Beaver Dam Lake Aquatic Plant Management Plan

Prepared for
Beaver Dam Lake Management District

February 2019

4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
952.832.2600
www.barr.com

Acknowledgments

The Beaver Dam Lake Aquatic Plant Management Plan (APM Plan) was completed with the assistance of the Beaver Dam Lake Management District. A special thanks to the following for their help during the project:

Tom Schroeder	Current President - Beaver Dam Lake Management District and Member of Committee on Aquatic Plant Management
Alan Carlson	Treasurer - Beaver Dam Lake Management District
John Bavier	Commissioner – Beaver Dam Lake Management District
Don Phernetton	Commissioner – Beaver Dam Lake Management District
Mike Werner	Commissioner – Beaver Dam Lake Management District
Doris Laursen	Acting Secretary, Cumberland City Council Representative to Beaver Dam Lake Management District
Donald Horstman	County Board Representative to Beaver Dam Lake Management District
John Thon	Past Commissioner – Beaver Dam Lake Management District and Member - Committee on Aquatic Plant Management
John Epple	Past Commissioner – Beaver Dam Lake Management District
Dave Evenson	Past President - Beaver Dam Lake Management District and provided support to Committee on Aquatic Plant Management
Nancy Bentz	Past Commissioner/ Secretary - Beaver Dam Lake Management District
Tony Curella	Past Commissioner - Beaver Dam Lake Management District
Paul Flottum	Past Commissioner - Beaver Dam Lake Management District
Bert Skinner	Past Cumberland City Council Representative to Beaver Dam Lake Management District
Marty Peters	Past Cumberland City Council Representative to Beaver Dam Lake Management District
John Ostrem	Chairman - Committee on Aquatic Plant Management
Robert Ruppel	Member - Committee on Aquatic Plant Management
Ann Mike	Member - Committee on Aquatic Plant Management
Bob Fleming	Member - Committee on Aquatic Plant Management

Thanks to Jay Michels of Emmons & Olivier Resources for providing the *Beaver Dam Lake Stormwater Management Plan* and *Library Lake Management Plan*. Thanks to Kevin Gauthier, Alex Smith, and Pamela Toshner of Wisconsin DNR and Frank Koshere, independent consultant, for assistance with the planning process. Thanks to Tyler Gruetzmacher of Barron County for providing watershed information. Thanks to Keith Hardie of the City of Cumberland for providing the City of Cumberland Comprehensive Plan and results of Clean Boats/Clean Waters boat monitoring program. Thanks to Matthew, Mitchell, and Noah Berg, as well as other staff of Endangered Resource Services, LLC., for completion of the plant surveys and summarization of the plant survey data. Thanks to the Wisconsin Department of Natural Resources for providing monies to help fund the 2011, 2013, and 2014 aquatic plant surveys and 2013 and 2014 herbicide residue monitoring programs.

Executive Summary

Eurasian watermilfoil (EWM) was accidentally introduced to Beaver Dam Lake in 1991 and was allowed to grow and spread without management from 1991 through 1999. From a 1999 plant survey, it was estimated that 73 percent of the lake's littoral area was infested with EWM. Herbicide treatment during 2000 through 2005 reduced the area of EWM infestation to 47 percent of the lake's littoral area by 2005. Herbicide treatment during 2006 through 2018 reduced the area of EWM infestation to 18 acres by 2018, which is 3 percent of the littoral area.

EWM was accidentally introduced into Beaver Dam Lake, pictured above and was allowed to grow and spread without management from 1991 through 1999, when it was estimated that 73 percent of the lake's littoral zone was infested with EWM. Photo Credits: Lake Restoration, Inc. (top) and Endangered Resource Services, LLC (bottom).

The Beaver Dam Lake Management District (District) considers the present reduction successful. The District has established a goal to reduce EWM extent (expressed as a percent of the littoral area) to 7 percent or less. The current area of EWM infestation is less than 7 percent. Hence, the District goal has been met. However, the District plans to continue EWM management in an attempt to reduce EWM to the lowest possible extent and to prevent a return of EWM to pre-management conditions.

While EWM is the primary invasive species of concern, the presence of curly-leaf pondweed (CLP) in the lake also poses a threat to the lake's native plant community. CLP currently occupies less than 7 percent of the lake's littoral zone and seems to be a latent problem. However, management of CLP may be needed to contain it to a low occurrence (i.e., less than 7 percent of the littoral zone) and prevent the accumulation of turions (i.e., similar to seeds). This approach is intended to prevent CLP from establishing dominance. It may avoid the need for subsequent long-term annual treatments to reduce an established CLP population that can rebound once larger numbers of turions are present in the sediments. This approach, (i.e., to treat or remove small areas of CLP when warranted), is similar to what may be achieved and would be necessary after a large-scale control as post-treatment containment to prevent a return of CLP to pre-treatment conditions. A large majority of respondents to a citizen survey (83 percent) support reducing the amount of CLP in the lake.

Respondents to a citizen survey indicated Beaver Dam Lake is a busy lake with broad recreational use. About 60 percent of respondents feel their activities are negatively affected by aquatic plants. When asked to rank the degree of impact that invasive species have on use or enjoyment of the lake, more than half of the respondent's selected high impact. A huge majority (15:1) support the use of herbicides to remove plants that are not native to Wisconsin. A third of respondents indicate native plants had a high impact on use or enjoyment of the lake. A huge majority (93 percent) support removing native plants in navigation channels if they interfere with boat navigation.

The negative impact to the lake's plant community caused by the accidental introduction of EWM clearly shows the vulnerability of the ecosystem to harmful introductions of invasive species. Beaver Dam Lake is a busy lake and, hence, vulnerable to the accidental introduction of additional invasive species. A huge majority (96.5 percent) support the City of Cumberland boat inspection program or increasing the program to protect the lake from the accidental introduction of additional invasive species.

Results of the citizen survey were used to select six aquatic plant management goals for Beaver Dam Lake. The goals are shown on Figure ES-1.

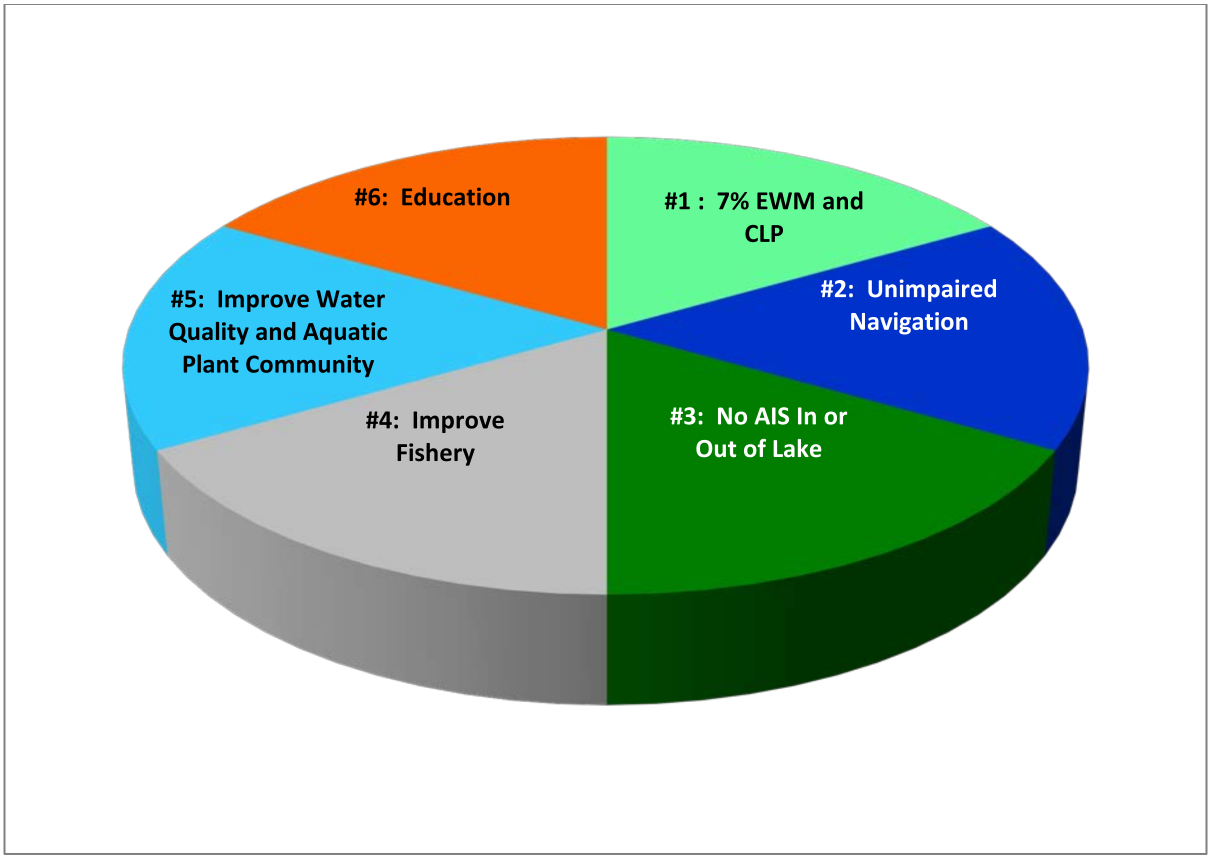


Figure ES-1 Beaver Dam Lake Goals

This APM Plan details objectives and strategies to attain the six goals as well as measurements to determine if the strategies were successful. Goals, objectives, strategies, and measurements of the Beaver Dam Lake APM Plan are summarized in Table ES-1.

This APM Plan intends to meet the permitting requirements of State Statute 23.24(3)(b) and Wisconsin Administrative Code NR 109.04(3) that state: "The department may require that an application for an aquatic plant management permit contain a plan for the department's approval as to how the aquatic plants will be introduced, removed, or controlled." The APM Plan intends to meet the requirements in Wisconsin Administrative Code NR 198.43 (Table 1-1) as well as the requirements in Aquatic Plant Management in Wisconsin (Table 1-2).

With an approved APM Plan, the District may apply for cost-share dollars from the Wisconsin Department of Natural Resources (WDNR). The District is firmly committed to continue implementation of this APM Plan if cost-share money is not available. However, it will continue to address ways to improve this APM Plan to make it more competitive for grant cost-share and seeks feedback to accomplish that goal.

The District intends to continue AIS management in Beaver Dam Lake indefinitely. This APM Plan is not limited to a five year period. Up to this point, the District has funded all elements of the APM Plan implementation as needed, and intends to continue funding the implementation of the plan. This APM Plan describes a framework for annual AIS control activities that include the required elements of an APM Plan. Those elements of an APM Plan that involve annual management activities are updated annually. Remaining elements that may remain relatively unchanged such as watershed information will be reviewed for new information when it becomes available and updated when new information becomes available. Herbicide treatment (and all attendant monitoring) is a critical element to be reviewed annually and will be used to plan and apply for each annual NR 107 permit. Updated as it is each year, the APM Plan fulfills the need of a long-term commitment to AIS management. Updated annually, it will include new technical developments for control of AIS.

Table ES-1 Beaver Dam Lake APM Plan Goals, Objectives, Strategies, and Measurements

Goals	Objectives	Strategies	Measurements: Yes	Measurements: No
Goal 1: Reduce Eurasian watermilfoil (EWM) and curly-leaf pondweed (CLP) levels to seven percent of the littoral zone while minimizing harm to native aquatic plants	*Objective 1: Protect the lake's ability to support recreational uses such as boating, fishing, swimming, and enjoying the view*	Strategy 1: Fall whole lake point intercept plant survey completed to determine EWM and CLP locations		
		Strategy 2: Planning meeting completed to determine treatment/manual removal plans for subsequent year		
		Strategy 3: Amended APM Plan completed		
	Objective 2: Protect fisheries habitat and the overall health of the lake	Strategy 4: Amended APM Plan adopted at public noticed Board meeting and submitted to WDNR		
		Strategy 5: Application for permits completed and submitted to WDNR		
		Strategy 6 (Optional): Pre-treatment spring CLP delineation completed		
	Objective 3: Prevent CLP dominance and the subsequent long-term annual control to hold the plant back from resurgence to dominance.	Strategy 7: Permitted spring treatment/manual removal completed		
		Strategy 8: Herbicide residue monitoring program completed when required by WDNR permit		
		Strategy 9 (Optional): June post-treatment survey to assess CLP treatment results completed		
		Strategy 10: Summer whole lake point intercept survey of all plants completed		
	Objective 4: Reduce the annual EWM and CLP management cost	Strategy 11: Summer plant survey data assessed to verify need for treatments/manual removal		
		Strategy 12: Updated EWM management plan and permit applications submitted to WDNR		
		Strategy 13: If fall treatment plan updated based upon summer data, updated fall treatment plan submitted to WDNR		
		Strategy 14: Permitted treatment/manual removal completed		
Goal 2: Maintain navigation channels that are not impaired by native plants and invasive plant growth	*Objective 1: Protect the lake's ability to support recreational uses such as boating, pontooning, and fishing*	Strategy 1: Navigation channels inspected annually during July by selected contractor and any impairment by plants documented. Contractor proposes navigation channels needing treatment.		
		Strategy 2: Impaired access corridors reported as impaired by riparian residents inspected by selected contractor during annual July inspection and any impairment by plants documented. Contractor proposes access corridors needing treatment.		
		Strategy 3: Permit application to treat impaired navigation channels and/or impaired access corridors completed and submitted to WDNR. Documentation of impairment submitted with permit application		
		Strategy 4: Permitted treatment completed		
	Objective 2: Provide riparian owners with the ability to access the lake with their boats and pontoons	Strategy 5: Whole lake point intercept summer survey completed and data assessed to evaluate plant community in treated areas		
		Strategy 6: Treated navigation channel and access corridor areas mapped		
		Strategy 7: Amended APM Plan completed and any needed changes to the unimpaired navigation channel program included		
		Strategy 8: Amended APM Plan adopted at a public noticed Board meeting and submitted to WDNR		
Goal 3: Prevent transfer of invasive plant and animal species both to and from Beaver Dam Lake	*Objective 1: Protect the lake's ability to support recreational activities*	Strategy 1: The City of Cumberland's Clean Boats/Clean Waters boat inspection program fully funded if grant money not available. If grant money available to fund 75 percent of program cost, the 25 percent local cost share funded		
	Objective 2: Protect the lake's fishery	Strategy 2: Educational material given to each lake user whose boat was inspected by the Clean Boats/Clean Waters program		
	Objective 3: Containment of EWM to prevent the introduction of EWM and CLP to other lakes and prevent introduction of other invasive species to Beaver Dam Lake.	Strategy 3: Sign placed at each boat landing educating boaters to clean boats and trailers of any plant materials before entering and leaving the lake		
		Strategy 4: Each newsletter contained information that educated readers to remove plants and animals from boats before entering or leaving the lake		

Table ES-1 Beaver Dam Lake APM Plan Goals, Objectives, Strategies, and Measurements (Continued)

Goals	Objectives	Strategies	Measurements	
			Yes	No
Goal 4: Improve the fishery resource through proper management of aquatic plants and stocking of extended growth walleyes to control rainbow smelt, an invasive species.	*Objective 1: Improve fishery habitat through the reduction of EWM and CLP to 7 percent of the littoral area*	Strategy 1: Herbicide treatment of invasive species completed during spring and fall when native plants are seasonally suppressed		
	Objective 2: Protect fishery habitat by minimizing harm to the native plant community during the treatment of EWM and CLP	Strategy 2: Summer whole lake point intercept survey completed and data assessed to determine treatment effectiveness and native plant response to treatment		
	Objective 3: Protect plants found in critical habitat areas of the lake because these plants are important to the lake's fishery	Strategy 3: When WDNR has completed the proposed critical habitat areas designation for Beaver Dam Lake, plant data collected from critical habitat areas during summer whole lake point intercept survey assessed to determine the condition of critical habitat areas. A subjective rating system annually tracked the status of critical habitat areas (e.g., "status stable, improving, loss, threats present, or watch status"). Species involved in changing status noted		
	Objective 4: Improve the fishery resource by controlling rainbow smelt, an invasive species, through the stocking of extended growth walleyes.	Strategy 4: Stock extended growth walleyes every other year to increase predation on rainbow smelt and improve walleye natural reproduction, stock recruitment, and abundance.		
Goal 5: Improve water quality and aquatic plant community through management of stormwater and riparian shoreline areas	*Objective 1: Improve the lake's ability to support recreational uses such as boating, fishing, swimming, and enjoying the view*	Strategy 1: Supported City of Cumberland's efforts to implement the City of Cumberland Stormwater Management Plan		
		Strategy 2: Constructed Library Lake wetland treatment cell and implemented additional stormwater treatment measures recommended in Library Lake Management Plan if funding became available		
	Objective 2: Improve fisheries and wildlife habitat and the overall health of the lake	Strategy 3: Worked with Barron County and WDNR and determined if feasible to restore drainage basin to lake's natural watershed (Figure 2-1). If feasible, completed project to restore lake's natural watershed		
		Strategy 4: Provided information to help riparian residents voluntarily establish buffer areas		
Goal 6: Provide stewardship educational materials to help area residents manage riparian land and water areas and educate the Public about progress on goals and strategies of the Beaver Dam Lake Management District	*Objective 1: Help residents protect the attributes of the lake they most enjoy*	Strategy 1: Provided education materials and reported progress on attaining District goals and strategies at annual meeting		
	Objective 2: Help residents protect fish and wildlife habitat and the overall health of the lake	Strategy 2: Provided education materials and reported progress on attaining District goals and strategies in District newsletters and on the District website		
	Objective 3: Keep the Public informed about progress on attaining District goals and strategies of the Beaver Dam Lake Management District	Strategy 3: Used other media to provide education materials and report about progress on attaining District goals and strategies		
		Strategy 4: Provided education materials and reported progress on attaining District goals and strategies in annually amended APM Plan		

Beaver Dam Lake Aquatic Plant Management Plan

February 2019

Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

Beaver Dam Lake in Barron County, Wisconsin is valued by lakeshore property owners, area residents, the City of Cumberland, Barron County, and the Wisconsin Department of Natural Resources (WDNR) for its fisheries and for recreational uses (see Figure 1-1). The lake notes a surface area of 1,186 acres, a maximum depth of 106 feet, and an average depth of 32 feet. Beaver Dam is the deepest lake in Barron County and the sixth deepest lake in Wisconsin.

Eurasian water milfoil (EWM), an invasive plant not native to Wisconsin, was accidentally introduced into the lake in 1991. EWM spread throughout the lake's shallow region where plants grow, termed the littoral area, and caused problematic conditions. Because of concern for Beaver Dam Lake, the Beaver Dam Lake Management District approached the Wisconsin Department of Natural Resources (WDNR) to discuss ways to solve the lake's EWM problem. The WDNR recommended the completion of an aquatic plant survey and an APM Plan of Beaver Dam Lake. In 1999, the Beaver Dam Lake Management District completed an aquatic plant survey and in 2000 completed an APM Plan of the lake. The APM Plan was implemented during 2000 through 2005. Implementation included herbicide treatment of navigation channels, boat landings, the fishing pier area, and swimming beaches annually to provide nuisance relief as well as annual treatment of EWM beds to reduce the coverage and density of EWM in the lake.

After being accidentally introduced into the lake, Eurasian watermilfoil spread throughout the lake's littoral region and caused problematic conditions, such as the dense EWM growth in Beaver Dam Lake pictured above. Photo Credit: John Skogerboe

In 2005, the Beaver Dam Lake Management District completed an aquatic plant survey and in 2006 updated the lake's APM Plan. Implementation of the APM Plan occurred during 2006 through 2012. The updated APM Plan focused on reducing EWM coverage and density in the lake using an adaptive management approach. The adaptive management approach included annual summer and fall plant surveys and a planning effort following the fall plant survey to design the treatment program for the next year. The treatment design was customized and not only included design of treatment areas, but also included selection of herbicide or combination of herbicides, dose and application details (e.g., herbicide dose applied all at once or split into two applications timed a few hours apart). The large lake was divided into 8 treatment zones that corresponded to morphologically separate areas within the lake and a customized treatment program was designed for each treatment zone. The treatment zones are: West Lake, Library Lake, Rabbit Island Bay, and Williams Bay located in the western basin; East Lake, Cemetery Bay, City Bay, and Norwegian Bay in the eastern basin (Figure 1-2).

Figure 1-1 Beaver Dam Lake

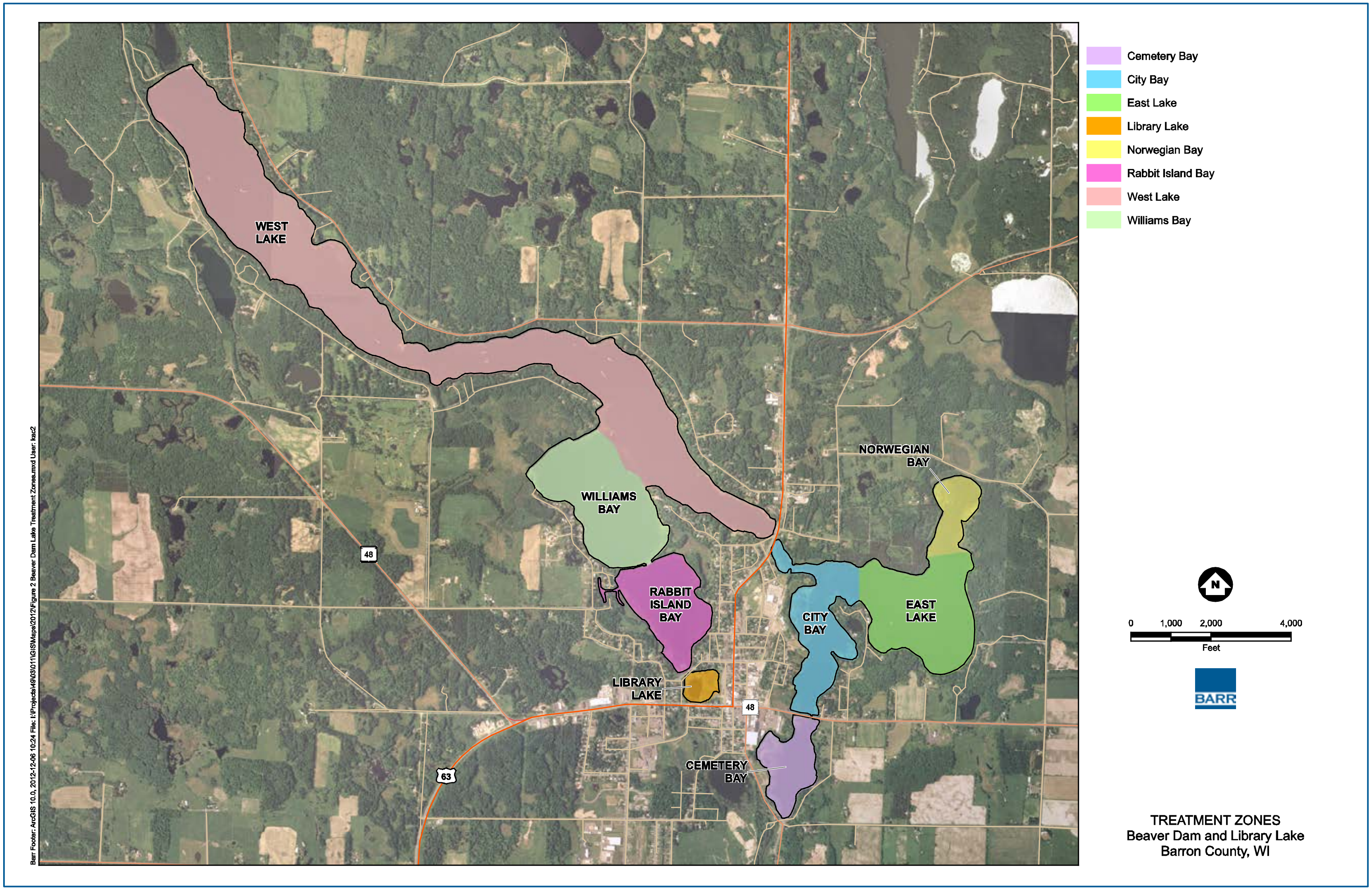


Figure 1-2 Beaver Dam Lake Areas (West Basin, East Basin, and Bays)

The adaptive management approach utilized a rigorous monitoring program to assess effectiveness of the program, assess response of the native plant community to the program, and collect data needed to design the subsequent year's program. Annual summer plant surveys assessed the effectiveness of the spring treatment program with respect to EWM control and response of native plants. Annual herbicide residue monitoring determined the herbicide concentration following treatment and the rate of decline after treatment. As noted earlier, annual fall plant surveys assessed EWM to determine treatment needs for the following year.

