Fairfield Pond
Aquatic Plant Inventory

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Contents

1. Introduction

In 2018, Arrowwood Environmental (AE) was retained by the Town of Fairfield and the Fairfield Pond Recreation Association to conduct an aquatic plant inventory of Fairfield Pond. The purpose of the inventory was twofold: First, to document and map the current status of Eurasian water-milfoil (EWM) and secondly, to conduct an inventory for rare, threatened and endangered (RTE) aquatic plant species in the Pond. In addition, aquatic plant natural communities were characterized and mapped as part of this inventory. This report outlines the methodology and results of the study and presents management recommendations based on those results.

Fairfield Pond is a 446-acre surface water located in the town of Fairfield in Franklin County, Vermont. It is underlain by the Fairfield Pond bedrock formation which consists of metasedimentary phyllites. The underlying bedrock can impact the chemistry of the water, in this case resulting in a moderate-alkalinity lake. Chemistry and nutrient content of the water is also highly influenced by the nature of the surface water inputs. Fairfield Pond has a drainage basin area of 3,758 acres and a ratio of drainage basin to lake area of 8:1. In general, the larger an area that drains into a lake (or the higher the basin:lake area ratio) the more nutrients that will enter the lake from surface water inputs. The amount of nutrients entering the lake is also impacted by the landuse of the surrounding drainage basin. In the Fairfield Pond basin, landscape is a mixture of forested natural communities, rural residential development and agriculture. Both the residential development and the agricultural landuses have the potential to increase nutrients such as nitrogen and phosphorus into Fairfield Pond.

The main inlet to Fairfield Pond is on the southern end of the Pond and runs through a large wetland complex of water lily and shallow emergent marsh. To some degree, these wetlands can filter the water by removing nutrients before they reach the Pond. Two other minor inlets occur on the western side of the Pond and the wetland across Pond Road from the town beach also drains into the Pond. The main outlet is located in a cove along the eastern shore where waters leave the Pond and become part of the Missisquoi River drainage basin.

Based on the nutrient content of the water in lakes and ponds, surface waters can be classified into different trophic status. Since phosphorus is typically the limiting nutrient for aquatic plant growth, a common measurement to determine trophic status is to measure the phosphorus content of the water that is entering the lake during spring runoff and snow melt. Oligotrophic lakes are those that are nutrient poor and typically have <7 ug/l spring P. Mesotophic lakes are moderately nutrient-rich and have a spring P reading between 7-15 ug/l. Eutrophic lakes are nutrient-rich lakes that have a spring P reading > 15 ug/l. In these eutrophic lakes, because phosphorus is not limiting, aquatic plant growth (algae, cyanobacteria and aquatic macrophytes) is typically prolific often resulting in reduced water clarity. In addition, EWM typically thrives in eutrophic systems and can become a nuisance to users and threaten native aquatic communities. Spring phosphorus readings in Fairfield Pond are consistently in the 20-40 ug/l range, classifying it as a eutrophic lake.

2. Methods

The study area for the inventory consisted of the open water of Fairfield Pond and based on the boundaries of the Pond from the Vermont Hydrography Dataset. The inlet at the south end of the Pond includes extensive wetlands associated with a stream, which were not inventoried as part of this study. Only aquatic species and emergent species that typically occur within aquatic plant communities were included in this inventory. Three days of field work were conducted in mid-late July 2018 by Michael Lew-Smith. The primary inventory method used during this study was based on the Vermont Water Quality Division Field Methods Manual (2006).

Prior to field work, aerial ortho imagery of Fairfield Pond was analyzed. This included various imagery from the 1990s up to 2016 and included black and white as well as full color and color-infrared imagery. The purpose of this analysis was to create a preliminary base map of vegetation in the Pond. The most easily observed vegetation is the Water Lily Aquatic Community because this vegetation is readily visible on the surface of the water. In late-season imagery, dense beds of submerged aquatic plants could also be detected and mapped. Though this preliminary map was significantly revised during the field work, it provided a valuable base map as well as insight into the seasonal variations present in some of the aquatic vegetation.

During the field work, the littoral zone was circumnavigated with a motor boat or a kayak. The motor boat was used for the majority of the inventory while the kayak was used to inventory the shallow areas. Data was taken using a Trimble Juno GPS unit with custom data entry forms so that all data collected is linked to a specific geographic location. Narrative data not entered into the digital data forms was recorded in a field notebook. At strategic locations, data was taken on the composition and abundance of native aquatic vegetation and the abundance and distribution of EWM. If, during the inventory process, a dense infestation of EWM was encountered, the infestation was circumnavigated and the boundaries of the infestation were recorded with the GPS unit.

At selected points in each representative aquatic community (see Section 3a), a 4'X4' vegetation plot was established. The vegetation plot was used to collect detailed data on the structure and composition of the plant communities. A total of 5 plots were established as follows: a plot for the Waterlily Aquatic Community was established near the inlet; plots for the Robbin's Pondweed Assemblage were established at the Outlet Cove and on the SW shore; and plots for the Arrowhead-Quillwort Assemblage were established on the NW shore and near the beach.

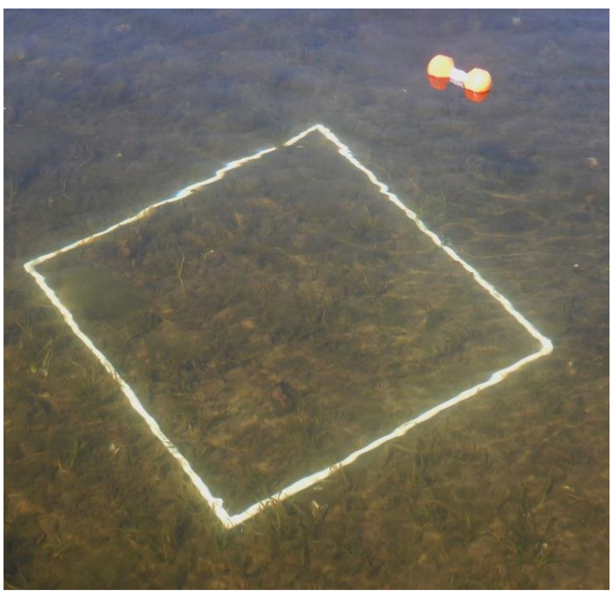

Figure 1. Vegetation Plot frame in the Arrowhead-Quillwort Assemblage

If aquatic vegetation could not be seen from the boat, an aquatic survey rake was used to take vegetation samples. In waters shallower than 12', a rake on a pole was used to sample vegetation. In waters deeper than 12', a survey rake attached to a rope was used to sample vegetation. In addition, each aquatic plant on the rake was identified to species (when possible). A view-scope was used to view the vegetation when necessary.

