intensity" burns, with flame lengths up to 1.2 inches (3 cm), were patchy and frequently extinguished within plots. These "low intensity" burns had little to no effect on garlic mustard plants, whether seedlings or adults, regardless of season of burning. It was suggested that abundant green garlic mustard plants frequently extinguished the "low intensity" fires. "Mid-intensity" burns, with flame lengths up to 3 inches (15 cm), burned through most of the plots and significantly reduced the presence of garlic mustard. Adult plant densities were reduced by both spring and fall burns, as well as repeated fires, although single spring burns were most effective [49].

In areas with long fire-return intervals where favorable conditions for conducting effective prescribed burns may be rare to nonexistent, especially repeated annual burns, or where fire-sensitive native species exist, prescribed fire may be unsuitable as a management tool. Nevertheless, in areas with a fire-tolerant native flora, frequent prescribed burning may deter garlic mustard invasion by both directly killing invading plants, and perhaps in some areas by enhancing growth of native herbaceous competitors and thereby reducing habitat for garlic mustard colonization [49,88]. It is highly likely that managers who use fire to control garlic mustard may need to augment burn treatments with 1 or more additional control methods, such as pulling or herbicide use to achieve acceptable levels of control (see Impacts And Control for more information on other control methods).

MANAGEMENT CONSIDERATIONS

SPECIES: Alliaria petiolata

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
Use of garlic mustard as a forage species by white-tailed deer is unclear [15,56]. White-tailed deer may avoid grazing garlic mustard in favor of native herbaceous plants, although this has not been empirically tested [3,49,56]. It is likely that white-tailed deer graze a variety of understory herb species in areas typically susceptible to garlic mustard invasion, and can have a dramatic negative impact on some native herb populations [1]. Deer grazing of native herbaceous plants may enhance garlic mustard at the expense of native species by providing small-scale soil disturbance and by reducing interspecific competition. White-tailed deer may provide small-scale disturbances suitable for garlic mustard colonization within forested areas by trampling and exposing soil. In addition, selective herbivory may enhance garlic mustard at the expense of the preferred native species [3,49,56].

Garlic mustard may be deleterious to some species of butterfly. Adults of several butterfly species lay eggs on garlic mustard instead of their native plant hosts. Because larval development on garlic mustard is often fatally inhibited, this can result in garlic mustard acting as a population sink for these butterfly species, a particularly perilous problem for rare species such as the West Virginia white butterfly (*Pieris virginiensis*) [10,56,59].

PALATABILITY:
Garlic mustard is apparently palatable to livestock. It is thought to taint the flavor of milk in dairy cattle [15].

IMPACTS AND CONTROL:

Impacts: The control of garlic mustard may be desirable to undisturbed deciduous forests of the eastern and midwestern United States and southern Ontario [3,15,17,49,55]. In forested natural areas, garlic mustard has the potential to dominate the herb layer [41,52,56,91]. Invasion of mature eastern deciduous forests by garlic mustard is notable because these habitats were thought to be relatively resistant to nonindigenous plant invasion, particularly by herbaceous species [43,45,55,56]. From the results of a greenhouse study examining the competitive potential of garlic mustard, Meekins and McCarthy [45] postulated that competition for light within dense garlic mustard stands might inhibit oak regeneration in the understory of eastern deciduous woodlands. However, this same study failed to show greater levels of interspecific competition among garlic mustard, jewelweed, and box elder, 2 potential understory associates.

McCarthy [43] demonstrated removal of garlic mustard from a deciduous forest understory resulted in increased richness and abundance of understory species, especially annuals and woody perennials. Garlic mustard may be particularly detrimental to native spring ephemerals in eastern deciduous forest understories [15]. McCarthy [43] failed to demonstrate a link between the magnitude of garlic mustard infestation and native species diversity. Removal experiments, while providing some insight into possible effects of nonindigenous plant invaders, may be inherently limited in their ability to reflect impacts of invasives on preinvasion communities [84]. Limited and conflicting evidence surrounding the assumption that garlic mustard infestation necessarily results in reduced richness and cover of native herbaceous species points out the critical need for more research in this area.

The allelopathic potential of garlic mustard has received some study, with mixed results. McCarthy and Hanson [44] found little evidence of allelopathic effects of garlic mustard on several plant species studied. They attributed the success of garlic mustard invasiveness strictly to its competitive abilities. Other evidence indicates at least the possibility for allelopathic interference between garlic mustard and neighboring herbaceous plants, as well as the possibility for toxicity against mycorrhizal fungi [35,80]. Roberts and Anderson [64] found a significant negative correlation ($r^2 = 0.29$; $P < 0.05$) between garlic mustard density in the field and the mycorrhizal inoculum potential of the soil. McCarthy [43] found garlic mustard inhibited establishment of seedlings of other species, yet no quantitative relationship could be discerned between garlic mustard biomass and native species diversity. This finding suggests that the mere presence of garlic mustard depresses native diversity, perhaps an allelopathic effect. Further research is needed to a) determine what mechanisms, if any, are responsible for garlic mustard allelopathy, and b) sort out the relative effects of allelopathy vs. resource competition in interactions between garlic mustard and native plants.

