State of Michigan's Species Profile for Mile-a-Minute weed (*Persicaria perfoliata*) Management

Created December, 2023

Introduction and Scope

Persicaria perfoliata (mile-a-minute weed, hereafter MAMW) is a terrestrial vine native to East Asia (Hough-Goldstein et al., 2015). In North America, MAMW is an herbaceous annual vine (Hough-Goldstein et al., 2015; Jackson et al., 2020). MAMW was first accidentally introduced to the Portland, Oregon area in the 1890s through ship ballast (Hickman & Hickman, 1978). Like the East Asian *Pueraria montana var. lobata* (kudzu), MAMW has the potential to negatively impact native ecosystems in the United States by outcompeting endemic plants. MAMW is considered a high-risk invasive by the Michigan Department of Natural Resources due to the risk it poses to the state's forests. It is a Watch List species (Michigan Department of Natural Resources, 2023). Today MAMW can be found in seventeen U.S. states and one federal district (EddMaps, 2023).

Synonyms

Scientific Name: *Polygonum perfoliatum*
Common Name: mile-a-minute, devil's tail, giant climbing tearthumb, Asiatic tearthumb, mile-a-minute vine, minuteweed, tearthumb, and devil's tearthumb.

This document is a product of an Environmental Protection Agency Great Lakes Restoration Initiative subgrant between the Michigan Department of Natural Resources and Lake Superior State University. It was made for the purposes of:

- Consolidating current science-based knowledge relative to the biology and ecology of MAMW.
- Summarizing scientific literature and research efforts that inform management options for MAMW in Michigan.
- Identifying future directions for research relative to successful MAMW prevention and management in Michigan.

This document was written by Zach Kassuba under the direction of Dr. Megan Butler and was reviewed by the Michigan Departments of Natural Resources and Agriculture and Rural Development. This document sources peer-reviewed journals and publications. Any chemical, company, or organization that is mentioned was included for its involvement in peer-reviewed, published, publicly shared information, not to imply endorsement of the chemical, company, or organization.

Biology and Ecology

I. Identification

Mile-a-minute weed is a fast-growing herbaceous annual vine (Hough-Goldstein et al., 2015). The vine may grow up to six meters in a single growing season (April through Oct.). MAMW stems may grow up to four and a half to seven and a half meters in length (15 to 25 ft). They also feature overlapping sections that are prone to creating a monocultures (Figure 1) (Okay, 1997 & Kim et al., 2021, Maine Dept. Inland Fisheries and Wildlife).

Figure 1. Mile-a-minute weed (P. perfoliata) in late summer (MDNR, 2020)

Mile-a-minute weed has triangular, cup-shaped leaves that are one to two centimeters wide. Each stem has small backwards-projecting prickles (Figure 2). Leaves are light green equilateral triangles between four and seven centimeters long and five to nine centimeters wide. MAMW has an ocrea that surrounds the base of each stem at the node (Hough-Goldstein et al., 2015, Jackson et al., 2020, NYIS, 2019).

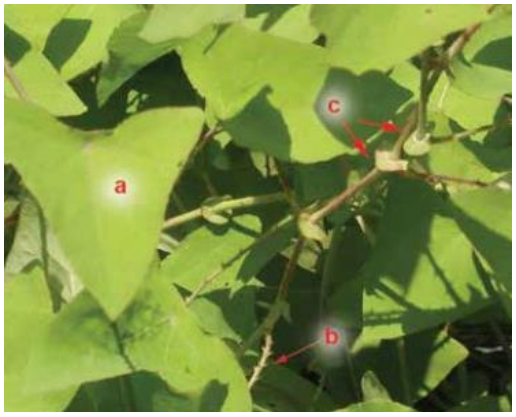


Figure 2. Mile-a-minute weed. The triangular leaves (a), small backwards projecting prickles (b), and ocreae around stems (c) (Hough-Goldstein et al., 2015).

The vine's small white flowers are self-fertile and peak in mid-summer (NYIS, 2019), but are able to produce seeds from late spring to late fall (Hough-Goldstein et al., 2015, Jackson et al., 2020, NYIS, 2019). Each flower produces a cluster of small green berry-like fruit (Figure 3) which, while maturing will turn a pink color, then to a blue-purple color. Each fruit contains a single small seed or achene (Hough-Goldstein et al., 2015).

There are a few species that are commonly confused with MAMW primarily due to characteristics such as leaf shape and vining nature. Like MAMW, many of these look-alike terrestrial vines are native to Asia or Eurasia, in particular kudzu (*Pueraria montana var. lobata*) and English ivy (*Hedera helix*). Both plants can be found in Michigan and like MAMW are terrestrial, rapidly growing vines that can take over a native ecosystem (Figure 4). English ivy and kudzu do not share many physical characteristics with MAMW, but their fast growth and quick seed dispersal also allows these vines to engulf forests (Forseth & Innis, 2004; Ingham & Borman, 2010; Quebbeman et al., 2013; *Washington State Noxious Weed Control Board*, 2023).

Figure 3. Mile-a-minute weed, the small berry-like clusters, show green berries that are immature and blueberries that are mature (P perfoliata) (MDNR, 2020).

