Surveys of Aquatic Macrophytes at Fort Custer Training Center

2020-2021

Figure 1. Aerial view of Site 10 at Fort Custer Training Center (A. Cole-Wick).

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Figure 2. American white waterlily (*Nymphaea odorata*) at Fort Custer Training Center (A. Cole-Wick).

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Introduction

Fort Custer Training Center (FCTC) is a federally owned and state operated Michigan Army National Guard (MIARNG) training facility located in Kalamazoo and Calhoun Counties, Michigan where it comprises 7570 acres. It is operated by the MIARNG and the Department of Military and Veterans Affairs (DMVA). Michigan Natural Features Inventory (MNFI; Legge et al.1995, Cohen et al. 2009, Bassett et al. 2021) and other researchers (INRMP 2020) have conducted vascular plant surveys at FCTC, but data on aquatic systems remain inadequate. To fill this knowledge gap, MNFI conducted comprehensive surveys for aquatic macrophytes at FCTC during the 2020-2021 field seasons.

The focus of this study is on the submersed and floating-leaf aquatic plant communities: aquatic macrophytes. These aquatic macrophytes consist of vascular plants and macroalgae that grow fully submersed in or float on top of water. Submersed and floating-leaf macrophytes play an important structural role in small shallow water systems as they influence biological structure and physio-chemical processes (Jeppesen 1998), yet they are often overlooked in botanical and biodiversity surveys, which tend to focus on terrestrial and emergent wetland species. Most aquatic macrophytes inhabit the shallow water or littoral zone of lakes and streams up to a depth of 5 – 6 m, although some species can grow much deeper (Hutchinson 1975). Interactions between aquatic macrophytes and littoral fauna are of vital importance to ecosystem processes (Carpenter and Lodge 1986). These plants provide critical habitat for fish and invertebrates, sustenance for waterfowl, are an important source of oxygen, and contribute to overall lake primary productivity. Submersed macrophytes slow water movement causing a zone of sedimentation and a reduction of erosion and resuspension (Horppila & Nurminen 2005). When abundant, aquatic macrophytes can also outcompete algae for nutrients and light, causing an increase in water clarity (Blindlow et al. 2002, Mulderij et al. 2007, Hilt and Gross 2008). Certain species, especially from the family Characeae, may also produce allelopathic chemicals that directly inhibit algae (van Dunk 2002).

For the purpose of this investigation, we defined aquatic macrophytes as any vegetation that is either entirely submersed or floating-leaved (either rooted or free-floating). These plants can live completely submersed in water for the entire growing season, with the exception of the growing tip, floating leaves, or emergent flower stalks. Our work did not cover emergent plants, as these species have been adequately addressed during other investigations at FCTC (e.g., *Typha spp., Decodon verticillatus*; Legge et al. 1995, Cohen et al. 2009), including a concurrent survey recently completed by MNFI (Bassett et al. 2021). As part of this investigation, we aimed to document aquatic invasive species and submit data to Michigan Invasive Species Information Network (MISIN) application (MISIN 2021).

MNFI is a member of the NatureServe Network. As a member of this program, we manage Michigan's Natural Heritage Database and have the responsibility of collecting information on Michigan's elements of biological diversity (MNFI 2021). Each occurrence of these elements is referred to as an "Element Occurrence" or "EO." In this database we currently track occurrences of 441 plant species, 332 animal species, and 77 natural communities. These data are used to guide conservation and management in Michigan (MNFI 2021). The database is the most comprehensive source of information on Michigan's endangered, threatened, or significant species and natural communities. In Table 1 we compiled a list of all rare aquatic macrophytes tracked by MNFI. During this study we focused survey efforts on the species that are likely to occur in FCTC (Table 1).

The goals of this project were to:

- Identify and map suitable habitat for aquatic macrophytes at FCTC
- Conduct surveys for aquatic macrophytes with a focus on documenting rare species with a probability of occurring in Kalamazoo and Calhoun Counties
- Transcribe all relevant species and community data into Michigan's Natural Heritage Database
- Submit plant voucher specimens to Michigan herbaria
- Identify threats and management opportunities for aquatic habitats at FCTC
- Conduct Floristic Quality Assessments for aquatic habitats

Table 1. Rare macrophytes known to occur in Michigan, we have grayed out species that are not likely to occur at Fort Custer Training Center.

Species	Likelihood of occurrence at FCTC	State Rank	State Status
Callitriche hermaphroditica	Unlikely (Upper Peninsula)	S2	SC
Callitriche heterophylla	Maybe (little known)	S1	T
Myriophyllum alterniflorum	Maybe (mostly Upper Peninsula, but a few collections in southern MI)	S2S3	SC
Myriophyllum farwellii	Unlikely (Upper Peninsula)	S2	T
Nelumbo lutea	Unlikely (Lake Erie)	S2	T
Nuphar microphylla	Unlikely (Upper Peninsula)	S1S2	E
Nymphaea leibergii	Unlikely (Upper Peninsula)	S1	E
Potamogeton bicupulatus	Softwater lakes	S2	T
Potamogeton confervoides	Unlikely (Upper Peninsula)	S3	SC
Potamogeton hillii	Cold, alkaline streams (mostly restricted to northern MI)	S2	T
Potamogeton pulcher	Softwater lakes	S1	E
Potamogeton vaseyi	Moderately alkaline to soft water	S1S2	T
Rorippa aquatica	Lake/stream edges	S2	T
Sagittaria brevirostra	Shallow marshes/muddy shores (last collected in Michigan in 1861, but occurs directly to SW in Indiana)	SX	SC
Sagittaria montevidensis	Unlikely (Lake Erie)	S1S2	T
Utricularia inflata	Unlikely	S1	E
Utricularia subulata	Unlikely (Interdunal wetlands)	S1	T
Wolffia brasilensis	Known to occur at FCTC in shallow softwater ponds and bog moats	S1	T
Zizania aquatica	Highly unlikely to have been overlooked in previous surveys	S2S3	T

State status categories are listed as endangered (E), threatened (T), or special concern (SC). State ranks are also listed: S1 - Critically imperiled, S2 – Imperiled, S3 – Vulnerable, SX – Presumed extirpated.

Methods

We identified and mapped survey areas at FCTC using ArcGIS Pro (ESRI 2021). We identified survey areas using our knowledge of FCTC, aerial imagery, and data from the National Wetlands Inventory. Each survey location was defined by a discrete polygon, which we hereafter refer to by "Sites". We identified 29 Sites for aquatic macrophyte surveys aimed to document the presence of all submerged and floating leaved species with particular attention to microhabitats of rare species (Table 1).