Although management of EWM has been the focus of the District's aquatic plant management program, the presence of a second aquatic invasive species (AIS), curly-leaf pondweed (CLP), has resulted in some management effort to control CLP. Plant surveys during 1999 and 2005 through 2012 documented the presence of CLP in Beaver Dam Lake. Although the coverage and density of the plant was not problematic, the District realized this species has the potential to cause problems similar to the EWM problems experienced by the lake. The District did not manage CLP during 2000 through 2005, but managed some CLP areas in 2006 through 2012 to prevent problematic conditions.

During 2011 and 2012, the Beaver Dam Lake Management District updated the lake's APM Plan. Beginning in 2013, those elements of the APM Plan that involve annual management activities have been updated annually and, continuing in the future, the Beaver Dam Lake Management District intends to annually update those elements. Remaining elements that may remain relatively unchanged, such as watershed information, are reviewed for new information annually and changed when new information becomes available. The APM Plan intends to fulfill the permitting requirements of State Statute 23.24(3)(b) and Wisconsin Administrative Code NR 109.04(3) that state: "The department may require that an application for an aquatic plant management permit contain a plan for the department's approval as to how the aquatic plants will be introduced, removed, or controlled." The APM Plan intends to meet the requirements in Wisconsin Administrative Code NR 198.43 (Table 1-1) as well as the requirements in Aquatic Plant Management in Wisconsin (Table 1-2)

Table 1-1 Report Directory of Fulfillment of NR 198.43 Requirements for an Aquatic Plant Management Plan

NR 198.43 Requirement				Section/Appendix
NR 198.3			NR 198.43 Sponsors shall prepare a management plan and submit it to the department for approval before applying for a control project under s. NR 198.42 (1) (a)	--
	(1)		A management plan shall include all of the following:	--
		(a)	An identification of the problems or threat to the aquatic ecosystem presented by the aquatic invasive species including recreational uses and other beneficial functions up to the time of application, and how these uses and functions may have changed because of the presence of aquatic invasive species	Section 10
		(b)	A description of the historical control actions taken or those that are in progress	Section 7
		(c)	A thorough characterization of the waterbody's aquatic ecosystem's historical and current condition, including at least one year of current base line survey data quantifying the extent of the population	Sections 4-8
		(d)	An assessment of the sources of watershed pollution and a strategy for their prevention and control.	Section 3
		(e)	An assessment of the fishery, wildlife, and aquatic plant community	Sections 4, 7, and 8
		(f)	An identification of the need for the protection and enhancement of fish and wildlife habitat, endangered resources, and other local natural resource concerns.	Sections 4 and 10
		(g)	Identification of the management objectives needed to maintain or restore the beneficial uses of the aquatic ecosystem including shoreland and shallow area protection and restoration.	Section 12
		(h)	Identification of target levels of control needed to meet the objectives.	Section 12
		(i)	Identification and discussion of the alternative management actions considered and proposed for aquatic invasive species control including expected results.	Section 11 and Appendix I
		(j)	An analysis of the need for and a list of the proposed control actions that will be implemented to achieve the target level of control.	Section 12 and Appendix J
		(k)	A discussion of the potential adverse impacts the project may have on non-targeted species, drinking water or other beneficial waterbody uses.	Section 14
		(l)	A strategy for effectively monitoring and preventing the reintroduction of the aquatic invasive species after the initial control and to reasonably assure that new introductions of aquatic invasive species will not populate the waterbody.	Section 12 and Appendix J
		(m)	A contingency strategy for effectively responding to the reintroduction of the aquatic invasive species after the initial control.	Section 12
		(n)	Sufficient information for determining the feasibility of alternative control measures, including costs; the relative permanence of the control; the potential for long-term control of the causes of infestation; and the baseline data required to measure subsequent change.	Section 11 and Appendix I; Sections 7 and 12; Appendix J

Table 1-2 Report Directory of Fulfillment of Requirements for an Aquatic Plant Management Plan in Aquatic Plant Management in Wisconsin

Chapter 2 Requirement	Section/Appendix
1. Goal Setting	Section 12
2. Inventory	Sections 2-9
3. Analysis	Sections 7-10
4. Alternatives	Section 11 and Appendix I
5. Recommendations	Section 12
6. Implementation	Section 12 and Appendix J
7. Monitor and Modify	Section 12 and Appendix J

The Beaver Dam Lake APM Plan includes management of non-native invasive species, such as EWM, shown in the top picture of City Bay, to prevent displacement of native species, such as white water lily, shown in the bottom picture of Cemetery Bay. Photo Credit: Endangered Resource Services LLC.

1.1 Public Input for the APM Plan

Public input was an important part of APM Plan development. Opportunities for public involvement in APM Plan development have included public meetings, board meetings, and committee meetings. Public notices in the local newspaper and an article in the local newspaper have informed the public of opportunities to provide input into APM Plan development (Appendix A). Public input details follow:

Public Meetings – Three public meetings were held during completion of the APM Plan. (1) At the Annual District Meeting on July 9, 2011, details of the APM Plan development were presented including work scope, schedule, and budget. The meeting attendees approved the APM Plan budget. Volunteers for a Citizen Committee on Aquatic Plant Management (Committee) were solicited and six citizens volunteered to be members of the Committee (Beaver Dam Lake Management District, 2011a). (2) A public hearing was conducted on May 23, 2012 to give citizens an opportunity to comment on the draft APM Plan. The draft APM Plan was posted on the District website and a copy was placed in the Cumberland Public Library in advance of the public hearing. The citizens who attended the public hearing made positive comments about the APM Plan. (3) At the Annual District Meeting on July 7, 2012, a summary of the draft APM Plan was presented and the public was given the opportunity to comment or ask questions. Minutes from the three public meetings are found in Appendix A.

Committee Meetings – On July 26, 2011 the Committee met and prepared a draft citizen survey. A Committee member presented the draft citizen survey to the Board at the August Board meeting. In September, members of the Committee compiled the results of the citizen survey. Two committee members presented the results of the survey at the September Board meeting. The Committee met on September 27, 2011 and prepared draft management goals. A member of the Committee presented the draft goals to the Board at their October Board meeting. Following completion of the draft APM Plan, members of the Committee reviewed the APM Plan and provided comments by email and telephone discussion. Changes were made in the APM Plan to address committee comments. The draft APM Plan was then submitted to the Board.

Board Meetings – On August 3, 2011 the Board reviewed and discussed the draft citizen survey prepared by the Committee. Following Board discussion and some changes, the Board approved the citizen survey and determined details for printing and sending out the survey to District members (Beaver Dam Lake Management District, 2011b). On September 14, 2011 the Board reviewed and discussed the results of the Citizen survey. On October 26, 2011 the Board reviewed and discussed the draft goals prepared by the Committee. A representative from the Wisconsin DNR attended the Board meeting and participated in the discussion. Following Board discussion and some changes, the Board approved the goals (Beaver Dam Lake Management District, 2011c). On May 23, 2012 following a public hearing, the Board approved the draft APM Plan and directed Barr Engineering to submit the draft APM Plan to the Wisconsin Department of Natural Resources (WDNR), the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), and the St. Croix Chippewa Indians for review and comment. On October 24, 2012, the Board changed the EWM and CLP goals from 5 percent to 10 percent of the whole lake littoral area. On December 12, 2012 the Board approved this final APM Plan and directed Barr Engineering Company to submit the final APM Plan to the WDNR for approval. The WDNR notified the Board on March 8, 2013 that the Beaver Dam Lake APM Plan had been approved. Minutes of the August 3, 2011, the October 26, 2011, the May 23, 2012, October 24, 2012, and December 12, 2012 Board meetings are found in Appendix A. The WDNR March 8, 2013 APM Plan approval letter is found in Appendix A.

The APM Plan was updated to include 2013 monitoring data and the 2014 herbicide treatment plan. The updated APM Plan was approved at the January 22, 2014 Board meeting and submitted to the WDNR.

Changes to the APM Plan goals were made at the November 20, 2014 Board meeting. The EWM goal was changed from 10 percent to 7 percent due to EWM reductions in the lake. Since CLP frequency was also less than 10 percent, the District also changed the CLP goal to 7 percent.

Beginning in 2015 and continuing through the present, the APM Plan was updated annually to include the previous year's monitoring data and the subsequent year's EWM management Plan. The revised APM Plan was then approved at the Beaver Dam Lake Management District Board meeting and submitted to the WDNR. The WDNR approved the updated plans.

Comments on Draft APM Plan from GLIFWC, the St. Croix Chippewa Indians, and WDNR – GLIFWC and the St. Croix Chippewa Indians had no comments on the APM Plan. WDNR submitted written comments on the draft APM Plan to the District on October 2, 2012. Representatives from WDNR met with the District Board on October 11, 2012 to discuss WDNR comments on the draft APM Plan. The District incorporated the comments into the APM Plan and submitted the revised APM Plan to the WDNR for approval.

2.0 Lake and Watershed Information

2.1 Lake

Beaver Dam Lake is a 1,186 acre lake located in and around Cumberland in Barron County, Wisconsin. It is a drainage lake with two streams flowing into the lake and the Hay River flowing from the lake. The maximum depth is 106 feet and the mean depth is 32 feet. Beaver Dam Lake is divided by US 63 into two parts, the western basin and eastern basin. The western basin notes a surface area of 845 acres is characterized by sharp drop-offs and little littoral area. The eastern basin notes a surface area of 341 acres and, except for one deep area, is fairly shallow. The lake is complex and includes several bay areas. The western basin notes three bay areas – Williams Bay, Rabbit Island Bay, and Library Lake (Figure 1-2) as well as West Lake. The eastern basin also notes three bay areas—Norwegian Bay, City Bay, and Cemetery Bay (Figure 1-2) as well as East Lake. Table 2-1 shows the surface area of East Lake, West Lake, and the six bay areas.

Beaver Dam Lake, shown above, is located in and around Cumberland, WI.

Table 2-1 Beaver Dam Lake Areas (West Basin, East Basin, and Bays)

West Basin Areas	Area (ac)	East Basin Areas	Area (ac)
Library Lake	14	Norwegian Bay	38
Rabbit Island Bay	94	East Lake	147
Williams Bay	155	City Bay	102
West Lake	582	Cemetery Bay	53
Total of all West Basin Areas	845	Total of all East Basin Areas	341

The lake has 18 miles of shoreline. The lakeshore is developed with dwellings and several parks and boat landings present. Specifically, the lake has six boat landings, two public swimming beaches, one fishing pier, one campground, and two City parks. Four of the boat landings provide a paved boat ramp and a boarding dock. At least one of the landings has a portable restroom. Collectively, the public boat landings provide a total of 40 car/trailer parking spaces, which satisfy the requirement of Wisconsin Administrative Code NR 1.91 Public boating access standards for WDNR decisions related to providing natural resource enhancement services.

2.2 Watershed

The lake's current watershed includes 16,819 acres. Historically, the lake's natural watershed totaled 6,755 acres (Figure 2-1). In 1937, a diversion ditch channeled water from an additional 10,064 acres into Norwegian Bay (Figure 2-1). The diversion occurred during a drought period because of the belief the lake needed additional water. Following construction of the diversion ditch, precipitation returned to normal. Hence, the diversion of drainage from an additional 10,064 acres substantially increased both the volume of water and nutrient mass entering the eastern basin of Beaver Dam Lake. In 1989 through 1990, a study to shut off the diversion to Beaver Dam Lake and restore the natural hydrology of the lake's watershed was completed by the WDNR.

In 1937, a diversion ditch channeled water from an additional 10,064 acres into Norwegian Bay. The ditch flowing into Norwegian Bay is pictured above.

The study looked at three scenarios: (1) leave the diversion ditch as it is; (2) control the flow in the diversion ditch; and (3) close the diversion ditch. The study concluded:

1. "If the diversion ditch is left as it is, eutrophication of Beaver Dam Lake will continue at an accelerated rate."
2. "The effect of controlling the flow in the ditch would be intermediate between the effect of uncontrolled flow (the present situation) and no flow (closed ditch)."
3. "There would be no water quality impact on Granite and Duck Lake if the diversion ditch was closed. The existing high water problems on these two lakes require a solution that may depend in part on how the ditch is managed. Closing the diversion ditch would result in more water flowing through Buck Lake and would help prevent winter kill in the small lake. No significant change in water quality in the rest of the Yellow River is predicted if the ditch was closed." (Smith, 1990).

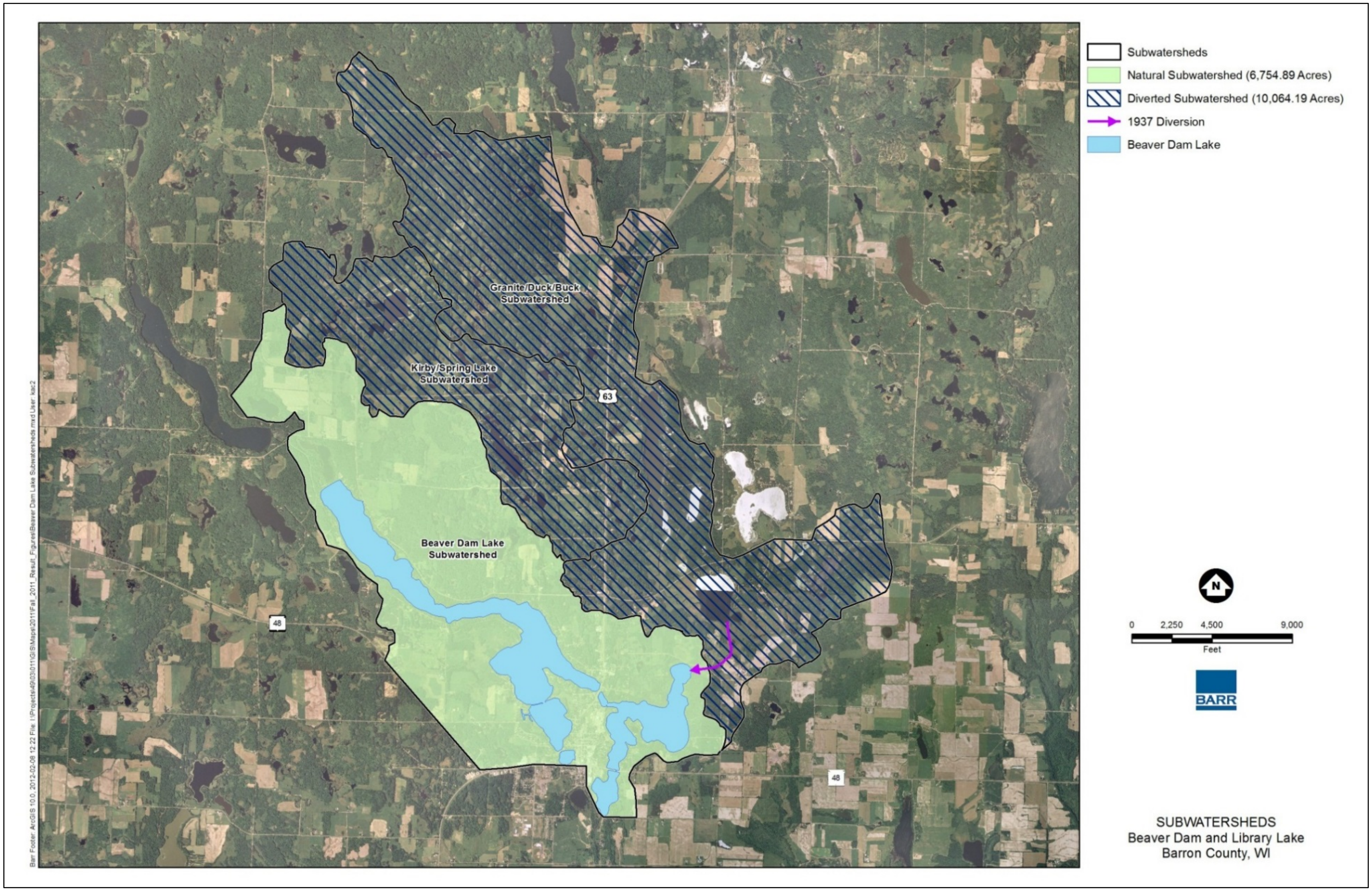


Figure 2-1 Beaver Dam Lake Natural and Diverted Subwatersheds

The study results were reviewed by WDNR staff. During the review process, fisheries staff expressed concern that closing the diversion ditch would have an adverse impact on the Yellow River trout fishery. The concern was based upon the hypothesis that runoff from the 10,064 acre watershed would increase water temperature and nutrient concentrations in the Yellow River and these increases would adversely impact the trout fishery. Because of concern for the Yellow River trout fishery, no change in the diversion ditch resulted from the study (Koshere, 2012; Evenson, 2012).

The lake's natural watershed (Figure 2-1) has a poorly defined drainage pattern. In the previous century, several ditches were constructed connecting small wetlands and pothole lakes. Land use in the lake's natural watershed is forest with some development. There is an 18-hole golf course covering 120 aces and 200 acres of agricultural land on the southwest side of the lake (Tyler Gruetzmacher, 2012).

The diverted watershed (Figure 2-1) is a glacial end moraine area of hummocky relief. Land use in the diverted watershed is similar to the lake's natural watershed. Watershed land use consists of hardwood forests above isolated wetlands. Many of the wetlands were connected by ditches in the previous century during an era when quantity of water was deemed to be priority over quality. Currently, beaver dam construction in the diverted watershed area impacts the destination of water flowing from the diverted watershed. Sometimes runoff from the diverted watershed goes into Beaver Dam Lake and at times it may go to the Yellow River system, its historic flow path (Tyler Gruetzmacher, 2012).

3.0 Watershed Management

The Beaver Dam Lake watershed was assessed to determine current sources of pollution, management of pollution from the lake's watershed that has occurred or is currently occurring, and future management opportunities.

An assessment of the Beaver Dam Lake watershed identified two major sources of pollution to the lake:

- Stormwater runoff from the City of Cumberland
- Runoff from the lake's expanded watershed resulting from construction of a diversion ditch in 1937 (see discussion in Section 2.0).

As discussed in the previous section of this report, closing the diversion ditch and restoring the lake's natural hydrology would substantially reduce sediment and nutrients added to the eastern basin of Beaver Dam Lake. For this reason, it is recommended that the District, Barron County, and the Wisconsin Department of Natural Resources engage in discussions to determine whether it is feasible to close the diversion ditch or whether management of runoff from the watershed tributary to the diversion ditch is the most feasible option to reduce sediment and nutrient loading to Beaver Dam Lake's eastern basin.

The City of Cumberland and the District are actively managing municipal stormwater runoff to the lake. The pollution sources and management efforts to reduce pollution to the lake are discussed in: Section 3.1 *City of Cumberland Comprehensive Plan;* Section 3.2 *City of Cumberland Comprehensive Plan*; and Section 3.3 *Library Lake Management Plan.*

During the 2011 plant survey, cattle were observed on the shoreline of the channel that connects Duck Lake to Norwegian Bay, one of the lake's bays. The cattle had access to the channel, and there was a potential for runoff from the grazing pasture reaching the channel; both were a source of pollution to the lake. The BDLMD brought the matter to the attention of the Barron County Department of Land Services (Barron County). In 2013, Barron County successfully completed a fencing project to prevent the cattle from having access to the lake, and providing a buffer zone along the channel, thus removing this source of pollution.

Cattle on the shoreline of the channel that connects Duck Lake to Norwegian Bay in Beaver Dam Lake are pictured above. Barron County successfully completed a fencing project to prevent the cattle from having access to the lake and providing a buffer zone along the channel, thus removing and reducing this source of pollution. Photo Credit: Endangered Resource Services, LLC.

3.1 City of Cumberland Comprehensive Plan

The City of Cumberland contracted with Short Elliott Hendrickson, Inc. to complete a Comprehensive Plan. The Comprehensive Plan articulated the City's intent to identify and manage pollutant sources to Beaver Dam Lake. The plan vision statement included: "Natural resources will be protected and serve as an environmental, recreational, and economic asset to the City." The goals and objectives included:

Housing

- ***Goal: Guide new housing development into areas that minimize impacts on sensitive natural resources so that the city continues to be an attractive place to reside.***
    - ***Objective:*** *Encourage development in areas that will not result in property or environmental damage.*
        - ***Action:*** *Encourage "low impact" development that strives to retain natural vegetation that can help reduce stormwater runoff and flooding.*
        - ***Action:*** *Encourage landscaping and natural screening between building sites.*

Utilities

- ***Goal: Implement a Stormwater Management Plan***
    - ***Objective:*** *The City of Cumberland will require necessary stormwater best management practices for new development and develop solutions to keep pace with evolving water quality regulations.*
    - ***Objective:*** *Implement a stormwater utility if necessary to help pay for improvements for stormwater management.*
    - ***Objective:*** *The City of Cumberland will develop a stormwater management plan in the future, with its apparent need or regulatory requirements.*
    - ***Objective:*** *Work with the Lake Associations to create awareness about water quality issues in Cumberland.*
- ***Goal: Maintain and enhance community facilities and services, which contribute to the quality of life for area residents.***
    - ***Objective****: Promote use of existing facilities and encourage development of public facilities, such as new parks, green spaces, and trails (e.g. walking, biking, skiing and snowmobile trails).*

Agricultural, Natural, and Cultural Resources

- ***Goal: Conserve, protect, manage, and enhance the town's natural resources, including but not limited to, lakes, rivers/streams, wetlands, groundwater, forestlands, and other wildlife***

habitats in order to provide the highest quality of life for city of Cumberland's citizens and visitors.