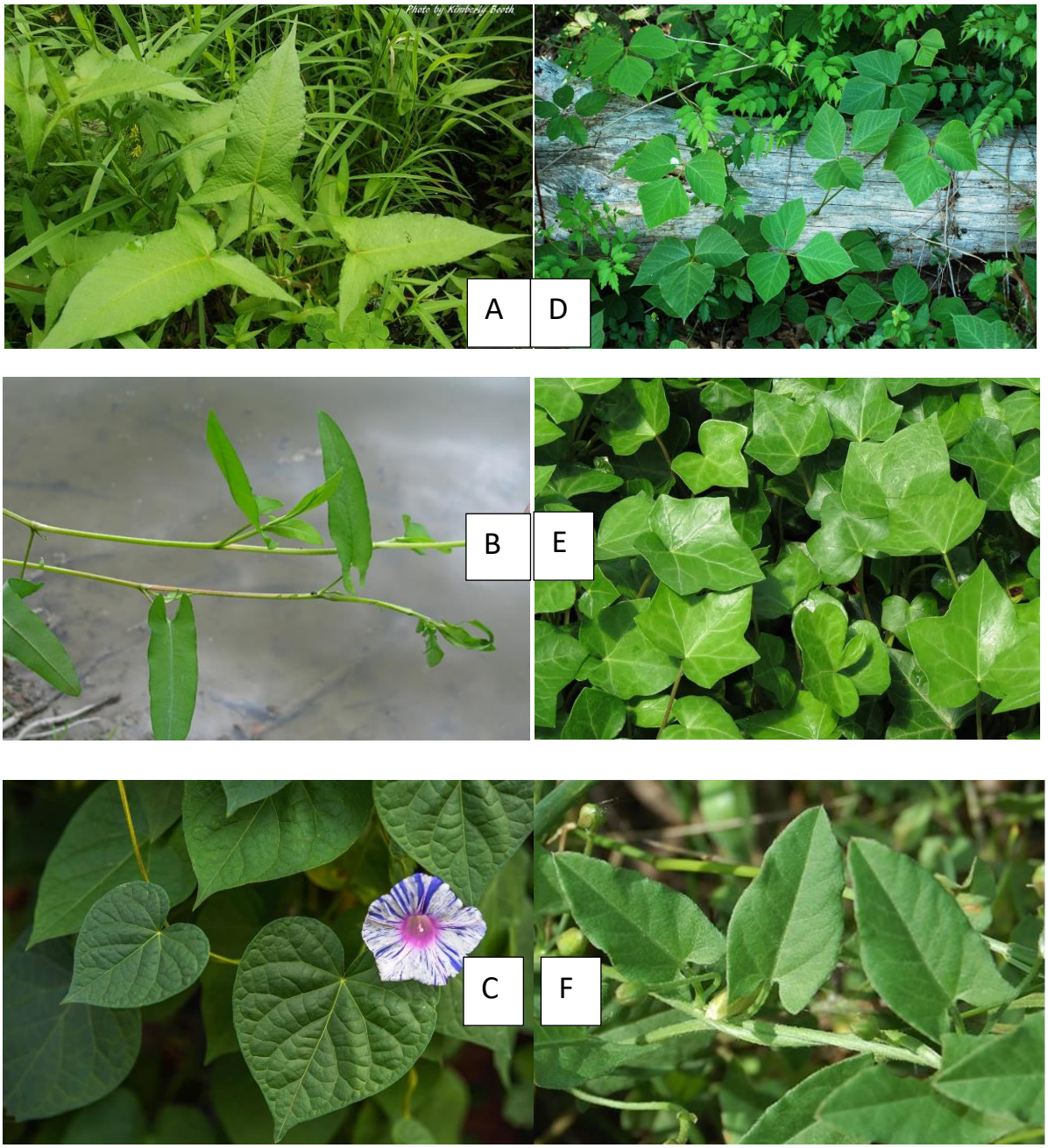


Figure 4. Similar species to mile-a-minute weed include (A) halberd-leaved tearthumb (Polygonum arifolium), (B) arrow-leaved tearthumb (Persicaria sagittata), (C) wild morning glory (Ipomoea purpurea), (D) kudzu (Pueraria montana var. lobata), (E) English ivy (Hedra helix), and (F) field bindweed (Calystegia arvensis) (Convolvulus Arvensis (Field Bindweed), 2023; Maryland Biodiversity Project - Halberd-Leaved Tearthumb (Persicaria Arifolia), 2015; Iannotti, 2022; Loewenstein & Enloe, 2018; Migneault, 2010; Wise, 2017).

Other common, look-alike species include halberd-leaved tearthumb (Polygonum arifolium), arrow-leaved tearthumb (Persicaria sagittata), wild morning glory (Ipomoea purpurea), and

field bindweed (*Calystegia arvensis)* (*Similar Species Guide*, 2023). In addition to being terrestrial vines, MAMW shares a similar unifoliate leaf structure with all four species above (Figure 4). The biggest key differences between these species and Mile a minute weed are MAMW's distinct triangular shaped leaf, the ocrea, and the presence of prickles (Figure 2). The halberd-leaved tearthumb and field bindweed also have a tri-pointed leaf shape, however, the leaves of the halberd-leaved tearthumb taper to a thin point while arrow-leaved tearthumb has an elongated triangular leaf rather than being nearly equilateral. Field bindweed has a flower that comes out of the center of the stem between the leaves (*Convolvulus Arvensis (Field Bindweed)*, 2023; *Maryland Biodiversity Project - Halberd-Leaved Tearthumb (Persicaria Arifolia)*, 2015) rather than out of the ocrea as MAMW does. In addition, wild morning glory has a distinct heart shape. Like MAMW, arrow-leafed tearthumb and halberd-leaved tearthumb have reverse prickles, while wild morning glory and field bindweed do not have any prickles. Finally, MAMW is unique among these vines in that it has round, cup-shaped leaves (ocreae) that surround the stem at nodes (Figure 3) and are a distinctive one to two centimeters in diameter (NYIS, 2019). These ocreae allow the MAMW to flower and bear fruit.