Once field work was completed, the data was analyzed on an ArcGIS platform. Data from the survey was used to create an aquatic natural community map, a map of EWM, and a map of RTE species.

3. Results

The results of the inventory are presented below. Section 3a outlines the results relating to native aquatic vegetation. Section 3b outlines the findings related to EWM and Section 3c includes a discussion of RTE species.

a. Native Aquatic Vegetation Communities

A natural community is an interacting assemblage of organisms, their physical environment, and the natural processes that affect them (Thompson and Sorenson, 2010). Most studies done by scientists on natural communities has been done in terrestrial systems. Much work still needs to be done on classifying groups of aquatic plants into natural communities. There are a few groups, such as the Water Lily Aquatic Community, that appear to be well-understood, common components of aquatic systems throughout the region. Other groupings of plants are referred to as “assemblages” because more studies are needed to determine if they are established groupings that warrant the “natural community” designation.

The native vegetation in Fairfield Pond has been categorized into four different types: the Robbin’s Pondweed Assemblage, the Arrowhead-Quillwort Assemblage, the Water Lily Aquatic Community and the Deep Broadleaf Marsh Community. Each of these is described below. In addition to these aquatic communities, some small areas of Cattail Marsh are present in the upland-wetland interface. Though some of these were included on the attached map, since these are mostly wetland (not aquatic) communities, they are not described below.

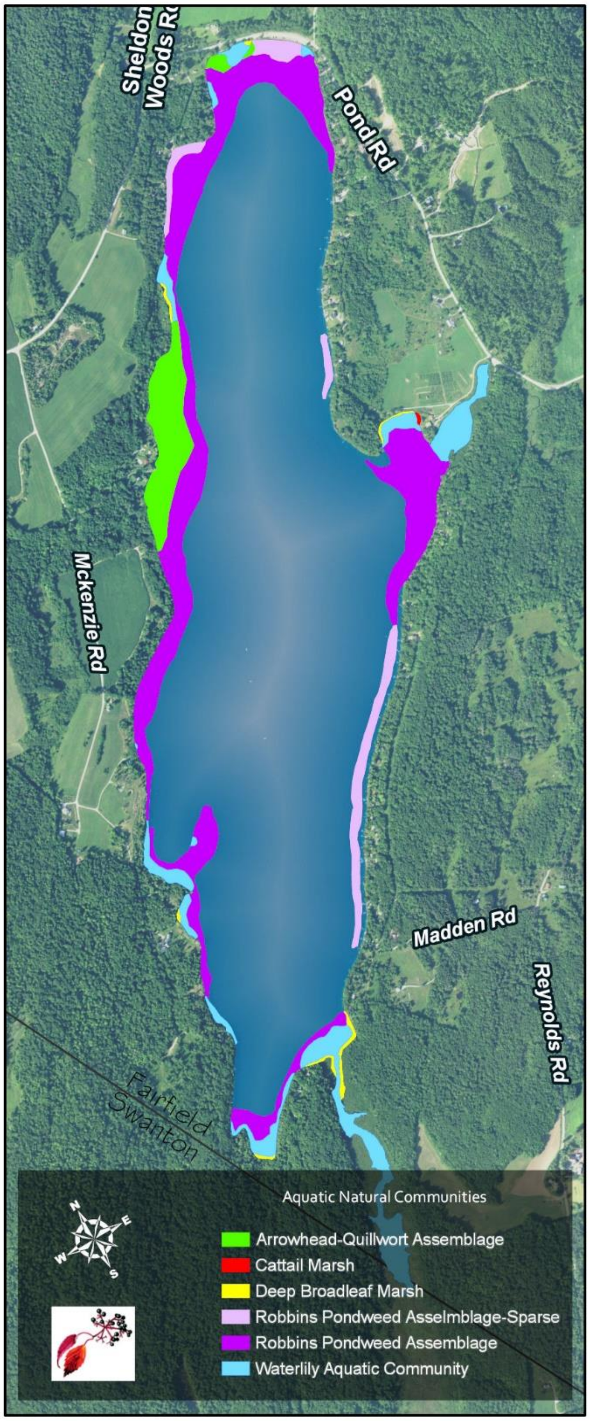

Figure 2. Native Aquatic Natural Communities in Fairfield Pond

Figure 2 shows the distribution and abundance of the different native natural communities in Fairfield Pond. As can been seen from this map, there are some areas that do not have any vegetation mapped. In general, aquatic vegetation in Fairfield Pond tends to fade out at a depth of 10-12 feet. In addition, there are many shallow, rocky areas which, in many cases, drop off steeply. While mapped as "unvegetated" these areas may contain a few scattered plants (typically large-leaved pondweed or EWM), but overall cover is less than 1%.

Robbin's Pondweed Assemblage

The Robbin's Pondweed assemblage is the most common aquatic assemblage in Fairfield Pond. It is dominated by Robbin's Pondweed, a relatively low-growing aquatic plant that is common throughout the region. This species often forms dense mats along the bottom of the Pond and can, in some areas, form mono-typic stands. However, this assemblage in Fairfield Pond also typically includes zigzag pondweed (*Potamogetom zosteriformis*) and broad-leaved pondweed (*P. amplifolius*) as co-dominants. As the waters become deeper towards the middle of the Pond, Robbin's pondweed becomes less dominant and broad-leaved pondweed becomes more common. In contrast to the low-growing Robbin's pondweed, broad-leaved pondweed can grow up to 9' tall and is the native species most often seen surfacing in Fairfield Pond.

Though dominated by those three species, this community assemblage is quite diverse and often includes other aquatic plants such as water-weed (*Elodea canadensis*), eel-grass (*Vallisneria americana*), water-naiad (*Najas flexilis*), common snailseed pondweed (*P. spirillus*) and Berchtold's pondweed (*P. berchtoldii*). Small areas of dense water-naiad can be found in some areas of this type. EWM is also found in most examples of this community throughout the Pond.

Figure 3. The Robbin's Pondweed Assemblage

In some areas of the Pond, the Robbin's pondweed vegetation is strikingly sparse, this occurs most typically on rocky shores. Overall, aquatic vegetation in these areas comprises 1-5% cover, though localized patches of more dense vegetation are present. These areas are transitional between the more densely vegetation Robbin's Pondweed areas and the areas considered "unvegetated". The distribution of both the sparse and the typical Robbin's Pondweed Assemblage is shown in Figure 2.