Control: The biology of garlic mustard presents significant challenges to its control because it simultaneously possesses characteristics of native forest herbs such as shade tolerance and relatively large seeds, as well as characteristics often ascribed to weeds such as xenogamy and autogamy, and high seed production and germination under a range of environmental conditions. It is also not impacted by its native herbivores and parasites [3,5,17,44]. While garlic mustard invades relatively undisturbed woodlands, invasion may be expedited by natural and anthropogenic disturbance that removes competing native vegetation. Once garlic mustard becomes established, further dispersal and perpetuation within a particular habitat may require little to no further disturbance [46,55].

Deciduous forest fragments that are isolated in an otherwise predominantly agricultural landscape may be more resistant to garlic mustard invasion, due to limited seed sources and inhibitive dispersal distances [12]. However, in areas with large populations of white-tailed deer, even these insular forest remnants may become colonized by garlic mustard.

As with most invasive plants, deterrence is the most effective strategy against garlic mustard. This includes annual monitoring and removal of all invading plants prior to seed production. Garlic mustard is prolific partly because of its ability to self-pollinate. A single individual can produce large numbers of genetically similar but interfertile progeny, which in turn may colonize even small, local microsite disturbances, leading to a potential garlic mustard outbreak. Allaying invasion may require reducing habitat perturbation in susceptible areas and promoting the health of native plant communities [3].

Garlic mustard population densities may oscillate widely from year to year [56]. Its biennial nature and its seed banking propensity can lead to occasions in which dense stands of garlic mustard appear where none were apparent the year before, and then seemingly disappear the following year only to reappear yet again in subsequent seasons. Further, in years where rosettes are apparently sparse and may evade detection, those monitoring such sites may easily but falsely conclude that garlic mustard is absent. In previously infested areas or areas of suspected susceptibility, careful annual monitoring may be the only way to ensure that garlic mustard is indeed absent from the site.

Once garlic mustard appears within an area, management activities should focus on preventing seed production. While most seeds of garlic mustard tend to germinate during the 1st or 2nd spring following their production, a small number of seeds remain within the seed bank and may germinate over the next several years. Because garlic mustard seed banks may remain viable for up to 6 years, long-term control for a particular stand requires vigilant attention for several consecutive seasons [3,7,14,49]. Even after successful management leads to the apparent absence of garlic mustard, continued periodic monitoring is prudent. A method for destroying seeds of garlic mustard in the soil that would not harm seeds of other species has not been determined [7].

Because of the biennial life-history strategy of garlic mustard, eradication treatments conducted during spring, after seedlings have germinated and before adults can produce viable seed, have the advantage of affecting 2 generations simultaneously [49]. Ideally, this maximizes the kill of new germinants and seedlings, as well as prevents seed production in adults. Since natural mortality is greatest at the seedling stage garlic mustard may be most vulnerable to control efforts during this time [20]. One potential downside to this strategy is that delaying treatment too late into spring risks unwanted effects on native spring emergents.

An alternative approach is to delay management activities until after the 1st growing season to take advantage of significant natural mortality of rosettes. First year garlic mustard mortality at a site in northern Illinois was estimated at greater than 95% between April and November [51]. This strategy may be especially prudent when the control method requires intensive labor, such as cutting or hand-pulling plants, if minimizing quantities of applied chemicals is desired, or simply if costs of more intensive management activities are prohibitive.

Control of garlic mustard has been tested using several different methods. Since a single control method is rarely 100% effective, a combination of more than 1 may often be a useful strategy. Regardless of methodology, treatments for eradication of garlic mustard must be applied over the entire area of infestation to prevent seed production.

Manual or Mechanical Removal: Pulling entire plants may be an effective method for control of garlic mustard. Care should be taken to remove as much of the root system as possible, to reduce resprouting potential. Pulling can cause soil disturbance and redistribute seeds stored within the upper soil horizons. This problem may be mitigated by thoroughly tamping disturbed soil after pulling. Generally speaking, cutting results in fewer disturbances than pulling. However, pulling may be done at any time during the plant lifecycle, while cutting must be performed during the 2nd growing season while the flowering stem is elongating. Due to the labor-intensive nature of cutting and pulling plants, these practices may only be practical in small or lightly infested areas, especially where burning or herbicide application is inadvisable [49,56]. Hand removal may be most useful for preventing establishment of new garlic mustard colonies in previously uninfested areas [43].

Control may be accomplished by cutting flowering stems, i.e. using sickles, clippers, or string trimmers, prior to seed production and dissemination. Cutting as close to ground level as possible appears to be most effective. Nuzzo [49] found that cutting at ground level killed 99% of plants and resulted in virtually no seed production, while cutting at 4 inches (10 cm) resulted in 71% mortality and 98% lower total seed production. Mortality was 6% in control plants during the 3-month study period. Cutting plants prior to full flowering or the onset of seed development may result in production of additional flowering stems from buds located on the root crown [56]. However, waiting until after plants have finished flowering risks dissemination of viable seed. Cut or pulled plant material should consequently be removed from the site and destroyed whenever possible to minimize the risk of inadvertently distributing viable seed [56,70].

Mowing may be similar in effect to cutting, but with more possible negative consequences. Mowing of flowering plants may result in regrowth of new flowering shoots, although this response reportedly diminishes as the season progresses [15]. While mowing may be convenient in large, relatively open areas of infestation such as roadsides, this practice may be more problematic than cutting, as described above. Mowing may promote seed dispersal and is more likely to be indiscriminate regarding which plant species are destroyed. Mowing equipment may also create more disturbed habitat that is likely to be recolonized by garlic mustard [56].