Figure 5. Mile-a-minute weed during ideal survey time (CDR EEE, 2017)

II. Detection

Mile-a-minute weed is typically found in temperate forests at different elevations across the eastern United States. In the Great Lakes region MAMW can be found in urban, suburban, and rural areas. While MAMW has historically been found in riparian zones (Van Driesche, 2002), it is also commonly found in open spaces, forest edges, fence lines, roadsides, construction sites, and utility right-of-ways (Michigan Department of Natural Resources, 2023; (Cusick & Ortt, 1987, Hough-Goldstein et al., 2015). The plant can tolerate a variety of conditions including partial shade and drier or wetter soil conditions (Rathfon & Forester, 2016). The best time to detect MAMW in the Great Lakes Region is in early June prior and during fruit maturation (Figure 5) to allow time to control the plant prior to seed germination (Jackson et al., 2020).

Remote sensing has become increasingly common for detecting invasive species, and could effectively be used to monitor invasive terrestrial vine populations (Joshi et al., 2004, Kim et al., 2021). Remote sensing can also be used to detect the types of landscape, bio-climatic conditions and other factors that may facilitate invasive species establishment and spread (Haltuch et al., 2000; Ismail et al., 2016; C. M. McCormick, n.d.; Rowlinson et al., 1999). Additional research focused upon MAMW is necessary to understand how remote sensing technology can facilitate the detection and management of this species in particular.

The use of ArcGIS Field maps has become increasingly popular over the last few years to track and mark locations of invasive species in the field (Hindy, 2022). In addition, southern Michigan natural resource managers use the MISIN app to find and monitor sites where MAMW has been reported (Savickas, 2023).

III. Life History and Spread

Reproduction

Mile-a-minute weed reproduces sexually via seeds and asexually via vegetative clones (Hough-Goldstein et al., 2015). In the mid-Atlantic, MAMW seeds begin germinating in March or April. Flowering begins in June or July. Fruit may be produced anytime from July to August depending on site conditions (Jackson et al., 2020). In Michigan's lower peninsula, invasive populations of MAMW begin flowering in late July or August (Savickas, 2023). However, because the state spans such a large area with growing seasons ranging from only 2-4 months in the upper peninsula to 4-6 months in the lower peninsula, it is expected that growth timelines will vary based upon local climactic conditions (Savickas, 2023).

Seeds are dispersed naturally via wind, water, birds, and mammals. Seeds can also be dispersed inadvertently by human activities such as recreation activities and under vehicle tires. Human disturbance often facilitates the spread of invasive species by physically spreading seeds or vegetative cuttings, or creating disturbed open spaces that favor the establishment of invasive plants. For example, degraded soil caused by unsustainable forestry can create open space that allows MAMW to establish. In addition, till farming practices can facilitate the spread of MAMW by potentially tilling stem nodes into the soil (Simberloff & Rejmanek, 2011).

Recent studies have analyzed invasive species seed viability after being eaten by small mammals, white tail deer, and agricultural livestock (calves, horses, sheep, hogs, or chickens). These studies have shown that nearly fifty percent of seeds that pass-through the digestive systems of these organisms remain viable and have the potential to germinate if released in fecal matter (Katovich et al., 2005; Myers et al., 2004; Palmer et al., 2021). More research is necessary to understand predation as a vector by which MAMW spreads.

Genetic analysis from plants picked from China, Japan, and eastern USA show no genetic variation. This suggests that the plant commonly reproduces vegetatively and that much of the invasive population in may be clones, however additional studies show that the plant reproduces sexually (Hough-Goldstein et al., 2012; Hough-Goldstein et al., 2015). More research should be done to determine how the plant primarily reproduces in its invasive and native ranges.

IV. Habitat

Native Range

Mile-a-minute weed is native to East and Southeast Asia (Price et al., 2003a). Specifically, it is native to Bangladesh, China, Japan, India, Korea, the Malay Peninsula (Ohwi, 1965), and Taiwan (Reed et al., 1977). There is no evidence that the vine is endangered anywhere in its native range. MAMW can be found in a range of habitats across its native range, from the eastern arid region of the Himalayan mountains to the tropical rainforests of the Malay Peninsula. In its native range, MAMW is often reported to grow as a perennial in regions with mild climates (Wu et al., 2002).

Figure 6. Global Distribution of mile-a-minute weed (P. perfoliata). (Chinese Virtual Herbarium, 2023)

Invasive Range

Mile-a-minute weed has expanded beyond its native range to both Africa and North America (Figure 6). In North America, MAMW was first introduced to the Portland, OR area in the 1890s accidentally through ship ballast (Hickman & Hickman, 1978). Reports conducted in the mid 1950's suggested that it was not found east of the Rockies (Oliver & Coile, 1994). However, the plant was accidentally introduced into the eastern United States via plants sent from Japan to the Gable Nursery in Stewartstown, PA in the 1930s (Moul, 1948). Prior to 1980, the plant was contained in five Pennsylvania counties and parts of Maryland (Hough-Goldstein et al., 2015). As of 2014, it was found in seventeen states and the District of Columbia (Figure 7). In the United States, MAMW has been detected almost entirely east of the Mississippi river in Connecticut, Delaware, Iowa, Massachusetts, Maryland, Michigan, New Hampshire, North Carolina, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Virginia, West Virginia, and District of Columbia (Hough-Goldstein et al., 2015). However, there is also a population of MAMW in Oregon (Berner et al., 2012) MAMW has also been identified in British Colombia, Canada (Bell, 2023).

