Report For:
Wildwood Property Association
Tolland, Massachusetts

CRANBERRY AND OTTER PONDS
Field Assessment - 2021

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Introduction

Aquatic Restoration Consulting, LLC (ARC) performed a field assessment of Cranberry and Otter Ponds within the Wildwood Property Owners Association community in Tolland, Massachusetts on September 25, 2021. The intent of the survey was to repeat prior surveys, conducted in 2011, 2014 and 2017 by Water Resource Services (WRS), and compare recent data with prior work. The motivation for these repeated surveys is to identify the risk of deleterious impacts to habitat quality and recreational opportunities and provide recommendations to reduce these risks. Much of the information herein is repeated from the prior assessments prepared by WRS for consistency, which was modified to include 2021 data and update recommendations.

Approach and Methods

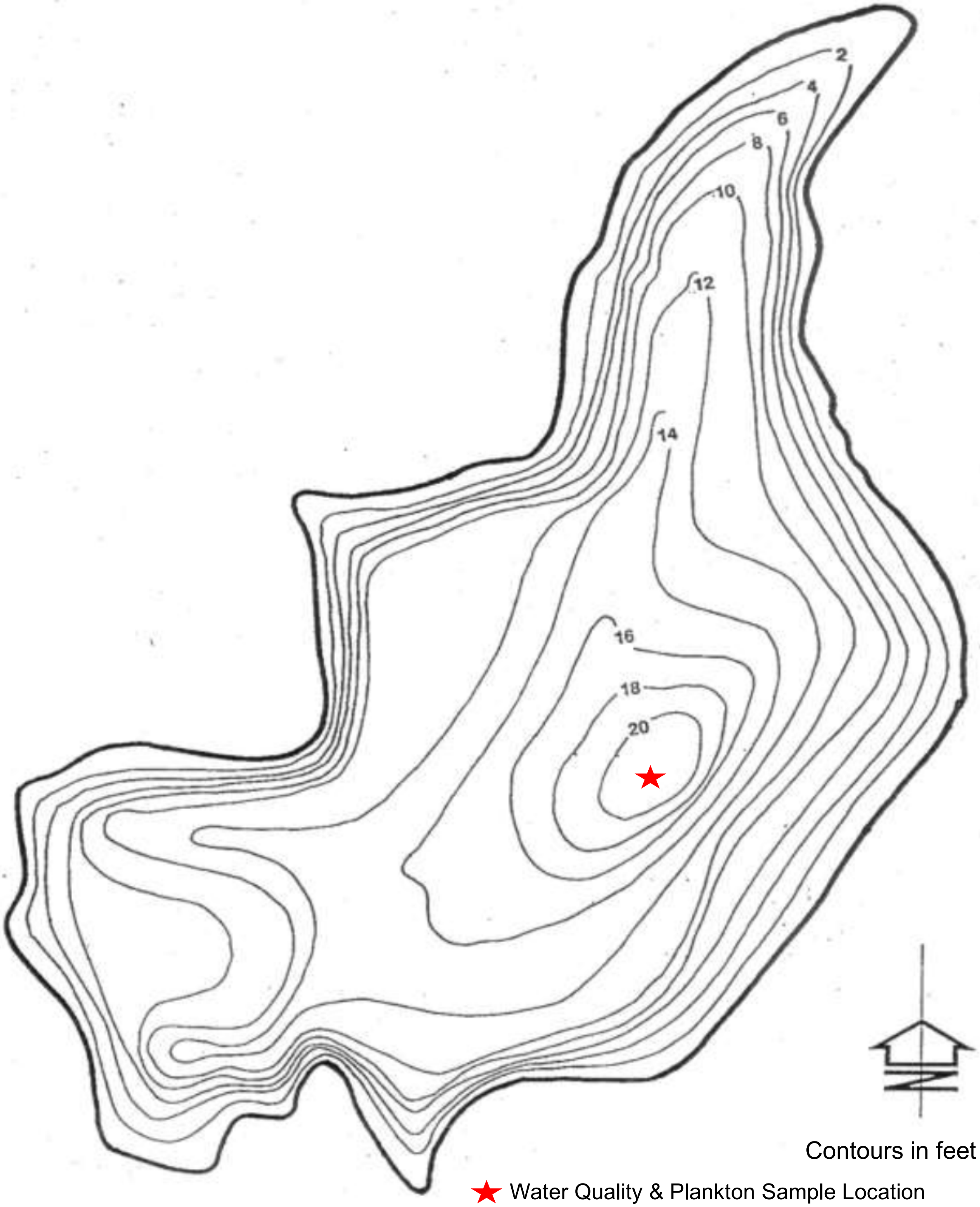
ARC performed the field survey on September 25, 2021. Prior surveys were conducted mid-summer in July. Scientists evaluated water quality in both ponds including depth profile in-situ measurements of temperature, dissolved oxygen, pH, conductivity and turbidity at Cranberry Pond and surface water measurements at Otter Pond. Scientists collected grab water samples at the surface in both ponds and near the sediment-water interface at a deep location in Cranberry Pond (Figure 1). A Massachusetts State Certified analytical laboratory analyzed samples for total suspended solids (TSS), dissolved organic carbon (DOC) and nutrients [total phosphorus (TP), dissolved phosphorus (DP), nitrite and nitrate nitrogen (NO_2+NO_3), total Kjeldahl nitrogen (TKN) and ammonia (NH_3)]. All samples were placed in laboratory provided pre-preserved bottles and stored on ice. A grab sample was also collected at the surface of both ponds for phytoplankton analysis. A scientist used a 30-meter plankton tow net with 80µ mesh to collect a zooplankton sample for analysis. Plankton samples (phyto- and zoo-) were preserved with glutaraldehyde and delivered to Dr. Kenneth Wagner, from WRS, who performed quantitative analyses using a phased contrast microscope at 100-400X magnification.

ARC scientists assessed the macrophyte (plants large enough to be seen with the naked eye) community along the same observation points used in prior surveys. The observation points (Figure 2) were located using a hand-held global positioning system (GPS). The scientists observed plants using an underwater video system (AquaVu®). A rake toss was also used to confirm plant species identification seen in the video monitor. The plant species observed were identified to the genus and species level when readily identifiable in the field.

At each location, a scientist recorded plant cover (the estimated areal occupation of plants in two dimensions) and plant biovolume (the estimated portion of the water column occupied with plants in three dimensions) and categorized these observations on a numerical scale (Table 1). The scientist estimated the density of each plant species observed and categorized as show in Table 1.

Table 1. Plant Survey Categories

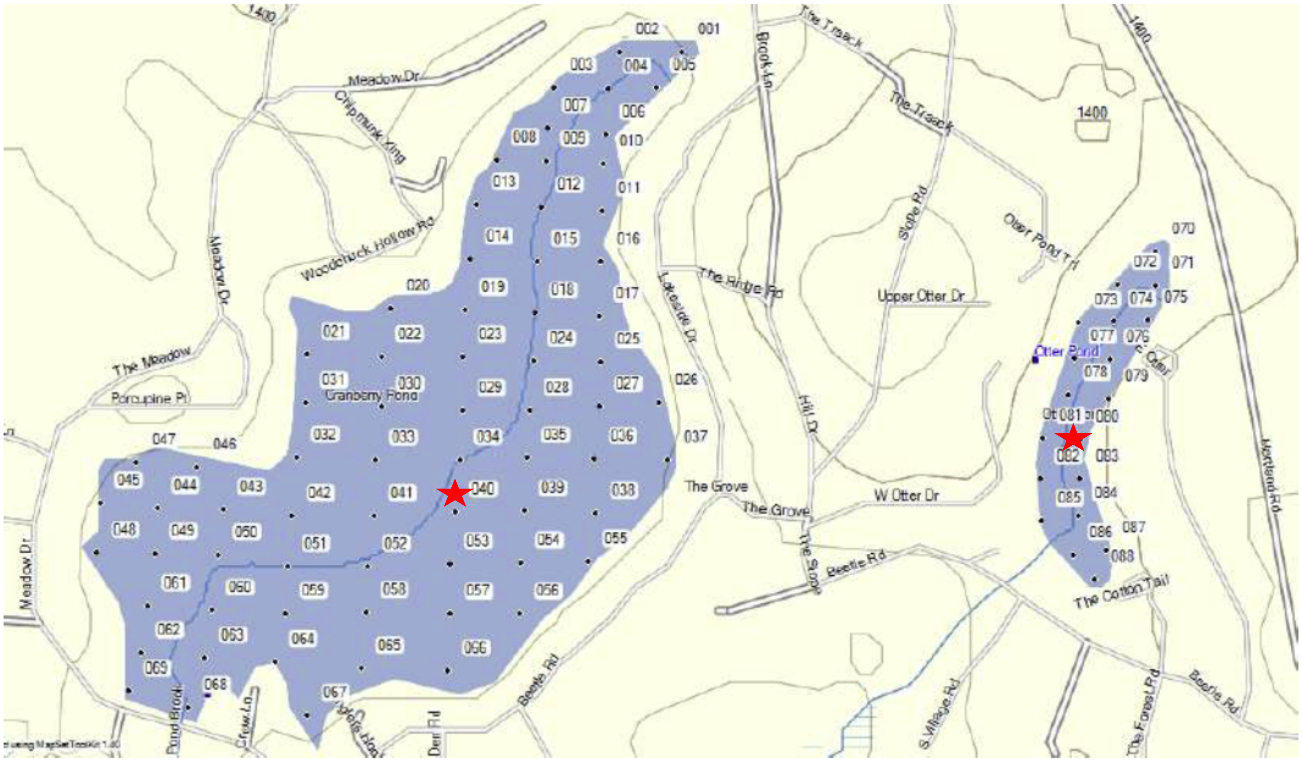
Plant Cover/Biovolume	Plant Density
0 = no plants	Trace – single to a few plants
1 = 1-25%	Sparse – multiple plants but not abundant, about a handful
2 = 26-50%	Moderate – numerous plants but not dominant, about a rake full
3 = 51-75%	Dense – very abundant, more than a rake full
4 = 76-100%	



Contours in feet

★ Water Quality & Plankton Sample Location

Figure 1. Cranberry Pond Bathymetry and Water Sample Location.



★ Water Quality & Plankton Sample Location

GPS pt #	Lat/Long.		GPS pt #	Lat/Long.		GPS pt #	Lat/Long.		GPS pt #	Lat/Long.
1	N42 04.120 W73 00.041		23	N42 03.923 W73 00.239		45	N42 03.829 W73 00.568		67	N42 03.691 W73 00.380
2	N42 04.121 W73 00.098		24	N42 03.921 W73 00.176		46	N42 03.852 W73 00.480		68	N42 03.696 W73 00.488
3	N42 04.097 W73 00.157		25	N42 03.920 W73 00.115		47	N42 03.855 W73 00.535		69	N42 03.707 W73 00.542
4	N42 04.097 W73 00.107		26	N42 03.893 W73 00.062		48	N42 03.797 W73 00.571		70	N42 03.991 W72 59.613
5	N42 04.097 W73 00.065		27	N42 03.891 W73 00.115		49	N42 03.796 W73 00.519		71	N42 03.969 W72 59.614
6	N42 04.067 W73 00.111		28	N42 03.889 W73 00.179		50	N42 03.795 W73 00.461		72	N42 03.970 W72 59.648
7	N42 04.071 W73 00.163		29	N42 03.889 W73 00.239		51	N42 03.788 W73 00.398		73	N42 03.946 W72 59.683
8	N42 04.051 W73 00.209		30	N42 03.891 W73 00.313		52	N42 03.788 W73 00.325		74	N42 03.946 W72 59.652
9	N42 04.050 W73 00.164		31	N42 03.893 W73 00.382		53	N42 03.789 W73 00.252		75	N42 03.947 W72 59.621
10	N42 04.048 W73 00.113		32	N42 03.858 W73 00.390		54	N42 03.790 W73 00.187		76	N42 03.922 W72 59.655
11	N42 04.018 W73 00.114		33	N42 03.856 W73 00.319		55	N42 03.791 W73 00.126		77	N42 03.922 W72 59.687
12	N42 04.020 W73 00.169		34	N42 03.857 W73 00.242		56	N42 03.757 W73 00.188		78	N42 03.898 W72 59.692
13	N42 04.022 W73 00.227		35	N42 03.858 W73 00.181		57	N42 03.757 W73 00.251		79	N42 03.896 W72 59.656
14	N42 03.987 W73 00.232		36	N42 03.857 W73 00.120		58	N42 03.758 W73 00.327		80	N42 03.870 W72 59.683
15	N42 03.985 W73 00.173		37	N42 03.856 W73 00.054		59	N42 03.757 W73 00.400		81	N42 03.870 W72 59.716
16	N42 03.985 W73 00.115		38	N42 03.822 W73 00.119		60	N42 03.759 W73 00.467		82	N42 03.844 W72 59.718
17	N42 03.949 W73 00.116		39	N42 03.823 W73 00.184		61	N42 03.762 W73 00.526		83	N42 03.845 W72 59.683
18	N42 03.952 W73 00.174		40	N42 03.823 W73 00.247		62	N42 03.732 W73 00.531		84	N42 03.820 W72 59.684
19	N42 03.954 W73 00.237		41	N42 03.820 W73 00.320		63	N42 03.729 W73 00.473		85	N42 03.817 W72 59.717
20	N42 03.955 W73 00.305		42	N42 03.820 W73 00.394		64	N42 03.726 W73 00.410		86	N42 03.795 W72 59.688
21	N42 03.925 W73 00.380		43	N42 03.824 W73 00.457		65	N42 03.722 W73 00.331		87	N42 03.798 W72 59.659
22	N42 03.924 W73 00.314		44	N42 03.825 W73 00.517		66	N42 03.720 W73 00.253		88	N42 03.780 W72 59.668

Figure 2. Cranberry and Otter Pond Water Sample and Plant Survey Observation Locations (modified from WRS 2017).

Assessment

Water Quality

In-situ measurements

Cranberry Pond is thermally stratified with the thermocline (boundary between upper, warmer, well lit layer and lower, colder, darker layer) present at approximately 3.5 meters (m) or 11.5 feet (ft) during the summer months. In 2021, the pond was not stratified during the survey because it was conducted later in the season when the lake started to turnover (i.e., mix)(Figure 3). Oxygen was depressed at the thermocline and hypoxic (low) to anoxic (no oxygen) in 2011, 2014 and 2021 at depths greater than 16 feet (Figure 3). The survey in 2017 did not exhibit anoxia and was conducted about 20 days earlier in the summer than previous July surveys. The bottom water layer covers only 10-15% of the lake bottom and represents only 3-4% of the lake volume (about 30 out of 900 acre-feet of water). With an average depth of about 12 ft, most of the 75-acre lake will not experience oxygen problems, but the deepest portion does experience low to no oxygen. Waters containing dissolved oxygen above 5.0 milligrams per liter (mg/L) are considered supportive for aquatic life, in accordance with Massachusetts State Water Quality Standards. In the absence of oxygen, certain undesirable chemical compounds will accumulate in the bottom water layer, most notably dissolved and particulate phosphorus, iron and manganese, ammonia, and possibly hydrogen sulfide.