Nomenclature is consistent with Aquatic Plants of the Upper Midwest (Skawinski 2019). When possible, all plants were identified to species *in situ*, as identification of aquatic plants is best done when the plants are fresh (Figure 3). Certain genera, such as *Sparganium* and *Sagittaria*, were identified to genus when only submersed sterile parts of the specimens were present. Non-angiosperms (e.g., Charales and Bryophytes) were identified to genus for Characeae and class for aquatic mosses (the liverworts were identified to species).

During field surveys we noted the presence of macrophytes using meander surveys, with a focus on surveying all microhabitats within the Site (Figure 4). Surveys took place by meandering through wetlands either by wading, swimming, snorkeling, or by use of watercraft. We used a combination of manual and visual searching, including using a double headed 14 tine rake attached to approximately 8 m of braided polypropylene rope to sample deep areas (>1.5 m deep). Efforts were taken to ensure that surveyors covered different zones and depths in the systems to capture the diversity of species in a given wetland. We also determined the natural community type for each aquatic system sampled (Table 2, Cohen et al. 2015, MNFI 2020), the presence of threats to systems, and any aquatic invasive species present.

Figure 3. We identified macrophytes *in situ* at Fort Custer Training Center, as identification of aquatic species is best done when the plants are fresh (T. Bassett).

Table 2. Natural communities at Fort Custer Training Center with potential for aquatic macrophyte habitat.

Natural Community	Description	Common Macrophytes
Bog	Nutrient poor; aquatic macrophytes concentrated in "moat" on border	*Lemna minor, Utricularia* spp.
Emergent Marsh	Shallow water wetland occurring along shorelines of lakes and streams	*Sagittaria* spp., *Nuphar advena., Myriophyllum* spp., *Utricularia* spp.
Inundated Shrub Swamp	Shrub-dominated in small kettles and depressions	*Potamogeton illinoensis, Utricularia macrorhiza, Lemna minor*
Prairie Fen	Alkaline, sedge-dominated wetland with seeps and springs	*Chara* spp., *Utricularia* spp.
Southern Hardwood Swamp	Minerotrophic forested wetland dominated by a mixture of lowland hardwoods with occasional seeps	*Chara* spp., *Lemna minor*
Submergent Marsh	Acidic to alkaline, occurs in deep to shallow water in lakes and streams	*Nymphaea odorata, Nuphar advena., Utricularia* spp., *Potamogeton* spp., *Lemna* spp., *Wolffia* spp.

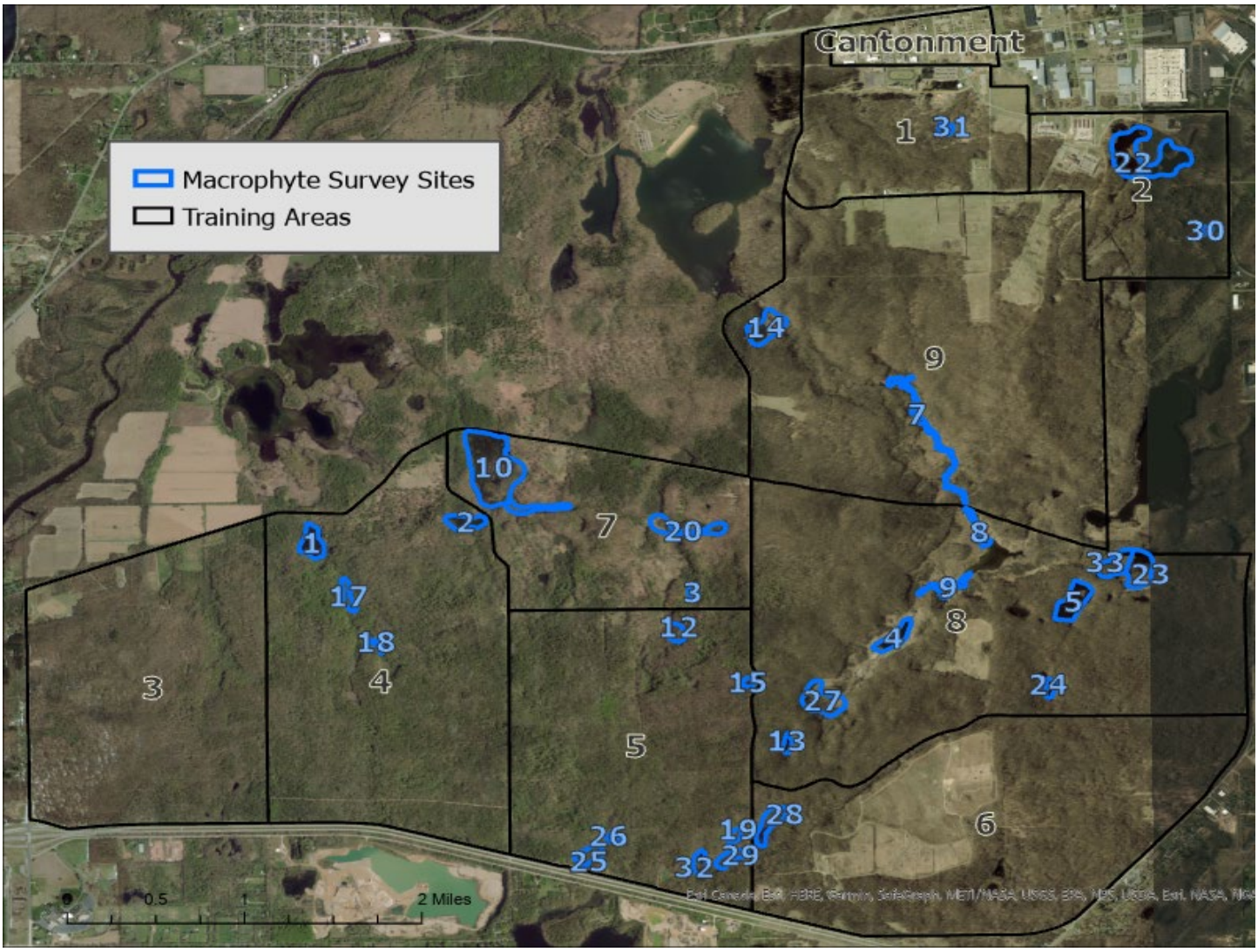

Figure 4. Mapped aquatic systems at Fort Custer Training Center. Sites are labeled by numbers.