MAMW will continue to grow in places with a plant hardiness zone of five through seven (Figure 8) due to adequate temperatures (Hough-Goldstein et al., 2015). Like the native range of MAMW, the invasive range experiences a wide array of climate conditions. Climate change is also increasingly becoming a concern for the near future of invasive plants. A warming climate may facilitate the growth and spread of MAMW, allowing it to thrive further north than before. More research is necessary to understand how factors like climate change will impact the range of this invasive species.

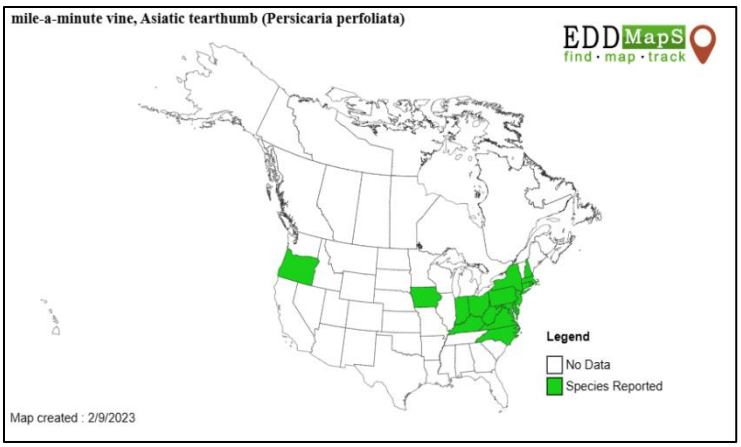


Figure 7. Distribution of mile-a-minute weed (Persicaria perfoliata) in the United Sates. Sightings are also reported in Calhoun County,

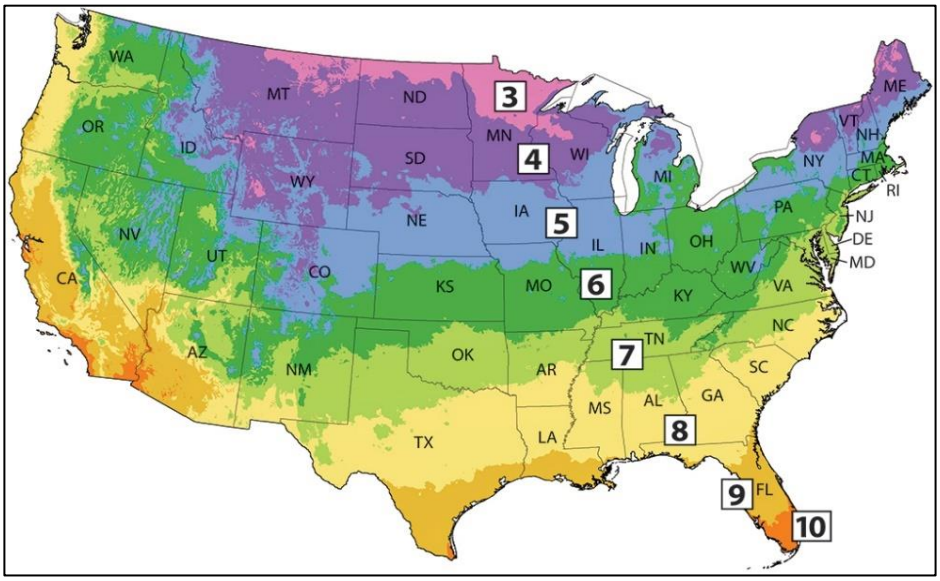


Figure 8. Distribution of Plant Hardiness Zone Map; MAMW thrives in zones 5-7. Michigan currently spans three hardiness zones. (USDA Zone Map Finder | Michigan Bulb Company, 2023)

V. Effects of Mile-a-Minute Weed

Negative Effects

MAMW is a threat to native vegetation, as it commonly outcompetes native herbs and shrubs. Where there are small or large infestations, MAMW forms a thick, dense canopy which kills young growth in the forest understory (L. H. McCormick & Hartwig, 1995; Price et al., 2003b; Steffen et al., 2012). Mile-a-minute weed can form stems up to six meters long that allow the plant to rapidly climb on existing forest vegetation. The stems also have barbs on them that can

restrict the movement of wildlife and humans alike. This growth tactic allows the vine to cover other plants and consume available sunlight, not allowing the understory to thrive (Price et al., 2003). The rapid expansion and quick growth rate of MAMW allows the plant to have significant impacts on tree canopies and shade density (Hough-Goldstein et al., 2015 & Jackson et al., 2020). Thick mats of living and dead MAMW also build up over seasons adding strenuous weight to older growth trees increasing the likelihood that they will break in the winter when they are already under the strain of ice and snow (Savickas, 2023). In Michigan, MAMW has engulfed forested edges, cropland and even prairie ecosystems (Savickas, 2023).

In addition, in some ecosystems that have invasive terrestrial vines such as Kudzu are having altered nutrient accumulation and cycling (Krajick & Adelman, 2010). Now additional studies should be conducted to see how MAMW may influence the hydrology, nutrient accumulation, and cycling in North American ecosystems (Joshi et al., 2004; Polley et al., 1997).

Positive Impacts

Mile a minute weed fruit are edible and contain a high potassium content (Fredericks, 2001). MAMW also has medicinal uses and has been used in China as a relief for fever, inflammation, cough, swelling, snakebites, and dysentery (Yun, 2006 & Chang et al., 2008). MAMW may also reduce blood sugar levels and inhibit cancer cell growth (Chang et al., 2008). Unlike Kudzu, a similar herbaceous vine species MAMW does not hold agricultural feed uses (*Kudzu*, 2019; Wong et al., 2011).