- ***Objective:*** *Enforce setback requirements for water resources by enforcing City shoreland standards when applicable.*
- ***Objective:*** *Endorse the Wisconsin Department of Natural Resources watershed initiatives to educate shoreland and basin property owners on the appropriate safe levels, application, timing and safe types of fertilizers and pesticides applied to lawns and fields in the City.*
- ***Objective:*** *Identify City stormwater inlets to lakes within the City and monitor for quality and quantity of runoff. Also monitor for signs of phosphorus entering lakes*
- ***Objective:*** *Endorse the Wisconsin Department of Natural Resources watershed initiatives to restore altered shoreland vegetation and prohibit removal of natural vegetation in critical shoreland areas.*
- ***Objective:*** *Promote the establishment and maintenance of natural buffers along water resources.*
    - ***Action:*** *Encourage Barron County and the Wisconsin Department of Natural Resources to fund buffer strips along streams and the lakeshores.*
    - *Collaborate with state and local organizations whose charge is to enhance water quality.*
- ***Objective:*** *Educate the public on best management practices that will ensure the protection of natural resources*
- ***Objective:*** *Protect and manage local forested areas and other wildlife habitats.*
    - ***Action:*** *Encourage selective cutting in forest stands.*
    - ***Action:*** *Coordinate with WDNR to identify and protect wildlife habitats.*
    - ***Action:*** *Inventory and map sensitive resources that should be preserved to the greatest extent possible.*
    - ***Action:*** *Encourage "low impact" development that strives to retain natural vegetation.*
    - ***Action:*** *Discourage habitat fragmentation by encouraging development on the fringes of identified habitat areas.*
    - ***Action:*** *Work and cooperate with local land trust and similar organizations on forest and wildlife habitat protection, management, and preservation.*

- ***Goal: Provide adequate amount of parkland or greenspace to serve existing and new development.***
    - ***Objective***: *Require developers to dedicate a portion of the development for park and open space purposes or cash-in-lieu of land for this purpose.*

Source: (SEH, 2006)

3.2 City of Cumberland Stormwater Management Plan

After completing the Comprehensive Plan, the City of Cumberland (City) contracted with Emmons & Olivier, Inc. to prepare a stormwater management plan. The plan identified sources of watershed pollution and detailed a strategy for their prevention and control. Stormwater Management Plan goals focus on reduction of stormwater volume, treatment of stormwater runoff prior to discharge to Beaver Dam Lake, and protection and improvement of shoreland and aquatic habitat within Beaver Dam Lake. Plan goals include:

- ***Goal 1: Reduce stormwater runoff volume, peak flows and flooding***
    - *Detain (and retain as technically feasible) up to the 1-inch, 24-hour storm event to reduce erosion, sediment transport and runoff temperature and to remove the first flush of stormwater pollutants.*
    - *Utilize stormwater management practices that emulate native hydrology including stormwater retention, infiltration and peak runoff reduction.*
    - *Protect US Highway 63 from flood damage.*
    - *Enhance highway safety by avoiding flooding hazards.*
- ***Goal 2 - Treat stormwater runoff prior to discharge to city of Cumberland waterbodies to reduce pollutant loading***
    - *Implement structural stormwater best management practices in priority watersheds.*
    - *Implement programmatic best management practices.*
    - *Restore trophic status of Beaver Dam Lake West including Rabbit Island Bay and Library Lake from eutrophic to mesotrophic.*
    - *Restore trophic status of Beaver Dam Lake East including Cemetery Bay and Norwegian Bay from hypereutrophic to mesotrophic*
    - *Continue on-going total phosphorus, chlorophyll a and Secchi depth monitoring.*
    - *Expand monitoring to Collingwood Lake and Hay River.*
    - *Conduct sediment sampling at major storm sewer outfalls to prioritize dredging.*
- ***Goal 3 - Protect and improve native aquatic and shoreland habitats***

- *Protect native shoreline habitat from erosion, scouring and sediment deposition at stormsewer outfalls.*
- *Through water quality improvements, enhance the Beaver Dam Lake fishery as it has a diverse fishery and is only one of a handful of lakes in Barron County that has a fishable population of smallmouth bass.*
- *Continue on-going aquatic plant surveys.*
- *Expand aquatic plant surveys to Collingwood Lake and Hay*

Source: (EOR, 2011)

3.2.1 Stormwater Management

Runoff to Beaver Dam Lake was modeled to determine sources of watershed pollution and a strategy for their prevention and control. Figure 3-1 and Figure 3-2 show the average annual total phosphorus and total suspended solids leaving city subwatersheds normalized by subwatershed area (existing landuse) and flowing into either Beaver Dam Lake (Figure 3-1) or Library Lake (Figure 3-2). After assessing the sources of phosphorus and total suspended solids to the lake, the City identified 11 subwatersheds as having the highest average total phosphorus and total suspended solids loading rates to the lake on a per acre basis (Table 3-1). These 11 subwatersheds were then prioritized for stormwater management to protect and improve lake water quality. Nine of the 11 subwatersheds drain to Library Lake, one drains to Cemetery Bay, and one drains to Norwegian Bay (lake areas shown on Figure 3-1 and Figure 3-2 (EOR, 2010).

Table 3-1 Priority Watersheds for Stormwater Management. Table Credit: EOR (2010)

Major Drainage Area	Priority Subwatershed
Beaver Dam Lake East – Norwegian Bay	c_NB-6
Beaver Dam Lake East – Cemetery Bay	c_CB-3
Library Lake	c_LL-Grove-1
	c_LL-Main-1
	c_LL-Main-3
	c_LL-Main-4
	c_LL-Main-5
	c_LL-6thSt
	c_LL-Library-2
	c_LL-Sorenson-2

After identifying the sources of watershed pollution to Beaver Dam Lake, the City determined a strategy for their prevention and control:

> *Priority subwatersheds were compared with findings from multiple field visits to identify feasible locations for stormwater best management practices (BMPs).* Figure 3-3 *identifies the BMPs and the*

subwatersheds draining to them. The BMP in subwatershed c_NB-6 and the southern BMP in subwatershed c_CB-3 is recommended to take the form of a bioretention facility. (The rectangular BMP in subwatershed c_CB-3 is recommended for enhanced shoreland buffer. All other BMPs are within the Library Lake Subwatershed and are discussed in greater detail in the section Library Lake Management Plan (Section 3.3) (EOR, 2010).

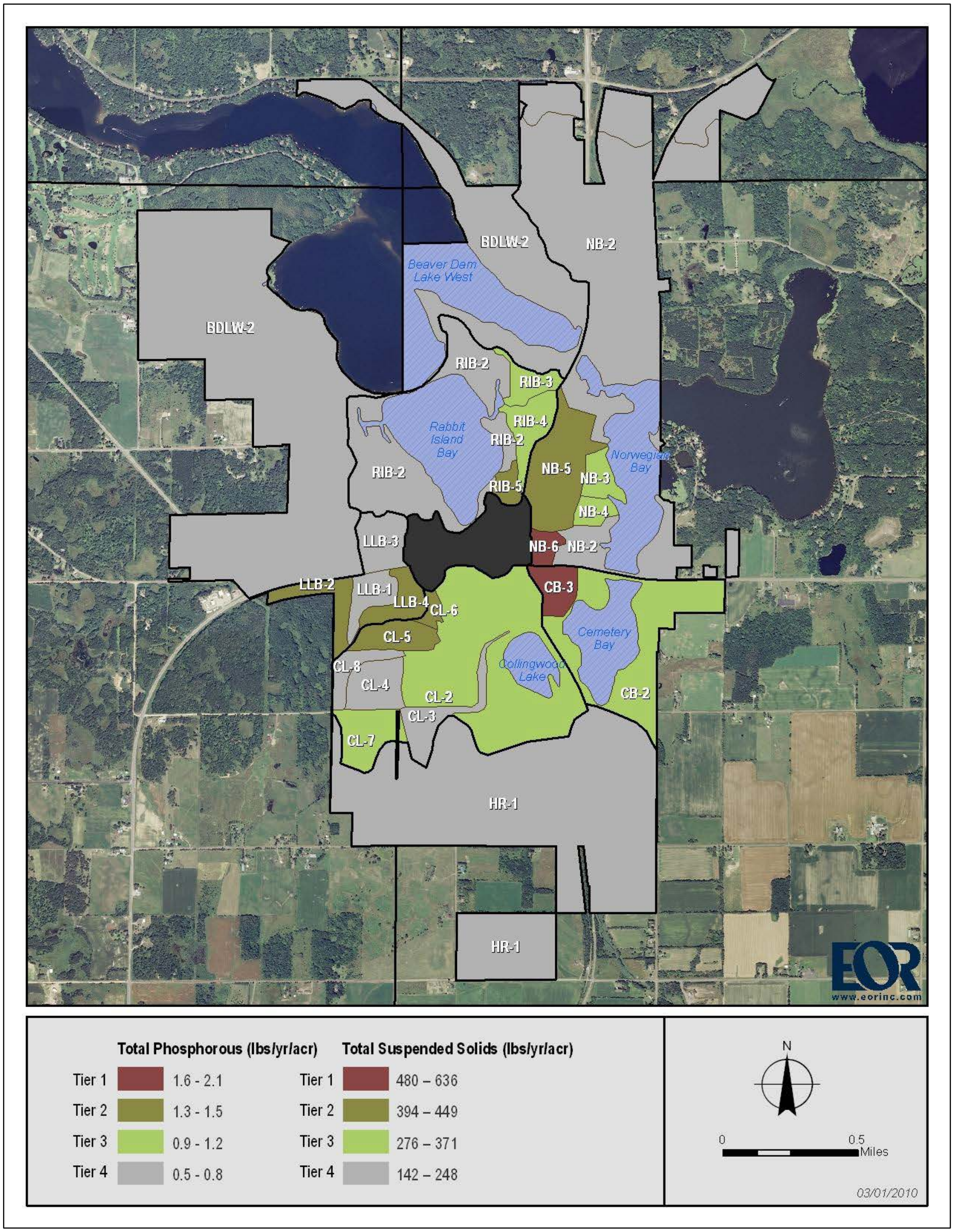


Figure 3-1 **Average Annual Total Phosphorus and Total Suspended Solids Leaving City Subwatersheds Normalized by Subwatershed Area (Existing Landuse). Figure Credit: EOR (2010)**

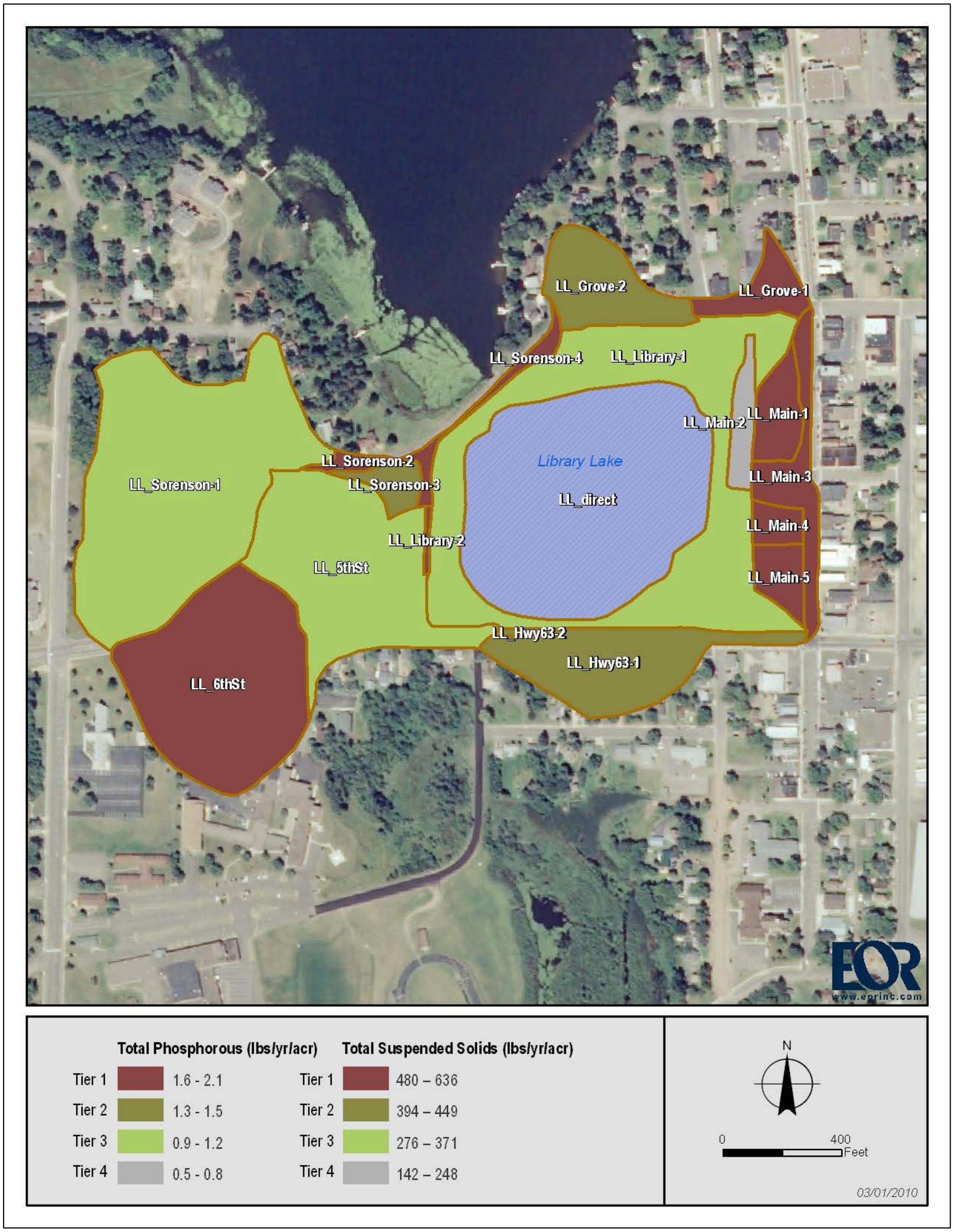


Figure 3-2 **Average Annual Total Phosphorus and Total Suspended Solids Leaving Library Lake Subwatersheds Normalized by Subwatershed Area (Existing Landuse). Figure Credit: EOR (2010)**

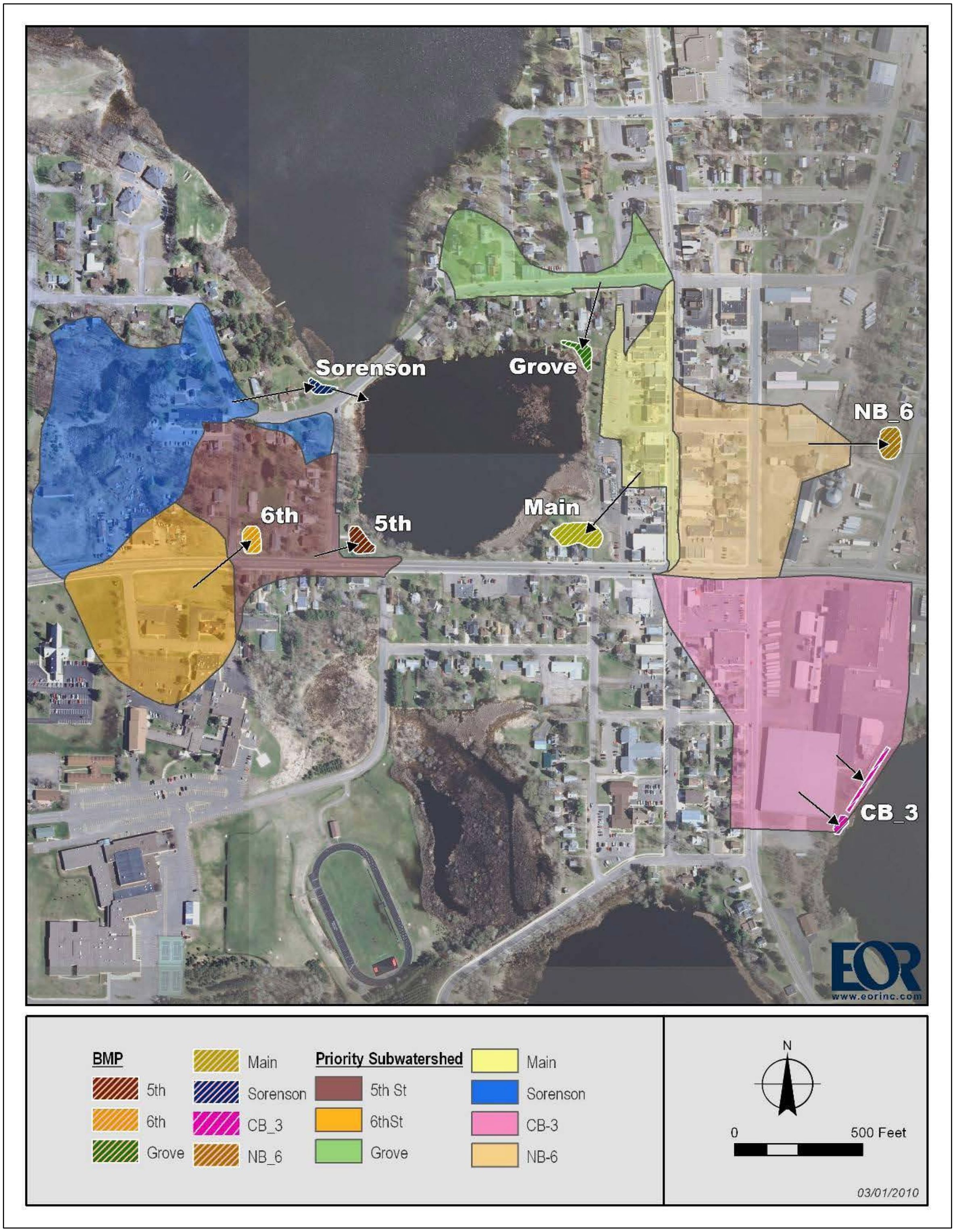


Figure 3-3 BMP locations for priority subwatersheds. Figure Credit: EOR (2010)

3.2.2 Aquatic Invasive Species (AIS) Management

Goal 3 of the Stormwater Management Plan addressed AIS Management in Beaver Dam Lake. The Stormwater Management Plan states:

> *In partnership with the Beaver Dam Lake Management District, the City will work to prevent the transport and spread of aquatic invasive species through existing programs and through education efforts. Education and inspections will be provided at the boat launch during times with higher numbers of boats entering and exiting the lake (e.g. weekends) to demonstrate proper boat cleaning measures, check that boats are following these measures, and to discuss why these measures are needed* (EOR, 2010).

The City has implemented this section of the Stormwater Management Plan by annually conducting inspections of boats entering and leaving the lake at three boat landings. A detailed discussion of the City's Clean Boats/Clean Waters boat inspection program is found in Section 6.0.

3.2.3 Monitoring and Data Assessment

The stormwater management plan discussed the City's support of the Beaver Dam Lake Management District water quality monitoring program. The City states its intention of using the data to adjust stormwater management strategy. The plan states:

> *The City will support the monitoring efforts of the Beaver Dam Lake Management District to annually measure key water quality parameters in its lakes. This ongoing monitoring allows the Beaver Dam Lake Management District and the City to track changes in lake quality over time in order to adjust its stormwater management strategy accordingly (EOR, 2010).*

The stormwater management plan also said the City may develop additional monitoring programs to monitor watershed runoff and to determine effectiveness of BMPs.

> *The City may also consider developing and implementing a lake inflow monitoring program or BMP monitoring program. The program could measure key water quality parameters such as suspended solids, total phosphorus, and flow in the inflow to the lake. This type of monitoring would reflect changes in the content of runoff more quickly than measurements in the lake. This monitoring could also be conducted close to constructed water quality practices before and after construction to measure the impact of the project (EOR, 2010).*

3.3 Library Lake Management Plan

Library Lake is a resource valued by the City of Cumberland, the Beaver Dam Lake Management District, the Wisconsin Department of Natural Resources, Barron County, and area residents. The lake is an important spawning area for the lake's fishery, particularly for northern pike, but also for perch, smallmouth bass, and panfish (e.g., crappies). The lake has a high degree of visibility due to its location within the downtown area of Cumberland and adjacent to U.S. 63. Residents use the lake for fishing, boating, or canoeing. Because sedimentation and excessive plant growth within the lake prevented the lake from fully supporting its beneficial uses, the District initiated the completion of a Library Lake Management Plan.

Library Lake, pictured above, is highly visible, located adjacent to downtown Cumberland. Sedimentation and excessive plant growth, however, prevent the lake from fully supporting its beneficial uses. Photo Credit: Endangered Resource Services, LLC.

In 2008, the Library Lake Committee of the District, with assistance from Barr, completed a Library Lake Restoration Scoping Study. The study included preparation of the work scope for a watershed and lake management plan. The objective of the plan was to identify sources of sediment, nutrients, and trash to Library Lake and to provide recommended improvements.

In 2010, the District and the City, with assistance from Harmony Environmental and Emmons & Olivier Resources, Inc., completed a management plan of Library Lake. A total of 5 project phases were detailed in the plan:

- **Phase 1 Stormwater Improvements and Park Development:** acquire land and construct stormwater practices and park.
- **Phase 2 Lake and Shoreline Restoration:** remove accumulated sediments.
- **Phase 3 Restore Hydrology:** restore Library Lake outlet under highway 63/48.
- **Phase 4 Community Connections:** create non-motorized trail passage over highway 63/48 and in the city of Cumberland.
- **Phase 5 Grove Street Bridge:** raise and widen the Grove Street Bridge to accommodate boat traffic safely. (Source: Harmony Environmental & EOR, 2010)

As noted in Section 3.2.1 (Stormwater Management), nine of the 11 Beaver Dam Lake subwatersheds identified as having the highest average total phosphorus and total suspended solids loading rates to the lake on a per acre basis (Table 3-1) drain to Library Lake (EOR, 2010). The District and the City have identified stormwater management projects to reduce total phosphorus and total suspended solids loading to the lake and BDLMD has implemented one of these projects.

The District and the City have identified stormwater management projects to reduce total phosphorus and total suspended solids loading to Library Lake, pictured above, and has implemented one of these projects. Photo Credit: Endangered Resource Services, LLC.