Prescribed Fire: In areas with a fire-tolerant native flora, frequent prescribed burning may deter garlic mustard invasion by both directly killing invading plants, and perhaps in some areas by enhancing growth of native herbaceous competitors and thereby reducing habitat for garlic mustard colonization [49,88]. For more information about using prescribed fire as a management tool to control garlic mustard, see the Fire Management Considerations section of this summary.

Chemical Control: Chemical control of invasive plants such as garlic mustard can be effective, particularly against large areas of infestation or dense monotypic colonies, and especially when considered within the context of an integrated management plan [47,49]. This report briefly examines the effectiveness of selected chemicals for controlling garlic mustard, some issues involved in the timing of application, and potential effects on native plant communities. Use of herbicides in natural areas should be cautiously considered, and appropriate education and training should be sought before proceeding. Particular caution should be exercised with the use of Bentazon or Acifluorfen. Bentazon is very soluble in water and does not bind to soil well, leading to potential groundwater contamination problems. Acifluorfen is toxic to fish, is moderately persistent in soil and kills native grasses and herbs, and can cause serious eye injury [79]. For further information regarding the use of herbicides in natural areas for control of this and other invasive plant species, see the Weed Control Methods Handbook [76].

The effectiveness of 2,4-D against garlic mustard is questionable [56]. Use of 2,4-D in mixtures with other chemicals may improve its effectiveness, but scant evidence is available [15,56].

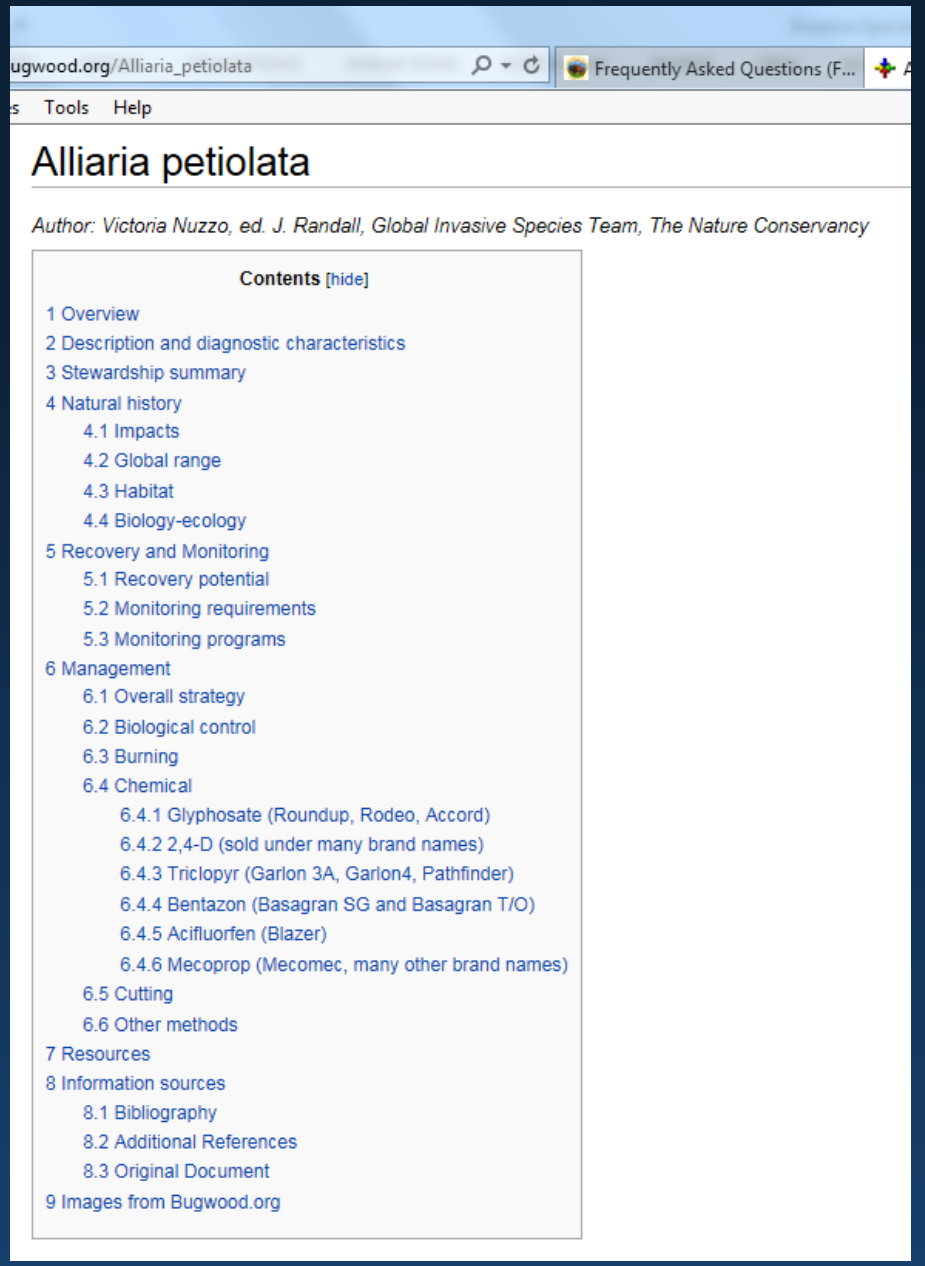
Application of 1% and 2% glyphosate during the dormant season significantly ($p < 0.05$) reduced adult garlic mustard cover and density in mesic and dry-mesic upland forest and mesic floodplain forest in northern Illinois, but also damaged other species that were green at the time, especially sedges and white avens [53]. Treatment with foliar-applied glyphosate also significantly ($p < 0.05$) reduced adult densities of garlic mustard, regardless of spring or fall application, in a northern Illinois oak woodland. Seedling frequency in these same plots was significantly ($p < 0.001$) reduced by spring application [49].