There is little to be found about positive ecological effects of the addition of mile-a-minute weed to an ecosystem. However, while MAMW foliage is not attractive to mammals it has been noted that nearly thirty species of herbivorous insects were found to consume the plant in Virginia and Pennsylvania and MAMW fruit is consumed by birds, mammals, and insects (Fredericks, 2001 & Kumar & Ditommaso, 2005). There should be more research into the positive effects of MAMW ecologically, economically, and for health and wellbeing in North America.

Current Status and Distribution in Michigan

Mile-a-minute weed was first documented in Michigan in 2020 at the Whitehouse Nature Center at Albion College in Calhoun County (Michigan Department of Natural Resources, 2020). It is unclear how the plant was transported into this region of Michigan. In the last few years, the local Barry, Calhoun, Kalamazoo CISMA started a MAMW management project working with local faculty at the Whitehouse Nature Center of Albion College and the local Calhoun County Road Commission. This project also provides funding to research MAMW (Savickas, 2023). As of 2023, there have been ninety-five reports of mile-a-minute weed in Calhoun County (Figure 9) on the Midwest Invasive Species Information Network (MISIN) app (MISIN, 2023).[1] The sightings are predominantly located along the eastern side of the county and are very close to jumping over to the neighboring counties (Figure 10).

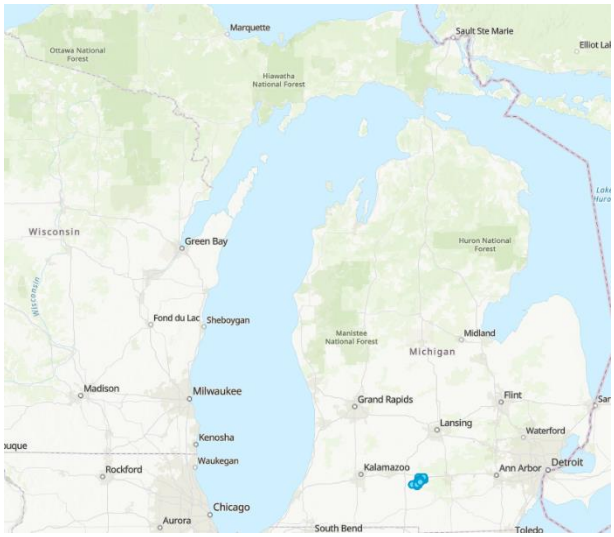


Figure 9. Blue dots indicate counties in Michigan where mile-a-minute weed (Persicaria perfoliata) has been sighted (Michigan Free Map, Free Blank Map, Free Outline Map, Free Base Map Boundaries, Counties, 2023)

Management of MAMW

I. Prevention

Preventing the spread of MAMW into further regions is the best most time and cost-efficient course of action when managing the plant. Preventing disturbance is a key practice for preventing the spread of MAMW. For example, preventing human disturbance in forested ecosystems by avoiding activities such as road construction can help prevent the plant from being transported to a new area and becoming established (Binion, 2005; Gerlach Okay et al., 2010; Yun, 2006; Tyser & Worley, 1992; Johnson, 1999). In addition, it is important to conduct regular surveys monitoring existing populations (Tyser & Worley, 1992; Johnson, 1999; Travis & Kiviat, 2016). Prevention of MAMW should be incorporated into management plans throughout the state, including plans for timber harvesting and site preparation, grazing allotments, road buildings and maintenance (USDA, 2001). In addition, it is important to educate the public with signs explaining the negative impacts of MAMW and how to identify it and prevent its spread. Consistently using decontamination practices such as using boot brushes and cleaning equipment when visiting any site are also important preventative measures.

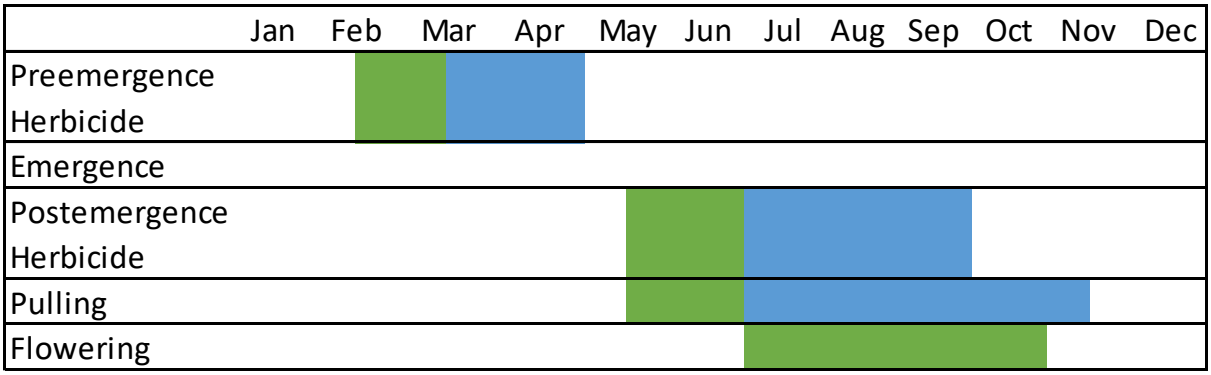
[1] Some of these reports are misidentifications. The BCK CISMA has spent considerable time reviewing sightings and correcting sites that have been mislabeled on MISIN (Savickas, 2023)