The BDLMD constructed a stormwater treatment pond to treat stormwater runoff to Library Lake. The stormwater pond is expected to reduce the sediment going into Library Lake by 82 percent and reduce phosphorus loading by 62 percent. The completed stormwater treatment pond is located at the northwest side of Grove Street. Storm water from a 13-acre drainage area (from Eighth Avenue near the Burger King to Grove Street north of Library Lake) is treated by the basin. To date, the goal of capturing and treating the first ½-inch of stormwater has been exceeded by the pond. An underground 60-inch diameter pretreatment chamber was installed to collect sediment, trash, debris, and chemicals before the overflow water goes to the stormwater pond. The basin cleans the stormwater flowing from the pretreatment chamber through an 18-inch layer of a clean mix of 70 percent sand and 30 percent aged organic leaf compost. Additional treatment is provided by deep rooted native vegetation including wild flowers and grasses. The design of the basin encourages groundwater recharge by allowing stormwater to soak into the ground. Besides the seeding of grass around the pond, over 2,500 wildflower and grass plants were planted. Information about the stormwater treatment pond is found on the District's website at *http://www.beaverdamlake.org/storm-water-ponds.html*.

Stormwater runoff is treated by a recently constructed stormwater treatment pond, pictured above, before entering Library Lake. Photo Credit: EOR, Inc.

4.0 Shoreline, Fishery, and Wildlife Management

4.1 Shoreland Assessment and Restoration

Shoreline restoration projects have been completed to reduce stormwater runoff to the lake as well as improve wildlife habitat. The BDLMD fully funded and completed a shoreland restoration project in Tourist Park. A lake resident also funded and completed a shoreland restoration project. The District website presents information about the projects.

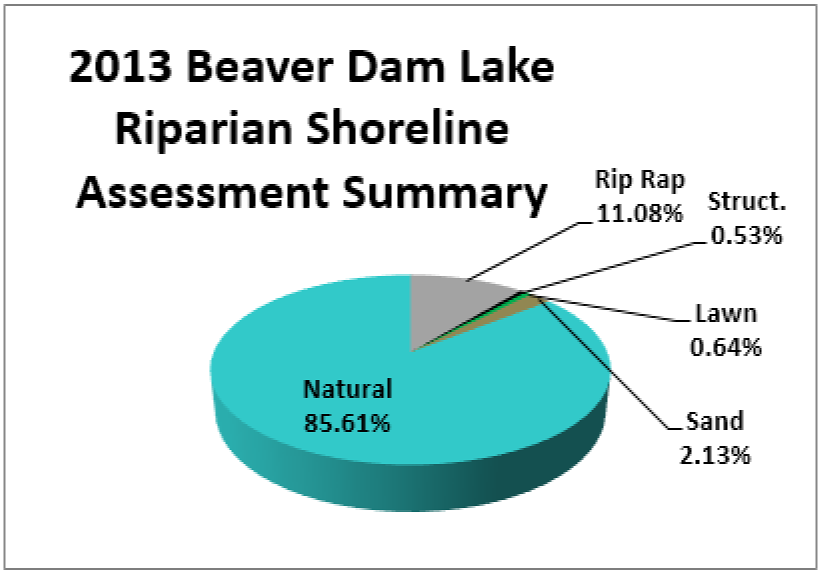
Shoreline restoration projects were completed at Tourist Park, pictured above, and at a residence, pictured below, to reduce stormwater runoff to the lake. Photo Credit: Beaver Dam Lake Management District

The District conducted an assessment of Beaver Dam Lake riparian properties during 2012 through 2013.[1] [2]. A group of 12 volunteers assessed every parcel on the entire lake. Survey results indicate approximately 86 percent of the shoreline and 67 percent of the upland riparian area is natural. The results of the survey were shared with the City of Cumberland, Barron County, and WDNR and will be used by BDLMD to educate and encourage riparian residents to voluntarily establish buffer areas

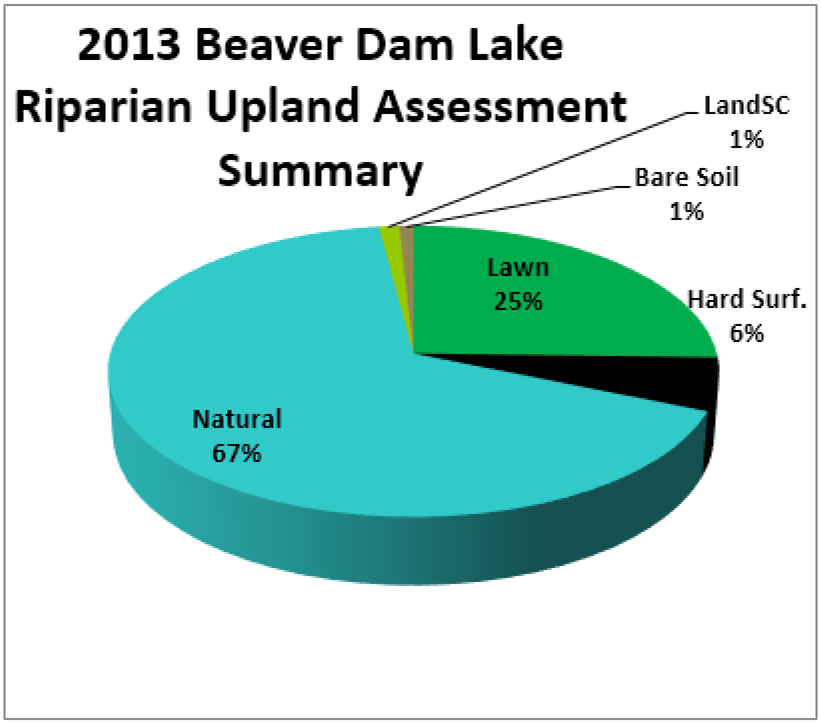
To support the efforts of residents to voluntarily establish shoreline buffers, the District has helped fund workshops to train area landscapers to install rainwater gardens and complete shoreline stabilization projects. The workshops were held at the UW campus in Rice Lake, WI on March 27, and April 17, 2012. Workshop topics included shoreline buffers, runoff mitigation, and shoreline stabilization.

[1] Evenson, Dave. 2012. President, Beaver Dam Lake Management District. Personal Communication.

[2] Schroeder, Tom. 2013. President, Beaver Dam Lake Management District. Email Communication.



Results of a shoreline assessment survey shown above and below indicate 86 percent of the lake's shoreline and 67 percent of riparian upland are natural.



4.2 Fisheries

The Beaver Dam Lake fishery was surveyed in 2005 through 2007 by the Wisconsin Department of Natural Resources. Survey results indicate the fishery is diverse and includes walleye, northern pike, largemouth bass, smallmouth bass, bluegill, black crappie, pumpkinseed, green sunfish, yellow perch, rock bass, common carp, white sucker, cisco, rainbow smelt and bullheads (Benike and Disrude, 2008). Following is an excerpt from the Executive Summary from the survey report:

> *Projected angler effort for all species of fish was 41.4 hours/acre, of which 83% was during the open water fishery. Largemouth bass were most common gamefish caught by anglers followed by northern pike, smallmouth bass and walleye; but northern pike were the most common gamefish harvested by anglers. The 2006 adult walleye population estimate of 0.7 fish/acre was similar to a past survey of 0.6 fish/acre in 1993. However the adult walleye population was lower than a 1979 estimate of 1.4 fish/acre. Historic data documents a decrease in walleye abundance that roughly coincides with an illegal introduction of rainbow smelt that was believed to have occurred at or near 1980. The introduction of trout along with changes to walleye stocking and regulations are recommended to increase predation on rainbow smelt and improve walleye natural reproduction, stock recruitment and abundance* (Source: Benike and Disrude, 2008).

Survey data are presented in Table 4-1 and Table 4-2. In Table 4-1, 1993-1994 creel survey data on Beaver Dam Lake is compared to 2006 survey data for major game and panfish species. In Table 4-2, fall electrofishing catch per effort of gamefish (fish/hour) is provided for survey years of 1970 through 2006.

Table 4-1 Summary of Creel Survey Data by Season for Major Game and Panfish Species in Beaver Dam Lake during 1993-1994 and 2006[1]

Species	Season	Year	Directed Effort (%)	Catch Rate (fish/hr)	Harvest Rate (fish/hr)	Mean Length Harvested (in)
Walleye	Open Water	1993	9.6	0.0339	0.0110	18.8
		2006	9.0	0.0231	0.0111	17.2
	Ice	1994	13.1	0.0000	0.0000	N/A[2]
		2006	1.8	0.0000	0.0000	N/A[2]
Northern Pike	Open Water	1993	16.3	0.4054	0.0462	19.9
		2006	13.2	0.3834	0.1250	20.0
	Ice	1994	57	0.3002	0.1466	21.4
		2006	57.4	0.3296	0.1200	20.3
Smallmouth Bass	Open Water	1993	11.9	0.2082	0.0137	15.5
		2006	25.1	0.3664	0.0074	16.4
	Ice	1994	5.8	0.0000	0.0000	N/A[2]
		2006	0	0.0000	0.0000	N/A[2]
Largemouth Bass	Open Water	1993	21.4	0.2095	0.0051	15.6
		2006	24.2	0.5961	0.0061	15.6
	Ice	1994	3.2	0.0599	0.0599	16.4
		2006	29.4	0.0568	0.0378	15.6
Bluegill	Open Water	1993	21.3	2.8061	1.2788	6.9
		2006	20.6	3.9616	1.0932	6.8
	Ice	1994	10.8	3.5205	1.6760	6.7
		2006	3.8	1.3013	0.4042	6.5
Black Crappie	Open Water	1993	18.1	0.8566	0.5088	9.2
		2006	5.5	0.6012	0.3862	9.2
	Ice	1994	8.8	0.0147	0.0147	8.8
		2006	5.6	0.0779	0.0564	9.5
Yellow Perch	Open Water	1993	0	N/A[2]	N/A[2]	9.4
		2006	0	N/A[2]	N/A[2]	N/A[2]
	Ice	1994	1.3	0.1523	0.0000	7.2
		2006	1.9	0.3402	0.0000	N/A[2]

[1]Table Credit: Benike and Disrude (2008); [2]N/A = Not Available

Table 4-2 Fall Electrofishing Catch per Effort of Gamefish (fish/hour) in Beaver Dam Lake[1]

Date	Walleye	Northern Pike	Largemouth Bass	Smallmouth Bass
1970	54	7	9	0
1979	12	16	3	1
1984	67	26	14	4
1988	13	7	6	3
1989	12	7	6	1
1993	6	27	4	6
2006	N/A[2]	22	22	12

[1]Table Credit: Benike and Disrude (2008)
[2]N/A = Not Available

The fishery survey results indicate the adult walleye population has decreased over time. The decrease roughly coincides with an illegal introduction of rainbow smelt, an aquatic invasive species (AIS) that was believed to have occurred at or near 1980. The WDNR has recommended walleye stocking to increase predation on rainbow smelt and improve walleye natural reproduction, stock recruitment and abundance (Benike and Disrude, 2008). The Beaver Dam Lake Management District stocks the lake with extended growth (large) fingerling walleye every other year. In 2012, BDLMD stocked Beaver Dam Lake with 6,500 extended growth walleyes (6 to 8 inch). WDNR stocked Beaver Dam Lake with 16,000 extended growth walleyes in 2013. The stocking provides added protection for walleye, a native species, through increased predation on rainbow smelt, an AIS.

4.3 Wildlife

WDNR prepared a general overview of wildlife on Beaver Dam Lake in 2012. The document is quoted in the following paragraphs (Morgan, 2012):

This document is a very general overview and should not be considered to be all inclusive in regard to wildlife species presence and abundance in Beaver Dam Lake. It is a cursory review of wildlife that is present or could be present on the lake itself or the area immediately adjacent to the lake. A comprehensive overview is difficult because the lake is very extensive and includes areas that are almost subdivisions of the lake, such as Norwegian Bay and Library Lake. The DNR also does not have the money or staff to perform surveys on every lake.

Waterfowl are what everyone expects to see in any waterbody, but they are really a function of the emergent and submergent vegetation that is present. Small numbers of mallards and wood ducks are found throughout the lake in summer on the small bays that still have some emergent vegetation left. Library Lake has some good areas of emergent vegetation and mallards and wood ducks are present throughout the summer, as is a small resident flock of Canada geese. The city beach has a larger resident flock of Canada geese that can reach nuisance status at times. These geese can travel a good distance and probably use much of the lake in the summer. Large flocks of Canada geese are present in the fall, especially on Norwegian Bay along Highway 48 on the east side of town. Species of ducks other than mallards and wood ducks use the lake during fall and spring migration but no formal study has been done to document species presence and abundance.

Common loons use the lake in summer and during spring and fall migration. I have no information on nesting attempts or success but it is possible if a secluded location with suitable nesting habitat was present, nesting could occur. Production and survival of young is difficult on heavily used lakes like Beaver Dam but it is possible loons could successfully reproduce if conditions were right.

Bald eagles frequent the area to feed upon fish and waterfowl but I am not aware of any nests right on the lake. There are some nests in the vicinity, however. Osprey use the area as well and there was a nest on a platform along the old railroad grade south of Hwy 48 on Hwy P, west of the veterinary clinic. Trees have grown over the platform and it is no longer used.

Great blue herons are everywhere in the county and they frequent shallow water areas hunting for fish. You would expect to find them on Beaver Dam Lake and they are. Other species of shorebirds and water birds are probably present but no surveys have been done to document them.

Furbearers such as beaver and muskrat are found wherever there is suitable emergent vegetation to provide food and cover. Library Lake has some good habitat as does Norwegian Bay. River Otter are found on most lakes in the county and some probably occur here at some time throughout the year.

Amphibians and certain reptile species are wetland dependent but are often overlooked because of their small size and inconspicuous nature. Many species are found here or would expect to be found here.

Painted turtles are found everywhere and are present in Beaver Dam, as are snapping turtles. Spiny softshell turtles are found in other Barron County lakes but there are no specific records they are found in Beaver Dam Lake.

Frog surveys have documented 7 species of frog and one toad that are present nearby and are probably found in Beaver Dam Lake. These are: spring peeper, wood frog, chorus frog, eastern gray tree frog, green frog, leopard frog, mink frog, and American toad.

Certain species of snake do not necessarily live in wetlands but use them for feeding or escape cover. Snakes often feed on frogs or invertebrates associated with wetlands. Snakes found or that could be expected to be found in or immediately adjacent to the lake include common garter snake, smooth green snake, western fox snake, and red-bellied snake. It should be mentioned there are no venomous snakes in Barron County.

Overall, Beaver Dam Lake has some good habitat but there is potential for much better. The sensitive area exam that was performed years back showed that except for a few bays that were undeveloped and had some emergent vegetation, habitat for waterfowl and furbearers was not very prevalent. The area along the wetland/upland interface also could be much more productive if it had more vegetation. Buffers that allowed herbaceous and woody vegetation to develop would provide more food and cover for a lot of the species mentioned and new ones. A more diverse system would be healthier and would also bring more enjoyment to lakeshore owners and users as they would get to see more wildlife.

A loon nesting platform in Rabbit Island Bay, pictured above, has resulted in the successful hatching of 6 loon chicks during 2007 through 2011. Two of the chicks are pictured below with their mother. Photo Credit: John Ostrem

A resident of Rabbit Island Bay applied for and received a WDNR wildlife permit in 2008 to annually place a loon nesting platform in Rabbit Island Bay (Beaver Dam Lake, Figure 1-2). The project resulted in the successful hatching of 6 loon chicks during 2007 through 2011. The floating platform, shown in the picture to the left, is installed each spring within a week of "ice-out" which generally occurs during April 1 through 15. The pair of loons usually mate and lay eggs (26-day gestation) that hatch in the first week of June. A picture of two chicks that are two weeks old is shown to the left. Generally the fisherman and boaters have been respectful of the platform and other than some initial curiosity, leave it alone. To our knowledge these loon chicks are the only ones on Beaver Dam Lake, probably because of the lack of natural habitat for their nesting needs. The amount of boat traffic creates a challenge for the loon parents, but they keep the chicks away from the main boat channels and seem to co-exist. The boaters and homeowners have enjoyed the loon chicks and have learned a great deal about their life cycle (Ostrem, 2012).

4.4 Need for Protection and Enhancement of Fish and Wildlife Habitat

Fish and wildlife habitat in Beaver Dam Lake is in need of protection to insure the current diverse and valuable fish and wildlife community are fully supported in the future. Fish and wildlife habitat protection includes protection of woody debris, shoreland vegetation, and lake water quality. The City of Cumberland Stormwater Management plan and the Library Lake Management Plan strive to protect and improve the lake's water quality, thereby protecting and improving fish and wildlife habitat. This APMP includes an education program to encourage residents to plant shoreland buffers to optimize the health of the shoreland areas. However, the focus of this APMP is management of the lake's plant community to protect, and whenever possible, improve the native plant community. Protection and improvement of the native plant community will protect and improve fish and wildlife habitat. Threats to fish and wildlife habitat from adverse changes to the lake's native plant community include rapid expansion of invasive species currently residing in the lake and a concurrent reduction of native species that currently provide important habitat for the lake's fish and wildlife community. Introduction of additional invasive species to the lake, such as zebra mussel, could adversely impact the lake's fish and wildlife community through habitat alteration. This aquatic plant management plan addresses the need for protection, and whenever feasible, enhancement of fish and wildlife habitat in the lake by managing invasive species, protecting native species, and encouraging buffers to optimize shoreland health. The District continues to support the City of Cumberland's efforts to implement its stormwater management plan and also continues implementation of the Library Lake Management plan to protect, and whenever possible, improve the lake's water quality, thereby improving fish and wildlife habitat.

4.4.1 Critical Habitat Areas Designation

Critical habitat areas designation is a WDNR program that identifies and maps areas of each waterbody that is most important to the overall health of the aquatic plants and animals. Critical habitat areas include both sensitive areas and public rights features. Administrative Code 107.05(3)(1)(1) gives WDNR the authority to identify and protect sensitive areas. Sensitive areas are defined by Administrative Code 107 as areas of aquatic vegetation identified by WDNR as offering critical or unique fish and wildlife habitat to a body of water, including seasonal or life stage requirements, or offering water quality or erosion control benefits to the body of water. Public rights features are defined in Administrative Code NR 1.06 as areas that fulfill the rights of the public for navigation, quality and quantity of water, fishing, swimming, or natural scenic beauty. The WDNR is currently completing a habitat areas designation for Beaver Dam Lake. The field work and habitat areas' designations have been completed by WDNR, but the report has not yet been published (Paul Cunningham, 2012). When completed, the annual amending of this APM Plan will address protection to critical habitat areas designated within Beaver Dam Lake.

5.0 Water Quality Studies

Water quality studies of Beaver Dam Lake have included data collected by the WDNR, water quality studies by the Beaver Dam Lake Management District, and sample collection by volunteers as a part of the WDNR Citizen Lake Monitoring Network.

WDNR data collection occurred during 1975 through 1979 and during 1981 through 1987 at several stations. However, in many years only one sample was taken from a lake station and often only during the Fall, Winter, or Spring. The study results are summarized in Short Elliot Hendrickson, Inc. 1995.

During 1992, the Beaver Dam Lake Management District, with assistance from Short Elliot Hendrickson Inc., completed a lake monitoring program during the lake's growing season (i.e., May through August). Samples were collected from seven locations.

In 2007, the Beaver Dam Lake Management District, with assistance from Barr Engineering Co., completed a lake water quality study during the lake's growing season (i.e., May through September). Samples were collected from seven locations.

Volunteers participating in the WDNR Citizen Monitoring Network have collected data from Beaver Dam Lake since 1981. The data are posted on the WDNR website.

A summary of historical Secchi disc data is presented on Figure 5-1 through Figure 5-7. A detailed discussion of Beaver Dam Lake water quality is found in *2007 Beaver Dam Lake Water Quality Study* (Barr, 2008a).

Water quality of Beaver Dam Lake has varied, depending upon location. Water quality in West Lake, Williams Bay, and Rabbit Island Bay (locations shown on Figure 1-2) has generally been excellent to good, ranging from oligotrophic (low nutrients, crystal clear) to mesotrophic (moderate nutrients, good water quality) (Figure 5-1 through Figure 5-4). Water quality in Library Lake (location shown on Figure 1-2) has been good to poor, ranging from mesotrophic (moderate nutrients, good water quality) to eutrophic (high nutrients, poor water quality) (Figure 5-5). Water quality in East Lake (location shown on Figure 1-2) has been excellent to very poor, ranging from oligotrophic (low nutrients, crystal clear) to hypereutrophic (extremely high nutrients, extremely poor water quality) (Figure 5-6). Cemetery Bay (location shown on Figure 1-2) water quality has been good to very poor, ranging from mesotrophic (moderate nutrients, good water quality) to hypereutrophic (extremely high nutrients, extremely poor water quality) (Figure 5-7).