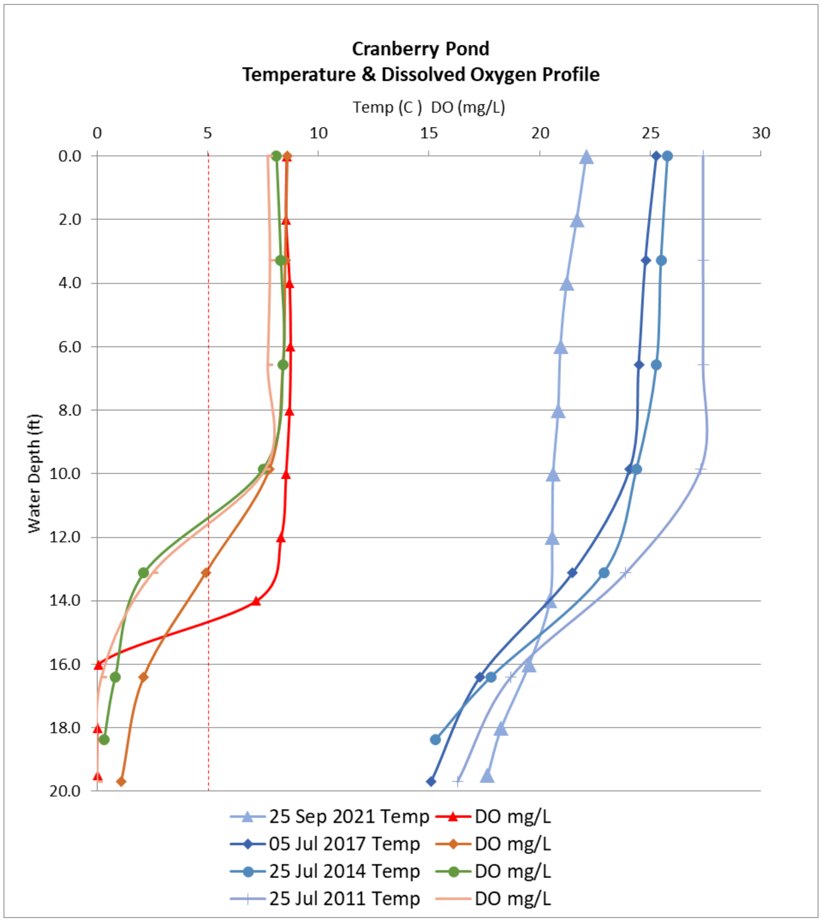


Figure 3. Cranberry Pond Temperature and Dissolved Oxygen Depth Profile.

Otter Pond was sampled at one location at the surface and contained ample oxygen (8.3 mg/L) in 2021 (Table 2), which is similar to prior years (Appendix A). Otter Pond is shallower than Cranberry Pond and does not stratify to any great extent, but low oxygen near the bottom is still possible in the deepest parts. Otter Pond has a maximum depth of about 10 ft and an average depth of about 5 ft. Because it is relatively shallow, the pond will occasional mix from wind which will limit accumulations of undesirable compounds near the bottom; however, the circulation of these compounds into the upper waters may foster greater algal growth and a less desirable appearance.

Table 2. In-Situ Water Quality Data.

Cranberry Pond								
	Depth (m)	**Depth (ft)**	**Temp (°C)**	**DO (mg/L)**	**DO Sat (%)**	**pH (SU)**	**Sp. Cond. (µS/cm)**	**Turbidity (NTU)**
	Surface	Surface	22.12	8.56	97.3	7.0	49	0.9
	0.6	2	21.69	8.53	96.4	7.0	49	1
	1.2	4	21.23	8.69	97.1	7.0	48	1
	1.8	6	20.95	8.74	97.2	7.0	49	1
	2.4	8	20.85	8.69	96.7	7.0	49	1.1
	3.0	10	20.62	8.53	93.9	7.0	49	1.1
	3.7	12	20.58	8.31	92.3	6.9	49	1.2
	4.3	14	20.47	7.20	79.2	6.8	49	1.3
	4.9	16	19.53	0.05	0.6	6.9	59	1.4
	5.5	18	18.27	0.00	0	7.0	107	1.3
	5.9	19.5	17.65	0.00	0	6.9	133	0.8
Otter Pond								
	Surface	Surface	21.39	8.26	92.6	6.7	49	0.0

Conductivity measures the quantity of dissolved solids in water. It is a rough indicator of overall fertility, or potential productivity. Conductivity in Cranberry Pond is low [<100 microsiemens per centimeter (µS/cm)] and fairly uniform throughout most of the water column. Conductivity is higher right at the bottom, undoubtedly in response to release of compounds from the bottom sediment in the absence of oxygen, however, concentrations are low and not a concern in this instance. Surface conductivity was slighter higher in 2017 (76 & 95 µS/cm in Cranberry and Otter Ponds respectively) than 2011 (51 and 59 µS/cm) and 2014 (44 & 54 µS/cm). The results of the 2017 assessment raised some concerns about road salt impact to the ponds, but 2021 values (49 µS/cm at both ponds) were lower than 2017 and more similar to 2011 and 2014 (Appendix A).

Turbidity measures the amount of suspended solids in the water column, including algae and suspended sediment. Turbidity values in Cranberry Pond were low [<1.5 Nephelometric Turbidity Units (NTU)] in 2021. Values were slightly higher in 2014 and 2017 (Appendix A), but none of the values were concerning and surface values were comparable (2.5 and 2.7 NTU in 2014 and 2017 respectively). Otter Pond values were higher than Cranberry Pond in the past, but 2021 surface turbidity was 0.0 NTU compared to Cranberry Pond with 0.9 NTU.

Turbidity affects water clarity. Field measurement of water clarity are made using a Secchi disk. Secchi disk transparency (SDT) in Cranberry Pond in 2021 was 2.8 m (9.3 ft) slightly lower than the past three sampling years (maximum difference 0.9 m or 2.8 ft; Figure 4; Table 3). This could be the result of survey timing: 2021 the pond was nearly mixed whereas the prior years were mid-summer during stratification. SDT in Otter Pond was 2.3 m in 2021 and reached the pond bottom at 2.6 m in 2014 and 2.8 m in 2017.

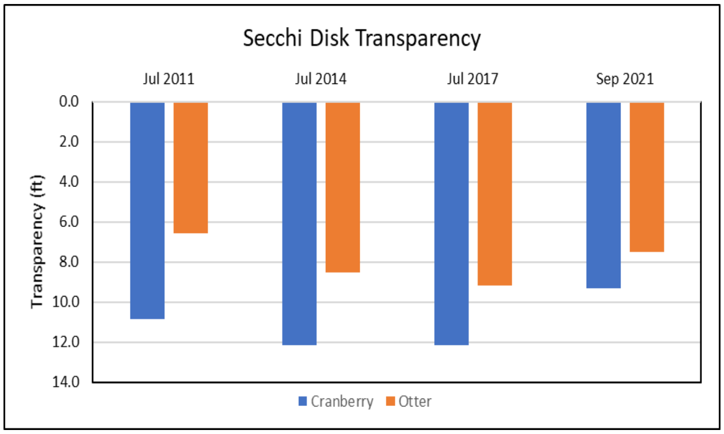


Figure 4. Secchi Disk Transparency.

Table 3. Secchi Disk Transparency.

	Cranberry SDT		Otter SDT	
	m	ft	m	ft
Jul 25, 2011	3.3	10.8	2.0	6.6
Jul 25, 2014	3.7	12.1	2.6	8.5
Jul 5, 2017	3.7	12.1	2.8	9.2
Sep 25, 2021	2.8	9.3	2.3	7.5

pH is a measure of hydrogen ion concentration and provides an indication of whether the water is acidic [pH <7 standard units (SU)] or basic (pH>7 SU)]. Values for Cranberry Pond were nearly neutral with little variance (difference of 0.2 SU; ranged from 6.8 to 7.0 SU; Table 2). pH in prior years ranged from 6.3 to 7.4 SU in 2011, 6.4 to 7.5 SU in 2014 and 6.2 to 6.7 SU in 2017 (Appendix A). As pH is on a logarithmic scale and as such, small differences can indicate large changes. The change in pH in Cranberry Pond from top to bottom during the summer surveys indicate different water quality in the two water layers. The difference is mainly due to photosynthesis by algae in the upper water and decomposition of organic matter in the lower water; these influences can vary over time within a season and among years. The pH in Otter Pond was slightly acidic in 2021 (6.7 SU) and comparable to prior years, which ranged from 6.8 to 7.4 SU (Appendix A). Based on the geology of the area, one might reasonably expect slightly acidic values, so the higher values in the ponds during the summer suggest algal activity with little buffering capacity.

Buffering capacity is the ability of water to withstand changes in acid content and is measured as alkalinity. Alkalinity values <20 mg/L are considered low, and values <10 mg/L are very low. Alkalinity was not measured in 2021, but prior values for each pond were 8-10 mg/L. The ponds are subject to swings in pH relating to algal activity, acidic precipitation, snowmelt, and other such influences due to low buffering capacity. This is a natural condition, but not necessarily a desirable one.

Nutrients, Total Suspended and Dissolved Organic Carbon

Grab water samples for Cranberry Pond suggest that nutrients are present in moderate to high concentrations (Table 4). Total phosphorus (TP) is above the threshold that is capable of supporting algal blooms. This threshold is generally 0.025 mg/L, although in some lakes concentrations as low as 0.020 mg/L are supportive of blooms. Much of the phosphorus in Cranberry Pond is in the dissolved form and readily available for algal uptake. Otter Pond TP is excessive (0.060 mg/L) and well above the threshold known to support blooms. The dissolved portion was much lower, although still elevated. It is difficult to draw conclusions based on one sample. ARC understands that the Wildwood Property Owners Association performs routine monitoring and these data should be compared to Association's data to determine if 2021 is an outlier or if these data are representative of average conditions. TP values this high are concerning.

Table 4. Nutrients, TSS & DOC in Cranberry and Otter Ponds.

	TP	DP	NO_2+NO_3	TKN	NH_3	TSS	DOC
Cranberry							
Surface	0.028	0.029	<0.03	0.62	0.13	<5	6.80
Bottom	0.025	0.013	<0.03	1.40	0.78	8	6.26
Otter							
Surface	0.060	0.021	<0.03	0.63	0.12	<5	8.24

Total nitrogen concentrations [(the sum of total Kjeldahl nitrogen (TKN) and nitrate+nitrite nitrogen)] less than 0.3 mg/L in lakes is considered low, values between 0.3 and 1.0 mg/L are moderate and values exceeding 1.0 mg/L are high. TN was in the moderate range at the surface in both ponds but elevated at the bottom sample in Cranberry Pond. This elevated value was primarily driven by increased organic nitrogen and ammonia concentrations. Elevated ammonia is common in anoxic waters and suggest undesirable conditions for fish and aquatic life.

Both total suspended solids (TSS) and dissolved organic carbon (DOC) reduce water clarity. TSS in both Cranberry and Otter Ponds were below detection at the surface, but an elevated near the bottom in Cranberry Pond. DOC values in this range are typical of ponds in this ecoregion. It is a relatively stable water quality variable and large changes over time can suggest climate and watershed changes.

Plankton

Samples for phytoplankton and zooplankton were collected from each pond during the September 2021 assessment. Analysis of phytoplankton (algae in the water column) suggests that golden algae (chrysophytes) were dominant in both Cranberry and Otter Ponds in September. Although it is very common for golden algae to dominate this time of year, biomass of golden algae was high (20,823 ug/L) in Cranberry Pond (Table 5, Figure 5). Samples collected mid-summer in prior years suggest that golden algae (chrysophytes) and dinoflagellates were most abundant in Cranberry Pond; however, biomass of golden algae in prior years was one to two orders of magnitude lower than 2021 (Figure 5; Appendix A). Otter Pond algal biomass was much lower (1,415 ug/L) than Cranberry Pond and within the range of prior years. Green algae (chlorophytes) and dinoflagellates (pyrrhophytes) were the most abundant phytoplankton group in Otter Pond in the past. Of concern was the presence of *microcystis,* a cyanobacteria known to produce toxins, was observed but hasn't been reported in prior years (Appendix A). Other algal groups were represented but not abundant in each pond. Generally, biomass below 1,000 ug/L is considered low and between 1,000 and 3,000 ug/L algae issues become more noticeable, with variation based on the types of algae dominating. During golden algal blooms the water may appear yellowish or coppery brown color and can cause taste and odor issues for drinking water supplies. During a cyanobacteria blooms water may appear green to green-blue, like pea soup.

Table 5. Cranberry and Otter Ponds Phytoplankton September 2021.

SEPTEMBER 25, 2021	**PHYTOPLANKTON DENSITY (CELLS/ML)**		**PHYTOPLANKTON BIOMASS (UG/L)**	
TAXON	**Cranberry**	**Otter**	**Cranberry**	**Otter**
BACILLARIOPHYTA				
Centric Diatoms				
Urosolenia	0	57	0.0	68.4
Araphid Pennate Diatoms				
Synedra	0	23	0.0	18.2
Monoraphid Pennate Diatoms				
Biraphid Pennate Diatoms				
Navicula/related taxa	0	23	0.0	11.4
Nitzschia	0	46	0.0	36.5
CHLOROPHYTA				
Flagellated Chlorophytes				
Coccoid/Colonial Chlorophytes				
Elakatothrix	41	46	4.1	4.6
Filamentous Chlorophytes				
Desmids				
CHRYSOPHYTA				
Flagellated Classic Chrysophytes				
Chrysosphaerella	8096	228	3238.3	91.2
Dinobryon	5850	205	17551.2	615.6
Mallomonas	0	23	0.0	11.4
Synura	41	0	33.0	0.0
Non-Motile Classic Chrysophytes				
Haptophytes				
Tribophytes/Eustigmatophytes				
Raphidophytes				
CRYPTOPHYTA				
CYANOPHYTA				
Unicellular and Colonial Forms				
Microcystis	412	22230	4.1	222.3
Filamentous Nitrogen Fixers				
Filamentous Non-Nitrogen Fixers				
EUGLENOPHYTA				
Trachelomonas	21	137	20.6	136.8

SEPTEMBER 25, 2021	PHYTOPLANKTON DENSITY (CELLS/ML)		PHYTOPLANKTON BIOMASS (UG/L)	
TAXON	**Cranberry**	**Otter**	**Cranberry**	**Otter**
PYRRHOPHYTA				
Ceratium	0	11	0.0	198.4
Peridinium	41	0	86.5	0.0
DENSITY (CELLS/ML) SUMMARY				
BACILLARIOPHYTA	**0**	**148.2**	**0.0**	**134.5**
Centric Diatoms	0	57	0.0	68.4
Araphid Pennate Diatoms	0	22.8	0.0	18.2
Monoraphid Pennate Diatoms	0	0	0.0	0.0
Biraphid Pennate Diatoms	0	68.4	0.0	47.9
CHLOROPHYTA	**41.2**	**45.6**	**4.1**	**4.6**
Flagellated Chlorophytes	0	0	0.0	0.0
Coccoid/Colonial Chlorophytes	41.2	45.6	4.1	4.6
Filamentous Chlorophytes	0	0	0.0	0.0
Desmids	0	0	0.0	0.0
CHRYSOPHYTA	**13987.4**	**456**	**20822.5**	**718.2**
Flagellated Classic Chrysophytes	13987.4	456	20822.5	718.2
Non-Motile Classic Chrysophytes	0	0	0.0	0.0
Haptophytes	0	0	0.0	0.0
Tribophytes/Eustigmatophytes	0	0	0.0	0.0
Raphidophytes	0	0	0.0	0.0
CRYPTOPHYTA	**0**	**0**	**0.0**	**0.0**
CYANOPHYTA	**412**	**22230**	**4.1**	**222.3**
Unicellular and Colonial Forms	412	22230	4.1	222.3
Filamentous Nitrogen Fixers	0	0	0.0	0.0
Filamentous Non-Nitrogen Fixers	0	0	0.0	0.0
EUGLENOPHYTA	**20.6**	**136.8**	**20.6**	**136.8**
PYRRHOPHYTA	**41.2**	**11.4**	**86.5**	**198.4**
TOTAL	**14502.4**	**23028**	**20937.8**	**1414.7**
CELL DIVERSITY	**0.37**	**0.09**	**0.21**	**0.75**
CELL EVENNESS	**0.44**	**0.09**	**0.25**	**0.72**

Table 6. Summary of Phytoplankton Biomass - All Assessment Years.