II. Management/Control

Key Considerations

Once MAMW populations are established in a region or eradication may not be possible (Kim, Huebner, Reardon, et al., 2021). Current research suggests that the most efficient methods of eradicating MAMW are chemical and mechanical/physical control (Chandran, 2019; Jackson et al., 2020; Simmen & Senasac, 2015; Lake & Minteer, 2018; Travis & Kiviat, 2016). Some sources recommend a variety of control methods throughout the season (Table 1). The best time to work on chemically and physically eradicating MAMW is during the preemergence stage when the plant has not germinated. If the plant has already germinated, management should occur before fruit has ripened. Once the fruit has ripened it is very difficult to remove the adult plants for the season (Miller et al., 2013), especially as it is an annual. During management is imperative that the plant is removed with as much care as possible. If parts of the plant are left in the soil, they can regrow (Hough-Goldstein et al., 2015 & Jackson et al., 2020). If biomass is allowed to build up over several seasons, the weight of the live and dead plants will begin to add extra stress that can kill native trees and the thick growth will make accessing the area to conduct management actions very difficult (Savickas, 2023). When managing MAMW, it is especially important to properly decontaminate both people and equipment in order to prevent unintentionally spreading the plant to other areas.

Table 1. Summary of management techniques used to control mile-a-minute weed (Persicaria perfoliata) over the course of a year emphasizing treatment prior to seed set. The green bars reference when this treatment would be most effective, where the blue bars show when the treatment would be less effective because of ripening seeds at that time Table modeled after the PSU mile-a-minute weed article (Jackson et al., 2020).



Physical or Manual Control

Physical or manual methods of controlling the vine while it is still a seedling before the barbs on the stem and leaves harden is one of the most common methods used to control MAMW. The roots are shallow and fibrous, so a hard pull can remove the seedlings. However, if some stem nodes remain in the soil, the plant is likely to regrow the following year (Jackson et al., 2020). As such, it is imperative that the roots are entirely removed during physical removal. Using a digging or hand tool to dig to a depth past the roots will allow for complete removal. If a shovel is used, it may accidentally cut parts of the plant and leave them in the soil to resprout

(Mattrick, 2006). Plants bearing fruit should also be bagged immediately and destroyed because the fruit may continue to ripen and spread seeds.

In addition, repeated mowing or heavy trimming of the vine prior to flowering will reduce fruit, thus reducing seed production. However, mowed or trimmed plant material should also be removed and bagged to prevent natural vegetative propagation (Hough-Goldstein et al., 2015; Jackson et al., 2020). The use of fire as a physical control for MAMW should be investigated further, especially on savanna and prairie landscapes where MAMW may be found. Similar herbaceous vine species such as English Ivy is completely eradicated by fire, while Kudzu is severely damaged (Miller, 1996; Wise, 2017).

Chemical Control

Herbicides are commonly used as a treatment for MAMW. Even with the use of herbicide, repeat treatments will likely be necessary and it may be an extensive process to fully eradicate the plant. A management plan timeline of multiple seasons or years may be necessary to achieve complete eradication (Forseth & Innis, 2004). Table 2 below (Jackson et al., 2020) lists five different herbicides that are legal in the state of Michigan that allow for mitigation or eradication of MAMW over the course of spring to summer. Preemergence refers to the period prior to seed germination, postemergence refers to after the plant germinates in the soil. For short-term use over the course of a season any of the following chemicals may be used to control MAMW; prodiamine, pendimethalin, imazapic, and sulfometuron (Jackson et al., 2020). Chemicals used during preemergence (primarily prodiamine or pendimethalin) are used by spraying the regions where the plants have grown in the past. Preemergence herbicides slowly break down in the soil over time (roughly two to three months) and do not dissolve well in water. However, heat does decrease how long these chemicals remain in the soil (Chopra et al., 2015; Kent et al., 2023). Chemicals used in the late preemergence and postemergence (imazapic, sulfometuron, and triclopyr) tend to stay in the soil from one to three months. All three chemicals break down over time with interaction with water and light (Obregón Alvarez et al., 2021; Strid et al., 2018; Yavari et al., 2019). MAMW populations in Michigan have primarily been treated postemergence with triclopyr (Savickas, 2023). When using chemical treatments to manage invasive plant populations, it is particularly important to understand how the target species (in this case MAMW) and other local non-target species in the area may react to the herbicide and how long the chemicals will remain in the soil (US EPA, 2015) and to take steps to minimize unintended impacts on native ecosystems during treatment.

Table 2. Summary of effective herbicides and treatment techniques over the course of a Spring and Summer on mile-a-minute weed (Pericrania perfoliata). The herbicides are currently approved by the United States Environmental Protection Agency. Table is broken down by Treatmenfigt, Timing of treatment, Herbicide, product Rate at recommended use, and further comments about the products. Table modeled after Jackson et al (2020).