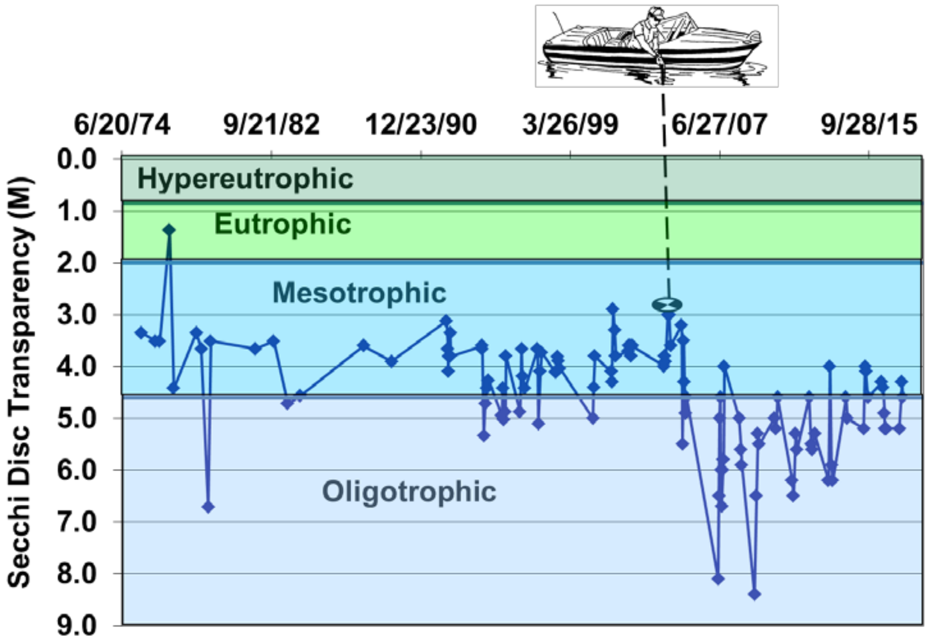


Figure 5-1 **1975-2017 Beaver Dam Lake Secchi Disc Transparencies: West Lake (West End)**

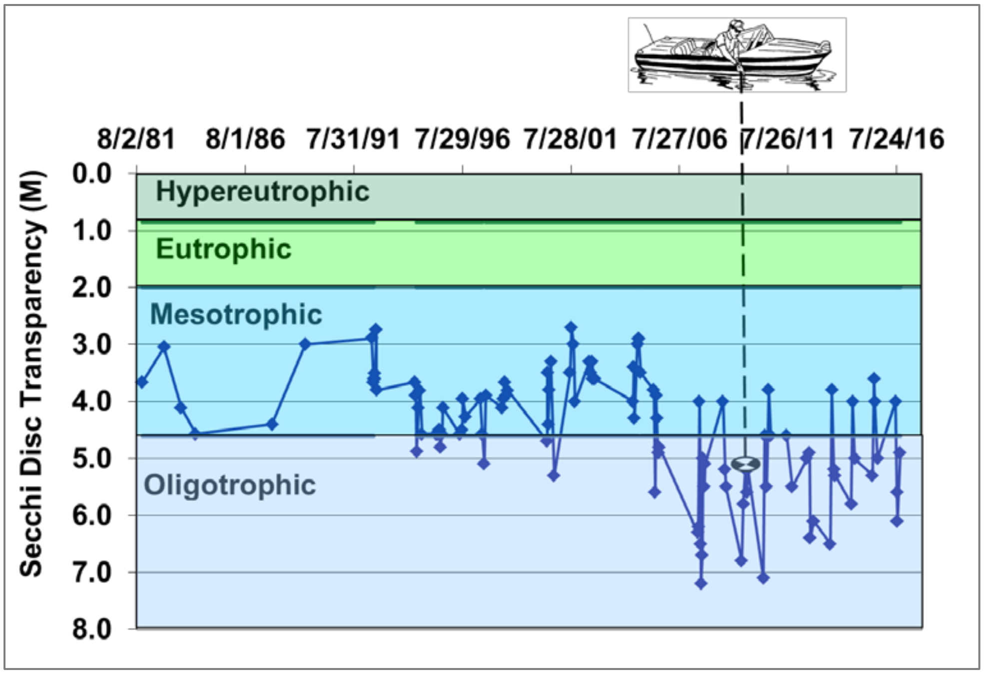


Figure 5-2 **1981-2016 Beaver Dam Lake Secchi Disc Transparencies: West Lake (NE of Eagle Point)**

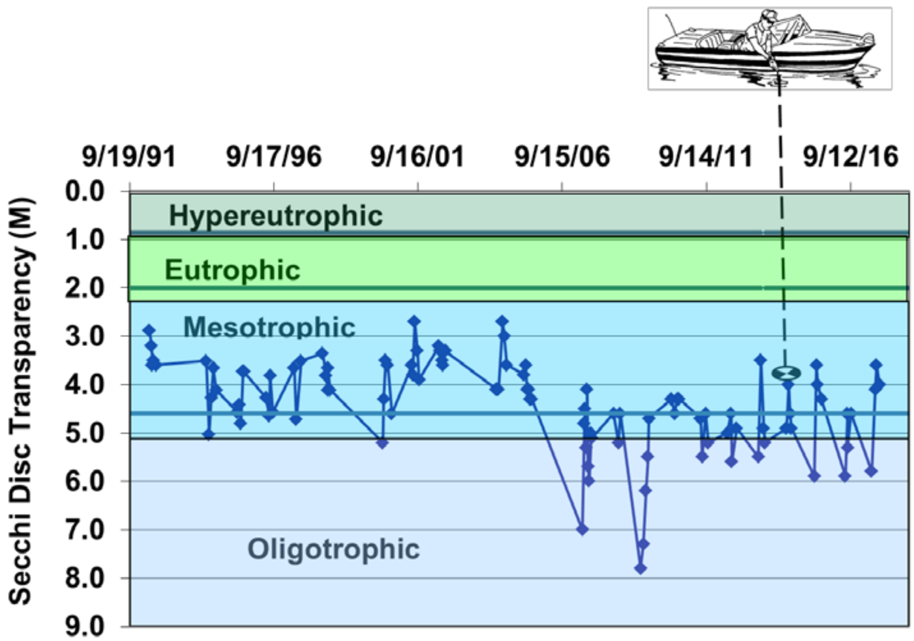


Figure 5-3 **1992-2017 Beaver Dam Lake Secchi Disc Transparencies: Williams Bay**

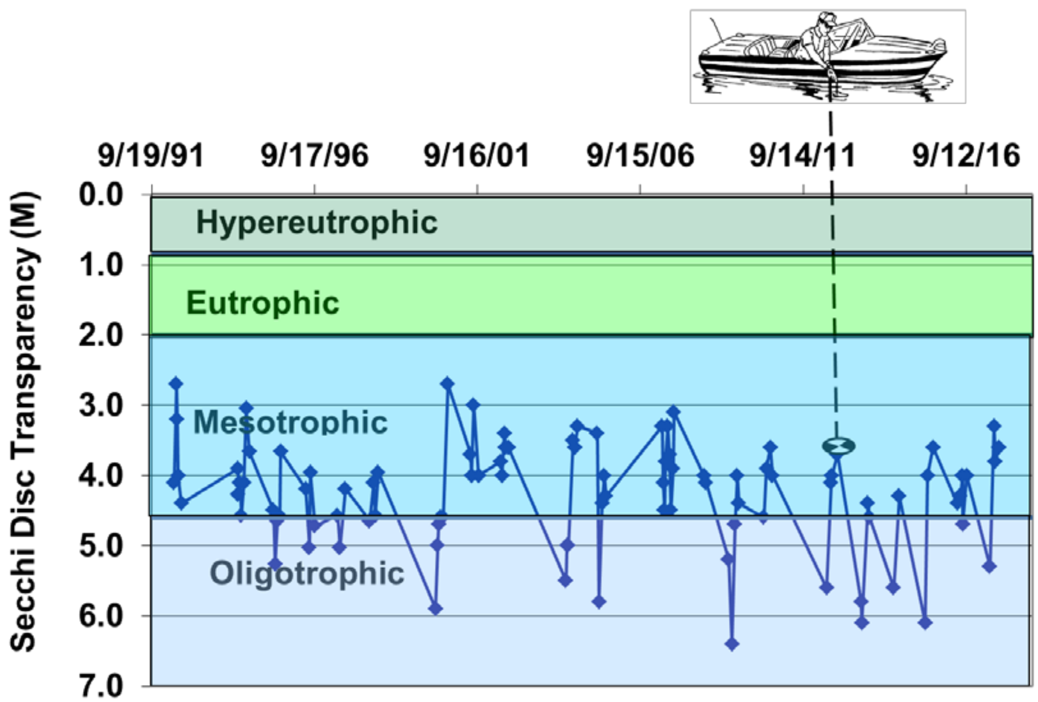


Figure 5-4 **1992-2017 Beaver Dam Lake Secchi Disc Transparencies: Rabbit Island Bay**

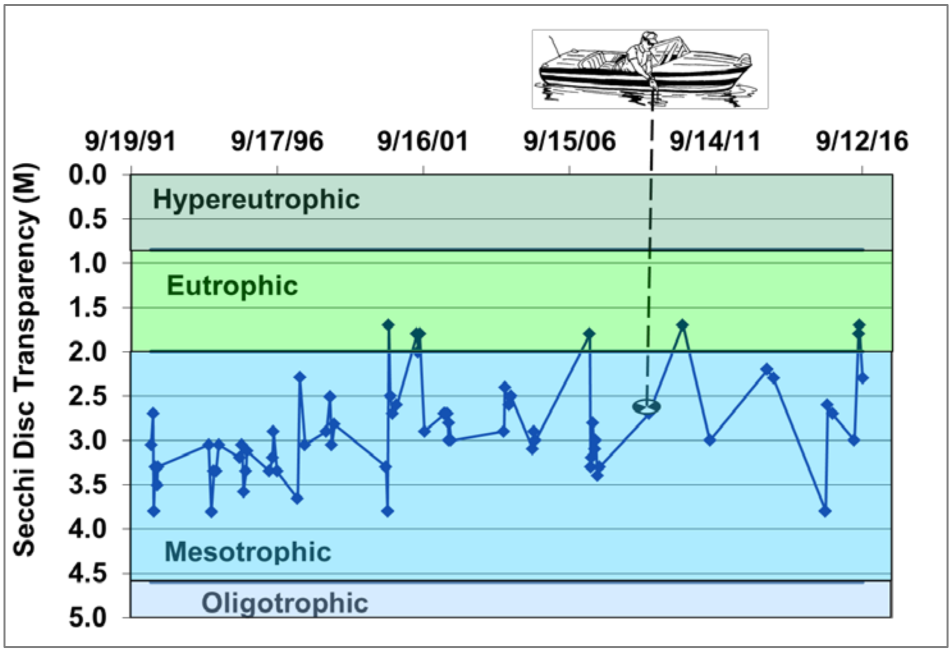


Figure 5-5 1992-2017 Beaver Dam Lake Secchi Disc Transparencies: Library Lake

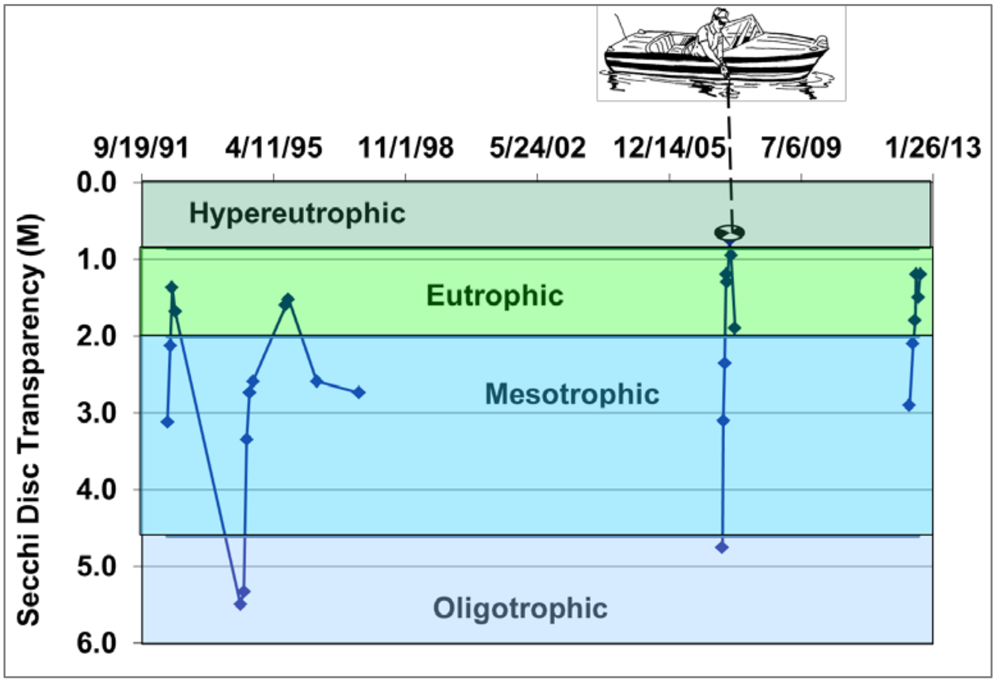


Figure 5-6 1992-2012 Beaver Dam Lake Secchi Disc Transparencies: East Lake

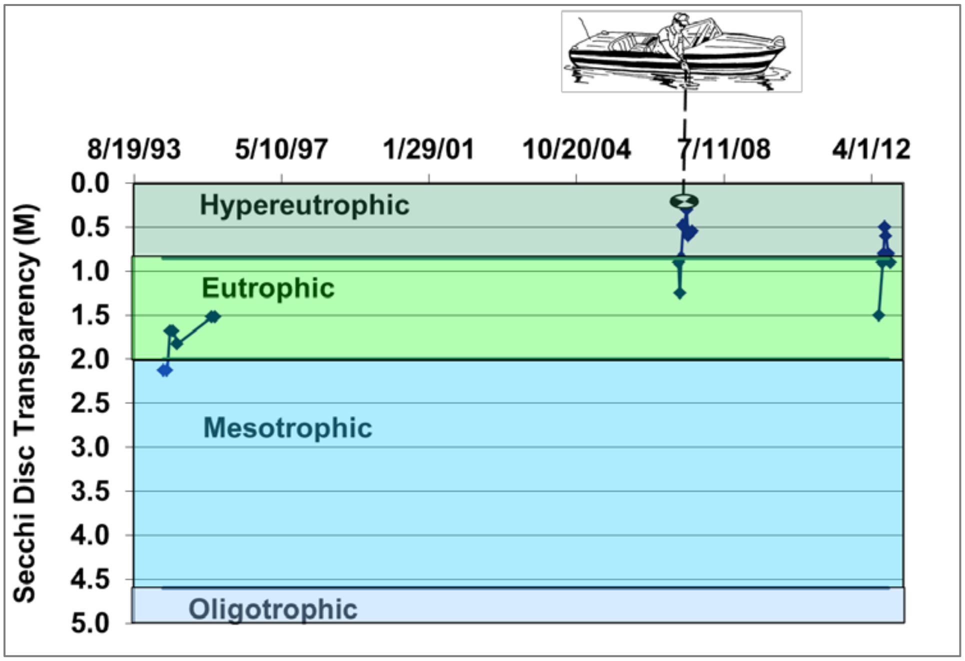


Figure 5-7 **1994-2012 Beaver Dam Lake Secchi Disc Transparencies: Cemetery Bay**

6.0 Clean Boats/Clean Waters

During 2007 through 2018, the City of Cumberland has generally obtained WDNR grant money to help fund a Clean Boats/Clean Waters inspection program. Whenever the boat inspection program was not funded by grant monies, the Beaver Dam Lake Management District has funded the program. The City has generally hired three boat monitors and the boat monitors have generally inspected boats entering the lake at three boat landings: (1) Eagle Point, (2) Tourist Park, and (3) City Bay (Figure 6-1). Occasionally boat monitors have inspected boats entering the lake at the landing located at 4th Avenue and Water Street. Boats entering and leaving the lake during noon to 8 PM each Friday, Saturday, and Sunday from Memorial Day weekend through Labor Day weekend were inspected. The results of the inspection were recorded on forms provided by the WDNR and the information was then electronically entered on the DNR on-line data base known as Surface Water Integrated Monitoring System.

The City of Cumberland conducted boat inspections on boats entering the Beaver Dam Lake, including the Eagle Point Boat Landing, pictured above

During the 2007 through 2018 period, the number of boats inspected annually has ranged from 191 to 1,724 (Table 6-1).

In 2011, a boat monitor found and removed a zebra mussel shell from one of the boats about to enter the lake (Hardie, 2012). This incident illustrates the value of the program and shows that the boat inspection program is preventing the spread of additional invasive species to the lake.

Detailed results of the 2011 and 2012 boat inspections are found in Appendix B.

Results of the boat inspections at the City Bay boat landing (also referred to as Norwegian Bay access off Comstock Avenue) are found on the DNR website: http://dnr.wi.gov/lakes/invasives/WatercraftSummary.aspx?show=efforts&landing=10017934

Results of the boat inspections at the West Lake boat landing at Tourist Park at east end of Lake Street are found on the DNR website: http://dnr.wi.gov/lakes/invasives/WatercraftSummary.aspx?landing=10017554.

Results of the boat inspections at the Eagle Point boat landing located in West Lake are found on the DNR website: https://dnr.wi.gov/lakes/invasives/WatercraftSummary.aspx?landing=10017932

Results of the boat inspections at 4th Avenue and Water Street located in West Lake are found on the DNR website: https://dnr.wi.gov/lakes/invasives/WatercraftSummary.aspx?landing=10017933

Table 6-1 Number of Boats Inspected During 2007-2018 Clean Boats/Clean Waters Boat Inspection Program

Year	# Boats Inspected
2007	1,387
2008	1,724
2009	1,219
2010	Data Not Available
2011	813
2012	1,374
2013	1,082
2014	786
2015	1,133
2016	1,198
2017	191
2018	787

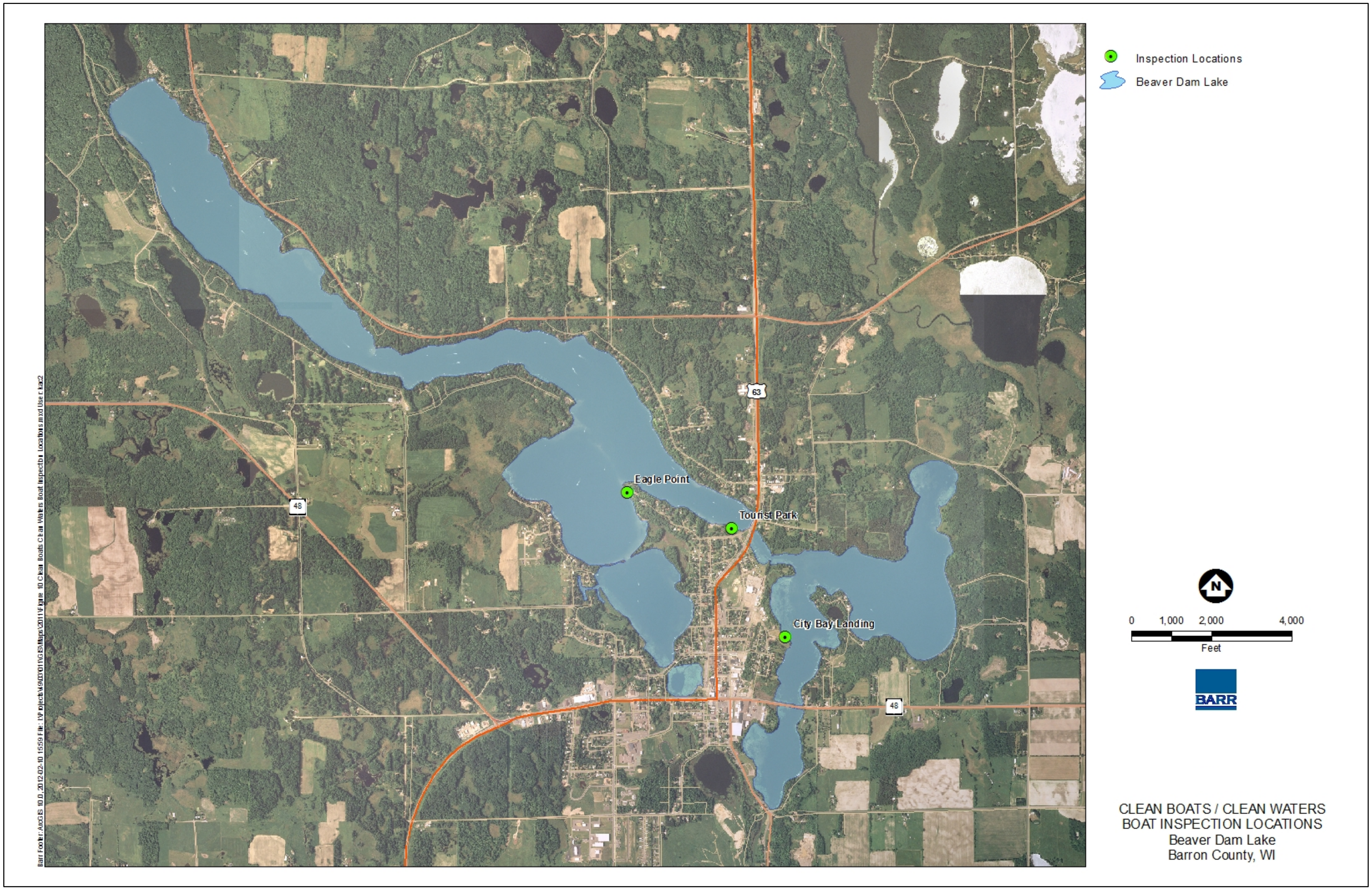


Figure 6-1 **Beaver Dam Lake Clean Boats/Clean Waters Boat Inspection Locations**

7.0 Beaver Dam Lake Invasive Species

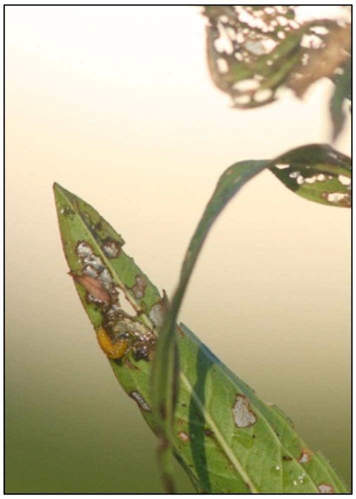
Three invasive species are currently present in Beaver Dam Lake: purple loosestrife, curly-leaf pondweed, and Eurasian watermilfoil.

7.1 Purple Loosestrife

Purple loosestrife, an emergent plant, is native to Europe and the temperate regions of Asia. Once introduced into an area, the plant typically replaces native vegetation and rapidly becomes the sole emergent species.

Although it is not known when purple loosestrife (*Lythrum salicaria*) was first introduced to Beaver Dam Lake, WDNR records indicate it has been observed in Library Lake since the mid-1990s. Volunteers and WDNR staff have used purple loosestrife-eating beetles and monitored biological control from the beetles in Library Lake since the mid-1990s. The WDNR used the Library Lake floating bog as one of the early release sites for the beetles (*Galerucella calmariensis* and/or *G. pusilla*) in the 1990s when the beetles were first approved for use. (Harmony Environmental and Emmons & Olivier Resources, Inc., 2010).

Purple loosestrife-eating *Galerucella* beetles in Library Lake control purple loosestrife by inflicting damage on purple loosestrife plants, shown in the pictures above and below. Photo Credit: Endangered Resource Services, LLC.



WDNR staff worked with a (now retired) teacher in the Cumberland schools to set up a beetle rearing station in 1998. Beetle rearing stations are established by collecting wild purple loosestrife plants and releasing a stock of beetles on the plants to allow them to multiply. Dave Blumer (former WDNR staff) reports that the purple loosestrife rootstock collected from Library Lake already had abundant beetles. This was very good evidence of a well-established beetle population on the bog in Library Lake. Library Lake was then used as a collection location for starter beetles for the Cumberland rearing program. Cumberland Middle and High School students assisted with rearing and distributing beetles to other locations on Beaver Dam Lake through the early 2000s. (Harmony Environmental and Emmons & Olivier Resources, Inc., 2010).

Recent plant surveys document purple loosestrife continues to be present in Library Lake (Appendix C). A 2010 beetle survey documented the presence of a high to moderate number of purple loosestrife-eating beetles on purple loosestrife plants in and near Library Lake (locations shown on Figure 7-1). Although the beetles have not eradicated this invasive species from the lake, the damage they have inflicted upon the purple loosestrife plants has effectively managed purple loosestrife such that its area of infestation has been contained. In 2018, all purple loosestrife plants were covered with beetles which were doing significant damage to the plants. Because the beetles have effectively contained purple loosestrife coverage in Library Lake, no other management measures have been used nor does there appear to be a need for additional management measures in Library Lake.

In 2018, purple loosestrife was also present in Cemetery Bay, City Bay, East Lake, West Lake, Williams Bay, and Rabbit Island Bay. The infestations were small and generally consisted of a few plants at a one to three locations in each bay/basin. Plants were found at three locations in Rabbit Island Bay, two locations in City Bay, and at one location in Cemetery Bay, East Lake, and West Lake. Manual removal of the purple loosestrife plants at these locations is recommended to prevent purple loosestrife from expanding its extent and displacing native emergent species.