Results & Discussion

In 2020-2021 we surveyed 26 of 29 macrophyte Sites we identified (Figure 4, Table 3). We were unable to access three Sites (Sites 4, 9, 14) for surveys because of schedules and military training activity (Table 3). Of the three Sites we did not survey, one of them (Site 14) we observed from the adjacent Longman Road, and for the others we include notes from previous MNFI surveys when possible (Bassett et al. 2021).

We documented 45 plant species in our surveys, 20 of which were not previously documented in FCTC (Table 4; Cohen et al. 2009). This high number of new species for FCTC supports the value of aquatic habitat surveys. Many newly documented species are not necessarily rare, but are often under-surveyed.

Six species were new county records, including three for Kalamazoo County (*Ceratophyllum echinatum, Wolffia brasiliensis, Zannichellia palustris*) and three for Calhoun County (*Lemna turionifera, Utricularia geminiscapa, Wolffia borealis*; Figures 5, 6). In the case of *Zannichellia palustris*, our detection also represents the first collection in southwest Michigan. This species is easily overlooked and occurs in a diversity of ponds, streams, and muddy lake bottoms (Michigan Flora Online 2011). While *Wolffia brasiliensis* has not been documented by the Michigan Flora project (Michigan Flora Online 2011), it has been observed elsewhere in Kalamazoo County (B. Slaughter, pers comm). Species richness ranged from two species (Site 18) to 20 species (Site 8). This range in species richness is expected as FCTC supports a variety of aquatic habitats that are ephemeral (prairie fen open water habitat) to large permanent waterbodies with a diversity of microhabitats (submergent marsh).

Ten macrophyte species were encountered only once, whereas four species were found at more than 15 Sites (Table 4). Of the 10 species that were rare at FCTC, several are fairly common across Michigan waterbodies (e.g., *Heteranthera dubia, Myriophyllum sibiricum*), and their local rarity may be due to the paucity of large and deep waterbodies at FCTC, such as lakes. We only encountered eastern purple bladderwort (*Utricularia purpurea*, Figure 7) in Site 10. While this species may not be particularly rare, it is conservative and not frequently observed in southern Michigan. The most frequently observed species were *Chara* spp., which was found in 16 Sites, as well as *Lemna minor, L. turionifera*, and *Utricularia macrorhiza*, each occurring in 15 Sites (Table 4). *Ceratophyllum demersum* was documented in 14 Sites. Interestingly, these five species are all non-rooted. As a part of this investigation, we did not identify Charales (*Chara* spp., stoneworts) to species, in the final section of this report we recommend future work to determine the diversity of this group at FCTC, as we encountered them in over half of the Sites surveyed. We confirmed the presence of only one species that is considered non-native (*Najas marina*), although this is debated, as well as one questionable specimen of *Myriophyllum* (details in the Discussion).

We documented a single specimen of freshwater sponge (*Spongilla* sp.) in Site 8, located south of Territorial Road. Of approximately 32 species of freshwater sponges found in North America, twelve have been documented in Michigan (Lauer and Spacle 2001). Sponges are filter feeders and can be used as predictors of high-quality water sources with low pollutant levels (National Parks Service 2018). We were only able to identify the single specimen of *Spongilla* to genus, and we recommend this Site for follow up surveys in the future (Table 3).

Figure 5. *Lemna trisulca* and *L. turionifera* were found at 4 and 15 sites, respectively (T. Bassett).