Arrowhead-Quillwort Assemblage

The Arrowhead-Quillwort Assemblage is found in shallow areas of silt and sand along the northern and western shores of the Pond. This assemblage is unique in that it does not contain many large submerged aquatic plants. Instead, most of the growth is in the form of short basal rosettes that escape the notice of the casual observer. It is likely that winter ice-scour and wave action play key ecological roles in the establishment of this suite of species (and the exclusion of others).

This assemblage is dominated by grass-leaved arrowhead (*Sagittaria graminea*), spiny quillwort (*Isoetes echinospora*) and leafless water-milfoil (*Myriophyllum tenellum*). A few scattered plants of the wispy Berchtold's and common snailseed pondweeds can also be found in these shallows.

Figure 3. The sparsely vegetated Arrowhead-Mud Rush Assemblage

In some areas, species such as eelgrass (*Vallisneria americana*), zigzag pondweed and common naiad (*Najas flexilis*) are also present, though typically less than 20% cover. On the deeper end of this mapped type, these larger species can become more common. Total cover of this assemblage ranges from 20% in the shallows to 60% in the deeper areas, where it grades into the Robbin's Pondweed Assemblage. The Arrowhead-Quillwort Assemblage reaches its fullest expression in shallow areas (0.5-3.5 feet in depth) where the substrate is a thin layer of silt over sand.

Figure 2 shows the distribution of this assemblage in the Pond. The northern occurrences are relatively small and sit adjacent to the boat launch and Water Lily Aquatic community. The occurrence on the western shore, however, is quite large and appears to be in excellent condition. No sign of EWM was detected in this area.

Water Lily Aquatic Community

The Water Lily Aquatic Community is a common and widespread community throughout the region. It occupies shallow, sheltered bays of many water bodies and is dominated by floating-leaved aquatic plants.

The largest occurrences of this community are found in the extensive shallow, mucky bays at the inlet and outlet of the Pond. Many smaller occurrences are also found all along the margins of the Pond where protected bays and coves form suitable habitat for this community. The dominant and most visible species in this community is water lily (*Nymphaea odorata*), which can cover 85-95% of the water's surface, where it is most dense. Another floating-leaved aquatic plant water shield (*Brasenia schreberii*) is also mixed in with the water lily, though typically at low percentage cover. Beneath these floating-leaved plants submerged aquatic plants such as grass-leaved pondweed (*P. gramineus*) and water bulrush (*Schoenoplectus subterminalis*) are present. Percent cover of these species is typically around 15%. Species such as water lobelia (*Lobelia dortmanna*) and pipewort (*Eriocaulon aquaticum*) may be present in shallow areas. In many places, this community grades into the Deep Broadleaf Marsh community. In that transition zone, species such as pickerelweed (*Pontederia cordata*) and marsh spike-rush (*Eleocharis palustris*) may also be present.

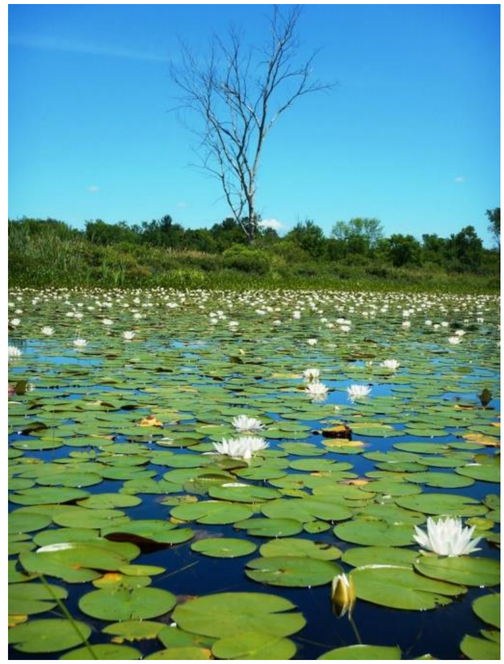

Figure 5. Water Lily Aquatic Community

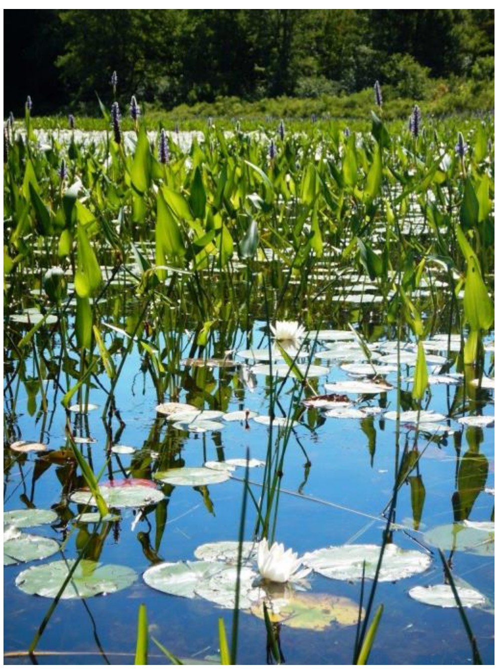

Figure 6. Deep Broadleaf Marsh

Deep Broadleaf Marsh

The Deep Broadleaf Marsh is a community that is transitional between the aquatic communities in the Pond and the more terrestrial wetland communities. As such, it has elements of both types of systems. Seven occurrences of this type have been mapped in Fairfield Pond, all narrow bands of vegetation along the shore. Most of these sit in between the Water Lily Community and the upland shore. In Fairfield Pond this community is dominated by pickerelweed. Other species such as marsh spike-rush and water lobelia are also common. Like the adjacent Water Lily Aquatic Community sites, the substrate is often organic (mucky) and the water depth is shallow (less than 2’ deep).

b. Rare, Threatened and Endangered Species

One objective of this inventory was to document and map occurrences of uncommon, rare, threatened or endangered plant species in the Pond. Appendix 1 consists of a list of all plant species documented during this inventory and includes scientific names, common names, plant family and S-rank. The “S-Rank” is a state ranking of the rarity of uncommon and rare species. An S-rank of S1 indicates that a species is “very rare” in the state. S2 indicates a “rare” species and S3 indicates an “uncommon” species in the state. The presence of one of these species could potentially have an impact on the methods and implementation of control activities. Numerous S1-S3 species have been historically documented for Fairfield Pond and are addressed below.