Purple loosestrife is present in Library Lake, pictured above. Photo Credit: Endangered Resource Services, LLC.

Figure 7-1 **2010 Locations and Density of Galerucella Beetles in Library Lake (Map Credit: Endangered Resource Services, LLC)**

7.2 Curly-leaf Pondweed (CLP)

CLP, a plant native to Europe, Asia, northern Africa, and Australia (U.S. Forest Service, 2012), was first introduced to the United States in 1859 (Nichols et al., 1986). CLP spread from Wilmington, Delaware, where it was first found, throughout the United States and was first reported in Wisconsin in 1905 (Bolduan et al., 1994, WDNR, 2012b).

CLP differs from native plants that generally begin their growth cycle in spring and end their growing season by fall. CLP begins its growing cycle in late summer, continues to grow through the fall and winter, grows very rapidly in spring after ice-out, and finishes its growing cycle in early summer (Figure 7-2). CLP generally reproduces from turions, overwintering buds, which perform a similar role as seeds in native species. Studies show that each CLP plant can produce up to 900 turions (Catling et al., 1985) and turions can remain viable for several years (Newman 2009). CLP's ability to produce large numbers of turions and its unique growing cycle give this species a competitive advantage over native species. CLP begins its growth cycle when native species have ended their growth cycle and are no longer competing for space on the lake bottom. CLP is actively growing when natives begin their growth cycle. Hence, natives are restricted to areas not occupied by CLP.

Plant surveys have documented the presence of curly-leaf pondweed (*Potamogeton crispus*) in Beaver Dam Lake since 1999. Table 7-1 and Table 7-2 summarize the estimated extent of curly-leaf pondweed and percent of littoral area with curly-leaf pondweed in Beaver Dam Lake during 2006 through 2018 based upon plant surveys. July surveys were completed annually during 2009 through 2018. Fall surveys were completed annually in 2006 through 2018 during the October through early November period. June surveys of selected areas were completed in 2012 and 2013. In May of 2013, a survey of selected areas was completed. Maps showing CLP extent during 2006 through 2018 are shown in Appendix D. The results of the 2012 and 2013 June CLP surveys are presented in Appendix L.

CLP was periodically managed during 2007 through 2013 to reduce extent. Details of the management are discussed in the following paragraphs.

CLP in eastern basins were treated with herbicide during 2007 through 2010 as part of a strategy to control CLP while concurrently controlling EWM. A combination of two herbicides, 2,4-D and Endothall, were applied to eastern basin treatment areas because each herbicide independently controlled EWM and Endothall also controlled CLP.

Because the extent of CLP observed during the fall of 2010 was less than half an acre in the eastern basin, it was determined that CLP treatment was not warranted in 2011 and, hence, no herbicide treatment of CLP occurred in the eastern basin during 2011. However, the 2011 fall survey indicated a rapid expansion of CLP occurred in the eastern basin during 2011. The extent of CLP in the eastern basin increased from less than half an acre in 2010 to more than 16 acres in 2011. To address this rapid expansion, Cemetery Bay received a whole bay treatment of 2,4-D and Endothall in 2012 to concurrently address both EWM and CLP.

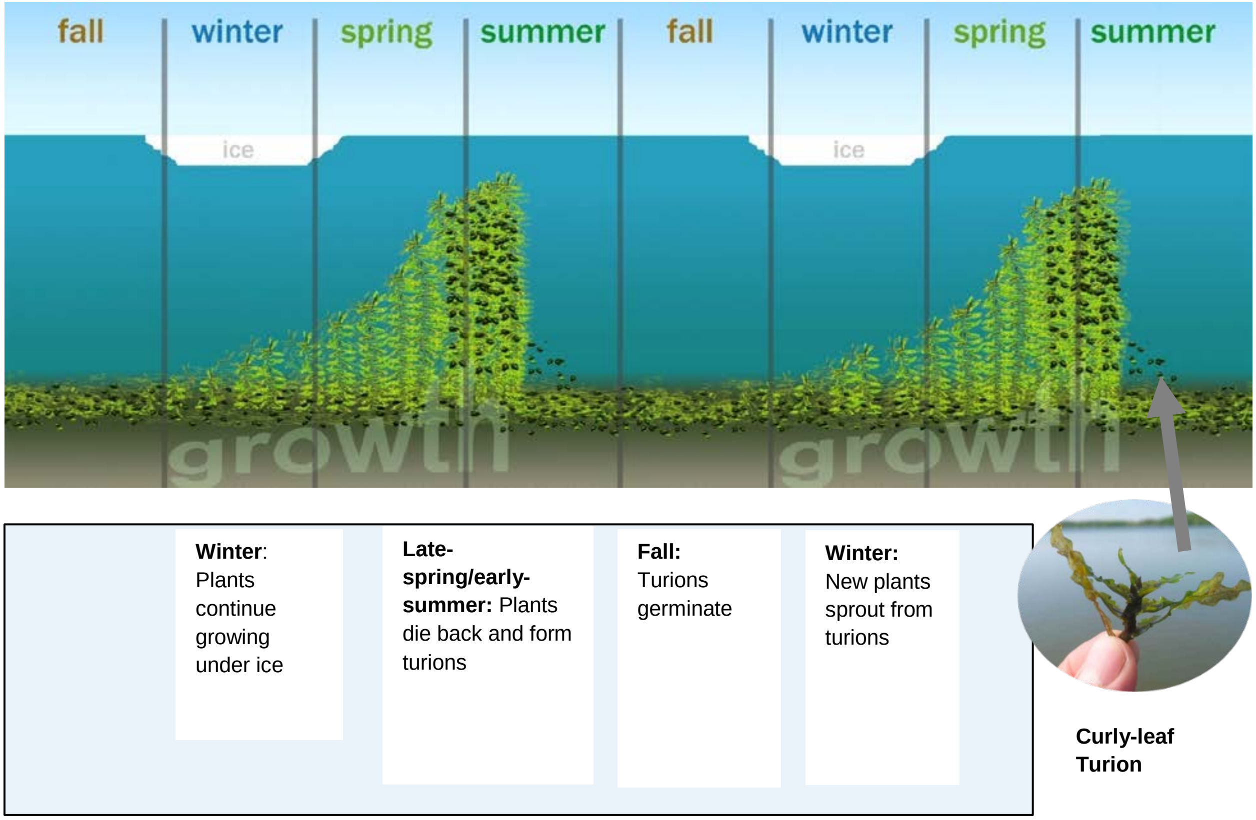


Figure 7-2 Curly-leaf Pondweed Growth Cycle

Table 7-1 2006-2018 CLP Extent in Beaver Dam Lake

Location	Acreage of CLP (based on plant surveys)																									
	Fall 2006	Fall 2007	Fall 2008	July 2009	Fall 2009	July 2010	Fall 2010	July 2011	Fall 2011	June 2012	July 2012	Fall 2012	May 2013	June 2013	July 2013	Fall 2013	July 2014	Fall 2014	July 2015	Fall 2015	July 2016	Fall 2016	July 2017	Fall 2017	July 2018	Fall 2018
Norwegian Bay	2.69	0.91	1.34	5.77	2.35	1.21	0	4.49	0.26	9.62	4.08	1.45	1.87	0	0.00	0.93	0.56	0.00	0.55	0.25	1.63	0.00	1.08	0.46	0.64	0.21
East Lake	6.73	0	0	3.07	3.02	0.00	0.28	1.46	0	NA*	0.61	0.00	NA*	NA*	0.00	0.00	0.00	0.00	0.00	0.00	1.03	1.60	0.00	0.00	0.00	0.00
City Bay	0.33	0.81	2.33	6.10	8.79	1.34	0	12.57	2.87	16.22	4.19	1.36	2.96	0	0.25	0.00	0.77	0.00	0.00	2.69	0.25	1.30	1.41	0.25	0.23	0.21
Cemetery Bay	0	0	0	1.00	0	0.00	0	7.84	13.14	NA*	1.45	5.16	NA*	0	0.00	0.51	0.00	1.09	9.10	5.59	0.50	0.50	0.00	1.38	0.21	0.85
West Lake	2.56	1.00	0	2.21	1.62	1.42	0.62	1.19	1.28	NA*	4.05	3.11	NA*	0.24**	1.19	0.63	0.59	0.00	1.54	0.66	0.70	0.00	0.97	0.00	0.00	0.00
Williams Bay	0.33	1.04	0.55	3.57	0.16	0.79	0	1.87	0.61	NA*	2.18	0.96	NA*	0.98**	0.26	0.00	0.49	0.00	0.00	1.06	0.67	0.00	1.13	1.14	0.25	0.45
Rabbit Island Bay	0.43	0	0.28	6.54	0	1.24	0	1.17	0.77	0.43	1.17	0.88	NA*	NA*	0.41	0.00	0.39	0.00	1.44	1.70	0.77	0.50	0.88	0.21	1.57	0.00
Library Lake	0	0	0	0.99	0	0.04	0	1.06	0	NA*	0.33	0.08	NA*	NA*	0.29	0.18	0.14	0.06	0.28	0.06	0.02	0.00	0.23	0.09	0.05	0.00
East Lake Basins	**9.75**	**1.72**	**3.67**	**15.94**	**14.16**	**2.55**	**0.28**	**26.36**	**16.27**	**NA*** **	**10.33**	**7.98**	**NA*** **	**NA*** **	**0.25**	**1.44**	**1.33**	**1.09**	**9.65**	**8.53**	**3.41**	**3.40**	**2.49**	**2.09**	**1.08**	**1.27**
West Lake Basins	**3.32**	**2.04**	**0.83**	**13.31**	**1.78**	**3.49**	**0.62**	**5.29**	**2.66**	**NA*** **	**7.73**	**5.02**	**NA*** **	**NA*** **	**2.15**	**0.80**	**1.60**	**0.06**	**3.26**	**3.47**	**2.16**	**3.90**	**3.21**	**1.44**	**1.87**	**0.45**
Beaver Dam Lake – All Basins	**13.07**	**3.76**	**4.50**	**29.25**	**15.94**	**6.04**	**0.9**	**31.65**	**18.93**	**NA*** **	**18.06**	**13.00**	**NA*** **	**NA*** **	**2.40**	**2.24**	**2.93**	**1.14**	**12.91**	**12.00**	**5.57**	**7.30**	**5.70**	**3.53**	**2.95**	**1.72**

N/A* CLP extent not available because the area was not surveyed

Table 7-2 2006-2018 % of Littoral Zone with CLP in Beaver Dam Lake

Location	% of Littoral Zone with CLP (based on plant surveys)																									
	Fall 2006	Fall 2007	Fall 2008	July 2009	Fall 2009	July 2010	Fall 2010	July 2011	Fall 2011	June 2012	July 2012	Fall 2012	May 2013	June 2013	July 2013	Fall 2013	July 2014	Fall 2014	July 2015	Fall 2015	July 2016	Fall 2016	July 2017	Fall 2017	July 2018	Fall 2018
Norwegian Bay	7.03	2.38	3.50	15.09	6.15	3.16	0.00	11.74	0.68	25.16	10.67	3.80	4.89	0.00	0.00	2.42	1.45	0.00	1.44	0.65	4.26	0.00	2.82	1.21	0.67	0.55
East Lake	10.68	0.00	0.00	4.87	4.79	0.00	0.44	2.32	0.00	NA*	0.97	0.00	NA*	NA*	0.00	0.00	0.00	0.00	0.00	0.00	1.63	2.54	0.00	0.00	0.00	0.00
City Bay	0.33	0.80	2.30	0.06	8.67	1.32	0.00	12.40	2.83	16.00	4.13	1.35	2.92	0.00	0.25	0.00	0.76	0.00	0.00	2.65	0.25	1.28	1.39	0.25	0.23	0.21
Cemetery Bay	0.00	0.00	0.00	1.85	0.00	0.00	0.00	14.53	24.36	NA*	2.69	9.57	NA*	0.00	0.00	0.95	0.00	2.02	16.88	10.37	0.93	0.93	0.00	2.57	0.39	1.58
West Lake	1.84	0.72	0.00	1.59	1.17	1.02	0.45	0.85	0.92	NA*	2.91	2.24	NA*	0.17**	0.86	0.45	0.43	0.00	1.11	0.47	0.50	0.00	0.66	0.00	0.00	0.00
Williams Bay	0.67	2.11	1.12	7.25	0.33	1.60	0.00	3.80	1.24	NA*	4.43	1.94	NA*	2.15**	0.53	0.00	0.99	0.00	0.00	2.14	1.36	0.00	2.35	2.37	0.25	0.45
Rabbit Island Bay	0.71	0.00	0.46	10.81	0.00	2.05	0.00	1.93	1.27	0.71	1.93	1.45	0.00	NA**	0.68	0.00	0.64	0.00	2.38	2.82	1.27	0.83	1.44	0.34	1.57	0.00
Library Lake	0.00	0.00	0.00	7.22	0.00	0.29	0.00	7.77	0.00	NA*	2.41	0.59	NA*	NA*	2.12	1.29	0.99	0.40	2.03	0.40	0.15	0.00	1.68	0.68	0.36	0.00
East Lake Basins:	**3.80**	**0.67**	**1.43**	**4.89**	**5.52**	**0.99**	**0.11**	**13.15**	**6.34**	**NA*****	**4.63**	**3.11**	**NA*****	**NA*****	**0.10**	**0.56**	**0.51**	**0.79**	**6.79**	**5.17**	**1.73**	**1.85**	**0.95**	**0.81**	**0.42**	**0.49**
West Lake Basins:	**1.27**	**0.78**	**0.32**	**10.24**	**0.68**	**1.89**	**0.24**	**5.47**	**1.01**	**NA*****	**4.45**	**1.91**	**NA*****	**NA*****	**1.59**	**0.31**	**1.16**	**0.15**	**2.10**	**2.22**	**1.25**	**1.02**	**1.19**	**0.53**	**0.69**	**0.17**
Beaver Dam Lake – All Basins	**2.52**	**0.72**	**0.87**	**2.92**	**3.07**	**0.56**	**0.17**	**3.59**	**3.65**	**NA*****	**1.75**	**2.51**	**NA*****	**NA*****	**0.33**	**0.43**	**0.32**	**0.18**	**1.71**	**1.43**	**0.57**	**0.55**	**1.07**	**0.67**	**0.56**	**0.32**

CLP observed in western basin areas during 2007 through 2011 (Table 7-1 and Table 7-2) was not treated because CLP infested areas were very small relative to lake area. Hence, it was determined that treatment was not necessary.

Reports of potential problematic CLP growth were provided to the District during the spring of 2012. Whole bay CLP surveys in Rabbit Island Bay, Norwegian Bay, and City Bay were completed by the District during June of 2012. The results indicated problematic beds of CLP were found in two channels adjacent to Rabbit Island Bay and in Norwegian Bay and City Bay. A detailed discussion of the results of the June 2012 CLP surveys is found in Appendix L. Based upon the data, a May 2013 plant survey was scheduled to determine whether management of CLP in Norwegian Bay, City Bay, and the two channels adjacent to Rabbit Island Bay in 2013 was necessary.

The May 2013 plant survey results indicated CLP management was needed in Norwegian Bay and City Bay. However, the long winter and late ice-out caused the demise of curly-leaf pondweed in the two channels adjacent to Rabbit Island Bay and CLP was not found during May. In 2013, 9.7 acres in Norwegian Bay and 19.1 acres in City Bay were treated with Endothall. CLP was not observed in Norwegian Bay or City Bay during a June 2013 plant survey.

CLP was not problematic during 2014 through 2018 because infested areas were very small relative to lake area. Hence, CLP management was not needed during this period.

Figure 7-3 summarizes CLP extent in the littoral area of Beaver Dam Lake during 2006 through 2018. Figure 7-4 summarizes the percent of the littoral area of Beaver Dam Lake with CLP during 2006 through 2018. The littoral area is defined as the area of the lake up to the 25-foot depth. The littoral area in Beaver Dam Lake was estimated from the depths measured during the fall plant survey. The percent of littoral area in Figure 7-4 was computed by dividing the CLP extent (Figure 7-3) by the littoral area and then multiplying by 100 to convert to percent.

During 2006 through 2018, CLP was found in less than 7 percent of the littoral area, ranging from a low of 0.2 percent in the fall of 2010 and fall of 2014 to a high of 3.6 percent in summer and fall of 2011 (Table 7-2 and Figure 7-4). Hence, the District CLP goal of CLP presence in no more than 7 percent of the littoral zone was attained throughout the period of record.

CLP extent has fluctuated during the period of record in response to CLP treatments and changing climatic conditions. Successful CLP treatments in 2012 and 2013 reduced CLP levels from 3.6 percent in the fall of 2011 to 0.3 percent during the summer of 2013 (Table 7-2 and Figure 7-4). The long snowy winter of 2013 through 2014 created adverse growing conditions for CLP and reduced CLP extent to 0.2 percent of the littoral area by fall of 2014 (Table 7-2 and Figure 7-4). The winter of 2014 through 2015 was more normal and CLP increased to 1.7 percent of the littoral area (Table 7-2 and Figure 7-4. CLP has generally declined since 2015 and was found in 0.3 percent of the littoral area during fall of 2018 (Table 7-2 and Figure 7-4). Because CLP is currently at a very low level and is not problematic, management is not needed.

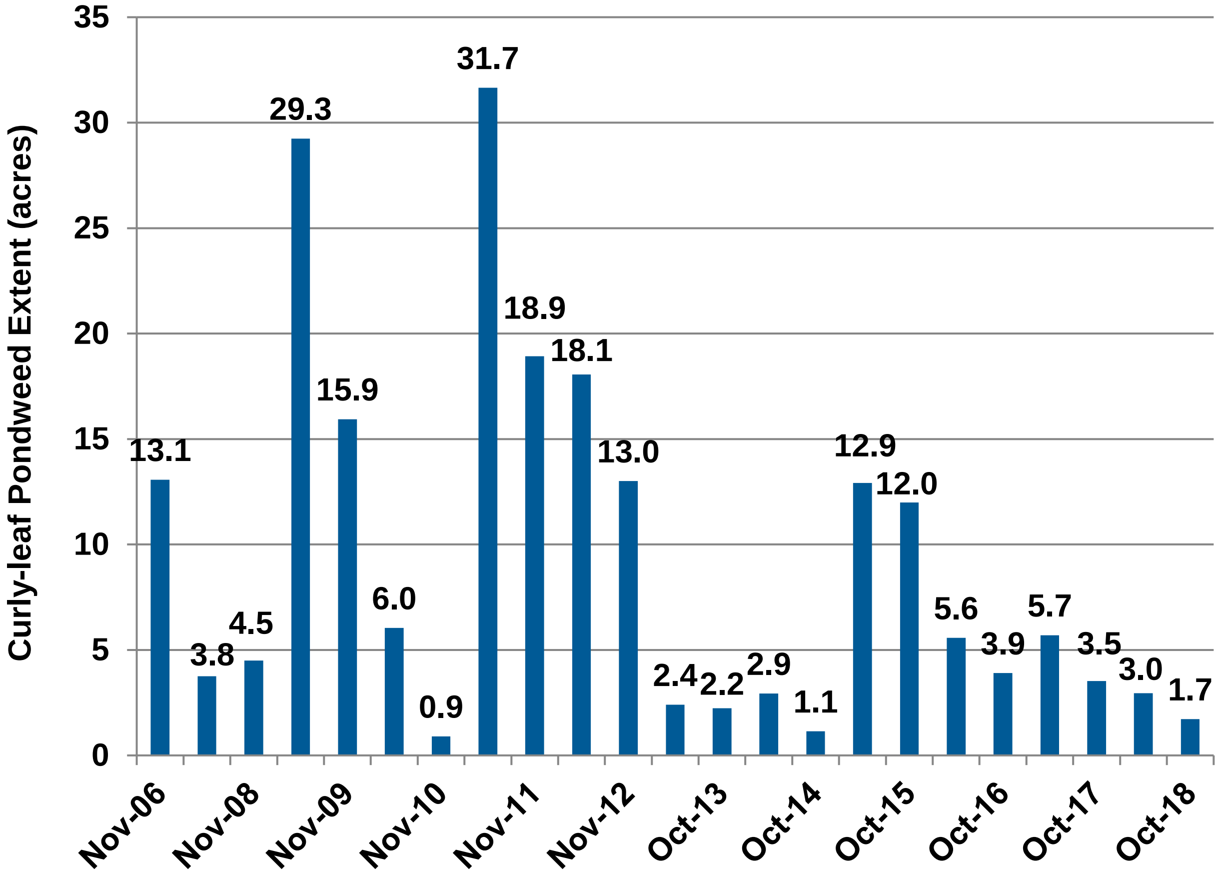


Figure 7-3 2006-2018 Beaver Dam Lake CLP Extent

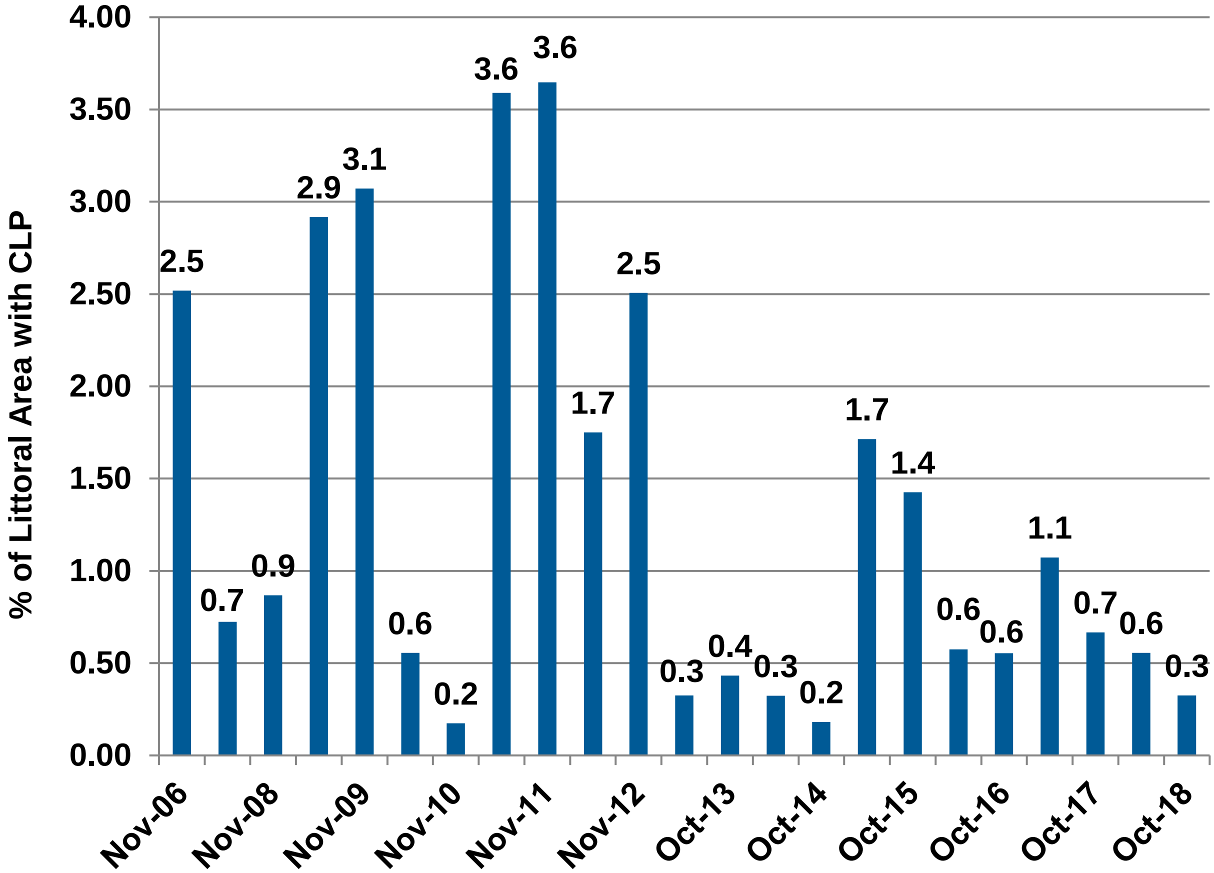


Figure 7-4 Percent of Littoral Area of Beaver Dam Lake with CLP during 2006-2018

7.3 Eurasian Watermilfoil (EWM)

EWM is a submersed aquatic plant native to Europe, Asia, and northern Africa (U.S. Forest Service, 2012). EWM was first introduced to the United States in the 1880s, being first observed in the Chesapeake Bay (Nichol's et al., 1986). EWM moved westward and was first introduced in southern Wisconsin in the 1960s (WDNR, 2012c). EWM moved northward in WI and was first observed in Beaver Dam Lake during 1991 (WDNR, 2012d).