Dormant-season application of bentazon was less effective at controlling garlic mustard in northern Illinois mesic deciduous forest, but showed none of the nontarget kill associated with glyphosate. At these same sites, application of acifluorfen during dormant season was highly effective againstgarlic mustard, but also killed most native herbaceous vegetation, which was mainly dormant at the time of application[53].

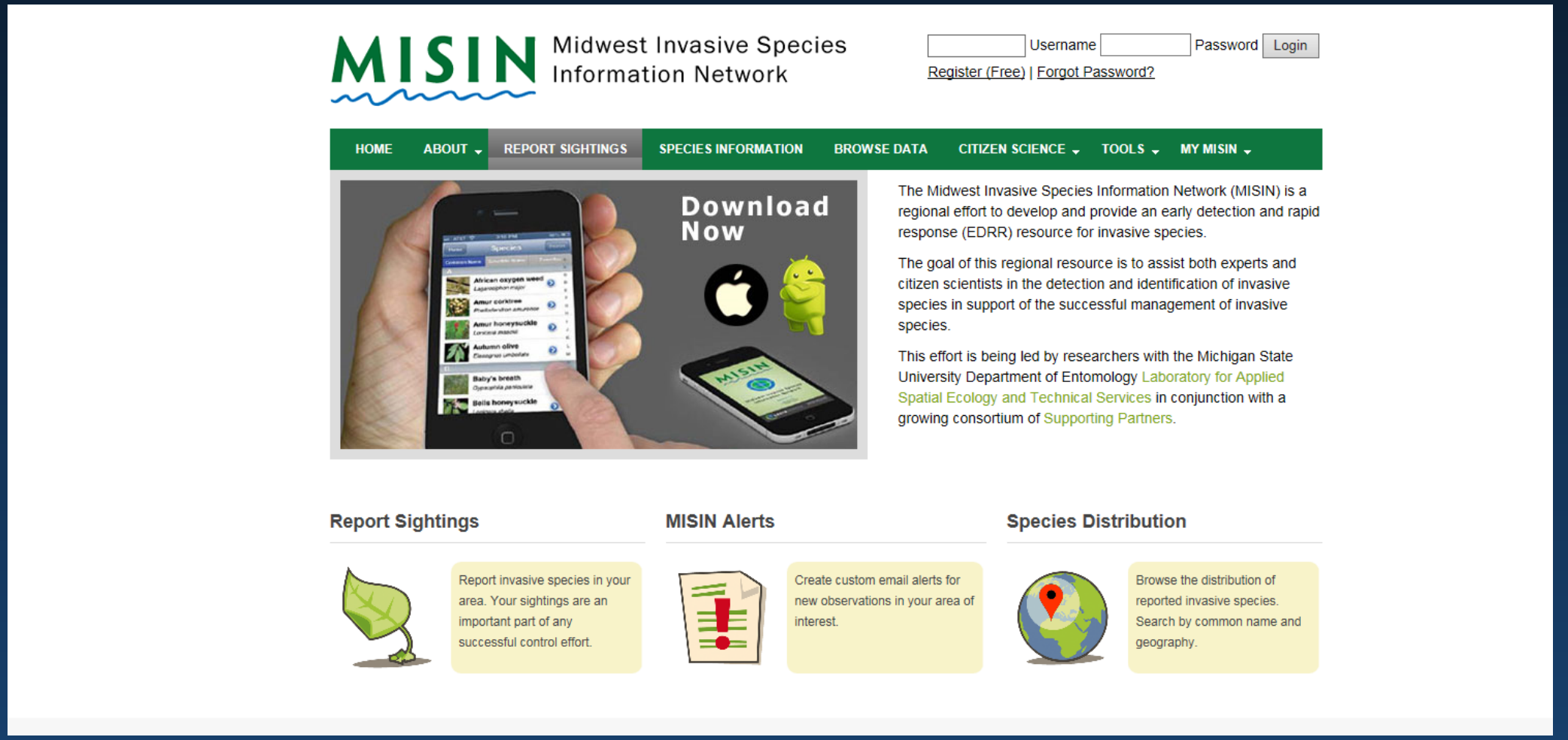
Use of systemic, nonselective herbicides during the growing season may not be practical in some areas due to deleterious effects on native ground-layer competitors. In these cases, dormant season application may be preferable in order to maintain viable populations of native competitors [49]. Nuzzo [49] found no difference in effect between single herbicide application and twice applied treatment to the same generation of plants (spring and fall of the same year, fall and the following spring, or 2 consecutive springs). It was suggested that management efforts focus on single applications to successive generations of plants. Fall herbicide application may be a prudent option when risk of negatively affecting native spring-emergent herbs exists. Higher garlic mustard rosette densities in fall may require higher volumes of applied herbicide to be effective [51].