Vasey’s Pondweed (Potamogeton vaseyi)

This species is ranked as S2 “rare” in the state and was first documented in Fairfield Pond in 1991 by the Vermont Lakes and Ponds Management and Protection Program staff. This species is a submerged aquatic plant with thin leaves but can form small floating leaves in the early part of the summer. It was documented on the northwestern shore of the Pond in what is currently mapped as the Arrowhead-Quillwort Assemblage. In other lakes in Vermont, Vasey’s pondweed has been documented as a component of this Assemblage. However, this species has not been observed in subsequent inventories of the Pond and was not documented during the current inventory. Since this species has not been documented in the 5 inventories performed since 1991, it is likely extirpated from this Pond.

Nutall’s waterweed (Elodea nutallii)

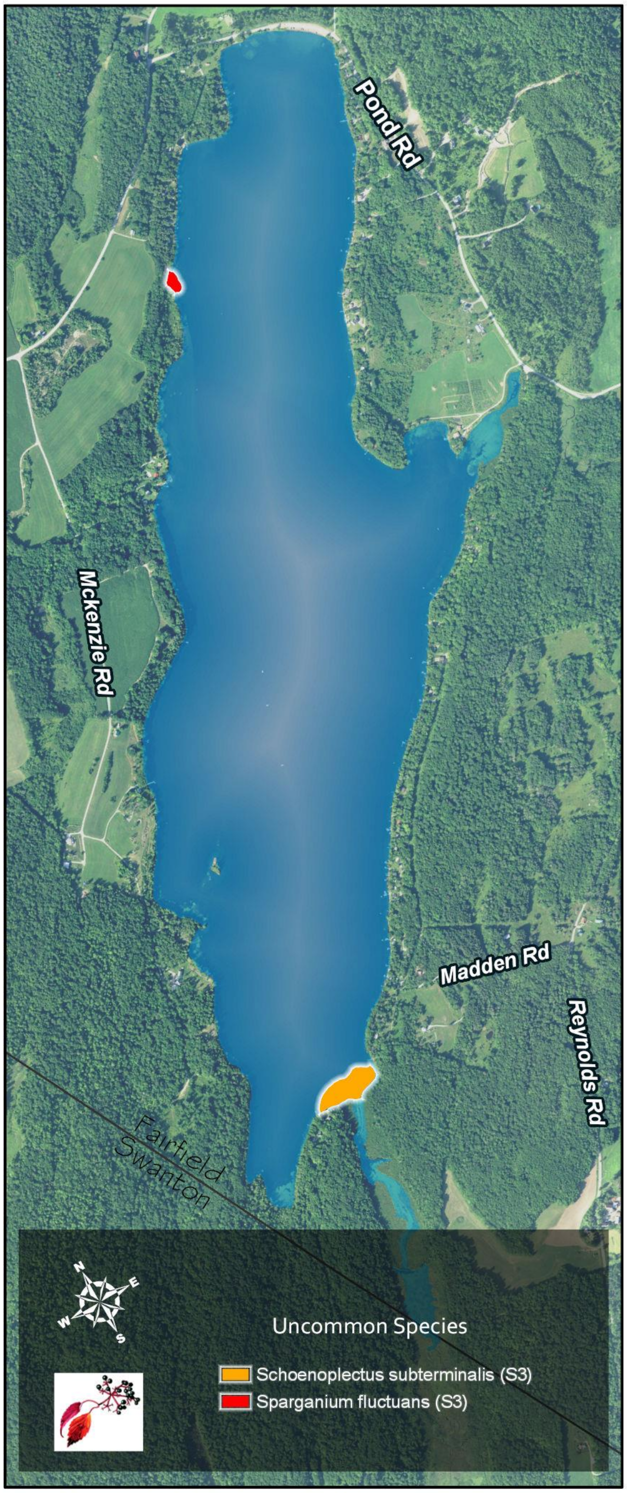

Figure 7. Uncommon Aquatic Species in Fairfield Pond

Nutall's waterweed is considered an "uncommon" (S3-ranked) species in the state and was first documented in Fairfield Pond in 1987 by the Vermont Lakes and Ponds Management and Protection Program staff. Nutall's waterweed is a close relative of the common waterweed, which is common throughout Fairfield Pond. Distinguishing between the two species based on vegetative characters can be problematic; in order to make a definitive distinction, reproductive structures should be examined. Unfortunately, this species does not always have flowers or fruits. This species was not documented during the current inventory, nor has it been observed in the 6 inventories performed since 1987. Given the difficulties is identification, it is likely that the 1987 determination was a mis-identified specimen of the common waterweed. In any case, Nutall's waterweed does not appear to be present in Fairfield Pond.

Bur-reeds (Sparganium spp.)

The bur-reeds are a genus of plants that occur with emergent leaves or, in some species, with floating leaves. Two different species of the floating-leaved bur-reeds have been documented in Fairfield Pond in the past: the common narrow-leaved bur-reed (*Sparganium angustifolium*) and the S3-ranked uncommon water bur-reed (*Sparganium fluctuans*). Both species were documented during the current inventory. The common narrow-leaved bur-reed was documented throughout the lake in shallow bays associated with the Water Lily Aquatic Community and Deep Broadleaf Marsh. The uncommon water bur-reed was documented in one area of the lake in a shallow bay on the western shore as shown in Figure 7. In this location, water bur-reed is common, comprising approximately 30% cover, many of which were in fruit during the time of the inventory.

Water bulrush (Schoenoplectus subterminalis)

Water bulrush is unlike any of the other bulrushes in that it is a fully aquatic, thread-like plant that grows in mucky substrate. In Fairfield pond, this S3-ranked uncommon plant was documented in the Water Lily Aquatic Community at the inlet. It is found throughout this community, typically at water depths between 1-3'. It grows in openings in between the water lily plants. The population is difficult to count because of its growth form but appears to be a minor but stable part of this community.

Slender Naiad (Najas gracillima)

Slender naiad is an aquatic plant that is rare (S2-ranked) in the state and was first documented in Fairfield Pond in 2012 by Vermont Lakes and Ponds Management and Protection Program staff. This species was not documented during the current inventory. In 2012, it was mapped where the inlet enters the Pond. This area is currently mapped as Robbin's Pondweed Assemblage and does not contain a dense infestation of EWM, though one does exist nearby. Since this species was not documented during the current inventory, it is unknown if it still exists in Fairfield Pond.

c. Aquatic Invasive Species

Eurasian water-milfoil (EWM) first became a problem in Fairfield Pond in the early 2000s. Since that time, EWM has spread throughout the Pond and now includes numerous dense infestations as well as moderate and low density stands. In 2005-6, as part of an effort to control EWM in the Pond, 37,000 milfoil weevils were introduced to the Pond (See Section 4a).