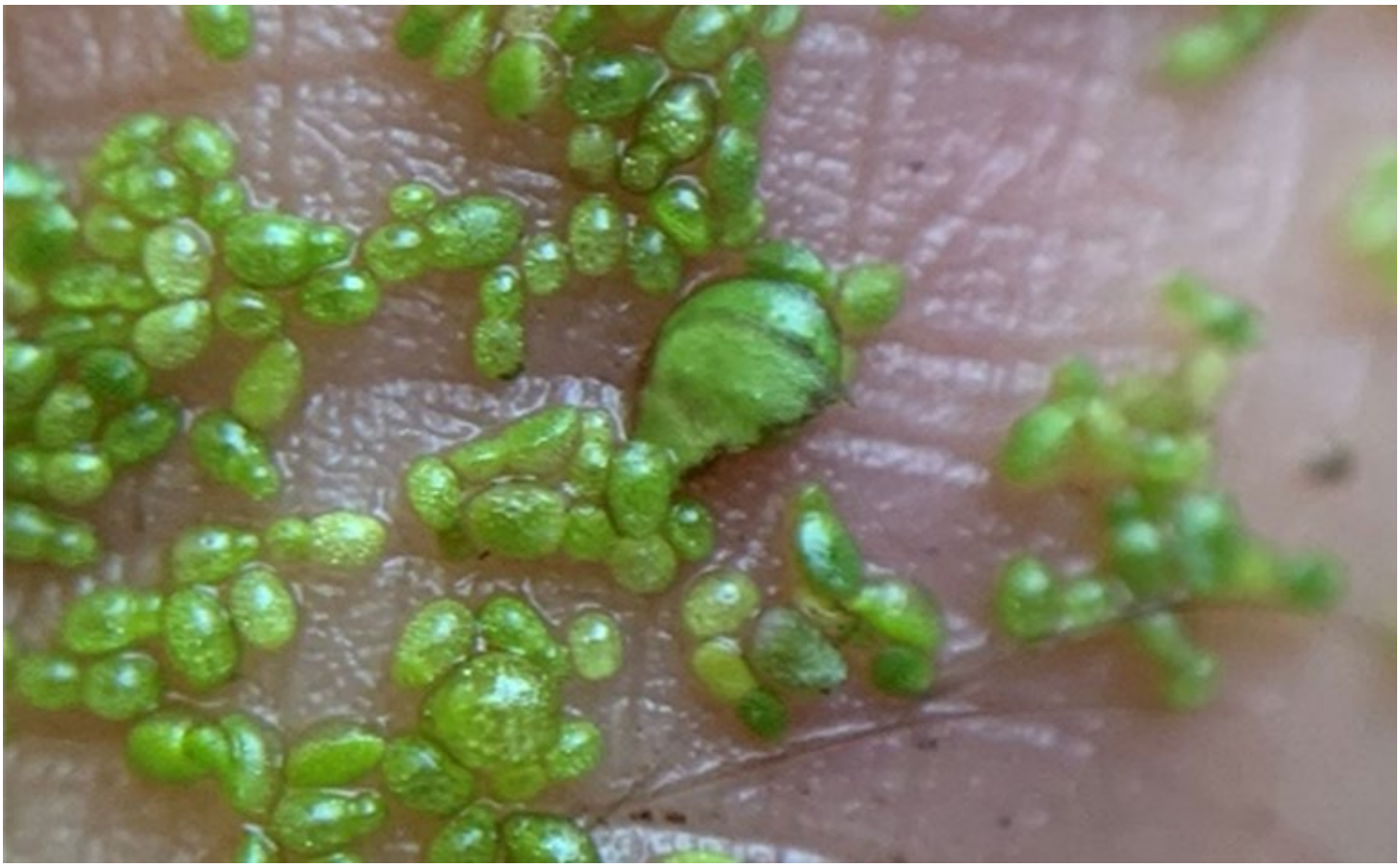

Figure 6. Northern watermeal (*Wolffia borealis*) photographed with a hand lens (A. Cole-Wick).

Table 3. Description of macrophyte survey Sites with Site name, Training Area, and natural community assignment. We noted if projects warrant additional survey work by bolding the natural community, and documented the presence of beaver activity. *Sites we were unable to survey.

Site Name	Training Area	Natural Community	Beaver Activity	Comments
1	4	**Submergent Marsh**	Yes	Site for follow up study on Chara / lake effects / beaver etc. Beaver dammed marsh dominated by *Chara* sp., surveyed via canoe. Lots of beaver activity, surveyed east side which was a higher (in elevation) beaver pond with giant floater mussel (*Pyganodon grandis*) and many fish: bluegill, small mouth, chub, common carp.
2	4	**Submergent Marsh**	Yes	A natural lake with deep seeps, greater than 3m deep with no plants, very cold water, leeches present.
3	7	Submergent Marsh	No	Man-made dammed pond north of Mott Road, dominated by peppermint (*Mentha x piperita*).
4*	8	**Submergent Marsh (Whitman Lake)**	Yes	*Unable to access.
5	8	**Submergent Marsh with Bog and Prairie Fen**	Yes	A large marsh with zonation. Mostly dominated by *Nuphar advena*, but open water zones with bladderwort, shrub zones, and a shrub-forb island.
7	9	**Prairie Fen**	Yes	Beaver flooding throughout, some plants found in seeps, most found in stream, survey could result in more species in wetter years.
8	8	**Emergent Marsh**	Yes	Survey via kayak on Territorial Road going south.
9*	8	**Emergent Marsh with Prairie Fen**	Yes	*Unable to access, extensive beaver flooding with multiple tiers documented from Longman Road.
10	7	**Submergent Marsh (man-made)**	Yes	Made two visits - one on foot from the west, one on canoe from the north. *Utricularia purpurea* found in the middle / deeper areas, muskrat / beaver den in the center (large) lots of fish including bass.
12	5	**Prairie Fen with Emergent Marsh**	Yes	Fen is extensively flooded from beaver, fen habitat is reduced in size, limited to peat mound.
13	8	**Inundated Shrub Swamp**	Yes	Interesting Site with some open water supporting *Potamogeton* spp., *Ceratophyllum* spp. and others, mostly knee deep.
14*	9	Prairie Fen	Yes	*Unable to access. A small band of partially-beaver-flooded prairie fen.
15	5	**Inundated Shrub Swamp**	Yes	Shallow water with only floating aquatics - *Lemna* sp. and *Wollfia brasiliensis*.
17	4	Southern Hardwood Swamp with seeps	Yes	Little aquatic habitat available to survey, all surveys took place in "Cemetery Seeps".
18	4	Prairie Fen	Yes	Little aquatic habitat available to survey, but some macrophytes (e.g., *Chara* sp.) found in marl flats.
19	5	Bog	Yes	Bog with Inundated Shrub Swamp with deep moat and ring of shrubs.
20	7	Prairie Fen	No	Fen complex includes many zones including few depressions with truly aquatic plants. We surveyed the entirety of the fen in 2021 but macrophytes (e.g., *Utricularia gibba*) were found only in stream and in small depressions.
22	2	**Submergent Marsh**	Yes	Surveyed via canoe, dominated by *Potamageton zosteriformis*.
23	8	Emergent Marsh	No	Dominated by *Nuphar advena* and *Decodon verticillatus*, with a few patches of *Typha*.
24	8	Emergent Marsh	Yes	Grass-shrub dominated, submergent marsh in center with mostly *Nymphaea odorata* and *Nuphar sp.* deep moat.
25	5	Bog	Yes	Bog with floating sphagnum mat.
26	5	Inundated Shrub Swamp	No	High quality natural community with no invasive species.
27	8	Prairie Fen	Yes	Many seeps and springs, Site is extensively affected by beaver flooding, more so than previous years.
28	6	**Bog**	Yes	Bog cooccurring with Inundated Shrub Swamp perhaps deleteriously affected from runoff from nearby road.
29	5	**Bog**	Yes	Moat around the bog is much wider and higher than it was in previous years.
30	2	Emergent Marsh	No	Very small, shallow depression.
31	1	Inundated Shrub Swamp	No	Located south of Cantonment Area, low species diversity.
32	5	Bog	Yes	Part of a complex of bogs with Sites 19 and 29 cooccurring with Inundated Shrub Swamp.
33	8	Bog	No	Dominated by Virginia chain fern with a wide shallow moat.

Figure 7. Eastern purple bladderwort (Utricularia purpurea) pictured here under ~30 cm of water was found in Site 10 at Fort Custer Training Center (A. Cole-Wick).

Table 4. Macrophyte species found at survey Sites in 2020-2021 at Fort Custer Training Center. Bolded species are those previously documented at FCTC. Sites 4, 9, 14 were not surveyed, and are left out of the table.