BIOMASS (UG/ML) SUMMARY								
	Cranberry				Otter			
	Jul 24 2011	Jul 25 2014	Jul 5 2017	Sep 25 2021	Jul 24 2011	Jul 25 2014	Jul 5 2017	Sep 25 2021
BACILLARIOPHYTA	106	120	20	0	181	182	29	135
CHLOROPHYTA	14	96	17	4	1477	266	18	5
CHRYSOPHYTA	420	2107	415	20822	0	123	0	718
CRYPTOPHYTA	6	0	0	0	0	0	0	0
CYANOPHYTA	42	0	0	4	36	14	17	222
EUGLENOPHYTA	14	0	17	21	0	0	29	137
PYRRHOPHYTA	1378	50	202	87	1319	1156	144	198

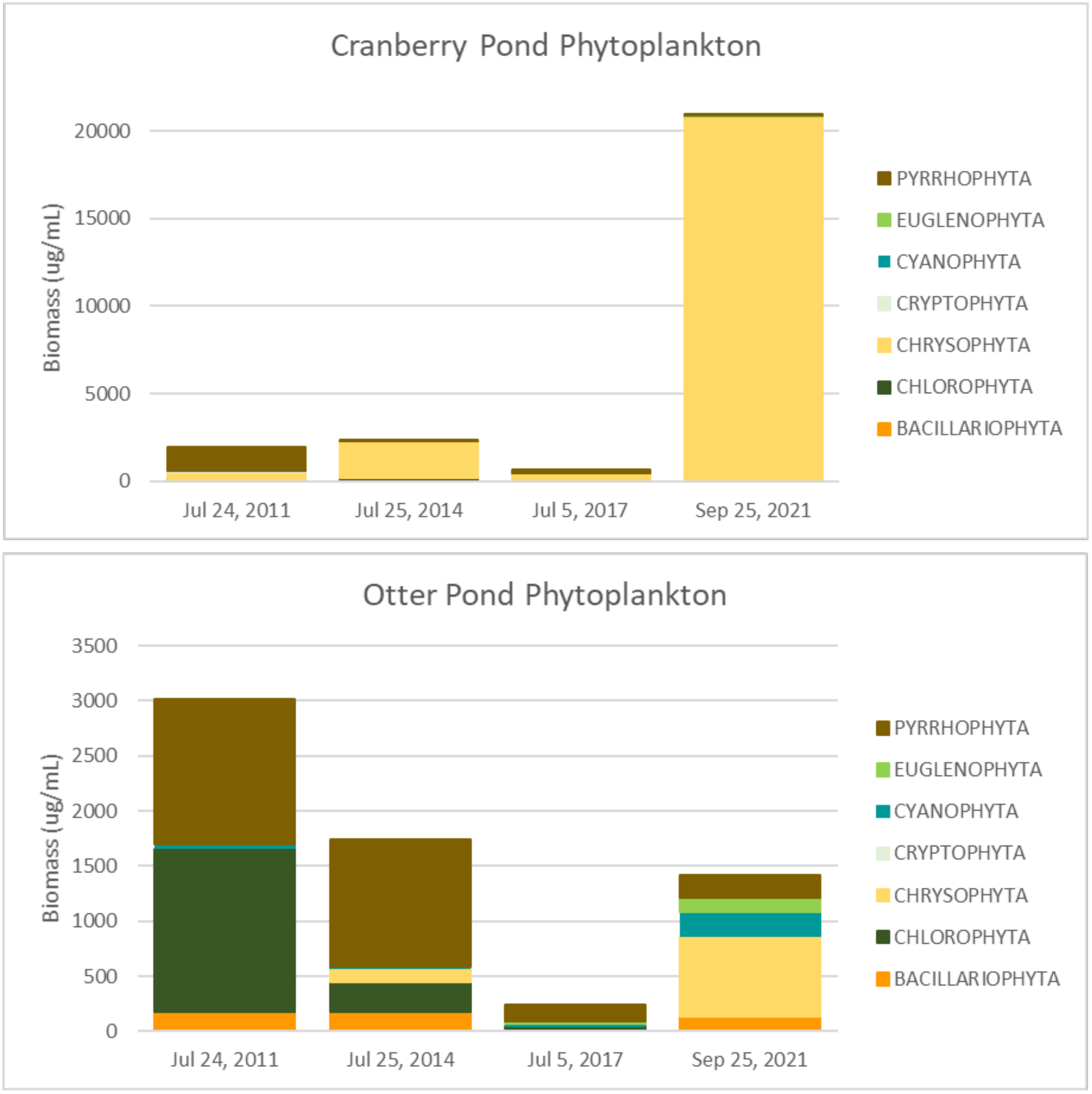


Figure 5. Phytoplankton Density – All Assessment Years.

Algal biomass hasn’t been high enough to be the primary determinant of water clarity in these ponds in the past, but golden algae were excessive in Cranberry Pond and could have imparted color and turbidity to the water. *Dinobryon*, the alga making up the majority of the phytoplankton biomass in Cranberry Pond, form large chain-like colonies making them difficult for zooplankton to graze. The observable water color and sometimes murky appearance in the summer is the result of non-algal turbidity and color; this condition is consistent with high concentrations of dissolved organic matter coming from wetlands in the watershed. These substances impart little conductivity to the water but increase color, decrease clarity, and bind up nutrients in a way that tends to limit algae production. The types of algae that are abundant (especially dinoflagellates and golden algae) are also known for use of dissolved organic compounds, suggesting elevated organic content. The presence of *microcystis* and elevated Chrysophyte biomass may be an indication that phosphorus concentrations are exceeding the binding capabilities of the humic substances and are fueling growth of algae. Something that should be monitored with interest.

Zooplankton were similar within ponds between years and were generally scarce (Table 7, Figure 6), with all common groups represented. Copepods and cladocerans are most abundant, but biomass for this group of organisms was low. There were some differences between the types of zooplankton in each pond, mainly in the types of cladocerans present, but these do not represent major ecological differences. Cladocerans are non-selective grazers but generally consume small phytoplankton whereas Copepods are thought to select for and consume larger phytoplankton.
Biomass values in excess of 100 ug/L is considered high, while values <50 ug/L are low and values <10 ug/L are very low; biomass in Cranberry Pond was <60 ug/L (slightly above the low threshold) and <15 ug/L for Otter Pond in 2021. Table 8 provides a summary from all assessment years. At this time of year biomass is often at its lowest point as a consequence of predation by small fish, but values as low as observed for both ponds suggest a minimal food base for small fish. There is also very little capacity to graze algae and keep them under control with density and biomass this low. This is further evidenced by the excessive density of *Dinobryon* (a large alga) in Cranberry Pond.

Average (mean) crustacean zooplankton length in 2021 was 1.01 millimeters (mm) in Cranberry Pond, twice as large as the average length in Otter Pond (0.51 mm) (Table 7, Figure 7). Prior year mean crustacean zooplankton length in Cranberry Pond was 0.49 mm in 2011, 0.62 mm in 2014 and 0.87 mm in 2017. The mean length has increased over time. Mean lengths between 0.4 and 0.8 mm indicate a balance between growth and predation, with smaller means suggesting intense predation and larger ones suggesting low predation. These data suggest that predation pressure has decreased in Cranberry Pond over time.

The trophic balance of the system cannot be fully assessed as fish and macroinvertebrates were not studied explicitly in this investigation, or during prior assessments. Caution should be exercised when interpreting data from zooplankton alone. Occasional observations of bass and sunfish were noted in both ponds during the 2021 investigation and prior. Newts were commonly encountered, with high numbers occurring in Otter Pond. Leeches were abundant in both waterbodies. These invertebrates are common in lakes and can become problems for swimmers.

Table 7. Cranberry and Otter Pond Zooplankton September 2021.

SEPTEMBER 25, 2021	**ZOOPLANKTON DENSITY (#/L)**		**ZOOPLANKTON BIOMASS (UG/L)**	
TAXON	**Cranberry**	**Otter**	**Cranberry**	**Otter**
PROTOZOA				
Ciliophora	0.0	0.0	0.0	0.0
Mastigophora	0.0	0.0	0.0	0.0
Sarcodina	0.0	0.0	0.0	0.0
ROTIFERA				
Kellicottia	0.0	0.4	0.0	0.0
Keratella	0.5	0.4	0.0	0.0
Polyarthra	1.1	1.3	0.2	0.2
Trichocerca	0.0	0.4	0.0	0.1
COPEPODA				
Copepoda-Cyclopoida				
Cyclops	0.0	0.9	0.0	2.1
Mesocyclops	0.5	0.4	4.4	0.6
Copepoda-Calanoida				
Diaptomus	1.6	1.8	25.7	3.7
Other Copepoda-Nauplii	1.6	3.1	4.2	8.2
CLADOCERA				
Bosmina	0.0	0.4	0.0	0.4
Daphnia pulex	1.6	0.0	26.1	0.0
OTHER ZOOPLANKTON				
SUMMARY STATISTICS				
PROTOZOA	0.0	0.0	0.0	0.0
ROTIFERA	1.6	2.6	0.3	0.3
COPEPODA	3.7	6.2	34.3	14.5
CLADOCERA	1.6	0.4	26.1	0.4
OTHER ZOOPLANKTON	0.0	0.0	0.0	0.0
TOTAL ZOOPLANKTON	6.9	9.2	60.7	15.3
TAXONOMIC RICHNESS				
PROTOZOA	0	0		
ROTIFERA	2	4		
COPEPODA	3	4		
CLADOCERA	1	1		
OTHER ZOOPLANKTON	0	0		
TOTAL ZOOPLANKTON	6	9		

SEPTEMBER 25, 2021				
TAXON	Cranberry	Otter		
S-W DIVERSITY INDEX	0.74	0.83		
EVENNESS INDEX	0.95	0.87		
MEAN LENGTH (mm): ALL FORMS	0.81	0.40		
MEAN LENGTH: CRUSTACEANS	1.01	0.51		

Table 8. Summary of Zooplankton Biomass - All Assessment Years.

BIOMASS SUMMARY (MG/L)								
	Cranberry				Otter			
	Jul 24 2011	Jul 25 2014	Jul 5 2017	Sep 25 2021	Jul 24 2011	Jul 25 2014	Jul 5 2017	Sep 25 2021
PROTOZOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA	0.9	2.1	0.0	0.3	0.0	0.4	0.0	0.3
COPEPODA	4.7	7.1	1.1	34.3	2.3	5.4	2.4	14.5
CLADOCERA	3.0	18.0	8.6	26.1	2.3	5.5	0.0	0.4
OTHER ZOOPLANKTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ZOOPLANKTON	8.5	27.2	9.7	60.7	4.6	11.4	2.5	15.3

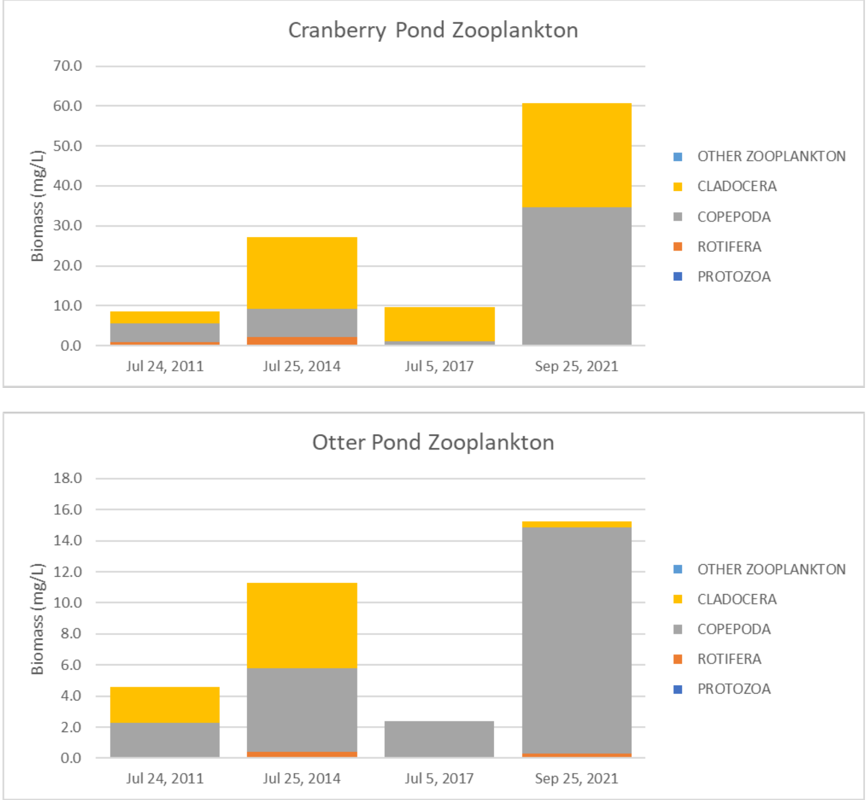


Figure 6. Zooplankton Biomass – All Assessment Years.

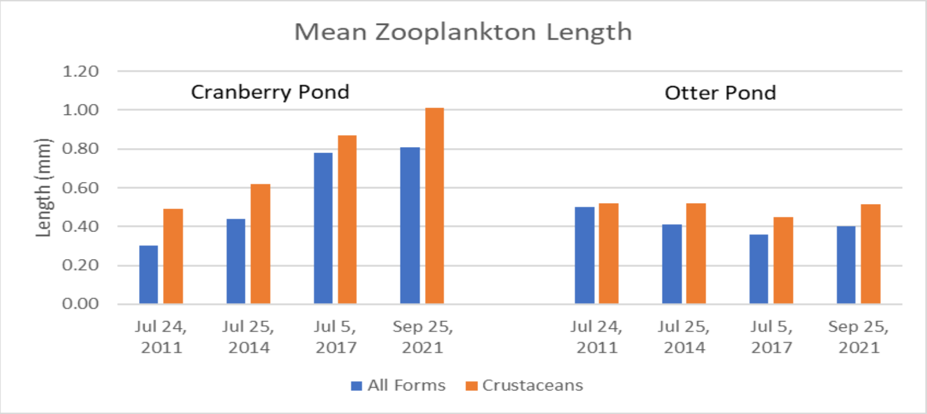


Figure 7. Mean Zooplankton Body Length - All Assessment Years

Aquatic Plants

The rooted plant communities of Cranberry and Otter Ponds were assessed at multiple points in each pond (Figure 2). The same locations were observed over the four separate assessments and allows comparisons over time (Table 9, Appendix A). Types and density of plants are dependent on water clarity (light penetration) and sediment features. Water quality can be influential, but most plants get their nutrition from the sediment, so water quality is secondary to sediment features other than the effect of turbidity (lowering light availability). The sediments of both ponds include rock and sand peripherally, but grade into muck at depths greater than about 2 ft in Otter Pond and 5 ft in Cranberry Pond. Sediment quality was not assessed, but it appears fertile enough to support substantial plant growths.

Plant richness (the total number of individual species identified) in both ponds combined over the assessment years is 22, although three listings (chlorophyta, cyanobacteria and *Nitella*) are actually algae, not higher plants. Unfortunately, a new species, non-native brittle naiad[1] (*Najas minor*), was observed this year in both ponds. Richness in Cranberry Pond has varied from a low of 11 (2011) to a maximum of 17 (2021)(Figure 8). Richness in Cranberry Pond has increased over time, but as previously mentioned this is not always beneficial as the new species identified is non-native and can become problematic. Otter Pond richness is generally around 14, but 2017 had a richness value half that.

Overall plant coverage was similar in Cranberry Pond to prior years (Figure 9), with average cover ratings ranging from 1.3 to 1.5, representing about 25% plant coverage. Otter Pond plant cover is higher than in Cranberry Pond, which is not surprising given its shallower depth. Otter Pond plant coverage in 2021 was a less than 2017 (2.7 vs 3.7) but comparable to 2014 (2.5). Biovolume (the portion of the water column filled with plants) was slightly less in 2021 than previous years in both ponds but does not represent a substantial change. The low biovolume indicates that most of the water column is open (not occupied by plants). This can be deceptive however if there is a predominance of floating leaf plants that cover the surface, like watershield. In such case the water column does not have high plant mass, but surface growth can still be a nuisance. One must therefore consider plant composition as well as numeric abundance ratings.