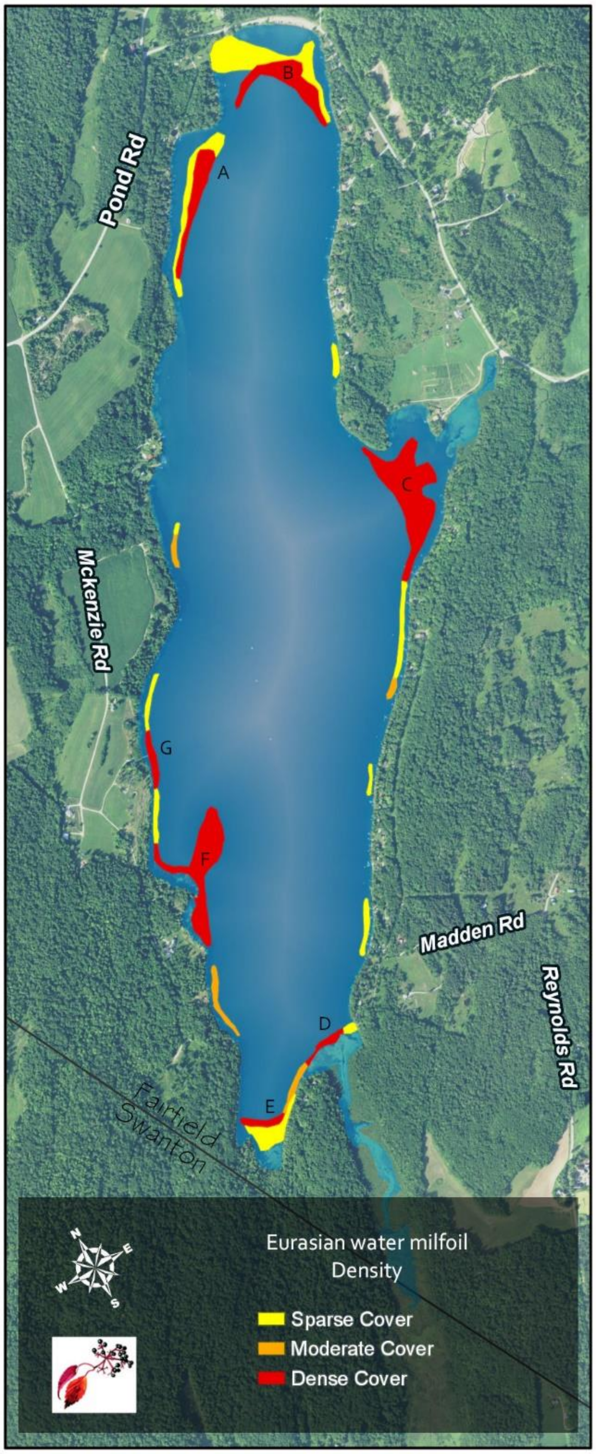

Figure 8. Distribution and Abundance of Eurasian water milfoil in Fairfield Pond

The current distribution and abundance of EWM in the Pond is shown in Figure 8 and includes areas of Sparse, Moderate and Dense cover. "Sparse" cover areas mostly consist of areas where EWM is present at 2-25% cover. In most of these mapped areas, however, cover is approximately 5% and areas up to 25% cover occur only as localized patches. The "Moderate" cover class consist of areas where EWM cover ranges from 25-50%. The "Dense" cover class includes areas where cover is in the 75-100% range. As noted in the natural community section above (Section 3a-c), there are Pond areas that are mapped as unvegetated. It should be noted that EWM is found throughout the Pond, and even these areas may contain small amounts of EWM.

Seven Dense infestations of EWM were documented in the Pond and are labeled A-G in Figure 8. These dense infestations likely serve as propagule sources for the continued spread of EWM throughout this water body. For this reason, management of these areas should be a priority. The acreage of each of these sites, along with the total acreages of the Sparse and Moderate infestations is shown in Table 1 (see Section 4b below). Each of the Dense infestation areas is briefly described below.

Dense Infestation A

On the northwestern shore of the Pond, there is a dense patch of EWM near the shoreline. This infestation is Dense (75-100% cover) on the deeper end and grades into an area of Sparse cover shoreward. This dense infestation occupies an area that was formerly occupied by the native Robbin's Pondweed Assemblage.

Dense Infestation B

The EWM in the beach area is a Dense infestation with percent cover in the 75-100% range. To the north, this dense mat of growth grades into an area with Sparse cover of EWM. The Fairfield Pond Recreation Association has placed buoys around this infestation to limit the motor-boat travel through this patch. However, expansion of EWM to the west has made avoidance of this population very difficult, especially when attempting to access the boat launch on the northern shore. EWM at this location appears to have supplanted the native Robbin's Pondweed Assemblage where it is Dense. This native community is still intact to the north where the EWM cover is Sparse.

Figure 9. Eurasian water milfoil infestation C in Fairfield Pond

Dense Infestation C

The EWM infestation in the outlet cove is also quite Dense, reaching 100% in places. EWM at this location has occupied an otherwise nice example of a native and diverse Robbin's Pondweed Assemblage. Further spread of this infestation to the east is likely, where it will continue to choke out this native community.

Dense Infestations D and E

The two infestations in the southern part of the Pond occur as relatively narrow bands of vegetation. The one near the inlet (Infestation D) is bounded on the southern side by a well-established Water Lily community. The presence of dense floating leaves of the water lily may be limiting the

EWM spread on this southern border. It is also unlikely that this infestation experiences much motor boat traffic since it is relatively shallow. The infestation in the south end cove (Infestation E) sits in a small bay and occupies an area previously occupied by the Robbin's Pondweed Assemblage. Though the Dense infestation occurs as a narrow band of vegetation, EWM at sparse low cover has begun to colonize the native vegetation to the southwest. It is likely that this infestation will continue to expand into this native community. The Fairfield Pond Association has also placed buoys around this infestation to limit the amount of boat traffic through this dense patch.

Dense Infestation F

This infestation on the western shore around the island area is also Dense, reaching 100% cover in places. It has virtually taken over the native community in this location, so it is difficult to determine what that community was prior to EWM invasion.