Invasipedia

- **Invasipedia** houses information on invasive plants, animals, and pathogens, and especially how to best manage them. http://wiki.bugwood.org/Invasipedia

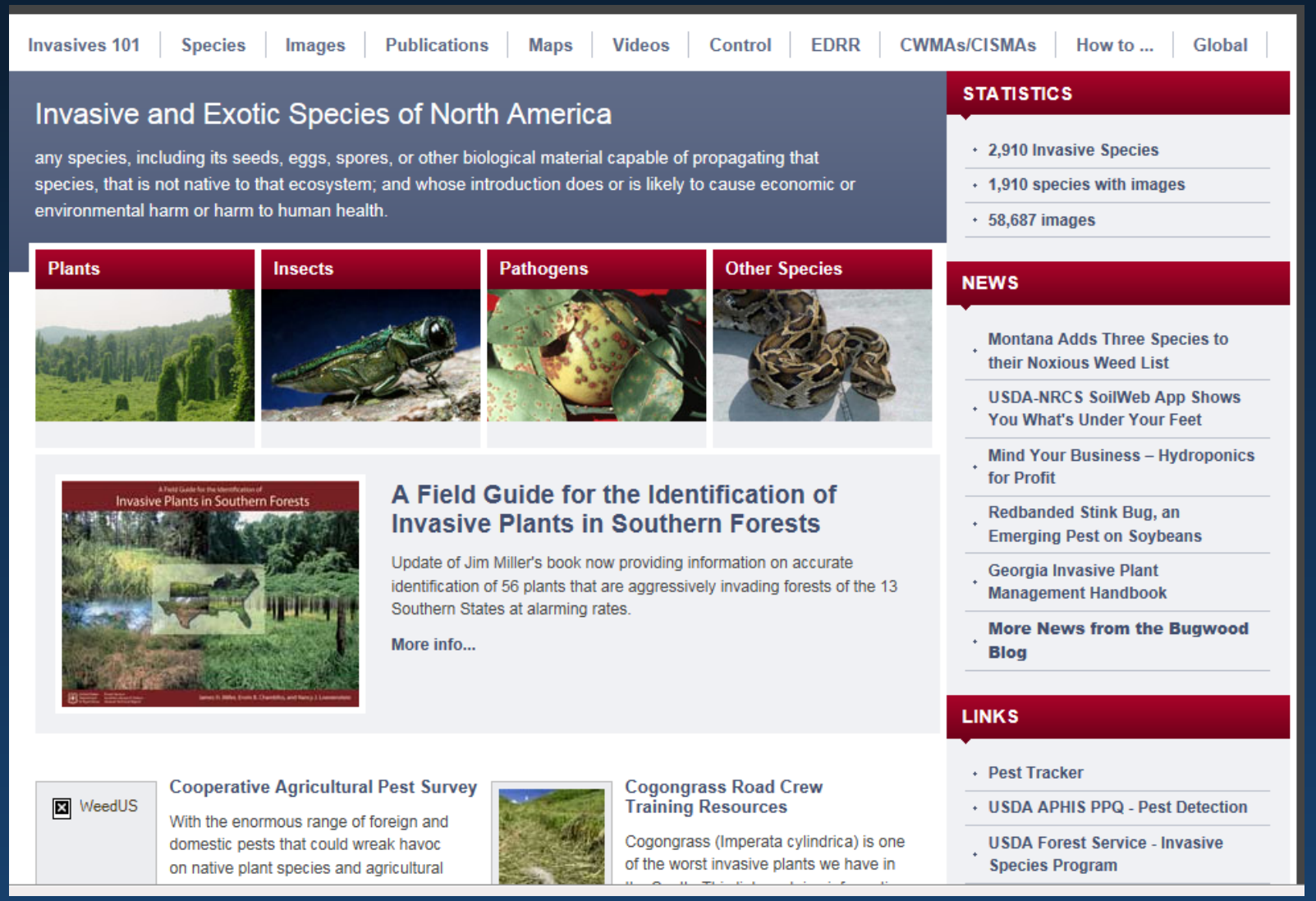


Midwest Invasive Species Information Network
http://www.misin.msu.edu/



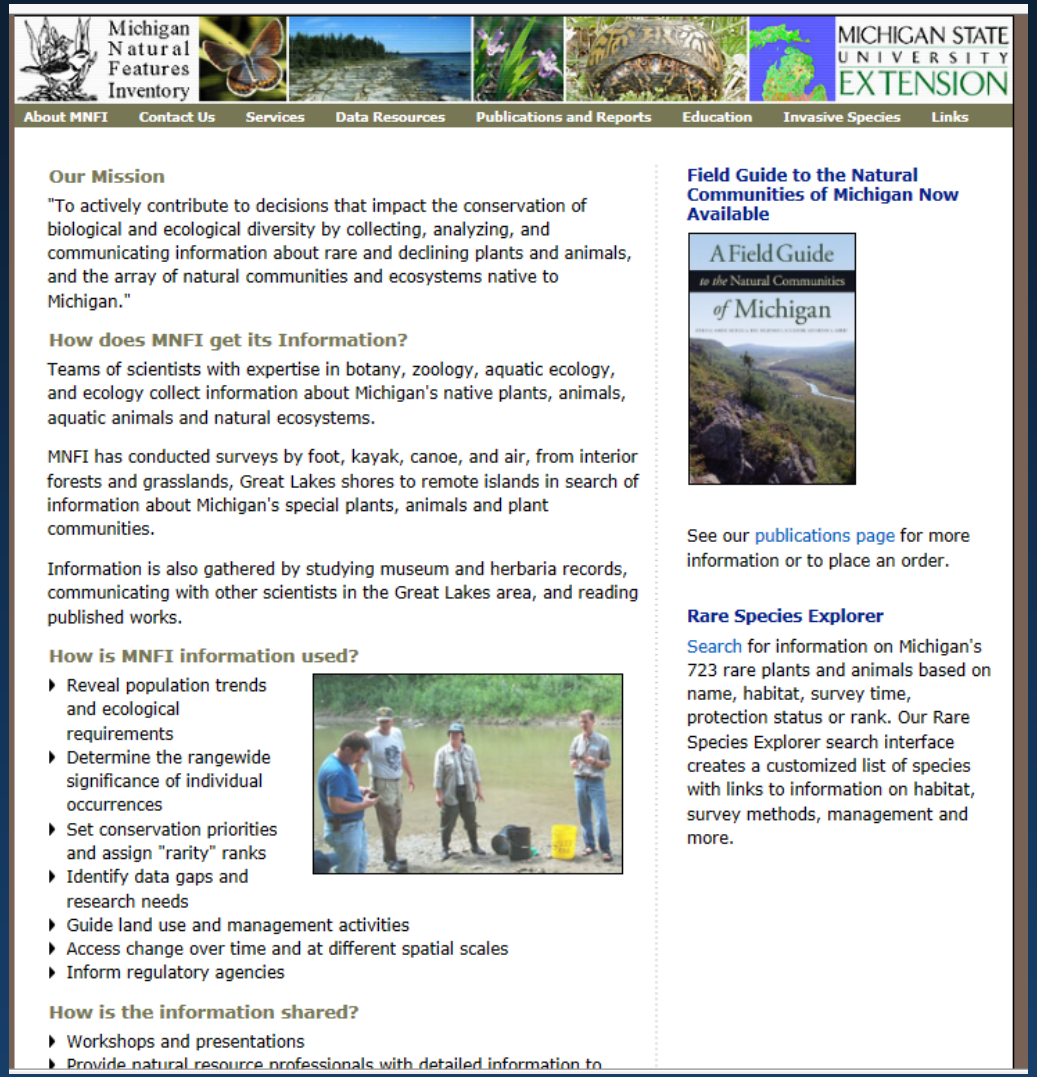
Center for Invasive Species and Ecosystem Health