	1	2	3	5	7	8	10	12	13	15	17	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33
Aquatic moss																								x	x	
Brasenia schreberi				x											x											x
Ceratophyllum demersum	x	x		x		x	x	x							x	x	x		x	x				x	x	x
Ceratophyllum echinatum				x													x	x			x	x			x	
*Chara spp.^*	x	x	x	x	x	x	x	x			x	x		x	x		x	x		x	x					
Heteranthera dubia	x																									
Lemna minor	x	x			x	x	x			x		x	x				x	x	x	x	x	x	x		x	
Lemna trisulca				x												x		x			x					
Lemna turionifera			x				x	x	x	x	x		x	x		x	x	x				x		x	x	x
Myriophyllum sibiricum															x											
*Myriophyllum sp.***		x																								
Myriophyllum verticillatum						x																				
Najas flexilis					x	x								x	x											
Najas marina	x	x																								
Nasturtium officinale		x	x		x		x				x			x						x						
Nuphar advena	x	x		x		x	x							x		x	x				x					x
Nuphar variegata						x															x					
Nymphaea odorata	x				x	x	x								x		x				x					
Potamageton amplifolius						x																				
P. foliosus		x			x	x																				
P. friesii							x																			
P. gramineus	x																							x		
P. illinoensis	x	x			x	x			x																	
P. natans	x	x		x		x	?		x																	
P. zosterformis	x			x		x								x	x		x					x		x		
Persicaria amphibia	x					x	x	x										x			x	x	x		x	
Riccia fluitans										x	x						x	x	x		x	x	x	x	x	x
Ricciocarpos natans																									x	
Sagittaria sp.*+	x	x				x								x						x						
Sparganium sp.+	x	x			x		x						x							x					x	x
Spirodela polyhoriza				x		x	x		x	x			x			x	x				x					x
Spongilla sp.						x																				

Stuckenia filiformis	x	x			x	x	x																						
Stuckenia pectinata	x	x				x	x											x											x
Utricularia geminiscapa																								x					x
Utricularia gibba		x					x								x								x						
Utricularia intermedia				x	x																								
Utricularia minor								x											x	x				x			x		x
Utricularia purpurea							x																						
Utricularia macrorhiza~	x	x		x		x	x		x				x			x			x	x				x			x		x
Wolffia borealis							x						x						x					x			x		
Wolffia brasiliensis	x						x			x			x											x			x		
Wolffia columbiana													x						x	x				x					
Zannichellia palustris	x																												

* Listed species in Michigan
** Possible hybrid of *Myriophyllum spicatum x sibricum*
\+ Submersed sterile form of plant, such that identification to species is not possible.
^ Identified to genus in this study
~ *U. macrorhiza* is in Michigan Flora as *U. vulgaris*

Table 5. Natural Heritage Database Summary for high quality natural community Element Occurrences (EOs). EO ID is a unique identifier assigned to each EO record in the Natural Heritage Database.

EO ID	Community Name	Natural Community	State/Global Rank	EO Rank	Training Area	Macrophyte Survey Sites
3093	Cemetery Seeps	Southern Hardwood Swamp	S3/G3	B	4	17, 18
5258	Mott Road Fen	Prairie Fen	S3/G3	B	5	3, 12, 20
7503	Whitman Lake Fen	Prairie Fen	S3/G3	B	8	4, 27
16989	Territorial Road Fen	Prairie Fen	S3/G3	B	9	7
17650	Longman Road Bogs	Bog	S4/G3G5	BC	5,6	19, 25, 28, 29, 32
23896	Perimeter Road Bog	Bog	S4/G3G5	C	8	33
23900	Bullfrog Marsh	Submergent Marsh	S4/GU	C	8	5
23901	Longman Road Swamps	Inundated Shrub Swamp	S3/G4	C	5,6,9	13, 15, 26, 28

Rare Species Summary

We documented several occurrences of one rare aquatic macrophyte species at FCTC in 2020-2021. We documented four Element Occurrences (EOs) of State Threatened watermeal (*Wolffia brasiliensis*) in six Sites (EO 23902 [Site 1], EO 23903 [Site 10], EO 23904 [Site 15], EO 23905 [Sites 19, 29, 32], Table 4). *W. brasiliensis* is a floating aquatic plant without roots with boat-shaped tiny (<1 mm) leaves with a dotted surface (Penskar 2009). This species is documented from only four counties in Michigan's Natural Heritage Database (MNFI 2021), with four of 12 occurrences at FCTC. Multiple Sites are included in the same EO when they do not meet the separation distance criteria for new EOs, although these Sites may not necessarily be connected. The small size of this species has likely hindered the reporting of its occurrences in the past. This often-overlooked plant has been recommended for delisting. The majority of reported occurrences are newly documented, and it is likely that several additional occurrences will be reported (A. Reznicek, pers comm). Focused surveys for this species, including the work at FCTC, contribute to delisting.

Natural Communities Summary

Of the 26 aquatic macrophyte Sites we surveyed in 2020-2021, 18 met the criteria of an exemplary natural community occurrences to be entered into the Natural Heritage Database (Table 5, MNFI 2021). These 18 Sites are represented by five updated EOs and three new EOs. Site 28 is represented by two natural community EOs. We documented eight occurrences of five high quality natural community types during in this study: one hardwood swamp, three prairie fen, two bogs, one submergent marsh, and one inundated shrub swamp (Table 5). Below we briefly describe the macrophyte communities in each natural community EO and suggest management strategies when applicable. Here we focus on the macrophyte communities, for further description of these EOs, see Bassett et al. (2021).

Cemetery Seeps (Southern Hardwood Swamp)

The Cemetery Seeps comprise a sinuous forest complex containing numerous seeps in both mineral and organic soil, associated spring runs that often occur on a substrate comprised of a precipitate of calcium carbonate called tufa, which feed into a small stream with a mixture of gravel, sand, and tufa as substrates. These seeps and streams, as well as the underlying soils, are highly alkaline. This, combined with the steady flow of water in runs and the stream, limits the species that can occur here (Figure 8). Three macrophytes are present in the Cemetery Seeps: *Chara spp.*, *Lemna turionifera*, and *Riccia fluitans*. The aquatic habitats in Cemetery Seeps are dependent on the maintenance of groundwater hydrology, which is conserved by maintaining natural land cover and therefore

Figure 8. Spring run over tufa in Cemetery Seeps at Fort Custer Training Center (T. Bassett).

groundwater recharge in both immediately adjacent habitats and ideally the larger landscape. Invasive plant species, such as narrow-leaved and hybrid cattails (*Typha angustifolia* and *T. x glauca*), are present at this site and can increase shade and evapotranspiration in wetlands, modifying hydrology, but invasion is generally limited to portions of wetlands with still water, which are limited at Cemetery Seeps. Control of invasive species in the surrounding uplands, such as multiflora rose (*Rosa multiflora*) and barberry (*Berberis thunbergia*), may help to maintain groundwater recharge by maintaining a diverse ground layer and facilitating native tree recruitment.