Dense Infestation G

Finally, Infestation G exists as a Dense narrow band of EWM along the southwestern shore of the Pond just north of the island. Since the depth drops off steeply at this location, EWM is unlikely to expand to the southeast. Expansion to the northeast and southwest, however, is likely to occur.

The EWM infestations in Fairfield Pond tend to occupy the deeper areas more than the intact native vegetative communities. It is typical for these infestations to be more prevalent in water 4-10' deep and occur as a narrow band on the deeper margin of the native communities. Since EWM is known to be tolerant of low-light conditions and deeper water, it is likely that the infestations start in these areas and, in some cases, colonize the shallower areas once they are well-established. Douglas Grant from the Fairfield Pond Recreation Association noted that EWM colonizes depths of 15-17' in Fairfield Pond. While EWM is known to grow at these depths, the current inventory documented a fairly sharp and consistent lack of vegetation at depths greater than 10-12'. Seasonal population variations and local lake conditions may account for this discrepancy.

Mr. Grant also noted that the infestations of EWM tend to move around the Pond, being present at a particular location one year and then gone the next. This is not a common or well-documented phenomenon with this species. Misha Cetner, from the Vermont Lake and Ponds Management and Protection Program noted that the only other times he has seen this occur was where the milfoil weevils had been introduced (M. Cetner, personal communication 9/25/18). More work is needed to determine if this is actually the cause of these population fluctuations.

4. Management Recommendations

Control of EWM is a substantial undertaking. The best approach is often multifaceted and based on an interacting set of factors. The size and distribution of the infestation is, of course, a main determinant of which methods should be employed. Just as important, however, are the amount of budget that is available for the tasks, recreational use of the lake, desired outcome of management, rare species in the vicinity, and the time and energy available to manage a control program. No matter what methods are employed, there are no magic bullets and control of EWM will take a prolonged and continued effort.

A wide range of tools and techniques have been developed to manage and control EWM since its introduction into North America in the 1940s. Section 4a, gives description of these different EWM management techniques. Section 4b gives recommendations about management of EWM in Fairfield Pond.

a. EWM Management Techniques

The major types of aquatic nuisance plant control can be broken up into four different categories: Biological Control, Mechanical Control, Chemical Control and Hand-Harvesting. A brief summary for each of these types is outlined below.

Biological Control

Milfoil Weevils Since the early 1990s researchers have been investigating the efficacy of controlling EWM using a native insect known as the milfoil weevil (*Euhrychiiopsis lecontei*). This insect feeds preferentially on EWM, though it can also attack native milfoils. This feeding activity cuts off the flow of carbohydrates to the roots, reducing the plant's ability to store carbohydrates over the winter, resulting in poor survivorship. Unfortunately, experiments with this control option have been unpredictable, in many cases showing little to no response. In some cases, however, EWM populations have been shown to decrease as a result of the introduction of this insect. Due to the high cost and unpredictable outcomes, this control method is no longer recommended in Vermont. Future use of these weevils could be investigated as a potential part of a multifaceted management plan.

Grass Carp Grass carp are a non-native herbivorous fish that have been used to feed on dense infestations of EWM. State law does not permit their use in Vermont due to potential detrimental impacts on aquatic ecosystems.

Chemical Control

Aquatic herbicides act as either a "contact" herbicide or a "systemic" herbicide. Contact herbicides cause immediate necrosis upon contact and only impact the plants that come in contact with them. They are faster acting but may not kill the root tissue and therefore have a more temporary impact on plant growth. Systemic herbicides act as the plant uptakes the chemical. They may be slower acting but ultimately have a longer-term impact because they can kill the entire plant.

Chemicals are generally used to treat large, lake-wide infestations of EWM. Depending on the herbicide use, however, they can also be used for treating populations that have not become established lake-wide. There are no aquatic herbicides that are specific to EWM, so their use is "non-selective" and will impact native vegetation as well. Unlike many other types of control, they have no impact on the lake sediment (nor any of the consequences associated with such perturbations). Obtaining a permit for the application of aquatic herbicides in Vermont can be a significant hurdle. In addition, in some cases there is resistance to herbicide use from property owners and citizens.

If herbicides are determined to be the best approach and these hurdles can be overcome, there are two main chemicals that are allowed in Vermont: Floridone (aka Sonar) and Triclopyr (aka Renovate or Garlon). Each of these is briefly described below.

Fluridone (Sonar) Floridone is a non-selective, systemic herbicide which disrupts carotenoid syntheses, causing bleaching of chlorophyll and ultimate death of the plant. It requires very long exposure times (30-60 days) and is therefore not appropriate in areas with currents or low residence times. Spot treatments may not therefore work that well, but it can be effective in entire lake management situations. It can be used effectively in low concentrations. Since this is a non-selective herbicide, native (and beneficial) aquatic plants will also be impacted by this herbicide.

Triclopyr (Renovate) Triclopyr is a systemic herbicide which kills the stems and roots by mimicking plant growth hormones. It is somewhat selective in that it works on broad-leaf plants like EWM but not on most monocots like pondweeds and water naiads. Exposure times are intermediate (12-60 hours) and results can be seen in 5-14 days. It can be effective for spot treatments and smaller patches due to systemic activity and shorter exposure times. Other aquatic dicots such as native milfoils, waterweeds and waterlilies can be impacted by this herbicide.

As mentioned above, a big problem with EWM is ongoing and long-term control. One problem with herbicide treatments is that without continued control activities, populations can rebound to pre-treatment levels just a few years post-treatment.

Mechanical Control

Diver-Assisted Suction Harvesting (DASH) This method of control is conducted by trained SCUBA divers pulling EWM up by the roots and using a suction harvester to transport it to the surface. On the surface, EWM is sorted from the other plants and materials that come through the harvester and the EWM is set aside. Once the boat has reached its storage capacity, it is unloaded onto shore for off-site disposal. Though a fairly expensive endeavor, this method can be quite effective since the entire plant is being removed and regrowth of EWM post-treatment is typically minimal. However, because it is labor-intensive, it is slow (averaging approximately 100m2/day (Eichler 1993)) and most appropriate for infestations under 1 acre. This method may be cost-prohibitive on populations larger than that size.