Unlike many other plants, EWM does not rely on seed for reproduction. Its seeds germinate poorly under natural conditions and it generally reproduces by fragmentation—each fragment can grow into a new plant. The plant produces fragments after fruiting at least once or twice during the summer. These fragments can be carried downstream by water currents or spread by waves or boaters throughout a waterbody (WDNR, 2012d).

Once established in an aquatic community, EWM reproduces from fragments and stolons (runners that creep along the lake bed). Stolons, lower stems, and roots persist over winter and store the carbohydrates that help EWM claim the water column early in spring, photosynthesize, divide, and form a dense leaf canopy that shades out native aquatic plants. EWM's fast growth rate, up to 2 inches per day in spring and summer, its ability to spread rapidly by fragmentation, and its ability to effectively block out sunlight needed for native plant growth often result in monotypic stands. Monotypic stands of EWM provide only a single habitat, and threaten the integrity of aquatic communities in a number of ways; for example, dense stands disrupt predator-prey relationships by fencing out larger fish, and reducing the number of nutrient-rich native plants available for waterfowl. EWM spreads rapidly and can grow to dominance in as little as two years (WDNR, 2012c and 2012d).

Dense stands of EWM also inhibit recreational uses like swimming, boating, and fishing. Cycling of nutrients from sediments to the water column by EWM may lead to deteriorating water quality and algae blooms of infested lakes (WDNR, 2012c).

After EWM was accidentally introduced into Beaver Dam Lake in 1991, it spread quickly, displaced native plants, and inhibited recreational use of the lake. A District plant survey of the lake in 1999 estimated EWM coverage at approximately 73 percent of the littoral area of the lake (Barr, 2011c). The District completed an APM Plan in 2000 (Barr, 2000). The APM Plan recommended treatment of EWM infested areas with 2,4-D. During 2000 through 2005, the District implemented the APM Plan. 2,4-D treatments of EWM infested areas generally occurred twice during each growing season. The first treatment generally occurred in June and the second in August. In 2004, a third treatment was added to the program. Treatment areas were determined by annual inspections to identify problematic EWM infested areas in the lake. EWM infested areas treated with 2,4-D during the 2000 through 2005 period are summarized in Table 7-3 and discussed in detail in the Beaver Dam Lake (East and West) Macrophyte Surveys and Management Plan (Barr, 2006).

Table 7-3 2000-2005 Beaver Dam Lake EWM Infested Areas Treated with 2,4-D

Year	1st Treatment (ac)	2nd Treatment (ac)	3rd Treatment (ac)	Total Treated Areas (ac)
2000	50	67	--	117
2001	85	75	--	160
2002	80	18	--	98
2003	84	58	--	142
2004	102	44	25	171
2005	53	66	--	119

The District completed an aquatic plant survey in 2005 and updated its APM Plan in 2006. The District plant survey of the lake in 2005 estimated EWM coverage at approximately 47 percent of the littoral area of the lake. The updated plan recommended an adaptive management strategy to reduce EWM coverage and density in Beaver Dam Lake. The strategy employed annual plant surveys that identified areas of the lake infested with EWM and used a customized treatment program to control EWM. The customized program considered locations in which EWM was found, lake volume, mixing potential, flow, and current research information. A customized treatment strategy (herbicide or combination of herbicides, dose, application strategy, and timing) was annually selected. Treatments occurred during early spring prior to the native plant growing season. In some years, selected areas were treated in fall after the native plant growing season had concluded. The treatment timing, either before or after the native plant growing season, protected native species from harm. In addition, control of EWM prior to the native plant growing season encouraged native species to claim areas vacated by EWM and, hence, encouraged restoration of the native plant community.

The District again updated its APM Plan in 2012. Since 2012, the District has annually updated its APM Plan. The District uses an adaptive management approach, striving for continuous improvement. Aquatic plant surveys are annually completed to determine EWM management results and areas requiring management in the subsequent year. The current program customizes EWM management for each basin—management method (manual removal or herbicide treatment) and for herbicide treatment, herbicide type and dose, are determined for each basin.

Table 7-4 summarizes EWM frequency of occurrence in the littoral areas (shallow areas where plants grow) during the 2006 through 2018 period. The littoral areas of the lake include water depths up to 25 feet, the area of the lake where EWM has been found. The frequency of occurrence is based upon whole lake point intercept plant surveys in which approximately 1,346 sample points in the lake were surveyed. Lake area locations are shown on Figure 1-2. Maps showing sample points are found in Appendix E.

Table 7-5 summarizes EWM extent—the number of acres of EWM in the lake—during the 2006 through 2018 period. The EWM extent is based upon whole lake point intercept plant surveys in which approximately 1,346 sample points in the lake were surveyed. Lake area locations are shown on Figure 1-2. Maps showing EWM extent are found in Appendix F.

Table 7-6 summarizes the percent of the littoral zone with EWM during the 2006 through 2018 period. The percent of the littoral zone with EWM was computed by dividing the EWM extent in acres by the area of the littoral zone in acres and multiplying by 100 to convert to percent. The littoral zone is the area of the lake to the 25-foot depth.

The data shows a rapid spread of EWM has generally occurred between summer and fall, except when a fall treatment occurred. EWM extent in eastern basins approximately doubled between summer and fall during 2009 through 2011 except in 2010 when a fall treatment in Norwegian Bay resulted in a reduction of EWM between summer and fall (Table 7-5). West Lake EWM extent approximately doubled between summer and fall during 2010 through 2012 except in 2009 when a fall treatment in West Lake, Williams Bay, Rabbit Island Bay, and Library Lake resulted in a reduction of EWM extent between summer and fall (Table 7-5).

Despite the spread of EWM between summer and fall, successful management of EWM has reduced EWM extent by 90 percent—from 176 acres in the fall of 2008 to 18 acres in the fall of 2018 (Table 7-4)—and EWM frequency by 88 percent—from 34 percent in the fall of 2008 to 4 percent in the fall of 2018 (Table 7-3).

Figure 7-5 summarizes the percent of the littoral area of Beaver Dam Lake with EWM during 2006 through 2018. The littoral area is defined as the area of the lake up to the 25-foot depth. The littoral area in Beaver Dam Lake, estimated from the depths measured during the fall plant survey, is 530 acres. The percent of littoral area on Figure 7-5 was computed by dividing the EWM extent (Table 7-4) by the littoral area, and then multiplying by 100 to convert to percent. During 2008 through 2018, the percentage of littoral area with EWM ranged from a low of 1 percent during July of 2015 to a high of 34 percent in the fall of 2008. During the fall of 2018, 3 percent of the littoral zone contained EWM (Figure 7-5).

The District has changed the EWM goal periodically. Beginning with the 2006 APM Plan and continuing through 2012, the District goal was to reduce EWM in Beaver Dam Lake to a littoral area frequency of 5 percent or less. In 2012, the goal was changed to reduce EWM to a littoral area extent of 10 percent or less. In 2014, the District changed the EWM goal to 7 percent or less of the littoral zone. The 2014 goal change reflects the will of the District to reduce EWM to the lowest possible level. The 2018 EWM level is 3 percent of the littoral zone. Although the District goal has been attained, the District plans to continue EWM management in an attempt to reduce EWM to the lowest possible extent and to prevent a return of EWM to pre-management conditions.

Table 7-4 2006-2018 Beaver Dam Lake EWM Frequency of Occurrence in Beaver Dam Lake

Location	% of sample points up to 25 foot depth with Eurasian watermilfoil, including visuals																									
	Fall 2006	**Fall 2007**	**Fall 2008**	**July 2009**	**Fall 2009**	**July 2010**	**Fall 2010**	**July 2011**	**Fall 2011**	**June 2012**	**July 2012**	**Fall 2012**	**May 2013**	**June 2013**	**July 2013**	**Fall 2013**	**July 2014**	**Fall 2014**	**July 2015**	**Fall 2015**	**July 2016**	**Fall 2016**	**July 2017**	**Fall 2017**	**July 2018**	**Fall 2018**
Norwegian Bay	28.57	16.39	52.46	39.71	80.00	33.82	28.36	11.76	51.52	13.24	54.41	72.13	39.71	0.00	7.35	58.82	4.41	44.12	1.47	1.47	8.82	22.06	10.29	17.65	1.47	2.94
East Lake	5.13	0.00	13.38	14.00	27.86	22.70	27.54	28.78	33.79	N/A*	17.57	27.86	N/A*	N/A*	2.88	19.73	0.73	2.10	0.00	0.00	0.00	1.36	1.41	1.36	0.00	0.00
City Bay	59.12	7.74	72.84	32.78	62.13	21.67	55.93	54.40	70.39	8.89	48.07	58.90	46.93	0.00	21.67	46.11	1.67	9.44	0.00	7.78	0.00	1.67	2.22	5.56	0.00	1.67
Cemetery Bay	41.10	0.00	40.00	0.00	6.82	0.00	10.23	3.37	47.73	N/A*	0.00	18.39	N/A*	3.37	0.00	2.25	0.00	1.14	4.49	44.94	5.62	26.97	0.00	0.00	0.00	0.00
West Lake	18.77	11.07	21.19	14.84	13.33	10.59	13.61	7.35	10.18	N/A*	8.64	14.15	N/A*	N/A**	6.69	17.31	5.50	11.52	0.00	1.21	4.28	8.36	5.83	11.64	2.76	6.83
Williams Bay	13.33	28.05	23.81	16.98	11.01	3.85	12.15	9.80	10.19	N/A*	3.85	15.96	N/A*	N/A**	0.96	6.36	0.00	9.43	0.00	0.00	1.87	8.33	1.89	0.93	0.94	1.90
Rabbit Island Bay	39.39	28.72	30.10	18.49	20.54	12.82	26.79	10.17	17.86	0.00	1.67	11.43	N/A**	N/A**	0.85	3.33	1.68	5.00	0.00	1.67	4.20	10.00	0.00	3.33	0.84	4.17
Library Lake	73.33	61.97	47.30	5.04	2.60	0.72	7.41	0.00	0.00	N/A*	2.88	1.79	N/A*	N/A*	0.00	0.72	0.00	1.44	5.76	12.23	0	0.00	1.44	3.60	5.76	10.07
East Lake Basins	**12.74**	**24.17**	**26.45**	**13.84**	**12.90**	**7.93**	**14.26**	**7.02**	**10.71**	**N/A***	**5.53**	**12.54**	**N/A*****	**N/A*****	**3.48**	**10.95**	**2.88**	**8.06**	**1.17**	**3.31**	**2.30**	**9.09**	**2.71**	**4.96**	**0.21**	**1.05**
West Lake Basins	**16.79**	**5.52**	**44.89**	**21.97**	**43.72**	**19.67**	**34.89**	**31.38**	**54.31**	**N/A***	**30.86**	**43.24**	**N/A*****	**N/A*****	**10.08**	**33.12**	**1.46**	**10.65**	**1.05**	**11.46**	**3.03**	**6.98**	**3.33**	**6.98**	**2.75**	**6.27**
Beaver Dam Lake—All Basins	**14.42**	**15.77**	**34.46**	**17.17**	**25.96**	**12.77**	**22.64**	**17.43**	**29.51**	**N/A*****	**16.03**	**26.16**	**N/A*****	**N/A*****	**6.17**	**20.29**	**2.30**	**9.11**	**1.12**	**6.64**	**2.73**	**7.84**	**3.08**	**6.16**	**1.71**	**4.12**

N/A* Frequency of occurrence not available because the area was not surveyed

N/A** Frequency of occurrence not available because limited areas were surveyed - not the whole lake/bay area. Rabbit Island Bay channels surveyed and small area near the Eagle Point Boat Launch.

N/A*** Frequency of occurrence not available because some areas were not surveyed and only limited areas were surveyed in West Lake (area near Eagle Point boat landing) and Rabbit Island Bay (only the channels)

Table 7-5 2006-2018 EWM Extent in Beaver Dam Lake

Location	Acreage of EWM (based on plant surveys)																									
	Fall 2006	Fall 2007	Fall 2008	July 2009	Fall 2009	July 2010	Fall 2010	July 2011	Fall 2011	June 2012	July 2012	Fall 2012	May 2013	June 2013	July 2013	Fall 2013	July 2014	Fall 2014	July 2015	Fall 2015	July 2016	Fall 2016	July 2017	Fall 2017	July 2018	Fall 2018
Norwegian Bay	3.64	4.75	18.12	8.65	28.23	12.09	9.61	1.99	19.67	3.36	21.21	26.91	15.16	0.00	2.19	23.37	1.10	17.89	0.45	0.81	2.48	6.94	4.66	6.19	0.30	0.65
East Lake	0.00	0.00	9.34	8.14	19.37	14.13	17.48	17.18	23.93	N/A*	11.33	19.98	N/A*	N/A*	1.18	15.72	0.33	0.90	0.00	0.00	0.00	1.97	0.63	0.48	0.00	0.00
City Bay	60.25	3.94	68.06	27.89	61.62	20.11	54.01	47.97	73.66	7.65	48.76	55.75	50.85	0.00	20.70	49.01	0.79	7.26	0.00	6.87	0.00	1.50	2.37	5.13	0.00	1.56
Cemetery Bay	10.90	0.00	17.80	0.00	1.81	0.00	3.97	0.86	21.32	N/A*	0.00	7.17	N/A*	0.75	0.00	0.51	0.00	0.26	1.54	31.56	1.70	13.76	0.00	0.00	0.00	0.00
West Lake	25.27	11.36	33.19	24.59	19.67	15.80	25.15	8.65	14.78	N/A*	15.31	23.11	N/A*	3.15**	10.05	29.13	7.23	29.94	0.00	1.72	6.83	20.64	9.46	21.05	5.46	12.35
Williams Bay	3.63	10.23	12.64	9.48	4.80	1.15	6.68	4.57	4.65	N/A*	1.68	6.92	N/A*	0.26**	0.33	2.46	0.00	7.45	0.00	0.00	0.92	5.78	1.89	0.26	0.72	0.54
Rabbit Island Bay	5.80	12.36	13.21	10.57	8.51	6.26	11.47	4.22	8.01	0.00	0.51	5.64	0.00**	N/A**	0.38	1.45	0.61	3.11	0.00	1.37	1.41	9.51	0.00	0.83	0.27	1.32
Library Lake	0.66	0.59	3.62	0.40	0.09	0.04	0.72	0.00	0.00	N/A*	0.20	0.04	N/A*	N/A*	0.00	0.06	0.00	0.14	0.70	1.90	0.02	0.00	0.20	0.43	0.76	1.85
East Lake Basins	**74.79**	**8.69**	**113.32**	**44.68**	**111.03**	**46.33**	**85.07**	**67.99**	**138.58**	**N/A***	**81.30**	**109.81**	**N/A***	**N/A***	**24.07**	**88.60**	**2.22**	**26.31**	**1.99**	**39.24**	**4.18**	**24.16**	**7.66**	**11.80**	**0.30**	**2.21**
West Lake Basins	**35.36**	**34.54**	**62.66**	**45.04**	**33.07**	**23.25**	**44.02**	**17.44**	**27.44**	**N/A***	**17.70**	**35.70**	**N/A***	**N/A***	**10.76**	**33.10**	**7.84**	**40.64**	**0.70**	**4.99**	**9.18**	**35.93**	**11.55**	**22.57**	**7.21**	**16.06**
Beaver Dam Lake—All Basins	**110.15**	**43.23**	**175.98**	**89.72**	**144.10**	**69.58**	**129.09**	**85.43**	**166.02**	**N/A***	**99.00**	**145.51**	**N/A***	**N/A***	**35.88**	**121.70**	**10.06**	**66.96**	**2.68**	**44.23**	**13.36**	**60.10**	**19.21**	**34.37**	**7.52**	**18.27**

N/A* EWM extent not available because the area was not surveyed

** EWM extent is based on survey of limited areas—not the whole lake/bay area. Rabbit Island Bay channels surveyed and small area near the Eagle Point Boat Launch.

N/A*** Frequency of occurrence not available because some areas were not surveyed and only limited areas were surveyed in West Lake (area near Eagle Point boat landing) and Rabbit Island Bay (only the channels)

Table 7-6 2006-2018 Percent of Littoral Zone with EWM in Beaver Dam Lake

Location	% of Littoral Zone with EWM (based on plant surveys)																						
	Fall 2006	Fall 2007	Fall 2008	July 2009	Fall 2009	July 2010	Fall 2010	July 2011	Fall 2011	July 2012	Fall 2012	July 2013	Fall 2013	July 2014	Fall 2014	July 2015	Fall 2015	July 2016	Fall 2016	July 2017	Fall 2017	July 2018	Fall 2018
Norwegian Bay	9.52	12.42	47.38	22.62	73.82	31.62	25.13	0.05	51.44	55.47	70.38	5.72	61.11	2.88	46.79	1.18	2.12	6.49	18.15	12.18	16.19	0.78	1.70
East Lake	0.00	0.00	14.83	12.92	30.75	22.43	27.75	27.27	37.98	17.98	31.71	1.87	24.95	0.53	1.43	0.00	0.00	0.00	3.13	0.93	0.71	0.00	0.00
City Bay	59.45	3.89	67.15	27.52	60.80	31.92	53.29	47.33	72.68	48.11	55.01	20.42	48.36	0.78	7.17	0.00	6.78	0.00	1.48	2.34	5.06	0.00	1.54
Cemetery Bay	20.21	0.00	33.00	0.00	3.36	0.00	7.36	1.59	39.53	0.00	13.29	0.00	0.94	0.00	0.48	2.86	58.51	3.15	25.51	0.00	0.00	0.00	0.00
West Lake	17.60	7.91`	23.12	17.13	13.70	11.01	17.52	6.03	10.30	10.67	16.10	7.00	20.29	5.04	20.86	0.00	1.20	4.76	14.86	6.43	14.30	3.70	8.37
Williams Bay	7.95	22.41	27.70	20.77	10.52	2.52	0.15	10.01	10.19	3.68	15.15	0.72	5.39	0.00	12.29	0.00	0.00	2.02	11.74	3.93	0.54	1.51	1.13
Rabbit Island Bay	9.56	20.38	21.78	17.43	14.03	10.32	18.91	6.96	13.21	0.84	9.30	0.63	2.39	1.01	5.13	0.00	2.26	2.33	15.72	0.00	1.36	0.44	2.16
Library Lake	4.81	4.30	26.40	2.92	0.66	0.29	5.25	0.00	0.00	1.46	0.27	0.00	0.45	0.00	0.99	5.11	13.86	0.15	0.00	1.44	3.14	5.54	13.49
East Lake Total:	**29.15**	**3.39**	**44.17**	**17.42**	**43.28**	**18.06**	**33.16**	**26.51**	**54.02**	**31.69**	**42.81**	**9.38**	**34.54**	**0.87**	**10.26**	**1.99**	**15.30**	**1.63**	**9.42**	**2.93**	**4.52**	**0.12**	**0.85**
West Lake Total:	**13.42**	**13.11**	**23.78**	**17.09**	**12.55**	**8.82**	**16.70**	**6.62**	**10.41**	**6.72**	**13.55**	**4.08**	**12.56**	**2.98**	**15.42**	**0.70**	**1.89**	**3.48**	**13.69**	**4.27**	**8.35**	**2.67**	**5.95**
Beaver Dam Lake Total	**21.18**	**8.31**	**33.84**	**17.25**	**27.71**	**13.38**	**24.82**	**16.43**	**31.92**	**19.04**	**27.98**	**6.90**	**23.40**	**1.93**	**12.87**	**2.68**	**8.50**	**2.57**	**11.58**	**3.62**	**6.47**	**1.42**	**3.45**

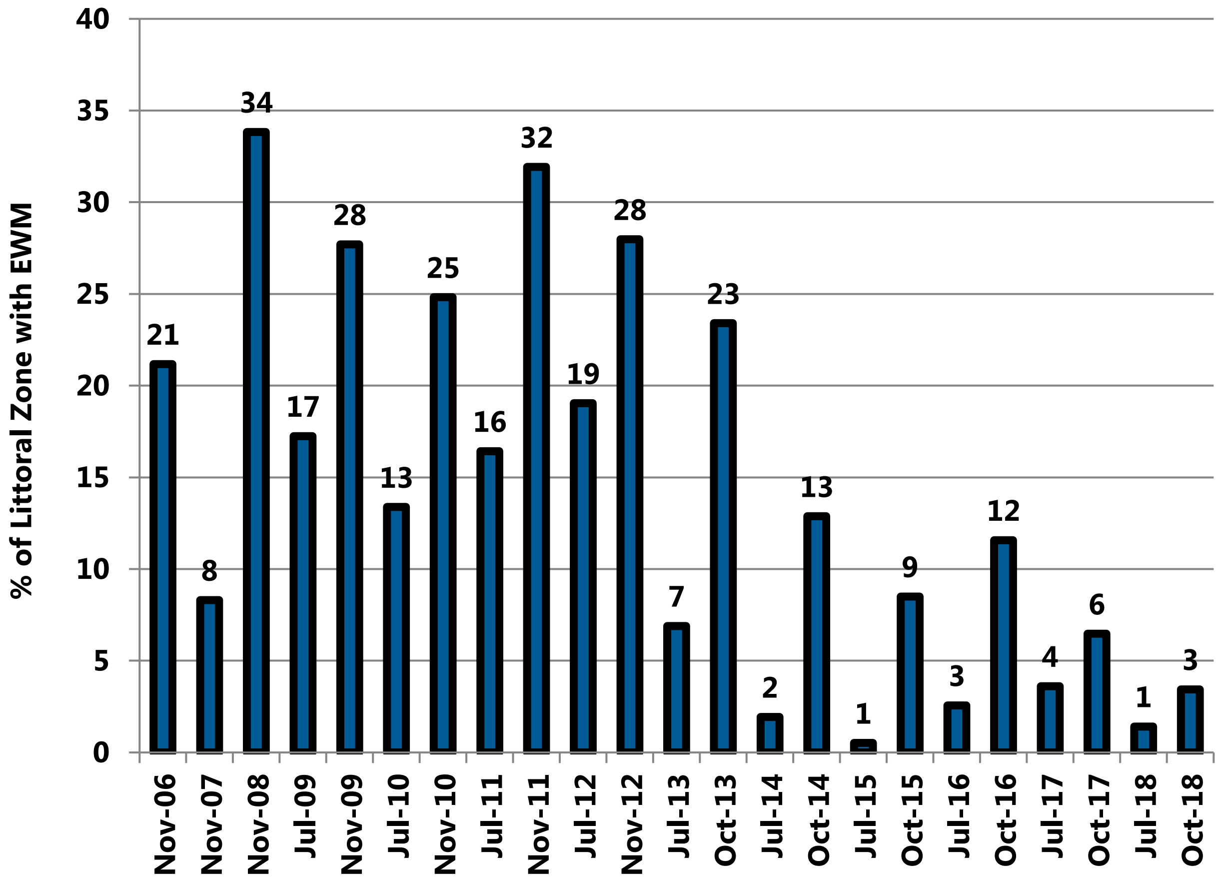


Figure 7-5 Percent of Littoral Area of Beaver Dam Lake with EWM during 2006-2018

Table 7-7 summarizes EWM herbicide treatment areas, both spring and fall, and shows the types of herbicide used for treatment during the 2006 through 2018 period. A detailed discussion of the treatments is found in treatment plans found in Appendix J. In addition, annual reports contain detailed discussions of the treatments completed during 2006 through 2011 (Barr, 2007a; Barr 2007b; Barr, 2009a; Barr, 2010a; Barr, 2011a, and Barr, 2012c).