Mott Road Fen (Prairie Fen)

The floristically diverse Mott Road Fen occurs on a series of peat domes north and south of Mott Road. It is surrounded by southern wet meadow, forested seeps, and dry-mesic forest. A stream running northwards, originating from seeps in the southern portion of the fen, contains most macrophytes found in this site. As in the Cemetery Seeps, the alkaline groundwater discharging from these seeps and the steady flow of water in the stream limits the aquatic macrophyte composition. *Sphagnum* hummock development generates micro-scale heterogeneity by creating fine-scale gradients of soil moisture and chemistry, including seeps where macrophytes such as *Utricularia minor* may occur in the stable, shallow water. Invasive species found here are primarily narrow-leaved cattail and purple loosestrife (*Lythrum salicaria*), These species may alter local hydrology directly through evapotranspiration or through modifying the structure and composition of the fen ecosystem, and should be controlled. Finally, a beaver flooding in the southern portion of Mott Road Fen (Site 12, Figure 9) has reduced the non-aquatic portion of the fen but provides a zone of moderately deep water suitable for common macrophytes such as *Ceratophyllum demersum* and *Perscaria amphibia*.

Figure 9. Site 12 (South Mott Road Fen) is now flooded with beaver creating new aquatic macrophyte habitat but reducing prairie fen habitat (A. Cole-Wick).

Whitman Lake Fen (Prairie Fen)

Whitman Lake Fen is comprised of areas sloping peat, punctuated with spring runs, and is found on the margins of Whitman Lake, which occurs in the course of a shallow, spring-fed stream. The lakebed comprises loose muck mixed with marl of varying depths, most of it around 1 m deep with deep areas of >4 m deep**.** We were unable to access Whitman Lake or the stream during this survey. The concerns related to invasive species and beaver damming discussed in relation to Mott Road and Territorial Road Fens likely apply here as well.

Territorial Road Fen (Prairie Fen)

Territorial Road Fen is characterized by sloping peat mounds with groundwater-fed streams and numerous seeps (Figure 10). Eagle Stream bisects the length of the fen, and is fed in part by extensive areas of seepage underlain by alkaline, calcium-rich marl substrates. Within the fen the organic soils are deep peats with well-developed sphagnum hummocks present. Sphagnum hummock development generates micro-scale heterogeneity by creating fine-scale gradients of soil moisture and chemistry. Most macrophytes, such as *Najas flexilis, Potamageton foliosis,* and *P. illinoensis*, are found within Eagle Stream. The habitat was dry when surveyed but *Chara* spp. and *Utricularia intermedia* were found in seeps throughout the fen. Beaver damming and ponding have altered the local hydrology, causing pooling and increased water temperatures, particularly in the southern portion of the site. Narrow-leaved cattail and purple loosestrife are present in Territorial Road Fen and should be controlled.

Figure 10. Common garter snake (*Thamnophis sirtalis*) on *Chara* in a seep pool in a prairie fen at Fort Custer Training Center (T. Bassett).

Longman Road Bogs (Bog)

Longman Road Bogs are dominated by leatherleaf (*Chamaedaphne calyculata*) on fibric peat soils derived from the decomposing *Sphagnum* moss. These sites are surrounded by inundated shrub swamp, wet meadow, and expanses of dry-mesic forest. The moats on the margins of these bogs contain the majority of the aquatic macrophytes. These sites contain typical bog species, such as bladderworts (*Utricularia macrorhiza and U. minor*), *Wollfia* spp., *Spirodela polyhoriza, Lemna minor, L. turionifera*, and *Riccia fluitans*. Three of the Sites that comprise Longman Road Bogs are among the few that contain *Ceratophyllum echinatum*, as well as *Wolffia brasiliensis*. In contrast to the groundwater hydrology of fens, bogs are characterized by acidic substrates and water. The hydrology of bogs is linked to overland flow from the peat mound comprising the bog mat and adjacent uplands. Therefore, protecting the integrity of adjacent uplands is paramount. Runoff from Longman Road may threaten the integrity of this ecosystem. The presence of the invasive glossy buckthorn (*Frangula alnus*) in the bog may modify the hydrology, by drawing down the water table and leading to drier conditions

overall. Treatment and removal of this invasive species is strongly encouraged, due to its profound impact on hydrology and therefore ecosystem modification in these bogs that are mostly free from invasive species.

Perimeter Road Bog (Bog)

This small bog contains a shallow, wide moat and is comprised of species typical of a southern Michigan bog. The aquatic macrophyte community is concentrated in the moat, and is dominated by *Ceratophyllum demersum*, *Nuphar advena*, with *Utricularia geminiscapa, U. macrorhiza, U. minor*, *Lemna turionifera, Riccia fluitans, Spirodela polyhoriza, Brasenia schreberi,* and *Stuckenia pectinata* also present. No invasive species were observed on the bog mat or in the aquatic margins during surveys, but hydrological modifications and warm, nutrient-rich runoff from the adjacent Perimeter Road pose a threat to the bog. Continued monitoring for invasive species is recommended to maintain this native species-dominated site.

Bullfrog Marsh (Submergent Marsh)

Bullfrog Marsh occurs in an isolated depression surrounded by dry-mesic southern forest. Hydrologically, this wetland is fed by surface water and a few springs within sloping peat mounds on its southern end, and has no apparent outlet. Dominated by *Nuphar advena*, this ecosystem has a relatively diverse aquatic macrophyte community, including *Chara spp., Lemna trisulca, Spirodela polyhoriza, Brasenia schreberi, Utricularia intermedia, U. macrorhiza*, and one of the few occurrences of *Ceratophyllum echinatum* at FCTC. A small sphagnum island is found on the north end of Bullfrog Marsh and contains the only invasive species, including narrow-leaved cattail and purple loosestrife. As these species occur at very low densities, eradication is feasible and is strongly recommended.

Longman Road Swamps (Inundated Shrub Swamp)

Longman Road Swamps is a cluster of inundated shrub swamps, occurring both on the margins of Longman Road Bogs and in nearby isolated depressions in dry-mesic southern forest (Figure 11). These swamps are dominated by buttonbush (*Cephalanthus occidentalis*) and winterberry (*Ilex verticillata*), and are characterized by 1-2 m deep water largely fed from overland flow. Longman Road Swamps support a moderately diverse aquatic macrophyte community, including *Potamogeton illinoensis*, *P. natans, Utricularia macrorhiza* and two Sites containing *Wolffia brasiliensis*. With the exception of the margins of Longman Road Bogs, which contain low density occurrences of glossy buckthorn, no invasives species were observed in these swamps. The woodlands surrounding these swamps contain dense populations of barberry and multiflora rose. Controlling these species may improve the hydrology of these swamps by facilitating the establishment of native vegetation.