Mechanical Harvesters Mechanical harvesters are large machines that cut and (typically) remove aquatic vegetation. These machines generally cut the vegetation 5-8 feet below water surface and are used for larger scale infestations. This process is non-selective in that all aquatic plants (including native species) are removed indiscriminately. In addition, because the entire plant is not removed, vigorous re-growth of EWM is nearly guaranteed. For this reason, mechanical harvesting is often compared to mowing your lawn and, like lawn mowing, it needs to be conducted multiple times/year in order to keep the continually growing aquatic plants in check. In addition, the harvester often releases many plant fragments, which can float away from the treatment area and, in the case of EWM, form new populations elsewhere on the lake. Finally, since the costs of owning or running these complex machines can be significant, they are most appropriate where aquatic nuisance species are a long term-problem for well-travelled areas and navigation lanes (marinas etc.).

Bottom Barriers This control method works by placing heavy opaque mats over EWM infestations to smother the plants, resulting in plant death and decay. These mats are best installed before plants start growing in the spring and must be removed before winter. When properly installed and maintained, plant mortality can occur within 1 month. Like many other control methods, bottom barriers are a non-selective treatment, meaning they will kill both native and non-native species. This is an effective method for small areas (typically <1 acre) but may be too expensive for widespread use. Bottom barriers are typically used for small intensively used areas (swim areas, launches, docks etc.) or small, newly established EWM infestations.

Hydroraking This method is a mechanical control that uses a large machine to rake or scoop up plants, plant roots and sediment. This material is then placed on a barge or on shore for off-site disposal. This process can be effective in that it removes both the EWM plant and the roots. However, regrowth of EWM the year following control is likely, making this process only a temporary solution. Some plant fragmentation (and subsequent EWM growth) can occur, though not to the extent that it occurs with Mechanical Harvesters. The cost of employing this method is quite high and it is typically used on large areas or infestations. It also has a high ecological cost in that, like dredging, it removes a fair amount of sediment along with the target plants.

Figure 10. Eurasian water milfoil in Fairfield Pond

Hand-harvesting

The Hand-harvesting technique consists of individuals manually removing EWM, either by hand or with hand-held tools. If this is to be conducted, proper training is required to ensure that the entire plant (including the root crown) is removed. Careless hand harvesting can lead to fragmentation and growth of the infestations. If conducted properly, hand harvesting can be a very effective management technique. However, because it is so labor intensive it is only feasible on small infestations (typically < 0.1 acre).

No action

Doing nothing about EWM is, in the short term, easy and inexpensive. However, this approach can have significant long-term ecological and monetary costs. Many studies have shown that rapid response to new infestations are the most effective way to deal with EWM. Even in well-established populations, management of EWM may be the only way to prevent the eradication of valuable native aquatic habitat. While none of the management techniques outlined above are without certain financial and ecological costs, these costs must be weighed against the costs of doing nothing.

b. Management of EWM in Fairfield Pond

As mentioned in Section 3c, EWM has established numerous dense patches and is found throughout the Pond. Given the widespread nature of EWM establishment, eradication of this species from Fairfield Pond is not realistic. In this regard, residents should understand that EWM is now a part of the Fairfield Pond aquatic ecosystem. No matter what the level of management that is employed, some degree of EWM will be present in the Pond, and likely at levels higher than in the past.

Two general approaches to EWM management in Fairfield Pond are outlined below. The Lake-Wide Approach is discussed, but ultimately not recommended for the reasons outlined. The Targeted Approach is the recommended approach to controlling EWM in Fairfield Pond.

Lake-Wide Approach

A Lake-Wide Approach to managing EWM in Fairfield Pond would have the objective of controlling all the Dense cover infestations in the Pond. This aggressive approach would employ every available and legal method to eradicate EWM with the goal of restoring the Pond to its natural condition. Indeed, this has been the approach taken in many lakes and ponds in the region since EWM control efforts have been initiated.

The most realistic option for Lake-Wide control of infestations of this size are to apply chemical treatments. Given the size of the dense infestations in Fairfield Pond, totaling 21 acres, hand harvesting and mechanical harvesting control methods are not a feasible alternative for this approach.

While chemical treatment has been a standard solution employed for many years at other lakes, there are several disadvantages to this approach. First, there is a misconception that herbicide use will eradicate the EWM. Long-term use of chemical treatment in other Vermont lakes has shown that while application of herbicide can give short-term control, long-term eradication is not obtained. In order to maintain even the short-term control effect, continual and repeated herbicide application is often required. Secondly, the widespread use of herbicide in aquatic systems has a negative impact on non-target organisms. For Fairfield Pond, this would include members of the diverse native plant communities as well as the three rare and uncommon plant species that may inhabit the Pond. Third, obtaining widespread community support for aquatic herbicide application will be difficult. Since a Lake-Wide herbicide application would impact all the users of the Pond, there would be many stakeholders (with widely varying viewpoints) involved in the decision-making process.

Finally, any control of EWM other than hand-pulling requires an Aquatic Nuisance Control permit from the Vermont Department of Environmental Conservation, Lakes and Ponds Management and Protection Program. This Program recently denied a permit to apply Triclopyr to control EWM in Lake Iroquois, where EWM has become much more widespread than in Fairfield Pond. One of the reasons cited was that not all of the other (non-chemical) options had been employed to control EWM. In general, the Lakes and Ponds Management and Control Program is moving away from allowing chemical treatment and focusing more on other methods of control. It is unlikely that a permit to conduct herbicide treatments in Fairfield Pond would be approved.

Targeted Approach

In contrast to the Lake-Wide Approach, the Targeted Approach does not rely on chemical treatment and focuses instead on controlling smaller areas of EWM infestation using non-chemical means. When employing this approach, it is critical that lake managers prioritize areas of control. This prioritization should consider a number of factors, including recreational use of different areas of the Pond, presence of native communities and rare species, and the degree of threat that EWM is posing to each of these factors. Based on data obtained during the current inventory, a draft prioritization is presented below. However, final prioritization should include input from Pond stakeholders including Fairfield Pond Recreation Association members, landowners, lake users and state officials.

Table 1 lists each of the EWM infestation areas that are shown in Figure 8 along with the acreage of each area, and a priority rank for control.

Table 1: Size of EWM Infestations in Fairfield Pond and Control Prioritization

Density	Label	Acres	Prioritization
Sparse Cover (Total)	NA	12.34	Control not recommended
Moderate Cover (Total)	NA	1.86	Control not recommended
Dense Cover	A	2.73	Low
Dense Cover	B	3.53	High
Dense Cover	C	7.78	Moderate
Dense Cover	D	0.53	Moderate
Dense Cover	E	0.70	Moderate
Dense Cover	F	5.42	Low
Dense Cover	G	0.74	Low
Dense Cover (Total)		21.44	

Given the number of Dense infestations, control activities in the areas of sparse and moderate cover are not recommended. In these areas, because EWM is sparsely distributed, control activities are not cost effective and the positive impact would be negligible.