Treatment	Timing	Herbicide	Product Rate	Comments
Preemergence	**Up to mid-March**	**Prodiamine or Pendimethalin**	**16–36 ounces/ acre or 64–128 ounces/ acre**	**Selective preemergence applications of prodiamine or pendimethalin prevent mile-a-minute establishment and have little effect on plants that are already present. These herbicides have only preemergence activity and must be applied 2 to 3 weeks prior to germination to get moved into the soil by rainfall. Use preemergence herbicides where infestations are dense, then follow up in May with postemergence herbicides to treat missed areas.**
Late Preemergence	**March to April**	**Preemergence herbicide plus Imazapic or Sulfometuron or Triclopyr**	**Preemergence herbicide plus 1 ounce/acre or 0.25–0.50 ounce/ acre**	**Adding a very low rate of imazapic or sulfometuron to a preemergence treatment allows you to apply closer to or even after germination with minimal injury to desirable vegetation. Both herbicides are soil active and have postemergence activity. Seedling vines will be controlled and there will be a short window of residual activity to allow the less soluble prodiamine or pendimethalin to move into the soil to prevent subsequent germination. Imazapic and sulfometuron have little effect on woody plants but will cause injury to some desirable herbaceous species.**
Pre- and Postemergence	**Early March through May**	**Imazapic or Sulfometuron or Triclopyr**	**4–12 ounces/acre or 1–4 ounces/acre**	**Imazapic and sulfometuron have pre- and postemergence activity against mile-a-minute. Preemergence applications will cause less damage to non-target species than postemergence applications. Sulfometuron has significant activity on a broad spectrum of herbaceous species and is best used where woody plant growth and forest regeneration is the objective. Imazapic can be used in specific herbaceous plantings, as some native warm-season grasses and forbs are tolerant.**

Biological Control

The mile-a-minute weed weevil (*Rhinoncomimus latipes*) has been used as biological control to delay and severely reduce plant growth and damage its nodes while it is budding. The mile-a-

minute weed weevil lays eggs in the buds, leaves, and stems of mile-a-minute weed until they pupate and fall to the soil. The insect's life spans about one month. Several generations can hatch, develop, and reproduce over the course of one growing season. During treatments, mile-a-minute weevils drastically eat away at MAMW biomass (Jackson et al., 2020). Releasing colonies of one hundred mile-a-minute weevils at a time are suitable enough to establish local populations. Using the weevil as a form of biological control will require consistent re-introductions. The mile-a-minute weed weevils' population dies off when the plant population decreases. However, once the mile-a-minute weevils die off the plant will continue to grow (Hough-Goldstein, 2015). As such, mile-a-minute weed weevils will never totally eradicate the plant, only mitigate its colonies (Pennsylvania DCNR, 2020). In addition, the weevil is sensitive to local climactic conditions. For example, cool, or wet summers slow the weevil's population growth, while allowing mile minute weed populations to thrive.

Indirect Management

It is currently thought that one of the main factors preventing MAMW from spreading into new ranges is low winter temperatures. However, with global climate change there is potential for the growing season to increase. Mitigating the current/future effects of climate change is a way to prevent the continued spread of invasive plants like MAMW into new ranges (Berg et al., 2015; Bhuju et al., 2016).

Research Needs

I. Biology and Ecology

There are several opportunities to advance understanding of the biology and ecology of MAMW. This literature review has identified several research gaps that, if addressed, would better inform MAMW management in Michigan. First, more research is necessary to understand MAMW reproduction. Little is known about how or why reproduction varies between the plant's invasive and native range. A deeper comparison of genetic diversity between MAMW's native and invasive range is necessary to understand the extent of sexual vs. asexual reproduction in each of these ranges. In addition, little is known about how the plant is able to act as a perennial on its native continent but is an annual in its invasive range (Wu, 2002).

It is also important to better understand the major vectors of distribution that exist in the United States. For example, are humans the main means by which MAMW is transferred between locations or is it also commonly moved by animals or other natural forces? Recent studies have also analyzed invasive species seed viability after being eaten by small mammals, white tail deer, and agricultural livestock (Katovich et al., 2005; Myers et al., 2004; Palmer et al., 2021). More research is also necessary to understand predation as a vector by which MAMW spreads.

In addition, research about how MAMW spreads vegetatively in its invasive range is necessary. There has also been little research into sexual reproduction via seed. It is important to answer questions such as how long seeds can stay dormant and remain viable in the soil seed bank, and how much light and water seeds require for germination. A better understanding of how MAMW reproduces in its invasive range vs native range will help managers develop prevention and eradication plans. Understanding MAMW reproduction and spread will allow us to better understand the history of MAMW introduction in North America.

Additional research in Michigan can also help provide more detailed information about growing seasons for the state's different hardiness zones. For example, In the mid-Atlantic, MAMW flowering begins in June or July (Jackson et al., 2020). In Michigan's lower peninsula, invasive populations of MAMW begin flowering in late July or August (Savickas, 2023). However, because the state spans such a large area with growing seasons ranging from only 2-4 months in the upper peninsula to 4-6 months in the lower peninsula, it is expected that growth timelines will vary based upon local climactic conditions.

Finally, additional research should be conducted on how MAMW interacts with native ecosystems and alters the biodiversity of native forests and grasslands across North America. More research is also necessary to understand whether the plant influences local hydrological cycles or soil chemistry and/or structure.

II. Detection

Future research should explore the effectiveness of using hyperspectral data and remote sensing to detect mile-a-minute weed. The use of remote sensing technologies could help detect mile-a-minute weed faster and keep populations under check in the Great Lakes Basin. In addition, looking at other ways to make data collection more cost effective and accessible would help improve monitoring and management.

More research should also focus upon how computer-based modeling and remote sensing technology can be used to facilitate early detection and monitoring. For example, research that works to statistically model the types of landscape, bio-climatic conditions and other factors that may facilitate invasive species establishment and spread may improve management by identifying locations that are most likely to have invasive species like MAMW. These locations can then be prioritized for monitoring.

Similarly, it is important to understand how factors like climate change will impact MAMW and its invasive range. Additional research on climate change and the impacts it will have on local ecosystems and invasive species like MAMW will help managers predict how plant hardiness zones and invasive species ranges will change with climate change. Predictive modeling focused upon climate change can help managers prepare for expanding invasive species ranges and take preventative action.