Figure 11. Inundated shrub swamp at Site 13, which is one of four sites comprising the Longman Road Swamps at Fort Custer Training Center (T. Bassett).

Floristic Quality Assessments

We conducted Floristic Quality Assessments (FQAs; Table 6) based on the species lists for each Site (Table 4) (Reznicek et al. 2014). The FQA utilizes vascular plant species composition to derive the Floristic Quality Index (FQI), a quantitative metric of habitat quality that can be used as a relatively objective comparison among natural community occurrences of a type. Drawing upon expert consensus among botanists familiar with the flora of Michigan, each vascular plant species in Michigan has been assigned an *a priori* coefficient of conservatism (C-value) that ranges from 1 to 10 on a scale of increasing fidelity to pre-European colonization habitats (Herman et al. 2001, Freyman et al. 2016). Non-native species have a C-value of 0. We calculated FQI for each natural community occurrence as $\bar{C}\sqrt{n}$, where C = C-value and n = species richness (Freyman et al. 2016). Sites with an FQI of 35 or greater are generally considered to possess sufficient floristic conservatism to be considered of high quality (Herman et al. 2001).

Table 6. Mean Coefficient of Conservatism (Mean C) and Floristic Quality Index (FQI) for aquatic habitats at Fort Custer Training Center (Site numbers follow Figure 4 and Tables 3,4). Note that these values are based on vascular plant species, so species richness may differ from Table 4, which includes non-vascular species.

			Native Species		Non-native Species	
Site	**FQI**	**Mean C**	**#**	**%**	**#**	**%**
1	21.4	5.2	16	94.12%	1	5.88%
2	19.8	5.1	14	93.33%	1	6.67%
3	6.4	4.5	2	100.00%	0	0.00%
5	19.9	6.3	10	100.00%	0	0.00%
7	16.8	5.6	9	100.00%	0	0.00%
8	22.3	5.4	17	100.00%	0	0.00%
10	25.5	5.7	20	100.00%	0	0.00%
12	11	5.5	4	100.00%	0	0.00%
13	12.1	5.4	5	100.00%	0	0.00%
15	15.7	7	5	100.00%	0	0.00%
17	6.4	4.5	2	100.00%	0	0.00%
18	5	5	1	100.00%	0	0.00%
19	18.3	6.1	9	100.00%	0	0.00%
20	14.8	5.6	7	100.00%	0	0.00%
22	14	5.3	7	100.00%	0	0.00%
23	13.2	5	7	100.00%	0	0.00%
24	20.8	6	12	100.00%	0	0.00%
25	18.3	6.9	7	100.00%	0	0.00%
26	4.2	3	2	100.00%	0	0.00%
27	10.3	4.6	5	100.00%	0	0.00%
28	22	6.1	13	100.00%	0	0.00%
29	23.2	6.7	12	100.00%	0	0.00%
30	12.1	5.4	5	100.00%	0	0.00%
31	11.6	5.2	5	100.00%	0	0.00%
32	19.9	6	11	100.00%	0	0.00%
33	19.9	6	11	100.00%	0	0.00%

Herbarium Specimens

We collected voucher specimens of macrophytes to submit to herbaria (Table 7). We transferred all vouchers to Michigan State University Herbarium in November 2021, where they agreed to transfer redundant species to the University of Michigan Herbarium. Some species that we encountered during surveys were not vouchered due to rarity or lack of exemplary specimens during the sampling time.

Table 7. List of specimens collected at Fort Custer Training Center which were sent to Michigan Herbaria.

Species	Location	Number of Vouchers	Year
Brasenia schreberi	Site 5	2	2021
Ceratophyllum demersum	Site 1	2	2020
C. echinatum	Site 22	1	2020, 2021
Heteranthera dubia	Site 1	1	2020
Myriophyllum sibiricum	Site 22	1	2020
M. verticillatum	Site 1	2	2020
Najas flexilis	Site 22	2	2020
Najas marina	Site 1	2	2020
Nuphar advena	Site 1	2	2020
Nymphaea odorata	Site1	2	2020
Persicaria amphibia	Site 10	2	2021
Potamageton foliosus	Site 22	2	2020
P. freisii	Site 10	2	2021
P. gramineus	Site 1	1	2020
P. illinoensis	Site 1	2	2020
P. natans	Site 1	1	2020, 2021
P. zosterformis	Site 22	1	2020, 2021
Sagittaria sp.	Site 1	1	2020
Sparganium sp.	Site 1	1	2020
Stuckenia filiformis	Site 10	2	2021
S. pectinata	Site 10	2	2021
Utricularia intermedia	Site 5	2	2021
U. minor	Site 10	2	2021
U. macrorhiza	Site 10	2	2021
Zannichellia palustris	Site 1	2	2020

Discussion

Through the course of conducting surveys and reviewing the data from macrophyte surveys, we have compiled recommendations for aquatic habitats at FCTC. Below we discuss the impacts on the aquatic and riparian communities we encountered. Currently, the leading threats to the integrity of wetland and aquatic communities are beaver activity as well as wetland and terrestrial invasive species.

Beaver Activity

The foremost threat to the integrity of natural communities at FCTC is the rampant beaver population. While the North American beaver (*Castor canadensis*) is a native species, without predators, populations have recently increased significantly in southern Michigan. We observed the impact of beaver activity at 22 out of 26 sites surveyed (Figure 12). Sites where we did not observe beaver flooding were either very small (Site 30), or were already flooded (Site 3). While beaver create habitat for aquatic macrophytes through flooding, this also reduces the amount of wetland with emergent vegetation, often flooding areas of high biodiversity (e.g., prairie fen, Sites 10 and 12). We did not observe any rare or uncommon macrophytes in beaver ponds, so we recommend consideration of installing a flow device (Taylor and Singleton 2014) to reduce the hydrologic impact of beaver activity in areas where beaver dams may impact high quality prairie fen habitat that we have identified and mapped in MNFI's Natural Heritage Database (MNFI 2021; Mott Road Fen, Territorial Road Fen, Whitman Lake Fen; Table 2). The conservation of prairie fen habitat and diversity outweighs the potential loss of habitat for common aquatic macrophytes.

Figure 12. A beaver lodge located along the edge of the natural lake comprising Site 2 at Fort Custer Training Center (T. Bassett).