The highest priority for control action should be Infestation B. This 3.5-acre patch sits just off shore of the public beach on the north end of the Pond and is hard to avoid when navigating a motor boat to and from the boat launch on the north end. Continued motor boat traffic through this area will serve to encourage fragmentation of the EWM plants, which will facilitate EWM spread throughout the Pond.

Control of Infestations C and E are listed as moderate because they may be threatening nearby diverse Robbin's Pondweed communities. Control of Infestation C in particular, however, will be very difficult because of its size. If control actions are undertaken at these sites, the focus should be on preventing EWM from spreading into the native aquatic plant communities. Infestation D is also listed as moderate priority. Spread may be somewhat contained to the north by water depth and to the south by the Water Lily Community. However, the potential presence of the rare water naiad plant to the east and the uncommon water bulrush to the south may warrant some action, especially if the naiad is documented in the Pond in a future survey.

The second largest area of EWM in the Pond is Infestation F. Because of its size, this infestation will be difficult to control. In addition, it already appears to have taken over much of the native vegetation in this area. This area is less of a priority since it is well-established and does not appear to be threatening any native vegetation or important human use.

The most appropriate methods for targeted control of priority infestations are DASH, Bottom Barriers or a combination of the two. As mentioned in Section 4a, both methods can provide effective control over small areas. Employing one or both of these methods is particularly recommended in Infestation B, where prevention of colonization of the beach area and maintaining a channel for navigation are a priority. Using these methods in other infested areas as appropriate would also be effective, at least locally in the area of control.

Additionally, "grassroots" control efforts that are currently being conducted, or could be conducted, should also be considered a component of the Targeted Approach method. The Fairfield Pond Recreation Association has placed buoys around some of the dense infestations in the Pond. This practice should be continued for several reasons. First, it can prevent motor boat traffic through some of these areas, which can help to decrease the rate of EWM spread. Secondly, it can raise awareness of the EWM problem in the Pond. Increasing the number of buoys around the infestations along with providing signage would help in both of these endeavors.

Members of the Recreation Association also regularly rake the beach to remove EWM fragments. This is an important way to slow or prevent the spread of EWM into this area and should be continued if possible. Finally, the shallow beach area should be scanned for EWM regularly during the growing season. Since EWM has not become established here yet, control can occur via hand-pulling. There is the potential to hold public EWM control events where volunteers are trained to extract the entire plant (roots and stems) and can help with this process. This would not only make the task easier, it would also raise awareness about the EWM issues in the Pond.

5. Conclusion

Fairfield Pond is home to a diverse assemblage of native aquatic vegetation which provides valuable habitat for benthic organisms and fish. Unfortunately, it is also an impaired waterbody with high levels of phosphorus loading from the surrounding landscape. These conditions have created ideal habitat for the invasion of Eurasian water milfoil. This invasive species is present throughout the Pond and has formed dense infestations in 7 different areas. While complete eradication of this invasive species is not realistic, targeted control should allow for maintenance of a healthy lake ecosystem and continued recreational use by people.

Appendix 1

List of Plant Species Documented in Fairfield Pond

Rare, Threatened and Endangered Plant Inventory

Report Date: 10/19/2018

Project Name Fairfield Pond

Botanist Michael Lew-Smith

Survey Date 7/1/2018

Description Aquatic Plant Inventory of Fairfield Pond

Plant List

note: plants with no listed S-Ranks are considered common in Vermont.

Plant Name	Common Name	S-Rank*	T/E	Plant Family
Sagittaria graminea	grass-leaved arrowhead			Alismataceae
Bidens beckii	water-marigold			Asteraceae
Lobelia dortmanna	water lobelia			Campanulaceae
Carex lasiocarpa	hairy-fuited sedge			Cyperaceae
Eleocharis palustris	marsh spike-rush			Cyperaceae
Schoenoplectus acutus	hard-stemmed bulrush			Cyperaceae
Schoenoplectus subterminalis	water bulrush	S3		Cyperaceae
Equisetum fluviatile	water horsetail			Equisetaceae
Eriocaulon aquaticum	pipewort			Eriocaulaceae
Myriophyllum spicatum	Eurasian water-milfoil			Haloragaceae
Myriophyllum tenellum	leafless water-milfoil			Haloragaceae
Elodea canadensis	water-weed			Hydrocharitaceae
Najas flexilis	common naiad			Hydrocharitaceae
Vallisneria americana	eel-grass			Hydrocharitaceae
Isoetes echinospora	spiny quillwort			Isoetaceae
Utricularia macrorrhiza	common bladderwort			Lentibulariaceae
Myrica gale	sweet gale			Myricaceae
Brasenia schreberi	water shield			Nymphaeaceae
Nuphar variegata	common yellow pond-lily			Nymphaeaceae
Nymphaea odorata	waterlily			Nymphaeaceae
Pontederia cordata	pickerelweed			Pontederiaceae
Potamogeton amplifolius	broad-leaved pondweed			Potamogetonaceae
Potamogeton berchtoldii	Berchtold's pondweed			Potamogetonaceae
Potamogeton epihydrus	ribbon-leaved pondweed			Potamogetonaceae
Potamogeton foliosus	leafy pondweed			Potamogetonaceae
Potamogeton gramineus	grass-leaved pondweed			Potamogetonaceae
Potamogeton natans	floating pondweed			Potamogetonaceae
Potamogeton perfoliatus	clasping-leaved pondweed			Potamogetonaceae
Potamogeton richardsonii	Richardson's pondweed			Potamogetonaceae
Potamogeton robbinsii	Robbins' pondweed			Potamogetonaceae

Rare, Threatened and Endangered Plant Inventory

Report Date: 10/19/2018

Plant Name	Common Name	S-Rank*	T/E	Plant Family
Potamogeton spirillus	common snailseed pondweed			Potamogetonaceae
Potamogeton zosteriformis	zigzag pondweed			Potamogetonaceae
Cephalanthus occidentalis	buttonbush			Rubiaceae
Sparganium angustifolium	narrow-leaved bur-reed			Typhaceae
Sparganium fluctuans	water-bur-reed	S3		Typhaceae