http://www.invasive.org/

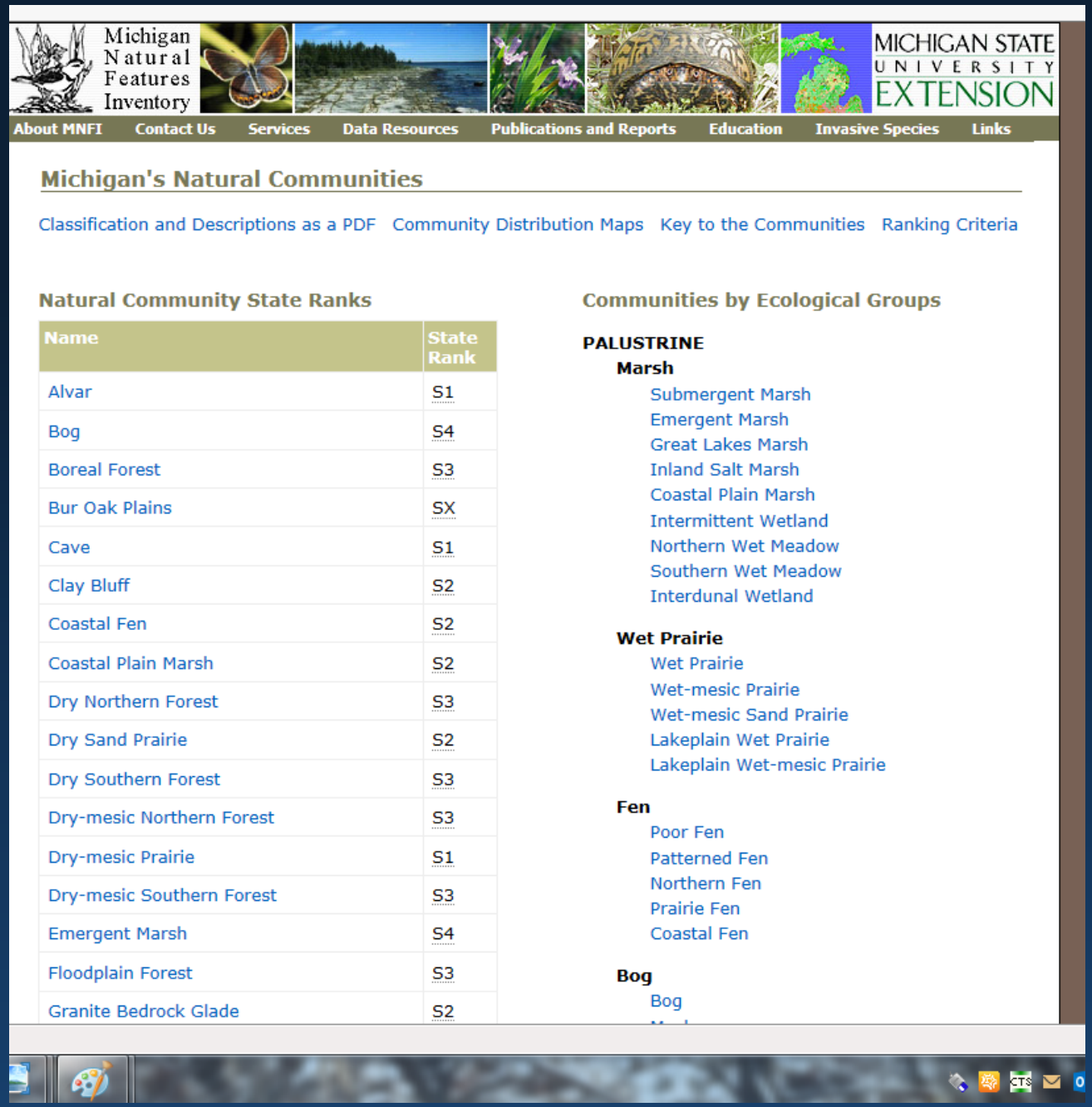


Michigan Natural Features Inventory
http://mnfi.anr.msu.edu/

- Presettlement Vegetation Maps (Data Resources>Vegetation Circa 1800)
  - Find Land Cover Type of management unit(s)
- Compare with Natural Community Types (Data Resources>Michigan's Natural Communities)
  - Compare site to Community Distribution Maps
  - Consider practices to restore plant species and other ecosystem elements