Hydrology & Terrestrial Invasive Species

Groundwater-dependent or spring-fed wetlands, such as prairie fens, require the maintenance of groundwater hydrology, which is conserved by maintaining natural land cover and therefore groundwater recharge in both immediately adjacent habitats and ideally the larger landscape (Abbas 2011). Spring-fed wetlands receive water from both local "groundwater mounds" and from multiple regional groundwater sources, making it difficult to predict which recharge areas (e.g., upland habitats receiving precipitation) are contributing to a specific discharge area such as a seep or spring. For example, one study showed that among six wetland complexes in the northern lower and eastern upper peninsulas of Michigan, it took between 25 days and 11 years for water to travel between recharge and discharge zones (Sampath et al. 2016). FCTC is manages large contiguous areas of the landscape that serves as the recharge areas for groundwater-dependent wetlands both on and off site. Maintaining native vegetated upland cover, ideally diverse high quality native habitats, is vital for reducing runoff and increasing infiltration into groundwater aquifers (Dripps and Bradbury 2010, Schenk et al. 2020). Some studies have shown that removing invasive honeysuckle (*Lonicera maackii*) from forests changes the hydrology of surrounding wetlands (Boyce et al. 2012). Although not the focus of this survey, hybrid cattail (*Typha x glauca*), purple loosestrife, and reed (*Phragmites australis*) are present at FCTC and pose threats to aquatic macrophyte habitat. Comprehensive wetland and terrestrial plant survey results and associated recommendations can be found in Bassett et al. (2021). These emergent invasive species can produce monotypic stands that reduce open-water zones in wetlands (Cressey 2016) and exclude native plant species, including certain aquatic macrophytes (Lawrence 2016). With a focus on macrophyte survey sites identified as Element Occurrences (Table 5), we strongly suggest mechanical or chemical removal of hybrid cattail and reed, as well as repeated releases of biocontrol loosestrife beetles. With a focus on maintaining and/or restoring native hydrology to wetlands, these actions will likely benefit aquatic macrophytes.

Aquatic Invasive Species

During surveys in 2020-2021, we did not confirm the presence of any aquatic invasive species. However, in Site 2 we found a single degraded specimen of watermilfoil (*Myriophyllum sp.)* that contained the features of the native *M. sibiricum* and the invasive *M. spicatum*. These two species can hybridize (Moody and Les. 2002) causing a highly invasive and sexually viable population (LaRue et al 2013). Unfortunately, hybrid milfoil is difficult to identify morphologically and genetic methods should be used to provide reliable identification (Pashnick and Thum 2020). We did not report this to MISIN, as they do not accept occurrences of this hybrid and we could not confirm the ID of this species based on a single degraded specimen. We revisited this site in 2021 to obtain additional specimens, but were unable to find any. Since this was the only potential aquatic invasive species documented in our surveys, this needs to be definitively identified so an appropriate response can be initiated (whether it be treatment or not). Site 2 is a natural lake in the northeastern portion of TA4, along Augusta Climax Road with relatively easy access. We recommend follow-up surveys in Site 2 and genetic analysis to determine the presence of the invasive *M. spicatum x M. sibiricum*. Additionally, we recommend placing a "Clean Drain Dry" sign at the site to help prevent the spread into other FCTC waterbodies.

We detected spiny naiad (*Najas marina*) at two sites (Sites 1 and 2). This species is considered non-native in GLANSIS (Great Lakes Aquatic Nonindigenous Species Information System). However, this species native status is debated as fossil records show that it was present in the Midwest prior to glaciation and that it is theorized to have expanded back into its former range post glaciation (Stuckey 1985). First collected in Michigan in 1938 (Michigan Flora Online 2011), we recommend monitoring these occurrences of *Najas marina* within Sites 1 and 2.

It is important to identify, map, and direct resources towards the management of priority aquatic invasive species in and around FCTC. Some invasive species, such as European frog-bit (*Hydrocharis morsus-ranae*) and yellow-floating heart *(Nymphoides peltata*) have been documented in southern Lower Michigan (MISIN 2021) and other aquatic invasive species have been documented in adjacent states and are likely to invade in the near future, such as hydrilla (*Hydrilla verticillata*) and water chestnut (*Trapa natans*; MDEQ 2013). The best option for managing invasive species is to prevent their introduction and detect an invasion early (Lodge et al. 2006). We recommend "Clean Drain Dry" signage at water access points and follow-up aquatic macrophyte surveys, which we discuss in the following section. These recommendations will help reduce invasion risk and help detect a possible invasion before the species can become established.

Future Research & Monitoring

Variation in water quality, season, weather, and other factors may affect habitat and probability of detecting aquatic macrophyte species during surveys. For example, some sites (e.g., North Mott Road Fen, Site 20) were uncharacteristically dry during survey times. Therefore, it is recommended to repeat aquatic plant surveys in future years. In Table 3, we specified 14 Sites we recommend for follow up surveys and continued research. We provided these suggestions because future survey efforts can be more efficiently employed to conduct in-depth surveys of highly diverse habitats where more macrophytes may be found, and where monitoring and management should be prioritized. Sites with low diversity, that are very small, or that we felt were thoroughly surveyed are not flagged for follow up surveys.

We detected the possibly invasive *Najas marina,* in two sites in in this study, and also recommend continual monitoring for this species. Future investigations should also focus on detecting and identifying individuals of *Myriophyllum* spp. to determine if invasive species or hybrids are present. Additionally, all wetlands at FCTC should be continually monitored for aquatic invasive species, so we recommend focusing these efforts on sites most vulnerable to invasion, and those listed as EOs in Table 5.

Characeae is a family of freshwater macroalgae, commonly known as the stoneworts (*Chara* spp.). Charales grow in a variety of freshwater environments in Michigan and play an important role in ecosystem structure and function (e.g. nutrient sink; Kufel and Kufel 2002), refuge and habitat for fish and macroinvertebrates (Diehl 1998, Hanson 1990), water clarity (Jeppesen et al. 1998), and are an important food source (Noordhuis et al. 2002). Although ubiquitous, the distribution of Charales in Michigan is relatively poorly known compared to other submersed macrophytes, likely due to the uncertainties and difficulties in species identification. In 2020-2021 surveys we identified Charales in 16 of 26 sites surveyed. In the future, we recommend further studies identifying the Characeae to species by laboratory identification from experts and/or by genetic analysis. The species would then be associated with habitat type to better understand aquatic systems within FCTC.

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