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[1] Brittle naiad is also known as spiny naiad, or brittle/spiny waternymph

Table 9. Cranberry and Otter Ponds Macrophytes September 25, 2021.

Pt	Depth (ft)	Cover	Bio-volum	Bschreb	Chloro	Cyano	Eacic	Gneg	Juncus	Lsal	Mhum	Nflex	Nmin	Nitella	Pamp	Pepi	Ppus	Prob	Pzos	Psp	Sval	Sparg	Tlat	Urad	Umin
1	2	1	1									s													
2	5.6	1	1			s	s									s									
3	5.7	1	1				s									t									
4	9.7	2	1			s								s			t		t						
5	5.3	3	1	s			s								t	t		t							
6	7	2	1									m				m									
7	10	3	1			t							d		t		t								t
8	5	1	1				m									s									
9	11.5	3	1			m							m		m										t
10	7	1	1		s		t																		
11	7.5	4	2				m						m			s		s						t	t
12	10	4	1		s	t									s		d								t
13	5.3	1	1													s									
14	10.7	1	1			s																			
15	12.7	4	1											d											
16	4.3	2	1		s		s	t								t	t								
17	10.3	1	1			t								s		s									
18	13.3	4	1			t								d	s										
19	11.7	4	1		s	t								m	m										
20	5	1	1		m		s					s		t										t	
21	10.3	1	1		s	t									s										
22	11	0	0																						
23	10.7	1	1			s								s	t										
24	13	1	1			s								s											
25	12.7	2	1			s								s											
26	3	0	0																						
27	13.5	1	1			s								t											
28	14.2	1	1			s								t											
29	12.7	2	1			s	m							s	d										
30	12.5	3	1		s									m	t										
31	6.7	2	1		s		s								t	m								t	
32	5	2	1		m										t	m	t							t	
33	11.3	1	1			t																			
34	14.3	1	1			s								t											
35	13.7	4	1		s									d	s										
36	13.5	4	1			s								d	t										t
37	3	1	1				s		t			t													
38	11.3	4	1									t		d	s		m								
39	15	1	1			s																			
40	21.5	0	0																						
41	18.7	0	0																						
42	11.3	2	1												m										
43	11.7	1	1			s																			
44	8.5	0	0																						
45	3	1	1				t									t									
46	3.3	1	1		s		t									t									
47	6.3	1	1		s							s				t									
48	4.6	1	1		s		t									t							s		
49	8.7	1	1											s										t	
50	9.3	0	0																						
51	12	1	1			t								s	s										
52	15.7	1	1			s																			
53	21.1	0	0																						
54	12.5	4	1		s	t								d	s		t								t
55	4	0	0																						
56	9.5	1	1			t									s										
57	15.5	1	1			t																			
58	13.1	3	1			t								d											
59	13.3	2	1			t								d											
60	12.9	1	1			s																			
61	7.9	1	1				t									t									
62	6.3	1	1												t	s	t							t	
63	8.3	1	1			t																			
64	3.7	0	0																						

Table 9 continued.
Cranberry Pond Continued

Pt	Depth (ft)	Cover	Bio-volum	Bschreb	Chloro	Cyano	Eacic	Gneg	Juncus	Lsal	Mhum	Nflex	Nmin	Nitella	Pamp	Pepi	Ppus	Prob	Pzos	Psp	Sval	Sparg	Tlat	Urad	Umin
65	3.5	0	0																						
66	7.5	2	1		s											s								t	t
67	9	0	0																						
68	10.3	1	1				t					t			t									t	
69	27	0	0																						
	Average	1.5	0.8																						
Frequency of occurrence				1	15	30	16	1	1	0	0	7	3	22	21	18	8	2	1	0	0	0	1	8	7
% Occurrence (all points)				1%	22%	43%	23%	1%	1%	0%	0%	10%	4%	32%	30%	26%	12%	3%	1%	0%	0%	0%	1%	12%	10%
Richness (S) # species present				17																					

Otter Pond

Pt	Depth (ft)	Cover	Biovolume	Bschreb	Chloro	Cyano	Eacic	Gneg	Juncus	Lsal	Mhum	Nflex	Nmin	Nitella	Pamp	Pepi	Ppus	Prob	Pzos	Psp	Sval	Sparg	Tlat	Urad	Umin
70	3.5	4	1	t			s	t					d			t									t
71	6	3	1		s								d	t											
72	2.6	3	1				m						d			s				t					
73	6	3	1										d										m		
74	11.3	0	0																						
75	2.6	4	1				s				m		m												
76	4.3	4	2				d						d				t								
77	4.6	2	1			t							m				t								
78	6.3	1	1		s	t							s				t								
79	4	4	1				d									s									t
80	3.3	4	1		t	t						t													
81	4.6	2	1		s	t	d					s											s		t
82	3	3	1		s		d						s	m											
83	5.6	4	2		s	t	d						t	m		s									
84	11.7	0	0																						
85	3.9	4	1				d	s					d			s									
86	5	2	1										d	d			m								
87	7	2	1				t	t	d		s					s									t
88	6	3	1		s		m	t								t				t					t
	Average	2.737	1																						
Frequency of occurrence				1	6	5	10	3	1	0	2	2	12	4	0	6	4	0	0	1	0	0	2	0	4
% Occurrence (all points)				5%	32%	26%	53%	16%	5%	0%	11%	11%	63%	21%	0%	32%	21%	0%	0%	5%	0%	0%	11%	0%	21%
Richness (S) # species present				15																					

Key to plant species abbreviations:

Abbreviation	**Scientific Name**	**Common Name**
Bschreb	*Brasenia schreberi*	Watershield
Chloro	*Chlorophyta*	Filamentous green algae
Cyano	*Cyanobacteria*	Bluegree algae
Eacic	*Eleocharis acicularis*	Spikerush
Gneg	*Gratiola neglecta*	Hedge hyssop
Juncus	*Juncus sp.*	Sedge
Lsal	*Lythrum salicaria*	Purple loosestrife
Mhum	*Myriophyllum humile*	Low watermilfoil
Nflex	*Najas flexilis*	Common (or slender) naiad
Nitella	*Nitella flexilis*	Nitella
Nmin	*Najas minor*	Brittle (or spiny) naiad (or waternymph)
Pamp	*Potamogeton amplifolius*	Big-leaved (or large-leaved, broad-leaved
Pepi	*Potamogeton epihydrus*	Ribbonleaf pondweed
Ppus	*Potamogeton pusillus*	Thin-leaf pondweed
Prob	*Potamogeton robbinsii*	Robbin's pondweed
Pzos	*Potamogeton zosteriformis*	Flatstem pondweed
Psp	*Potamogeton sp.*	Unidentified pondweed
Sval	*Schoenoplectus validus*	Bullrush
Sparg	*Sparganium sp.*	Burreed
Tlat	*Typha latifolia*	Cattail
Urad	*Utricularia radiata*	Little floating bladderwort
Umin	*Utricularia minor*	Lesser bladderwort

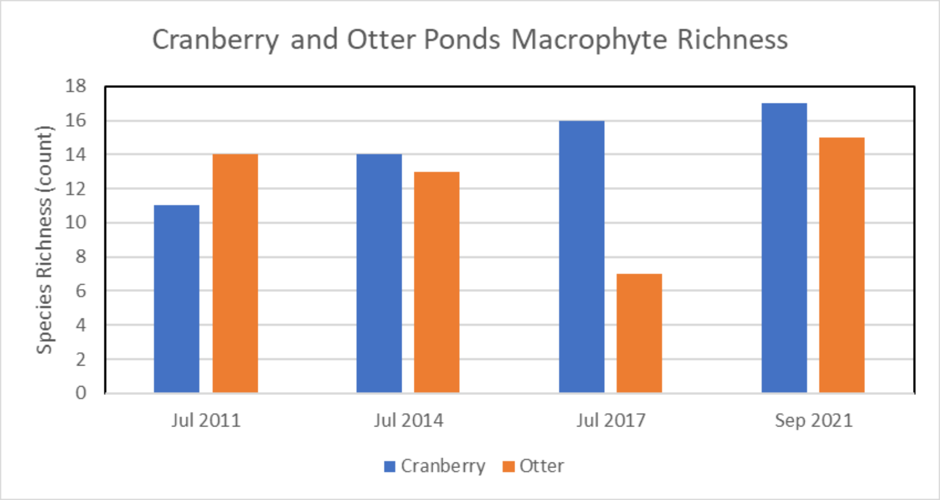
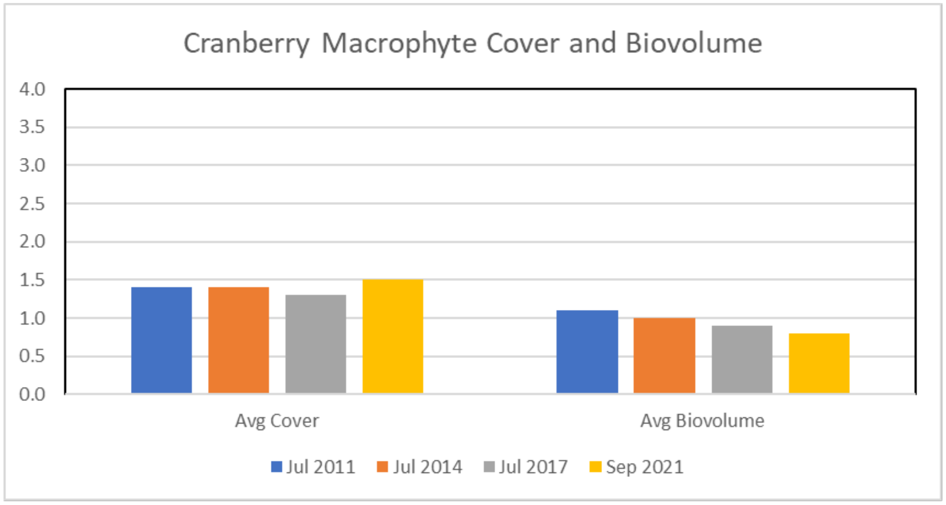


Figure 8. Macrophyte Richness - All Assessment Years.



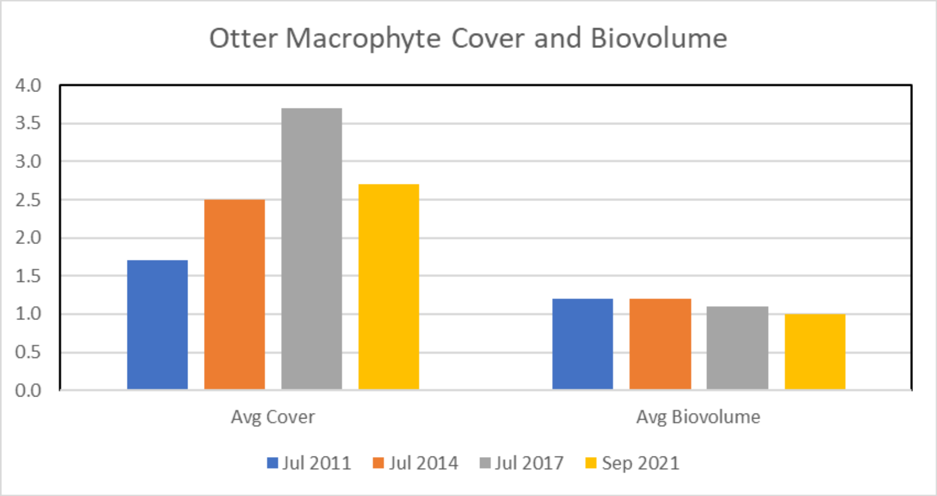


Figure 9. Macrophyte Cover and Biovolume - All Assessment Years

The most frequently observed species (not including algae) in Cranberry Pond in September 2021 were native pondweeds: big-leaved pondweed (*Potamogeton amplifolius*, at 30% of sites) and ribbonleaf pondweed (*P. epihydrus*, at 26% of sites). The non-native, brittle naiad, was observed at 4% of the observation locations (three locations). Also abundant were cyanobacteria mats (43%) and *Nitella* (32%). True rooted plants grow to a water depth of about 12 feet in Cranberry Pond and cyanobacterial mats can be found at the deepest depth (>20 ft). Changes greater than 15% in frequency of occurrence from 2017 data suggest that there were more algae (cyanobacteria and chlorophyta), ribbonleaf pondweed (*P. epihydrus*) and less common naiad (*Najas flexilis*) in Cranberry Pond (Figure 10).

The most frequently encountered plants in Otter Pond were brittle naiad (observed at 63% of the survey locations) and spikerush (*Eleocharis acicularis*; observed at 53% locations)(Figure 10). Algae and ribbonleaf pondweed were observed at about one third of the sites. Watershield (*Brasenia schreberi*) has apparently achieved nuisance levels in Otter Pond in the past, and hand-pulling has been conducted, but watershield was not abundant at the time of the September 2021 survey. It is unknown, as of the writing of this report, whether management activities for watershield were performed in recent years and has resulted in lower biovolume.

Otter Pond's plant community in 2021 was less similar to 2017. Data suggest that Otter Pond contained much more (>25% increase) cyanobacteria, chlorophyta, spikerush, ribbonleaf pondweed in 2021 than in 2017. The most striking difference was the introduction and distribution of brittle naiad, which was the most frequently encountered plant in 2021, but this plant was not observed in any of the prior year surveys. There was substantially less common naiad and *Nitella* in 2021. Minor changes in the plant community year to year are expected due to natural variability. More drastic shifts are generally associated with extreme weather conditions or introduction of new species. The introduction of brittle naiad has likely impacted abundance of native common naiad and potentially *Nitella* in Otter Pond.

As mentioned previously, non-native brittle naiad (native to Europe, western Asia and northern Africa) was identified this year. It is not known when it arrived. Introduction of brittle naiad into these ponds are likely from waterfowl or unintentional human transfer (recreation equipment – trailers, boats, fishing equipment etc.). If the plant becomes problematic, management in the future may be warranted. Brittle naiad can grow over eight feet high depending on water clarity and can form a dense monoculture (large growth area of single plant species) reducing the plant community diversity and decreasing aquatic habitat quality. Sometimes, however, this plant can co-exist within the waterbody without growing to great heights or become a nuisance. This plant reproduces primarily by seed but can also spread by fragmentation. Because it is an annual plant, it requires seed germination to survive year to year. It is tolerant to turbid eutrophic conditions. Plant management control measures for this species is generally limited to chemical treatment or benthic barriers in small areas (docks, beach, etc.). Additional information regarding this species can be found in Appendix B.

Identification of different naiad species can be difficult in the field in absence of seeds or without magnification which is required to see leaf base morphology. This plant produces flowers in July and seed production peaks in September. Seeds were not likely present during the July previous surveys. ARC collected representative specimens in September 2021 and viewed plant structures under magnification back at the office to confirm the identification of brittle naiad. Key identification features of this plant include a "toothed" appearance on the thin stiff leaves that curl resulting in a bushy form and shape of the leaf base seen under magnification.