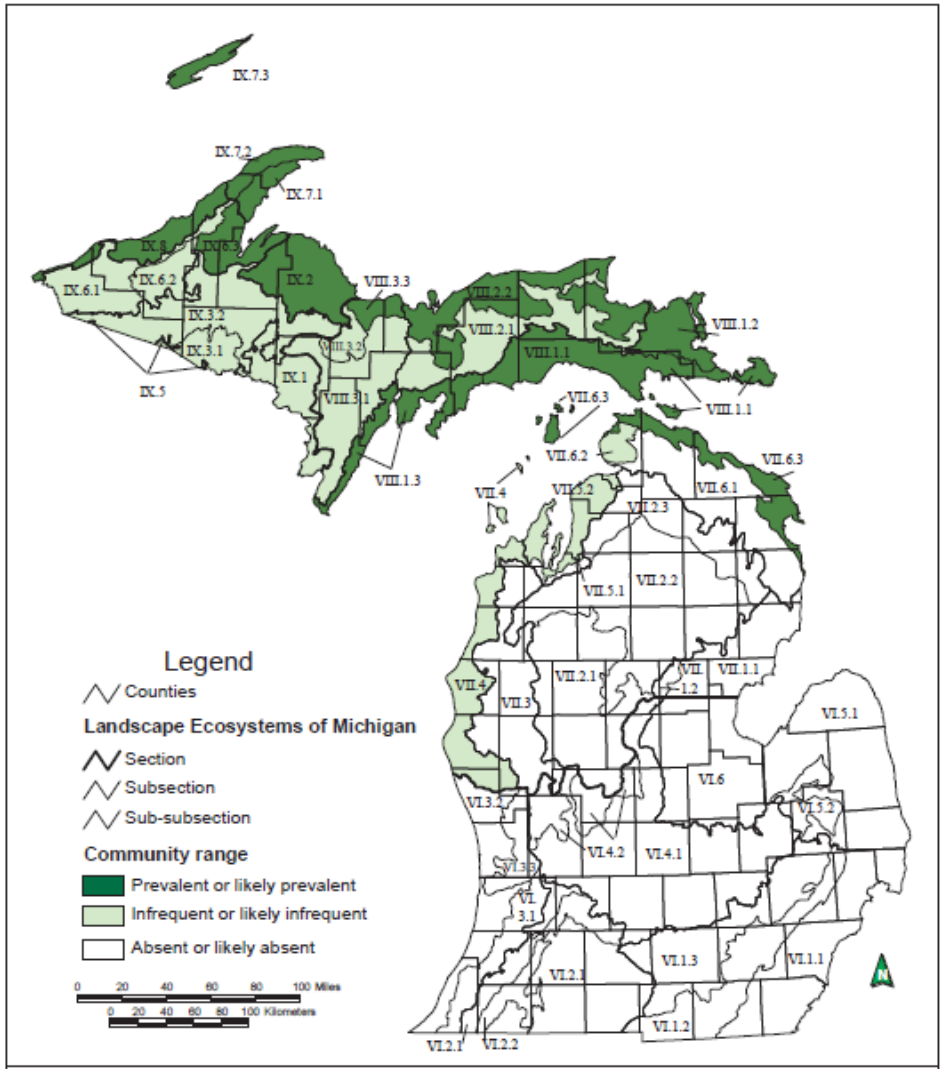


MNFI Natural Communities



Boreal Forest MFNI Community Description, Vegetation Section

- The boreal forest flora is circumboreal in distribution with a high degree of floristic homogeneity from site to site. Most species within boreal forests bloom in early spring or summer. The canopy of boreal forests is characterized by a prevalence of conical-shaped evergreens, which often form a closed canopy. The dense tree coverage often results in a scattered understory and sparse ground cover due to the low levels of light transmitted through the canopy and dense sod formed by the extensive network of the shallowly rooted trees. The canopy is dominated by balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), and northern white-cedar (*Thuja occidentalis*), often with lesser amounts of paper birch (*Betula papyrifera*) and quaking aspen (*Populus tremuloides*). Dominance shifts toward birch and aspen following fires, large blowdowns, and/or spruce budworm outbreaks, and back toward conifers in the absence of such disturbances. Northern white-cedar dominance is most prevalent in sand dunes and on thin soils over neutral to alkaline bedrock or glacial deposits, such as in the Straits of Mackinac. White spruce is more prevalent on drier sites while balsam fir and cedar are more common on wetter sites; all three of these conifer species increase in importance with time since fire, especially cedar. Additional canopy associates include white pine (*Pinus strobus*), balsam poplar (*Populus balsamifera*), and hemlock (*Tsuga canadensis*), and less frequently black spruce (*Picea mariana*), red pine (*Pinus resinosa*), jack pine (*Pinus banksiana*), and red maple (*Acer rubrum*). Inland boreal forests are often characterized by an increased canopy component of white pine, hemlock, and deciduous species. Mountain maple (*Acer spicatum*), striped maple (*A. pensylvanicum*), American mountain ash (*Sorbus americana*), and mountain ash (*S. decora*) are characteristic of the subcanopy and understory. Where aspen and/or birch dominate the canopy, conifers are prevalent in the subcanopy and understory. Additional understory or tall shrub species include round-leaved dogwood (*Cornus rugosa*), tag alder (*Alnus incana*), and soapberry (*Shepherdia canadensis*). Characteristic low shrubs include American fly honeysuckle (*Lonicera canadensis*), bearberry (*Arctostaphylos uva-ursi*), Canadian yew (*Taxus canadensis*), prickly gooseberry (*Ribes cynosbati*), Canada blueberry (*Vaccinium myrtilloides*), bush honeysuckle (*Diervilla lonicera*), common juniper (*Juniperus communis*), thimbleberry (*Rubus