III. Management

Several research gaps exist related to MAMW management especially when it comes to honing management to local conditions in Michigan. For example, the mile-a-minute weed weevil (*Rhinoncomimus latipes*) has been used as biological control agent for MAMW (Jackson et al., 2020; Hough-Goldstein, 2015). Future research should investigate the potential use of this weevil throughout Michigan as a biological control agent. Research focused upon the weevil's impact on local ecosystems, ability to survive in Michigan's varied climates, and techniques for cheaply rearing and distributing the species will be especially impactful. In addition to the weevil, many organisms have been known to consume MAMW: deer, chipmunks, squirrels, and many different species of insects (New York Invasive Species Information, 2019). It is possible that other species may also have the potential to be effective biological control agents. Future research can help identify other potential biological control agents. The use of fire as a physical control for MAMW should also be investigated further, especially on fire-adapted savanna and prairie landscapes where MAMW may be found. In addition, new methods of preemergence control should be investigated. If the plant can be greatly reduced at the beginning of the season, it will allow managers more opportunity to gain an upper hand and make progress with treatment. Finally, additional research on other indirect management methods for MAMW will also be very helpful.

Little research has been conducted on the economic costs and benefits of MAMW. An economic cost-benefit analysis that compares the cost of prevention vs. management and provides information about the potential loss of economic and ecological value caused by MAMW infestations would be very helpful (Wu et al., 2002). Finally, while MAMW is edible and utilized as a medicinal range, little research has focused upon potential positive uses of MAMW in its invasive range.

Future Directions for Michigan and Management

The rapid growth of MAMW has potential to hurt the Great Lakes region ecologically, economically, and socially. Thus, the invasion should be a great concern to states and provinces in the Great Lakes Basin, including Michigan. MAMW has been documented in Calhoun County (MDNR, 2023) and is dangerously close to crossing into Jackson County, Michigan. The species should continue to be on a top invasive species watchlist for the state of Michigan due to its ability to spreadily quickly (Savickas, 2023). Educating the public, having management plans for prevention, population monitoring, and rapid response will allow the state to prevent the spread of the species in Michigan. Active management to assess where MAMW may thrive and having plans in place to eradicate the plant immediately if it is sighted are critical.

Future research and management of MAMW should be informed by the experience of regional stakeholders currently working to manage the species in Michigan such as the CISMA working in Calhoun County, the Calhoun County Road Commission and local Albion College faculty working at the Whitehouse Nature Center. Academic research and the experience of these on

the ground experts should be utilized to develop best management practices for MAMW prevention and eradication.

Once MAMW populations are established in a region, eradication may not be possible (Kim, Huebner, Reardon, et al., 2021). Preventing MAMW from spreading or establishing in new locations is likely the most cost-effective way to manage MAMW. It is important to work with local states and provinces in the region to enact strict policies prohibiting the movement or sale of MAMW throughout the Great Lakes Basin, such as adding MAMW to Michigan's laws on limiting the import, sale, or possession of restricted species in Act 451 Section 324.41301 (The Michigan Invasive Species Program, 2023). In addition, it is important to establish a state-wide management plan for MAMW that will allow for consistent and collaborative prevention and eradication efforts. A statewide management plan should specifically address activities known to promote the spread of MAMW such as timber harvesting and site preparation, grazing allotments, road building and maintenance (USDA, 2001). A wide variety of stakeholders should be involved in the development of the management plan including representatives from the public and private sectors.

Educational programs and community outreach should work to promote awareness of MAMW, explain how it grows/spreads and share how to reduce human-caused spreading. Currently the BCK CISMA is using a variety of methods to educate the public, including sending postcards, and attending local gardener association meetings. The idea behind investing in outreach education is that once the local community is aware of the plant and can properly identify MAMW, they can become active participants in the management and monitoring process (Savickas, 2023).

Early detection of MAMW is imperative to eradication of new colonies. It is important to conduct regular surveys monitoring existing populations (Tyser & Worley, 1992; Johnson, 1999; Travis & Kiviat, 2016). Currently, the most effective monitoring system involves physical surveys of areas with existing populations and vulnerable nearby locations. To increase the possibility of eradication, MAMW should continue to be a key component of existing monitoring programs, particularly in the region of the state it is found. MISIN or a similar collaborative monitoring network is a key resource that allows managers to keep a keen eye on new locations of colony growth and initiate a rapid response if reported. The active use of an app such as MISIN may allow local community scientists to locate and report MAMW in the local region. Local outreach programs in collaboration with regional CISMAs and local park and recreation organizations could also be a very helpful way to involve the public in the process of monitoring MAMW.

Using GIS, remote sensing, or additional programs that include aerial photography could also be used to set up a statewide system to monitor the spread of invasive species such as MAMW. More support for research on how to use these technologies for invasive species monitoring is necessary. In addition, it is important to make these resources accessible to local land managers in Michigan.

Invasive species are much more difficult to keep under control after they have been established. Having the ability to respond rapidly to reports submitted by partners and the

public will help to keep new MAMW populations in the state under control. Increasing long-term funding for managing invasive species in the state will help ensure that managers have enough invasive species management staff to be able to respond rapidly and begin treatment before new populations become established.

When managing MAMW, it is important to keep the infestation limited. Existing populations should be eradicated as quickly as possible. However, if that is not possible it is important to begin to treat existing populations as soon as possible in the growing season. Treatment of existing populations will likely require multiple methods and applications. In addition, new methods of preemergence control should be investigated. If the plant can be greatly reduced at the beginning of the season, it will allow managers more opportunity to gain an upper hand and make progress with treatment.

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