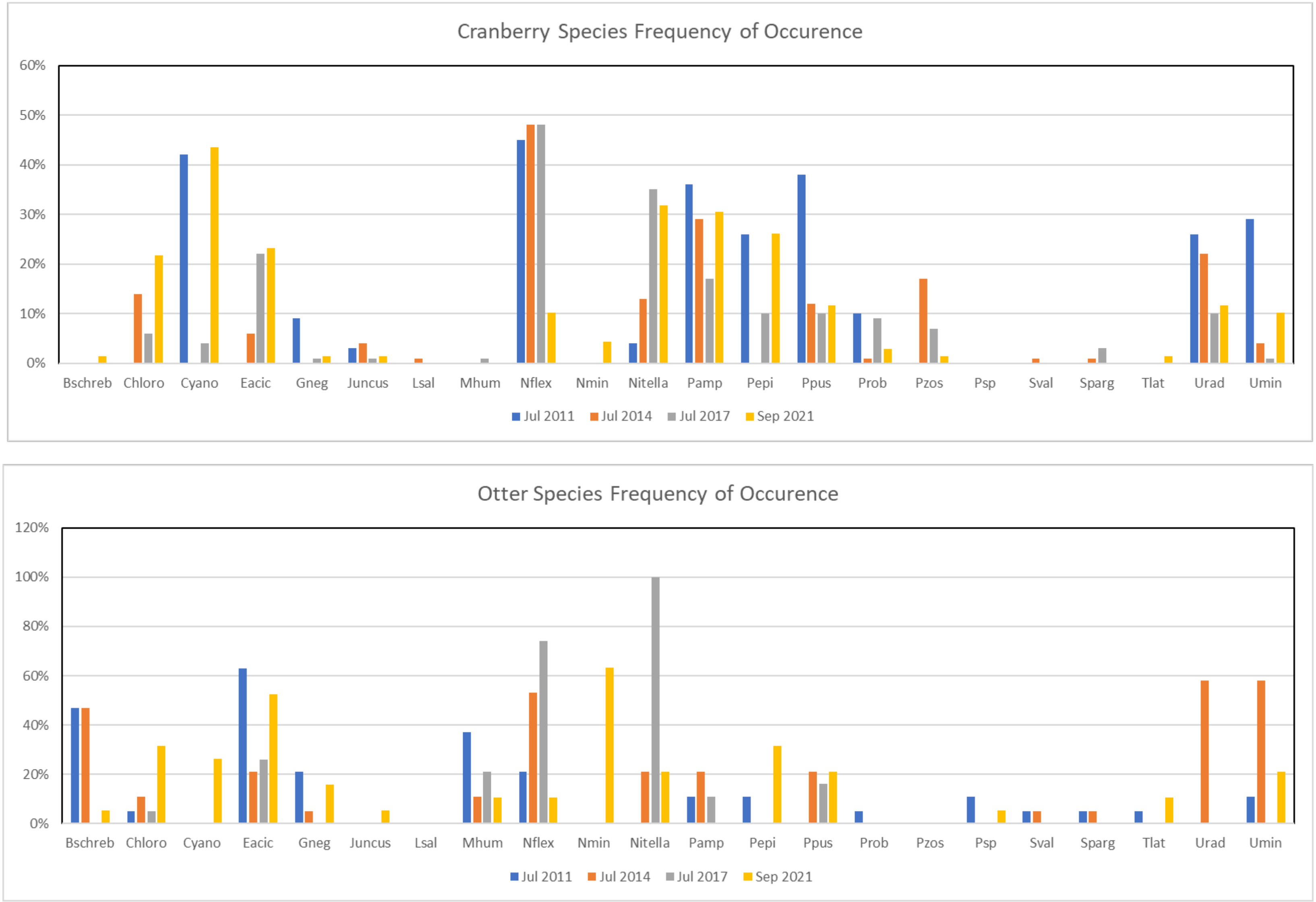


Figure 10. Macrophyte Frequency of Occurrence - All Assessment Years

Under 10X magnification. Photo by Wendy Gendron, source Otter Pond

Photo by Graves Lovell, Alabama Department of Conservation and Natural Resources, Bugwood.org

Figure 11. Brittle Naiad Photos

Conclusions and Recommendations

The following conclusions are drawn from data and observations documented during the four surveys conducted (2011, 2014, 2017 and 2021):

1. Muck sediment has accumulated in each pond over time, a natural occurrence that is often accelerated by human actions such as home construction. As the ponds have been created as part of a planned community, it is also possible that not all organic sediment was removed when the ponds were created, advancing that process. Muck depths were not measured, but coverage is extensive by sediments that will support much plant growth. This predisposes the ponds to both plant and water quality issues.
2. The organic bottom sediments generate an oxygen demand that cannot be met by oxygen reserves where the ponds are deep enough to thermally stratify. That is, where a deeper water layer is created and stable for the summer, it will lose its oxygen and become “anoxic.” This occurs in Cranberry Pond, but not in Otter Pond, as the latter is not deep enough. This limits fish distribution and encourages release of certain undesirable compounds from deep sediments. Impacts on Cranberry Pond have not been severe, and this condition is largely natural (observed in most area lakes), but is not desirable. Installation of a mixing or oxygenation system would counter any impacts but may not be justifiable at this time.
3. Even if not in deep water, muck sediments exert an oxygen demand that may cause localized anoxia at the sediment-water interface. Such conditions foster the release of phosphorus that can fuel algal blooms. Nutrient levels were elevated in this investigation in both ponds (extremely high in Otter Pond) but drawing conclusions from one round of sampling is not advisable. Results from this effort should be compared to those collected by the Wildwood Property Owners Association and evaluated.
4. The bottom mats of cyanobacteria in Cranberry Pond and the mats of green algae in shallower water of each pond are indicative of nutrient-rich bottom sediments. Cyanobacteria are not always present and green algae abundance varies. This suggests that such mats are not a severe problem and the conditions that foster mat development vary over time. It is likely that the oxygen status and ratio of nitrogen to phosphorus varies over time and is influential.
5. The phytoplankton (floating algae) in this assessment was different than prior assessments. Cranberry Pond contained an elevated density and biomass of chrysophytes, specifically *Dinobryon*. *Microcystis* (a known toxin producing cyanobacteria) was observed in moderate

concentrations in Otter Pond. The survey was conducted in the fall when contact recreation frequency is minimal, so risk of interaction with algal toxins is low but it is not known if this alga was present in high concentrations during the summer months. It is recommended that periodic sampling for phytoplankton occur in Otter Pond to ensure this species does not persist next summer when the risk of human and dog contact is much higher. Generally, the phytoplankton community includes mostly forms that are favored by high dissolved organic content, consistent with the muck sediments and low deep-water oxygen, and with inputs from wetlands in the watershed. Phytoplankton are generally indicative of higher N:P ratios in the water column; these do not favor cyanobacteria but phosphorus numbers are still high enough to support growth.

6. Zooplankton were scarce in both ponds. Typical forms are present, but biomass levels are low. Average crustacean body length in Otter Pond is in the desirable range, but body size in Cranberry Pond has increased over time. This suggests that there is not much grazing on algae, and food for small fish is limited. Large forms of algae, like *Dinobyron*, are difficult for zooplankton to consume and digest.
7. The rooted aquatic plant community of each pond includes mostly native species, but the recent introduction of brittle naiad should be monitored as this species has the potential to degrade habitat and recreation enjoyment. From time to time some native species can achieve nuisance densities, but biovolumes remained low in 2021. The invasive wetland plant, *Phragmites*, was observed in 2017 at the edge of Cranberry Pond and steps to eliminate are on-going. A team of volunteers were out marking locations for treatment at the time of the September 2021 survey.

The following monitoring recommendations are offered:

1. Water quality analyses should be conducted at least twice per year; once in spring and once in late summer, to allow longer term assessment of trends as well as immediate reaction to any problem conditions. Nitrate nitrogen, ammonium nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, pH, conductivity, turbidity, temperature and dissolved oxygen should be measured at the top and bottom of the ponds, and readings of Secchi disk transparency depth should be recorded.
2. Algae and zooplankton should be tracked along with water quality; a late spring sample may help warn of possible issues for the coming summer, while a later summer sample may be advantageous in warning of possible problems in future years, especially since microcystis was identified. The slow but steady increase in zooplankton size in Cranberry Pond could indicate trophic changes.
3. It is recommended that a baseline fish survey be conducted. These data will assist in evaluating changes over time and support an overall biological trophic assessment. Since algae and zooplankton communities indicated differing conditions, it is important to collect fish data before any long-term changes take place.
4. Water quality in any incoming tributary should be tested during a storm, as this is when the largest loads will occur. Sampling for forms of nitrogen and phosphorus, plus turbidity, is recommended. Assessment of water color would help identify water high in humic content.
5. Annual plant surveys are recommended, partly to detect any new species and partly to establish any trends in changes in coverage and biomass. Brittle naiad is a possible threat to both habitat and recreation, but it also could co-existing without issue. Annual plant surveys are recommended to track its spread. If plant density is higher than lake users would prefer, localized methods of control may be appropriate. These would include mainly hand harvesting (with mechanical aids as warranted, including rakes) but care must be taken to remove any brittle naiad fragments created to prevent distribution of this non-native in the lake. Bottom barriers that cover selected small areas are a better solution as this does not create plant fragments and will prevent naiad seeds from germinating.

6. Notification of brittle naiad presence should be posted at the public use areas at both ponds and caution the public about the potential to transport this species to other lakes.

In terms of management needs, Cranberry Pond is in good condition, with the main concern relating to the low oxygen in deep water and introduction of non-native brittle naiad. The plant is not widespread or at high biovolumes at this time, but it should be monitored closely. As mentioned in previous reports, the anoxic conditions, elevated nutrients could result in deteriorated conditions at any time. Otter Pond is shallower and provides an ideal environment for plants to grow to excessive levels. The past need for watershield control suggests that consideration of management options for plants is warranted on an as needed basis. The introduction of non-native brittle naiad was a new finding, and the plant is already well distributed throughout the pond, but its biovolume was low. Monitoring and potential management actions may be needed if this species becomes problematic. Also, cyanobacteria should be monitored and algaecide treatments may be needed if elevated density and biomass numbers are observed during summer months. Not only does this group of algae impair the appearance of the pond, but they also have the potential to release toxins and pose a human (and pet) health risk should blooms occur. Algal blooms are also known to strip the water of oxygen which can lead to fish kills and harm to other aquatic biota.

Plant controls can be physical, chemical or biological. Each has benefits and drawbacks. Each is appropriate in some cases and not others. Evaluation of technical applicability, affordability and social/regulatory acceptability is essential in the selection of any lake management option. Technical applicability is where consultants can help most. Consultants can also provide cost information, but affordability must be determined by the group doing the funding. Regulatory acceptability is fairly predictable at the state level, but local conservation commissions vary in their acceptance of different methods, and lake associations should become familiar with their local commission and its preferences. Consultants can help educate commissions that are resistant to some approaches, but sometimes acceptance is not a matter of education. Social acceptance is similarly influenced by education, but some deeply rooted beliefs are not alterable, and lake associations should discuss personal opinions as a group before deciding on a course of action.

There are a few invertebrates that have been used as biological controls for plants (e.g., the milfoil weevil for Eurasian watermilfoil), but these invertebrates are not known to control potential problematic plants at Cranberry or Otter Pond. Grass carp can be very effective at eliminating plants, but complete elimination is rarely desired, and the result is usually increased algae abundance. This approach is no longer accepted in Massachusetts. Biological control methods are therefore not applicable in these ponds, based on a combination of technical applicability and regulatory acceptability.

Chemical methods of control focus on herbicides. About 10 active ingredients are approved for use in Massachusetts under the direct control by certified, licensed applicators. Different formulations of each active ingredient exist, but herbicides must be matched with the target plants and environmental conditions to be effective. The appropriate herbicide for emergent vs. floating leaved vs. submergent plants usually varies, so it is unusual for one application to control all possible problem plants. Herbicide applications are temporary fixes as well; regrowth of plants is to be expected if light penetrates to a hospitable substrate, as is the case in these two ponds. Periodic maintenance using herbicides is an accepted approach in lake management, but many people object to such applications, and the long-term viability of such a maintenance approach should be discussed within the affected user group (Wildwood Property Owners Association) before going further.

For watershield, the only floating plant for which we are aware that control has been attempted, three herbicidal active ingredients are most appropriate: glyphosate, imazopyr and fluridone. Glyphosate or imazopyr can be sprayed on the surface leaves and is absorbed and translocated throughout the plant, killing it. It is not applied to the water per se, but rather to individual plants or plant patches, and is therefore fairly selective. Fluridone is applied to the water, can be taken up by any plants, but differentially affects some plants more than others. It is most often used against Eurasian watermilfoil in this area but will kill watershield (and many other plants) at a dose of about 20 parts per billion (ppb). In this case, use of glyphosate would be most specific and least obtrusive, if watershield is the only problem plant targeted. The cost is typically <$500/ac, so treatment of Otter Pond with glyphosate would not be a large expense.

For brittle naiad, state-approved herbicides with the following active ingredients have been found to provide the best control: diquat, flumioxazin, endothall, and fluridone. With the exception of fluridone, all of these herbicides' primary mode of activation is contact, meaning they kill the plant tissue in direct contact with the chemical. Systemic herbicides are absorbed into the plant and translocated to other parts of the plants such as roots (ex. fluridone mentioned above). Contact herbicides are less selective than systemic, and unless there is a monoculture, impacts to non-target plants are expected. Diquat is applied as a liquid but tends to bind quickly with suspended particles which can limit its efficacy. Given the shallow nature of Otter Pond and susceptibility to sediment resuspension, diquat may not be very effective when the waters are turbid. Flumioxazin is also broad spectrum contact herbicide but is available in both liquid and granular formulations. Endothall is somewhat selective and is available as a liquid and granular form. A licensed herbicide applicator should be consulted to select the most effective herbicide with the least non-target impacts based on the specific plant species present, density and location. This is usually determined following a pre-treatment survey.

Physical options are more varied, and most are applicable to Cranberry and Otter Ponds, where control would likely be on a smaller scale. Hand-pulling has already been employed for watershield in Otter Pond and appears to have been successful. Use of garden rakes or specialized aquatic plant rakes can be effective for watershield and other floating leaved plants with substantial root systems, such as water lilies, although this is exhausting work and may be ineffective if the root masses are especially dense. Raking can also physically remove brittle naiad but if plant fragments are not collected, it can spread the plant. Since brittle naiad produces seeds, eradication by physical removal (other than dredging) is not probable.

More mechanized approaches include mechanical harvesting, hydroraking and rotovation. It may be hard to get a harvester into Otter Pond, but one could be used at Cranberry Pond if the need arises. Regrowth of plants from unharvested roots is to be expected, and while some plant community shifts may occur over years with repeated harvesting, it should be assumed that mechanical harvesting is like mowing a lawn. If done early enough in the season with seed producing plants, production in later years may be reduced as a function of less seeds present to germinate. For perennial plants, regrowth the following year is normal. Mechanical harvesting can be contracted, and given the high cost of the machines (close to $200,000), this would be the logical route for the Association. Costs are typically on the order of $1,000 per day, with mobilization charges extra (usually about $1,000). Otter Pond could be addressed in a day, but with mobilization costs this may be cost prohibitive. As mentioned previously, brittle naiad can spread through fragments and is a negative side effect with mechanical harvesting. One would need to factor this risk prior to engaging in a harvesting program, especially in Cranberry Pond where brittle naiad presence isn't as expansive.

Hydroraking involves a York rake on pontoons that rips roots and related vegetation out of a target area. Hydroraked material is removed from the pond, usually deposited on shore for later disposal. For small areas of dense growth, this can be very effective, and multiple years of control can be expected. The cost is usually on the order of $10,000 to $15,000 per acre, but only small areas are typically addressed, and that would be the case at Otter Pond. A day of work with a hydrorake should limit watershield growth for 3 to 5 years. Access may be a consideration, but these machines are smaller than harvesters and should be deployable in this case.

Rotovation is just like rototilling a garden, but under water. Roots and associated plants are ripped up but not removed. Turbidity generation is high and oxygen demand from decaying weeds can be high. This is not recommended for Otter Pond if the problem is simply abundant watershield.
One issue with the above mechanical plant control methods is that they leave a hospitable growth area for other plants. This could include invasive species, but even the native species present could quickly fill the open space, negating most benefits of the treatment.