parviflorus*), and dwarf raspberry (*R. pubescens*). Ground flora includes species from both mesic northern forest and northern swamp communities such as red baneberry (*Actaea rubra*), wild sarsaparilla (*Aralia nudicaulis*), sedges (*Carex deweyana* and *C. eburnea*), bluebead lily (*Clintonia borealis*), goldthread (*Coptis trifolia*), bunchberry (*Cornus canadensis*), woodfern (*Dryopteris* spp.), large-leaved aster (*Eurybia macrophylla*), fragrant bedstraw (*Galium triflorum*), Menzies' rattlesnake plantain (*Goodyera oblongifolia*), creeping rattlesnake plantain (*G. repens*), wintergreen (*Gaultheria procumbens*), twinflower (*Linnaea borealis*), Canada mayflower (*Maianthemum canadense*), false mayflower (*M. trifolium*), naked miterwort (*Mitella nuda*), partridge berry (*Mitchella repens*), northern wood sorrel (*Oxalis acetosella*), bracken fern (*Pteridium aquilinum*), gay wings (*Polygala paucifolia*), rose twisted stalk (*Streptopus lanceolatus*), starflower (*Trientalis borealis*), and violets (*Viola* spp.). Ram's head lady's-slipper (*Cypripedium arietinum*, state special concern) and dwarf lake iris (*Iris lacustris*, federal/state threatened) are uncommon, but characteristic. Mosses and usnea lichens are often abundant due to favorable, moist conditions. Clubmosses, such as stiff clubmoss (*Spinulum annotinum*), running ground pine (*Lycopodium clavatum*), and ground pine (*Dendrolycopodium obscurum*), are often locally abundant, with ground pine more common following fire. Mosses, liverworts, usnea lichens, and saprophytic fungi often are common due to favorable, moist conditions.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Legend
Counties
Landscape Ecosystems of Michigan
Section
Subsection
Sub-subsection
Community range
Prevalent or likely prevalent
Infrequent or likely infrequent
Absent or likely absent
0 20 40 60 80 100 Miles
0 20 40 60 80 100 Kilometers
MICHIGAN STATE UNIVERSITY EXTENSION
Michigan Natural Features Inventory
Boreal Forest
Albert, D.A., J.G. Cohen, M.A. Kost, B.S. Slaughter, and H.D. Enander. 2008. Distribution Maps of Michigan's Natural Communities. Michigan Natural Features Inventory, Report No. 2008-01, Lansing, MI. 166 pp.
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Conservation Tree/Shrub Suitability Guide (CTSG)
http://efotg.sc.egov.usda.gov/ (Sec. II>Forestry Information)

- Provides a list of potential trees to plant on a site, based on Soil Series.
- Includes information on:
  - Form
  - Nativity
  - 20-year height
  - Mature height
  - Shade
  - Deer
  - Commercial availability
  - Region

Questions?

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