Bottom barriers are another physical method of plant control. Porous or non-porous materials are placed on the bottom, either before plants are growing or right on existing growths. Over about a month, the plants die, and the material can be removed or moved to another area in need of control. The materials can be expensive, and not all are intended to be moved after deployment, but re-useable mats are a fairly efficient means for localized plant control and would work well in Otter or Cranberry Pond. The cost for the best re-useable materials is up to $50,000 per acre, but typically an association would purchase much less material, create smaller panels (possibly with frames), and place these as needed. As a means to provide control in swimming areas, around docks, or in any small access area, this is a very flexible and workable option. It can also be more easily permitted under Massachusetts regulations than any other option besides hand-pulling.

An effective and affordable benthic barrier, called “lake bottom blanket”, is gaining popularity; it would be applicable for use in the Wildwood ponds at a cost <$0.75/square foot. It is a thin woven and plasticized material that has sleeves stitched into it where rebar is placed, weighting the sheet down and covering plants. Floats at the ends allow easy retrieval from the surface. This may be the best option for nearshore plant control on a small scale.

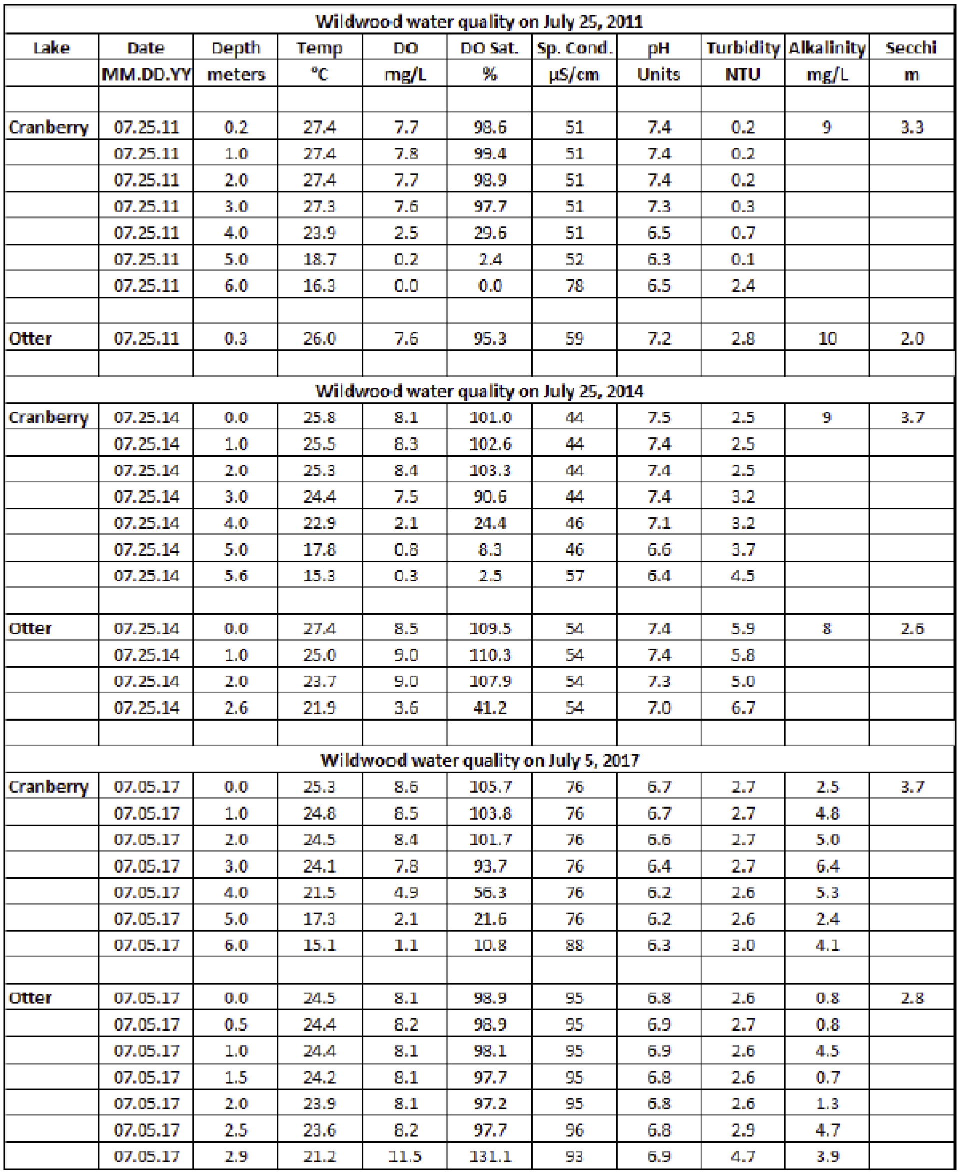
Dredging is another physical control option, one that provides many benefits but is very expensive. Dredging removes sediment and associated plants, roots and seeds, potentially improving water quality as well as controlling plants. It increases depth and sets the target area back in time. On a whole lake scale, it is true restoration to an earlier time. The cost is usually prohibitive, however, at a low end of $30 per cubic yard of clean material. An acre of sediment 1 ft deep is 1,613 cubic yards (cy) and would cost at least $50,000 to remove. If the sediment has any contamination, costs can rise quickly to >$100/cy as disposal becomes more difficult. Dredging is usually eliminated from consideration based on affordability.

Considering the plant problems reported in the past and the introduction of brittle naiad in Otter and Cranberry Ponds, the most applicable options for plant control are continued hand-pulling of watershield, bottom barriers and herbicides. It is not clear that any control of rooted plants is needed at this time, but the potential for problems exists. The plant community should be monitored more frequently (annual surveys are recommended) to document the impact of brittle naiad. With the observed levels of nutrients in these ponds, as well as identification of cyanobacteria in Otter Pond, greater attention to water quality appears warranted. Further knowledge of seasonal nutrient levels and the nature of inputs from the watershed could be important to the future health of the ponds.

Appendix – A

Tables and Figures from Prior Assessments

Table 1. Water quality measures for Cranberry and Otter Ponds.



Wildwood water quality on July 25, 2011										
Lake	Date	Depth	Temp	DO	DO Sat.	Sp. Cond.	pH	Turbidity	Alkalinity	Secchi
	MM.DD.YY	meters	°C	mg/L	%	µS/cm	Units	NTU	mg/L	m
Cranberry	07.25.11	0.2	27.4	7.7	98.6	51	7.4	0.2	9	3.3
	07.25.11	1.0	27.4	7.8	99.4	51	7.4	0.2		
	07.25.11	2.0	27.4	7.7	98.9	51	7.4	0.2		
	07.25.11	3.0	27.3	7.6	97.7	51	7.3	0.3		
	07.25.11	4.0	23.9	2.5	29.6	51	6.5	0.7		
	07.25.11	5.0	18.7	0.2	2.4	52	6.3	0.1		
	07.25.11	6.0	16.3	0.0	0.0	78	6.5	2.4		
Otter	07.25.11	0.3	26.0	7.6	95.3	59	7.2	2.8	10	2.0
Wildwood water quality on July 25, 2014										
Cranberry	07.25.14	0.0	25.8	8.1	101.0	44	7.5	2.5	9	3.7
	07.25.14	1.0	25.5	8.3	102.6	44	7.4	2.5		
	07.25.14	2.0	25.3	8.4	103.3	44	7.4	2.5		
	07.25.14	3.0	24.4	7.5	90.6	44	7.4	3.2		
	07.25.14	4.0	22.9	2.1	24.4	46	7.1	3.2		
	07.25.14	5.0	17.8	0.8	8.3	46	6.6	3.7		
	07.25.14	5.6	15.3	0.3	2.5	57	6.4	4.5		
Otter	07.25.14	0.0	27.4	8.5	109.5	54	7.4	5.9	8	2.6
	07.25.14	1.0	25.0	9.0	110.3	54	7.4	5.8		
	07.25.14	2.0	23.7	9.0	107.9	54	7.3	5.0		
	07.25.14	2.6	21.9	3.6	41.2	54	7.0	6.7		
Wildwood water quality on July 5, 2017										
Cranberry	07.05.17	0.0	25.3	8.6	105.7	76	6.7	2.7	2.5	3.7
	07.05.17	1.0	24.8	8.5	103.8	76	6.7	2.7	4.8	
	07.05.17	2.0	24.5	8.4	101.7	76	6.6	2.7	5.0	
	07.05.17	3.0	24.1	7.8	93.7	76	6.4	2.7	6.4	
	07.05.17	4.0	21.5	4.9	56.3	76	6.2	2.6	5.3	
	07.05.17	5.0	17.3	2.1	21.6	76	6.2	2.6	2.4	
	07.05.17	6.0	15.1	1.1	10.8	88	6.3	3.0	4.1	
Otter	07.05.17	0.0	24.5	8.1	98.9	95	6.8	2.6	0.8	2.8
	07.05.17	0.5	24.4	8.2	98.9	95	6.9	2.7	0.8	
	07.05.17	1.0	24.4	8.1	98.1	95	6.9	2.6	4.5	
	07.05.17	1.5	24.2	8.1	97.7	95	6.8	2.6	0.7	
	07.05.17	2.0	23.9	8.1	97.2	95	6.8	2.6	1.3	
	07.05.17	2.5	23.6	8.2	97.7	96	6.8	2.9	4.7	
	07.05.17	2.9	21.2	11.5	131.1	93	6.9	4.7	3.9	

Table 2. Phytoplankton data for Cranberry and Otter Ponds.

	PHYTOPLANKTON DENSITY (CELLS/ML)						PHYTOPLANKTON BIOMASS (UG/L)					
	Otter	**Cranberry**	**Otter**	**Cranberry**	**Otter**	**Cranberry**	**Otter**	**Cranberry**	**Otter**	**Cranberry**	**Otter**	**Cranberry**
TAXON	**07/25/11**	**07/25/11**	**07/25/14**	**07/25/14**	**07/05/17**	**07/05/17**	**07/25/11**	**07/25/11**	**07/25/14**	**07/25/14**	**07/05/17**	**07/05/17**
BACILLARIOPHYTA												
Centric Diatoms												
Cyclotella	0	224	0	0	0	26	0.0	89.6	0.0	0.0	0.0	2.6
Urosolenia	70	14	96	72	0	9	84.0	16.8	115.2	86.4	0.0	10.2
Araphid Pennate Diatoms												
Asterionella	0	0	0	72	8	0	0.0	0.0	0.0	14.4	1.7	0.0
Synedra	98	0	84	24	25	9	78.4	0.0	67.2	19.2	19.9	6.8
Tabellaria	14	0	0	0	8	0	11.2	0.0	0.0	0.0	6.6	0.0
Monoraphid Pennate Diatoms												
Achnanthidium/related taxa	0	0	0	0	8	0	0.0	0.0	0.0	0.0	0.8	0.0
Biraphid Pennate Diatoms												
Navicula/related taxa	14	0	0	0	0	0	7.0	0.0	0.0	0.0	0.0	0.0
CHLOROPHYTA												
Flagellated Chlorophytes												
Chlamydomonas	0	28	0	0	0	0	0.0	2.8	0.0	0.0	0.0	0.0
Coccoid/Colonial Chlorophytes												
Ankistrodesmus	462	0	1824	24	0	0	46.2	0.0	182.4	2.4	0.0	0.0
Crucigenia	0	0	48	48	0	0	0.0	0.0	4.8	4.8	0.0	0.0
Dictyosphaerium	0	0	0	0	66	0	0.0	0.0	0.0	0.0	6.6	0.0
Elakatothrix	196	0	360	24	50	0	19.6	0.0	36.0	2.4	5.0	0.0
Kirchneriella	0	0	48	0	0	0	0.0	0.0	4.8	0.0	0.0	0.0
Monoraphidium	364	0	0	0	0	0	70.0	0.0	0.0	0.0	0.0	0.0
Oocystis	56	0	96	24	0	0	22.4	0.0	38.4	9.6	0.0	0.0
Pediastrum	0	56	0	0	0	0	0.0	11.2	0.0	0.0	0.0	0.0
Quadrigula	28	0	0	0	0	0	5.6	0.0	0.0	0.0	0.0	0.0
Scenedesmus	28	0	0	48	0	0	2.8	0.0	0.0	4.8	0.0	0.0
Sphaerocystis	0	0	0	288	0	0	0.0	0.0	0.0	57.6	0.0	0.0
Filamentous Chlorophytes												
Desmids												
Closterium	168	0	0	0	0	0	672.0	0.0	0.0	0.0	0.0	0.0
Cosmarium	28	0	0	0	0	0	22.4	0.0	0.0	0.0	0.0	0.0
Mougeotia/Debarya	28	0	0	0	0	17	28.0	0.0	0.0	0.0	0.0	17.0
Spirogyra	28	0	0	0	0	0	560.0	0.0	0.0	0.0	0.0	0.0
Staurodesmus	0	0	0	24	0	0	0.0	0.0	0.0	14.4	0.0	0.0
Teilingia/related taxa	14	0	0	0	0	0	28.0	0.0	0.0	0.0	0.0	0.0
CHRYSOPHYTA												
Flagellated Classic Chrysophytes												
Chromulina	0	0	2460	336	0	0	0.0	0.0	123.0	16.8	0.0	0.0
Chrysosphaerella	0	0	0	0	0	272	0.0	0.0	0.0	0.0	0.0	108.8
Dinobryon	0	140	0	696	0	102	0.0	420.0	0.0	2088.0	0.0	306.0
Non-Motile Classic Chrysophytes												
Haptophytes												
Tribophytes/Eustigmatophytes												
Centritractus	0	0	0	12	0	0	0.0	0.0	0.0	1.8	0.0	0.0
Raphidophytes												
CRYPTOPHYTA												
Cryptomonas	0	28	0	0	0	0	0.0	5.6	0.0	0.0	0.0	0.0
CYANOPHYTA												
Unicellular and Colonial Forms												
Aphanocapsa	840	0	0	0	0	0	8.4	0.0	0.0	0.0	0.0	0.0
Woronichinia	0	0	1440	0	0	0	0.0	0.0	14.4	0.0	0.0	0.0
Filamentous Nitrogen Fixers												
Dolichospermum	140	210	0	0	83	0	28.0	42.0	0.0	0.0	16.6	0.0
Filamentous Non-Nitrogen Fixers												
EUGLENOPHYTA												
Euglena	0	0	0	0	8	0	0.0	0.0	0.0	0.0	4.2	0.0
Trachelomonas	0	14	0	0	25	17	0.0	14.0	0.0	0.0	24.9	17.0
PYRRHOPHYTA												
Ceratium	0	0	0	0	8	9	0.0	0.0	0.0	0.0	144.4	147.9
Peridinium	56	84	60	24	0	26	1318.8	1377.6	1155.6	50.4	0.0	53.6
DENSITY (CELLS/ML) SUMMARY												
BACILLARIOPHYTA	**196**	**238**	**180**	**168**	**49.8**	**42.5**	**180.6**	**106.4**	**182.4**	**120.0**	**29.1**	**19.6**
Centric Diatoms	70	238	96	72	0	34	84.0	106.4	115.2	86.4	0.0	12.8
Araphid Pennate Diatoms	112	0	84	96	41.5	8.5	89.6	0.0	67.2	33.6	28.2	6.8
Monoraphid Pennate Diatoms	0	0	0	0	8.3	0	0.0	0.0	0.0	0.0	0.8	0.0
Biraphid Pennate Diatoms	14	0	0	0	0	0	7.0	0.0	0.0	0.0	0.0	0.0
CHLOROPHYTA	**1400**	**84**	**2376**	**480**	**124.5**	**17**	**1477.0**	**14.0**	**266.4**	**96.0**	**18.3**	**17.0**
Flagellated Chlorophytes	0	28	0	0	0	0	0.0	2.8	0.0	0.0	0.0	0.0
Coccoid/Colonial Chlorophytes	1134	56	2376	456	116.2	0	166.6	11.2	266.4	81.6	11.6	0.0
Filamentous Chlorophytes	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Desmids	266	0	0	24	8.3	17	1310.4	0.0	0.0	14.4	6.6	17.0
CHRYSOPHYTA	**0**	**140**	**2460**	**1044**	**0**	**374**	**0.0**	**420.0**	**123.0**	**2106.6**	**0.0**	**414.8**
Flagellated Classic Chrysophytes	0	140	2460	1032	0	374	0.0	420.0	123.0	2104.8	0.0	414.8
Non-Motile Classic Chrysophytes	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Haptophytes	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Tribophytes/Eustigmatophytes	0	0	0	12	0	0	0.0	0.0	0.0	1.8	0.0	0.0
Raphidophytes	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
CRYPTOPHYTA	**0**	**28**	**0**	**0**	**0**	**0**	**0.0**	**5.6**	**0.0**	**0.0**	**0.0**	**0.0**
CYANOPHYTA	**980**	**210**	**1440**	**0**	**83**	**0**	**36.4**	**42.0**	**14.4**	**0.0**	**16.6**	**0.0**
Unicellular and Colonial Forms	840	0	1440	0	0	0	8.4	0.0	14.4	0.0	0.0	0.0
Filamentous Nitrogen Fixers	140	210	0	0	83	0	28.0	42.0	0.0	0.0	16.6	0.0
Filamentous Non-Nitrogen Fixers	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
EUGLENOPHYTA	**0**	**14**	**0**	**0**	**33.2**	**17**	**0.0**	**14.0**	**0.0**	**0.0**	**29.1**	**17.0**
PYRRHOPHYTA	**56**	**84**	**60**	**24**	**8.3**	**34**	**1318.8**	**1377.6**	**1155.6**	**50.4**	**144.4**	**201.5**
TOTAL	**2632**	**798**	**6516**	**1716**	**298.8**	**484.5**	**3012.8**	**1979.6**	**1741.8**	**2373.0**	**237.4**	**669.8**
CELL DIVERSITY	**0.95**	**0.79**	**0.66**	**0.80**	**0.87**	**0.61**	**0.72**	**0.41**	**0.54**	**0.26**	**0.63**	**0.65**
CELL EVENNESS	**0.75**	**0.83**	**0.66**	**0.70**	**0.83**	**0.64**	**0.57**	**0.42**	**0.54**	**0.23**	**0.60**	**0.69**

Table 3. Zooplankton data for Cranberry and Otter Ponds.

	ZOOPLANKTON DENSITY (#/L)							ZOOPLANKTON BIOMASS (UG/L)					
	Otter	Cranberry	Otter	Cranberry	Otter	Cranberry		Otter	Cranberry	Otter	Cranberry	Otter	Cranberry
TAXON	7/25/11	7/25/11	7/25/14	7/25/14	7/5/17	7/5/17		7/25/11	7/25/11	7/25/14	7/25/14	7/5/17	7/5/17
ROTIFERA													
Asplanchna	0.0	0.7	0.3	1.0	0.0	0.0		0.0	0.7	0.3	1.9	0.0	0.0
Conochilus	0.0	1.6	3.1	3.4	0.0	0.0		0.0	0.1	0.1	0.1	0.0	0.0
Kellicottia	0.0	1.7	0.0	0.0	0.2	0.0		0.0	0.1	0.0	0.0	0.0	0.0
Keratella	0.2	0.4	0.0	0.5	0.2	0.0		0.0	0.0	0.0	0.0	0.0	0.0
Ploesoma	0.0	0.0	0.5	0.0	0.2	0.0		0.0	0.0	0.0	0.0	0.0	0.0
Ptygura	0.0	0.0	0.3	0.5	0.0	0.2		0.0	0.0	0.0	0.0	0.0	0.0
COPEPODA													
Copepoda-Cyclopoida													
Mesocyclops	0.4	2.4	0.5	0.2	0.7	0.2		0.5	3.0	0.7	0.3	0.9	0.3
Copepoda-Calanoida													
Diaptomus	2.1	0.2	4.2	3.6	0.2	0.2		1.0	0.1	2.0	1.7	0.1	0.1
Other Copepoda-Nauplii	0.3	0.6	1.0	1.9	0.5	0.2		0.8	1.6	2.8	5.1	1.4	0.6
CLADOCERA													
Bosmina	1.9	0.3	3.9	0.0	0.0	0.0		1.9	0.3	3.8	0.0	0.0	0.0
Chydorus	0.0	0.1	0.0	0.0	0.0	0.0		0.0	0.1	0.0	0.0	0.0	0.0
Daphnia ambigua	0.1	0.0	0.3	0.0	0.0	0.0		0.2	0.0	0.4	0.0	0.0	0.0
Daphnia catawba	0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.0	8.6
Diaphanosoma	0.3	0.1	1.3	0.0	0.0	0.0		0.3	0.1	1.3	0.0	0.0	0.0
Holopedium	0.0	0.3	0.0	2.2	0.0	0.0		0.0	2.5	0.0	18.0	0.0	0.0
SUMMARY STATISTICS								Otter	Cranberry	Otter	Cranberry	Otter	Cranberry
DENSITY								7/25/11	7/25/11	7/25/14	7/25/14	7/5/17	7/5/17
PROTOZOA	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA	0.2	4.4	4.2	5.3	0.5	0.2		0.0	0.9	0.4	2.1	0.0	0.0
COPEPODA	2.8	3.2	5.7	5.8	1.4	0.7		2.3	4.7	5.4	7.1	2.4	1.1
CLADOCERA	2.3	0.8	5.5	2.2	0.0	1.0		2.3	3.0	5.5	18.0	0.0	8.6
OTHER ZOOPLANKTON	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ZOOPLANKTON	5.3	8.4	15.3	13.2	2.0	1.9		4.6	8.5	11.4	27.2	2.5	9.7
TAXONOMIC RICHNESS													
PROTOZOA	0	0	0	0	0	0							
ROTIFERA	1	4	4	4	3	1							
COPEPODA	3	3	3	3	3	3							
CLADOCERA	3	4	3	1	0	1							
OTHER ZOOPLANKTON	0	0	0	0	0	0							
TOTAL ZOOPLANKTON	7	11	10	8	6	5							
S-W DIVERSITY INDEX	0.63	0.86	0.81	0.77	0.69	0.60							
EVENNESS INDEX	0.75	0.82	0.81	0.86	0.89	0.86							
MEAN LENGTH (mm): ALL FORMS	0.50	0.30	0.41	0.44	0.36	0.78							
MEAN LENGTH: CRUSTACEANS	0.52	0.49	0.52	0.62	0.45	0.87							

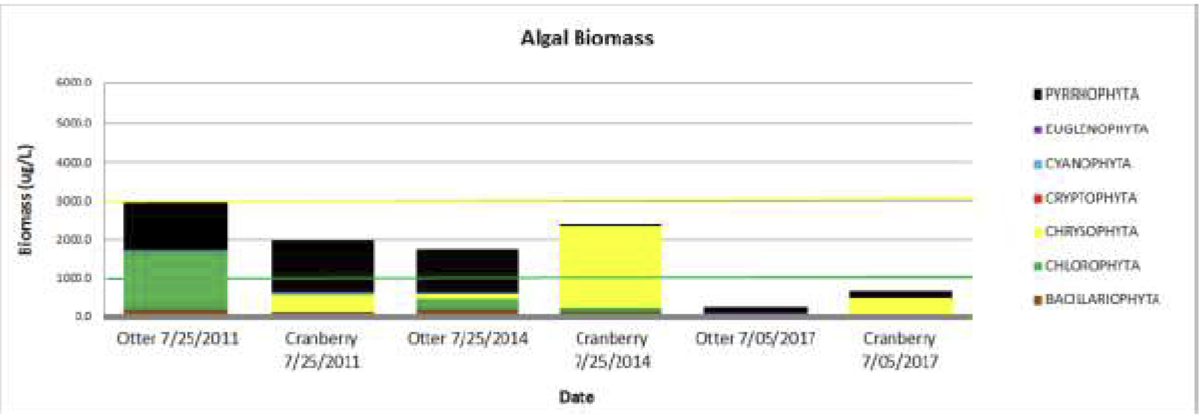


Figure 3. Phytoplankton biomass.

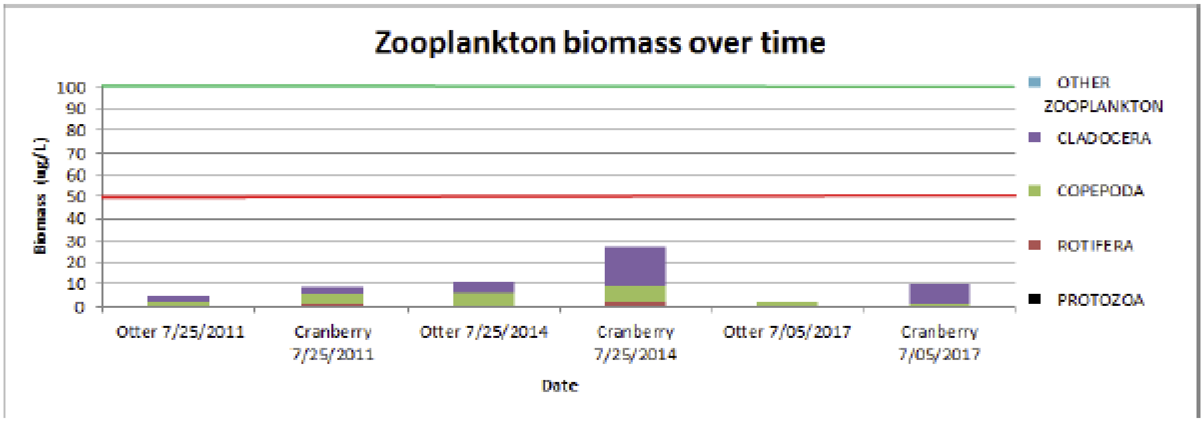


Figure 4. Zooplankton biomass.

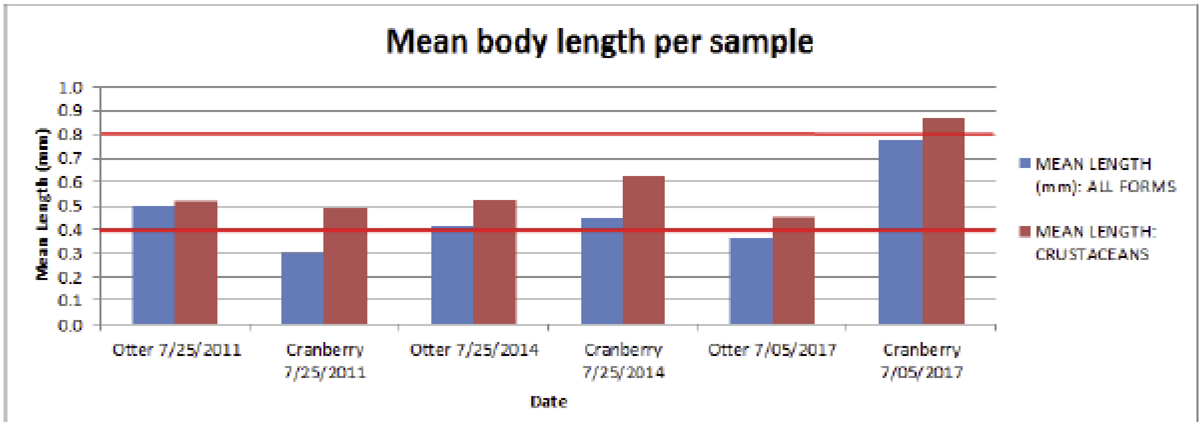


Figure 5. Zooplankton mean body length.

Table 6. Plant data for Cranberry Pond in 2011.

Wildwood Plant Survey, July 25, 2011					Plant Species																				
Station	Depth Ft	Cover	Biovol	Substrate	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
Cranberry																									
1	4.0	2	1	s,c									s				t	s							t
2	6.5	1	1	m									s				t							s	
3	5.6	1	1	m,c			t						t				t							t	
4	8.6	2	2	m			s						s		m									s	t
5	4.0	2	1	m,c,s			s						t											t	
6	8.6	2	2	m			m						t		s		t								s
7	8.8	2	2	m			m								m		s								s
8	4.7	3	2	m,c					s				t			m	t								
9	10.0	2	1	m			m								s		t								t
10	8.3	1	1	m									t		s	t									s
11	5.9	1	1	m													t							t	t
12	10.2	2	1	m			m								s		t								
13	6.4	3	2	m,c					s				m			m	t								
14	6.6	2	1	m									t				s								
15	11.8	1	1	m			s																		
16	9.7	1	1	m												s	s								t
17	8.7	1	1	m												s								t	t
18	11.4	1	1	m												t	t								
19	9.5	2	1	m,r									t		s	s	t								
20	4.0	1	1	m,s									s			t	t								
21	7.8	1	1	m			s								t									s	t
22	9.2	1	1	m			s								s										
23	12.2	1	1	m											t		t								
24	12.0	1	1	m			s											t							
25	12.0	2	1	m			m																		
26	3.0	0	0	s																					
27	9.4	2	2	m											m	s	s								s
28	13.0	1	1	m			s								t										
29	10.9	1	1	m											s		s								
30	10.6	2	2	m			s								m										
31	9.2	1	1	m,r									t		s		t							s	s
32	4.0	1	1	s									s			s									
33	18.0	2	1	m			s							s											
34	16.0	2	1	m			s							s											
35	14.3	2	1	m			s										t								

Table 6. Plant data for Cranberry Pond in 2011 (continued).

Wildwood Plant Survey, July 25, 2011					Plant Species																				
Station	Depth Ft	Cover	Biovol	Substrate	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
36	9.2	2	2	m											m										
37	2.3	1	1	s						s															
38	5.5	1	1	m,r									s		t		s							t	
39	12.4	1	1	m			s																		
40	20.9	1	1	m			s																		
41	20.2	1	1	m			s																		
42	10.6	2	1	m			s						t		s		t								
43	11.6	2	2	m			s								s										t
44	6.1	3	1	m									s			t								m	
45	3.2	2	1	s					t				s				t								
46	5.0	1	1	s,m									t			s									t
47	2.8	2	2	s					s				m												
48	4.5	4	1	m,s									m			s									
49	7.0	1	1	m,r									t		s									t	t
50	8.4	1	1	m																				s	
51	11.1	1	1	m																				s	s
52	14.8	1	1	m			s																		s
53	18.5	0	0	m																					
54	10.6	2	2	m			s								m		t	t							
55	3.8	0	0	s																					
56	5.0	1	1	m,s									s											t	
57	14.4	1	1	m			s																		
58	11.0	1	1	m			s								s			t							
59	11.6	1	1	m			s								s										
60	10.6	2	1	m			m																		
61	6.0	3	2	m									s			s	s							t	t
62	4.5	1	1	s,m									s			s									
63	9.8	2	2	m											s									t	s
64	3.7	0	0	r																					
65	3.3	1	1	s,r									s			t									
66	2.1	1	1	s,r					s				s					t							
67	7.6	1	1	m									t											s	
68	4.5	1	1	g,c,m									t			s		t							
69	3.4	1	1	s									s												
Average	8.7	1.4	1.1																						
Frequency					0.03	0.01	0.42	0.01	0.09	0.03	0.01	0.01	0.45	0.04	0.36	0.26	0.38	0.10	0.01	0.01	0.01	0.01	0.01	0.26	0.29

Table 7. Plant data for Otter Pond in 2011.

Wildwood Plant Survey, July 25, 2011					Plant Species																				
Station	Depth	Cover	Biovol	Substrate	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
	Ft																								
Otter																									
70	5.0	4	3	s,m	s			s				s											d		
71	4.0	2	2	s,m	s			s													m				
72	6.0	3	1	s				m				s													s
73	6.0	1	1	s,m	t			s				s													
74	10.0	1	1	m											s										
75	3.0	4	1	s,m	t			d																	
76	4.0	3	1	s,m	s			m	t													t			
77	8.0	1	1	m		s						s													
78	9.0	1	1	m											s										
79	2.0	2	1	s,m	s			m	t																
80	5.0	0	0	s								s													
81	5.0	1	1	s				s				s													
82	6.0	1	1	m,s				s																	
83	6.0	2	2	m,s	m			m					t			s									
84	10.0	0	0	m																					
85	6.0	2	1	m				s				s	t												
86	3.0	2	2	s,m				m	t				t			s		s							m
87	7.0	1	1	m	t								t							s					
88	7.0	2	1	m	t				s											s					
Average	5.9	1.7	1.2																						
Frequency					0.47	0.05	0.00	0.63	0.21	0.00	0.00	0.37	0.21	0.00	0.11	0.11	0.00	0.05	0.00	0.11	0.05	0.05	0.05	0.00	0.11

Table 8. Plant data for Cranberry Pond in 2014.

Wildwood Plant Survey, July 25, 2014					Plant Species																				
Station	Depth	Substrate	Cover	Biovol	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
	Ft																								
Cranberry																									
1	4.0	s,c	2	2		t							t				s		s					t	
2	6.5	m	2	1		t							s	t										s	
3	5.6	m,c	1	1									t		t										
4	8.6	m	3	2									s		s		t		t					t	t
5	4.0	m,c,s	2	2									s						s					t	
6	8.6	m	2	2									t	t	s									s	
7	8.8	m	2	1		t							s		t									s	
8	4.7	m,c	2	1		s							s						t						
9	10.0	m	2	2		t									s									s	
10	8.3	m	2	2											s									t	
11	5.9	m	3	2									t					t	s					s	s
12	10.2	m	1	1									t	t	t									t	
13	6.4	m,c	2	1		s							t				t								
14	6.6	m	1	1									t		t		t								
15	11.8	m	1	1		t																			
16	9.7	m	2	2									t		t				t					s	
17	8.7	m	4	1																				d	
18	11.4	m	0	0																					
19	9.5	m,r	2	2									t	t	t										
20	4.0	m,s	3	3									s						s						
21	7.8	m	1	1									t		t										
22	9.2	m	1	1											t										
23	12.2	m	1	1											t										
24	12.0	m	0	0																					
25	12.0	m	0	0																					
26	3.0	s	0	0																					
27	9.4	m	1	1									t	t											
28	13.0	m	0	0																					
29	10.9	m	1	1															t						
30	10.6	m	1	1													t								
31	9.2	m,r	3	2									s		t										
32	4.0	s	3	2									s	t					s						
33	18.0	m	0	0																					
34	16.0	m	0	0																					
35	14.3	m	0	0																					

Table 8. Plant data for Cranberry Pond in 2014 (continued).

Wildwood Plant Survey, July 25, 2014					Plant Species																				
Station	Depth	Substrate	Cover	Biovol	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
	Ft																								
36	9.2	m	1	1		t											t								
37	2.3	s	2	2				t		s			t												
38	5.5	m,r	2	1									s	t	t									s	
39	12.4	m	0	0																					
40	20.9	m	0	0																					
41	20.2	m	0	0																					
42	10.6	m	2	1									t		t										
43	11.6	m	1	1											t		t								
44	6.1	m	4	2									d				s								
45	3.2	s	2	2				t		s			s								t				t
46	5.0	s,m	4	2									m						s						
47	2.8	s	3	1		s		t		s	t		s									t		t	
48	4.5	m,s	3	1		s							m	t											
49	7.0	m,r	3	2									s	t	s										
50	8.4	m	2	2											s										
51	11.1	m	1	1															t						
52	14.8	m	0	0																					
53	18.5	m	0	0																					
54	10.6	m	1	1									t											t	
55	3.8	s	1	1				t																	
56	5.0	m,s	0	0																					
57	14.4	m	0	0																					
58	11.0	m	1	1											t										
59	11.6	m	0	0																					
60	10.6	m	0	0																					
61	6.0	m	3	1									s												
62	4.5	s,m	4	2									d												
63	9.8	m	3	2									s						s						
64	3.7	r	0	0																					
65	3.3	s,r	0	0																					
66	2.1	s,r	0	0																					
67	7.6	m	1	1									t												
68	4.5	g,c,m	0	0																					
69	3.4	s	0	0																					
Average	8.7		1.4	1.0																					
Frequency					0.00	0.14	0.00	0.06	0.00	0.04	0.01	0.00	0.48	0.13	0.29	0.00	0.12	0.01	0.17	0.00	0.01	0.01	0.00	0.22	0.04

Table 9. Plant data for Otter Pond in 2014.

Wildwood Plant Survey, July 25, 2014					Plant Species																				
Station	Depth	Substrate	Cover	Biovol	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
	Ft																								
Otter																									
70	5.0	s,m	2	1	t								t											s	s
71	4.0	s,m	1	1	t																				
72	6.0	s	2	1		t							t											s	s
73	6.0	s,m	3	1									t	t										m	m
74	10.0	m	3	1									m											s	s
75	3.0	s,m	2	2	s			s																	
76	4.0	s,m	2	2	s										t		t								
77	8.0	m	2	1		t							t											t	t
78	9.0	m	4	1									s	t										m	m
79	2.0	s,m	2	2	t			t	t												s	s			
80	5.0	s	2	2	t												s								
81	5.0	s	3	1									s	t										m	m
82	6.0	m,s	3	1									s	t										m	m
83	6.0	m,s	2	1	t								t											s	s
84	10.0	m	4	1									t		t									s	m
85	6.0	m	3	1				s																m	m
86	3.0	s,m	3	1				m																	
87	7.0	m	2	1	t							t			s		t								
88	7.0	m	2	1	t							t			s		t								
Average	5.9		2.5	1.2																					
Frequency					0.47	0.11	0.00	0.21	0.05	0.00	0.00	0.11	0.53	0.21	0.21	0.00	0.21	0.00	0.00	0.00	0.05	0.05	0.00	0.58	0.58

Table 10. Plant data for Cranberry Pond in 2017.

Wildwood Plant Survey 2017					Plant Species																				
Station	Depth	Substrate	Cover	Biovol	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
	Ft																								
Cranberry																									
1	4.0	s,c	4	2									d	s		s		t							
2	6.5	m	1	1									t	t		t									
3	5.6	m,c	3	1				t					m	s		t									
4	8.6	m	4	2									m	s	s									t	
5	4.0	m,c,s	2	2		s						t	s	t		s									
6	8.6	m	1	1		m									t									t	
7	8.8	m	4	3									d	s	s		t							t	
8	4.7	m,c	2	1		t		t					s	t		t		s							
9	10.0	m	4	2									s	t	s		t	t	t					s	
10	8.3	m	3	1									s	t					t					t	
11	5.9	m	1	1		t							t	t				t							
12	10.2	m	2	2									s	s	s										
13	6.4	m,c	4	1									d	m											
14	6.6	m	1	1									t	s											
15	11.8	m	0	0																					
16	9.7	m	3	2									s	t	s		s	t							
17	8.7	m	1	1									t	t											
18	11.4	m	1	1									t	t											
19	9.5	m,r	1	1				t					t	t											
20	4.0	c,s	1	1				t																	
21	7.8	m	0	0																					
22	9.2	m	1	1																				t	
23	12.2	m	0	0																					
24	12.0	m	0	0																					
25	12.0	m	0	0																					
26	3.0	s	0	0																					
27	9.4	m	4	2									m	s		s	s								
28	13.0	m	0	0																					
29	10.9	m	0	0																					
30	10.6	m	1	1											t										
31	9.2	m,r	0	0																					
32	4.0	s	1	1				t																	
33	18.0	m	0	0																					
34	16.0	m	0	0																					
35	14.3	m	0	0																					

Table 10. Plant data for Cranberry Pond in 2017 (continued).

Wildwood Plant Survey 2017					Plant Species																				
Station	Depth	Substrate	Cover	Biovol	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
	Ft												t	m	s	t	m		t						t
36	9.2	m	4	3																					
37	2.3	s	2	2				t	t													s			
38	5.5	m,r	1	1									t												
39	12.4	m	3	2									t	t	s		s		t					t	
40	20.9	m	0	0																					
41	20.2	m	0	0																					
42	10.6	m	1	1											t										
43	11.6	m	1	1									t	t											
44	6.1	m	1	1									t												
45	3.2	s	0	0																					
46	5.0	s,m	1	1				t					t												
47	2.8	s	2	2				t		s												s			
48	4.5	m,s	1	1			s	t					t												
49	7.0	m,r	2	1			s						s	s											
50	8.4	m	1	1			t						t												
51	11.1	m	1	1									t												
52	14.8	m	0	0																					
53	18.5	m	0	0																					
54	10.6	m	4	2									m	d	s		s	t	t						
55	3.8	s/r	1	1				t																	
56	5.0	m,s	1	1				t																	
57	14.4	m	0	0																					
58	11.0	m	1	1									t												
59	11.6	m	1	1											t										
60	10.6	m	0	0																					
61	6.0	m	1	1									t												
62	4.5	s,m	1	1				t																	
63	9.8	m	1	1									t												
64	3.7	r	0	0																					
65	3.3	s,r	1	1																					
66	2.1	s,r	2	1				s																	
67	7.6	m	1	1									t	t											
68	4.5	g,c,m	2	1				s																	
69	3.4	s	1	1				t																	
Average	8.7		1.3	0.9																					
Frequency					0.00	0.06	0.04	0.22	0.01	0.01	0.00	0.01	0.48	0.35	0.17	0.10	0.10	0.09	0.07	0.00	0.00	0.03	0.00	0.10	0.01

Table 11. Plant data for Otter Pond in 2017.

Wildwood Plant Survey 2017					Plant Species																				
Station	Depth	Substrate	Cover	Biovol	B shreb	Chloro	Cyano	E acic	G neg	Juncus	L sal	M hum	N flex	Nitella	P amp	P epi	P pus	P rob	P zos	P sp 1	S val	Sparg	T lat	U min	U rad
	Ft																								
Otter																									
70	5.0	s,m	3	1				t					m	t											
71	4.0	s,m	3	1				s				m	s	t											
72	6.0	s	4	1										m											
73	6.0	s,m	4	1									t	d			t								
74	10.0	m	4	1									t	d											
75	3.0	s,m	4	1				t				m	m	t											
76	4.0	s,m	4	1				t				m	s	m			t								
77	8.0	m	4	1									t	d			t								
78	9.0	m	4	1										d											
79	2.0	s,m	4	1				s				s	m	m											
80	5.0	s	4	1									d	m											
81	5.0	s	3	1									s	m											
82	6.0	m,s	4	1									s	d											
83	6.0	m,s	4	1									t	d											
84	10.0	m	3	2										m	t										
85	6.0	m	4	1									t	d											
86	3.0	s,m	3	1										m											
87	7.0	m	3	1										m											
88	7.0	m	4	1		s							m	m	t										
Average	5.9		3.7	1.1																					
Frequency					0.00	0.05	0.00	0.26	0.00	0.00	0.00	0.21	0.74	1.00	0.11	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix – B

Brittle Naiad Information

ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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Brittle Naiad

Species Description


Brittle Naiad *(Najas minor)*

Brittle naiad is a submerged aquatic plant with substantially branched stems that easily fragment. The leaves are curled, recurving (curled backwards) with age, and approximately one inch long with a noticeably serrated leaf-edge. The branching and curled leaves give brittle naiad a bushy appearance.

Brittle naiad can grow to a length or height of approximately 2.5 meters. Tiny flowers are produced in the leaf axils, which fertilize and mature into oblong seeds. Brittle naiad also reproduces and spreads with auto- and artificial- fragmentation. The plants are annual, not persisting past late fall, and depend on seed germination for continual infestation. It can form dense shoals and surface mats in water 12 feet deep. Brittle naiad is often confused with coontail, native naiad, and some macroalgae, such as *Chara*. Native naiad can be distinguished through its thicker, broader leaves.

Life Cycle

As an annual, brittle naiad rapidly and continuously grows until the parent plant dies in late fall. Tiny flowers are produced in leaf axils around July, which fertilize and develop seeds from September through October. Auto-fragmentation occurs with the seeds still attached and the fragments disperse using water currents. The seeds are then deposited in the fall after the plant dies or throughout the growing season by waterfowl defecation, and they germinate in early spring to late summer.

Species Range and U.S. Distribution

Brittle naiad grows natively throughout various countries in Europe and Asia. The Eastern U.S., California, and Ontario, Canada consider brittle naiad as an exotic invasive species. It has potential to proliferate in water bodies throughout the U.S.

How was Brittle Naiad Introduced?

Brittle naiad was initially brought into U.S. waterbodies as a food source for waterfowl, a popular idea in the 1930s. These birds consume brittle naiad throughout the year, spreading and establishing new populations though defecating viable seeds and dislodging seeds from the main plant as they eat.

Where Does Brittle Naiad Invade?

Brittle naiad can grow as deep as five meters and prefers calm environments. Areas with heavy boat traffic usually fragment established brittle naiad with propeller-activity and water current, preventing upward growth and spreading the infestation. Brittle naiad is tolerant of turbidity and eutrophic water – while the plant may not thrive, establishment is inevitable.

What Makes Brittle Naiad a Good Invader?

Artificial fragmentation easily occurs since brittle naiad is so fragile and is inherently prepared to auto-fragment. Small pieces get stuck to waterfowl, other animals or water-related equipment and are carried throughout and between water bodies. Fragments are small enough where they are often unnoticed. Any seeds present stay attached to the plant fragment, depositing and potentially establishing a new population. Waterfowl consume brittle naiad, where the seeds are still capable of germinating after being passed, also possibly establishing a population. The seeds disperse with any water movement and over-winter, making it hard to predict where new establishment might occur.

How Does Brittle Naiad Spread?

Brittle naiad mainly spreads by means of auto- and artificial- fragmentation. Fragments drift using water movement, and cling to boats, trailers and recreation equipment. Waterfowl further spread brittle naiad by consumption or accidental transportation and depositing seeds wherever they land.

Why is Brittle Naiad a Problem?

No natural controls are known for brittle naiad. While waterfowl may feed on the plant, any seeds consumed or fragments created are potential sources of new populations or infestations. Native and local vegetation, even milfoil and hydrilla, are outcompeted by brittle naiad growth. Chemical treatment can control the growth of multiple invasive exotics, but could possibly be accompanied by negative ecological impacts. Brittle naiad is also easily confused with natives, especially other naiads, making plant recognition and harvest a challenge.

What are Some Solutions to the Brittle Naiad Problem?

- Physical: Manual and mechanical harvesters have been used in Iowa and Wisconsin, but likely spread the plant further due to loose fragments and forced seed dispersal.
- Biological: No biological control is known.
- Chemical: Diquat, Endothall and Fluridone herbicides have been successfully used by US Army Corps of Engineers to control brittle naiad. These products do tend to have broader spectrum impacts, and are not as target specific as some herbicides; therefore, impacts to some native plants in the area of treatment may occur.

What Can I Do To Help?

Most importantly, ***recognize it***. Brittle naiad is best identified by its bushy appearance and visibly toothed leaves. Then, ***report it*** to authorities for official identification by NHDES. Other look-alike plants or macroalgae can be mistaken for brittle naiad. Please confirm the population even if you are unsure of the initial identification. Prevention is key, so follow Clean, Drain, Dry protocols for decontamination of transient recreational gear.

For more information about exotic aquatic plants, please contact the Exotic Species Program at (603) 271-2248, or go to https://www.des.nh.gov/ and search "Exotic Species."