Table 7-7 2006-2018 Beaver Dam Lake Herbicide Treatment Summary: Area Treated and Herbicide Used

Year	Spring Treatment				Fall Treatment			Sum of Spring and Fall (ac)
	Treat with 2,4-D (ac)	Treat with 2,4-D and Endothall (ac)	Treat with Diquot (ac)	Total Spring (ac)	Treat with 2,4-D (ac)	Treat with 2,4-D and Endothall (ac)	Total Fall (ac)	
2006	91	58	--	149	22	--	22	171
2007	63	90	4	157	10	--	10	167
2008	97	23	--	120	25	--	25	145
2009	154	24	--	178	23	2	25	204
2010	71	93	--	164	11	23	34	198
2011	181	--	--	181	--	--	--	181
2012	169	53	--	222	--	--	--	222
2013	218	29	--	247	--	--	--	247
2014	278	--	--	278	--	--	--	278
2015	336	--	--	336	--	--	--	336
2016	166	--	--	166	--	--	--	166
2017	177	--	5	182	--	--	--	182
2018	161	--	10	171	--	--	--	171

In 2015, the EWM management program was expanded to include manual removal of EWM in summer. In 2015, manual removal of EWM occurred in Norwegian Bay, Cemetery Bay, and Library Lake during late July and in Library Lake and Norwegian Bay in late August. In 2016, manual removal of EWM occurred in Rabbit Island Bay, the channel between Rabbit Island Bay and Library Lake, Cemetery Bay, City Bay, and Norwegian Bay during late August. In 2017, manual removal of EWM occurred in Library Lake during July. In 2018, a manual removal of EWM occurred in the west canal of Rabbit Island Bay in July.

7.3.1 Herbicide Residue Data

During 2006 through 2018, herbicide residue data were collected after each herbicide treatment. The data are summarized in Appendix M.

8.0 Beaver Dam Lake Native Plant Community

Beaver Dam Lake, pictured above, has a very healthy and high quality plant community. Photo Credit: Endangered Resource Services, LLC.

Summer plant surveys during 2009 through 2018 indicate the plant community within Beaver Dam Lake is very healthy and of very high quality. The number of species (including visuals and boat surveys) in Beaver Dam Lake during this period has ranged from 61 in 2012 to 74 in 2016, and was 70 in 2018 (Table 8-1). In 2018, the number of species in Beaver Dam Lake was 5 times greater than the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). The quality of the plant community, measured by Floristic Quality Index (FQI), has ranged from 45 in 2015 to 49 in 2016, and was 47 in 2018 (Table 8-1), which was more than double the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). The high FQI indicates: (1) the plant community is intolerant to development and other human disturbances; (2) the plant community has not been degraded by human impacts, including repeated herbicide treatment; and (3) the lake has high water quality.

In 2018, plant diversity as represented by Simpson's Diversity Index was similar to previous years—0.94 in 2018 compared with 0.94 to 0.95 during 2009 through 2017 (Table 8-1). The values indicate the probability that two individual plants randomly selected from Beaver Dam Lake will belong to different species—94 percent in 2018 compared with 94 to 95 percent during 2009 through 2017.

In 2018, the maximum and average depths of plant growth were relatively similar to previous years. The maximum depth at which plants were found has ranged from 20.5 feet to 28.0 feet, and was 23.0 feet in 2018. The average depth of plant growth has ranged from 5.3 feet to 6.1 feet, and was 5.5 feet in 2018.

In 2018, plant frequency and the average number of native plant species per sample location were similar to previous years. The plant frequency of occurrence at sites shallower than the maximum depth of plants has ranged from a low of 66 percent in 2015 to a high of 88 percent in 2013 and was 78 percent in 2018. More than 1 native plant species has generally been found at Beaver Dam Lake sample locations. The average number of native plant species at each sample location has ranged from a low of 1.7 in 2010 to a high of 2.6 in 2012 and was 2.3 in 2018 (Table 8-1).

During 2009 through 2018, plant species abundance was balanced between many different types and no single plant species dominated the plant community. In 2018, 88 percent of the lake's plant species had a frequency of less than 10 percent. The most prevalent native plant species in Beaver Dam Lake in 2018, ranging in frequency from 10 to 37 percent, were fern pondweed (*Potamogeton robbinsii*), common waterweed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), variable pondweed (*Potamogeton gramineus*), white water lily (*Nymphaea odorata*), muskgrasses (*Chara sp.*), slender naiad (*Najas flexilis*), and white-stem pondweed (*Potamogeton praelongus*) (Figure 8-1).

In 2018, as in previous years, species that are uncommon in Wisconsin lakes and designated by the Wisconsin Department of Natural Resources as Species of Special Concern were observed in Beaver Dam Lake—*Potamogeton vaseyi* (Vasey's pondweed) and *Utricularia purpurea* (purple bladderwort). The Natural Heritage Inventory Division of WDNR keeps a record of native species that are known or suspected to be rare in Wisconsin. The WDNR requires that all species that are considered Threatened, Endangered, or Species of Special Concern found in Wisconsin lakes be reported to the Natural Heritage Inventory Division of WDNR. During 2009 through 2018, three Species of Special Concern have been documented in Beaver Dam Lake: *Potamogeton vaseyi* (Vasey's pondweed), *Eleocharis robbinsii* (Robbin's spikerush), and *Utricularia purpurea* (purple bladderwort) (Figure 8-4 and Figure 8-5). Information about the location and population size of these species was reported to the Natural Heritage Inventory Division of WDNR whenever they were observed in Beaver Dam Lake.

Significant frequency changes have occurred in more than half of the lake's native species' since 2009 (Figure 8-1 through Figure 8-6):

- 36 of the lake's 69 native species collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 19 native species have both significantly declined and significantly increased in a year-over-year frequency since 2009.
- 11 native species have significantly increased in a year-over-year frequency since 2009.
- 6 native species have significantly decreased in a year-over-year frequency since 2009.

Significant frequency changes of native species in 2018 were documented by a Chi Squared analysis of 2017 and 2018 data. There were 6 significant decreases and 4 significant increase in native plant frequency in 2018 (Table 8-2 and Figure 8-1 through Figure 8-6).

Beaver Dam Lake is complex, consisting of two basins and six bay areas. Each of the eight distinct areas of the lake is managed as a separate entity based upon its unique management needs. For this reason, the plant community in each of the eight management areas is discussed separately in the following paragraphs. The discussion begins with the four areas in the western basin—West Lake, Williams Bay, Rabbit Island Bay, and Library Lake—and then proceeds to the four areas in the eastern basin – Cemetery Bay, City Bay, East Lake, and Norwegian Bay.

Table 8-1 2009-2018 Beaver Dam Lake Summary Statistics

Date sampled	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/15/12-7/20/12	7/16/13-7/21/13	7/12/14-7/16/14	7/14/15-7/15/15 & 7/17/15-7/20/15	7/19/16-7/24/16	7/19/17-7/23/17	7/23/18-7/26/18
Total number of points sampled	1,339	1,339	1,339	1,340	1,339	1,339	1,339	1,339	1,339	1,339
Total number of sites with vegetation	844	867	849	864	849	864	794	887	876	887
Total number of sites shallower than maximum depth of plants	1,052	1,159	1,020	1,033	968	1,175	1,207	1,160	1,163	1,135
Frequency of occurrence of all species at sites shallower than maximum depth of plants	80.23	74.81	83.24	83.64	87.71	73.53	65.78*	76.47	75.32	78.15
Simpson Diversity Index	0.94	0.94	0.95	0.95	0.95	0.94	0.94	0.95	0.94	0.94
Maximum depth of plants (ft)	26.5	25.0	22.0	21.0	20.5	25.0	28.0	24.0	24.5	23.0
Average number of all species per site (shallower than max depth)	2.31	1.82	2.59	2.73	2.40	2.10	1.75	2.25	2.41	2.30
Average number of all species per site (veg. sites only)	2.89	2.44	3.11	3.27	2.83	2.85	2.66	2.94	3.20	2.94
Average number of native species per site (shallower than max depth)	2.10	1.70	2.37	2.57	2.32	2.06	1.73	2.23	2.38	2.28
Average number of native species per site (veg. sites only)	2.69	2.34	2.93	3.10	2.76	2.81	2.63	2.92	3.17	2.92
Species Richness	59	59	59	55	56	61	58	62	59	59
Species Richness (including visuals)	62	61	60	56	61	61	62	68	64	66
Species Richness (including visuals and boat survey)	70	69	63	61	65	70	70	74	67	70
Mean depth of plants (ft)	5.37	6.09	5.72	5.26	5.55	5.72	5.56	5.78	5.86	5.54
Median depth of plants (ft)	4.50	5.50	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Mean Rake fullness (veg. sites only)		2.01	2.15	2.11	1.93	1.85	1.86	2.05	2.11	2.00
Mean C	6.38	6.46	6.51	6.41	6.42	6.46	6.41	6.39	6.30	6.36
FQI	47.33	48.37	48.27	45.79	46.32	47.49	44.86	49.08	46.27	47.19

*The only plant species growing deeper than 25 feet in 2015 was *Potamogeton robbinsii* found at one 26.5-foot location and one 28.0-foot location in 2015. The low plant frequency at depths greater than 25 feet skewed the 2015 data lower. When computations were performed using the depth range at which plant growth was observed in 2014, 0 to 25 feet, plant frequency was 68.10 percent in 2015.

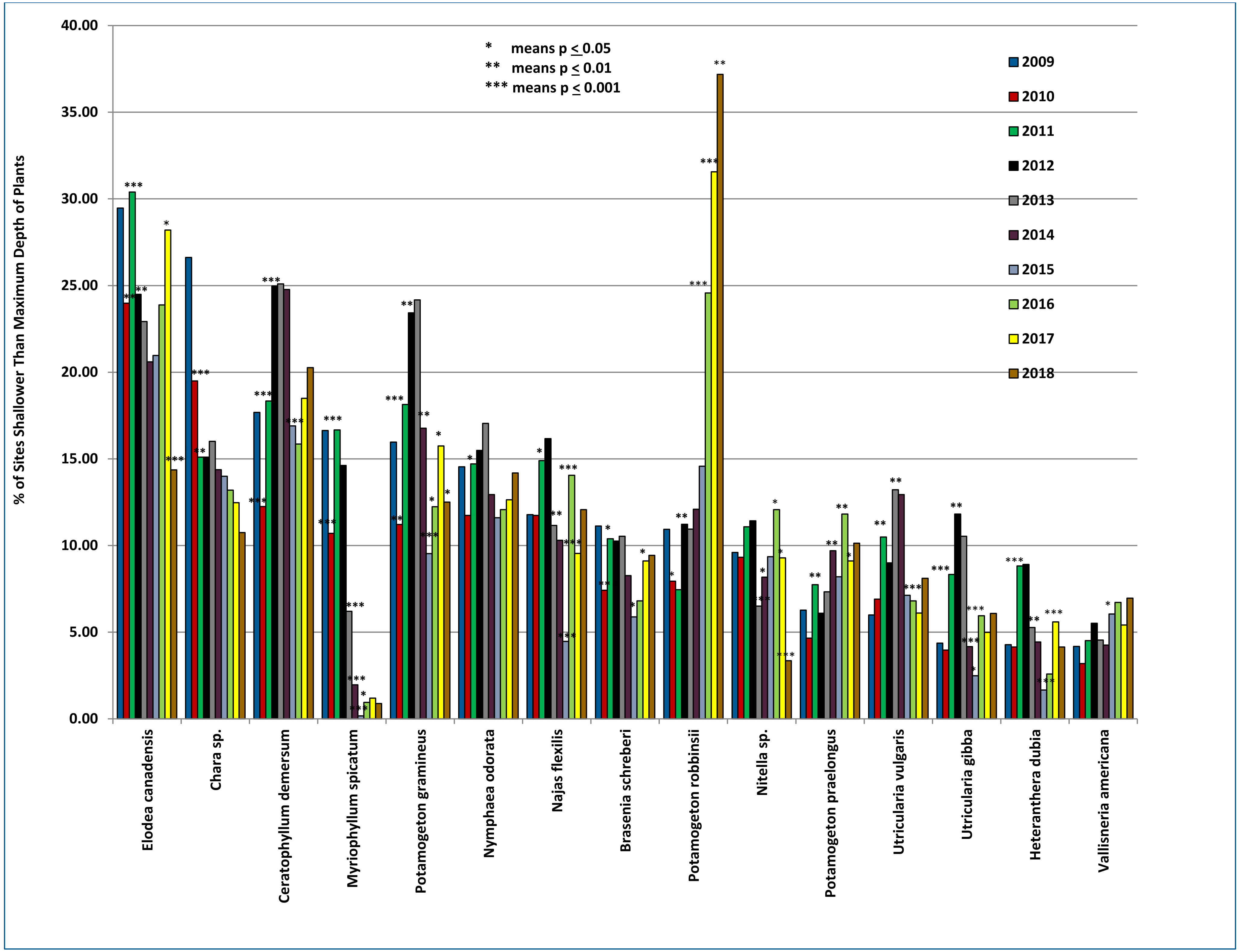


Figure 8-1 **2009-2018 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)**

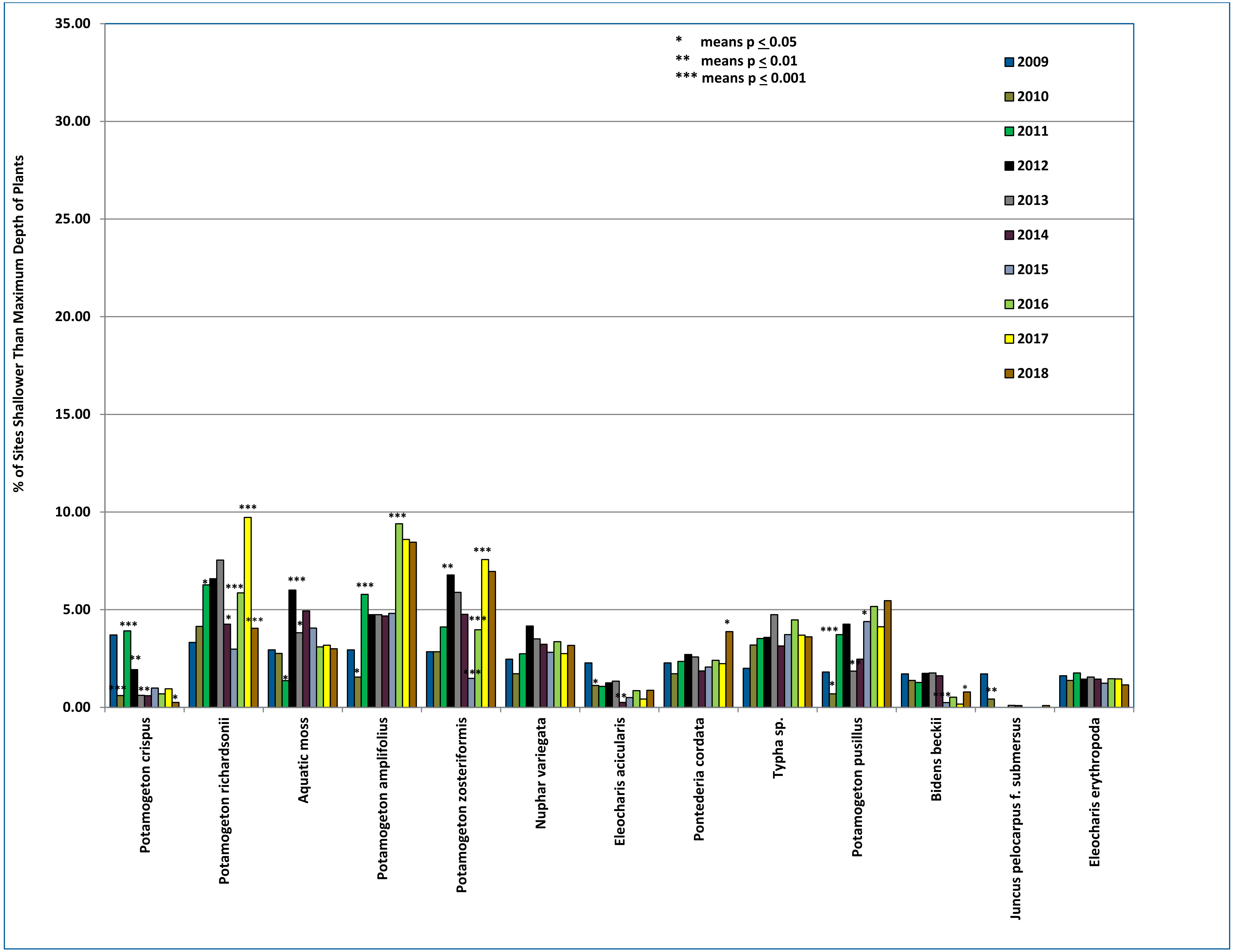


Figure 8-2 2009-2018 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

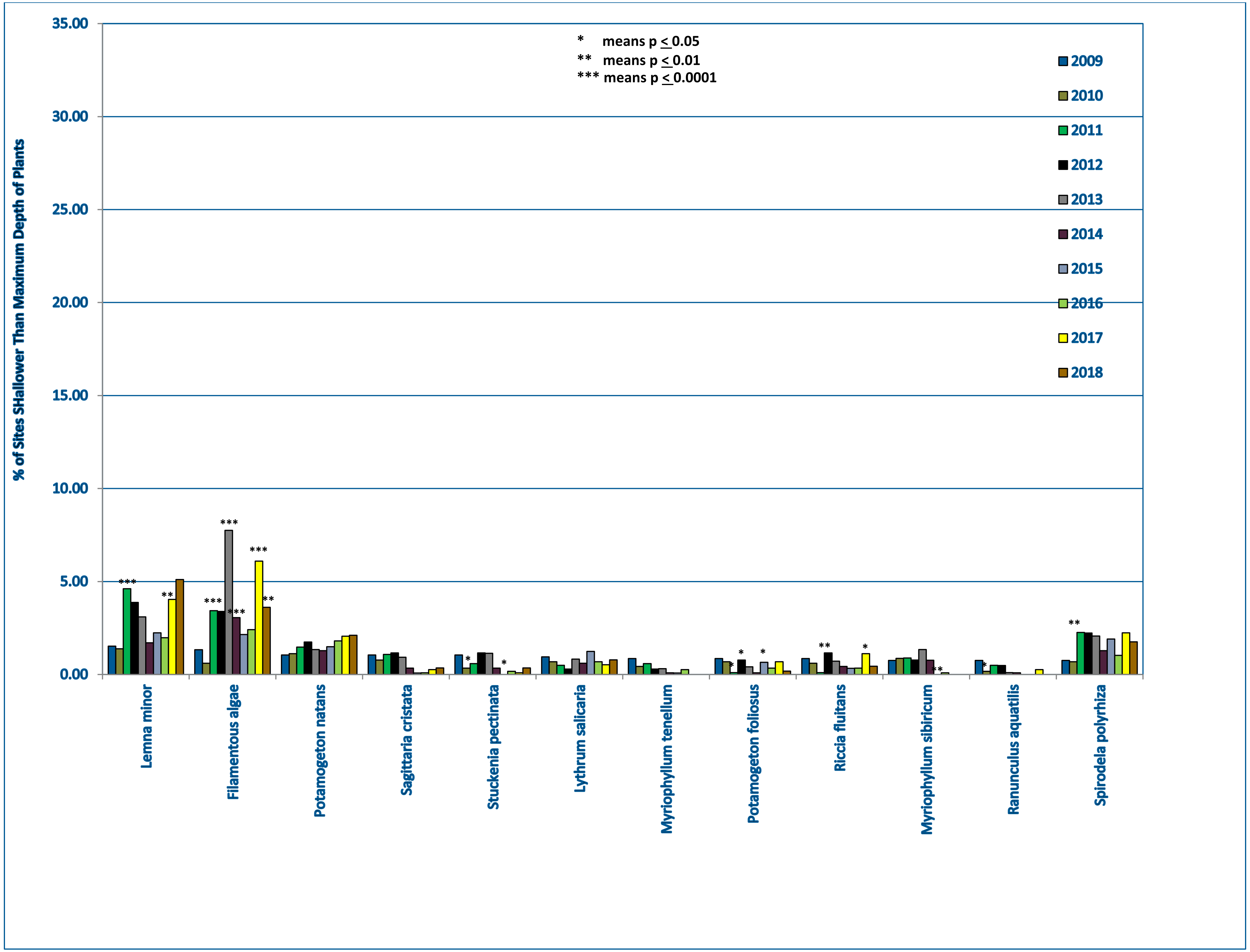


Figure 8-3 2009-2018 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

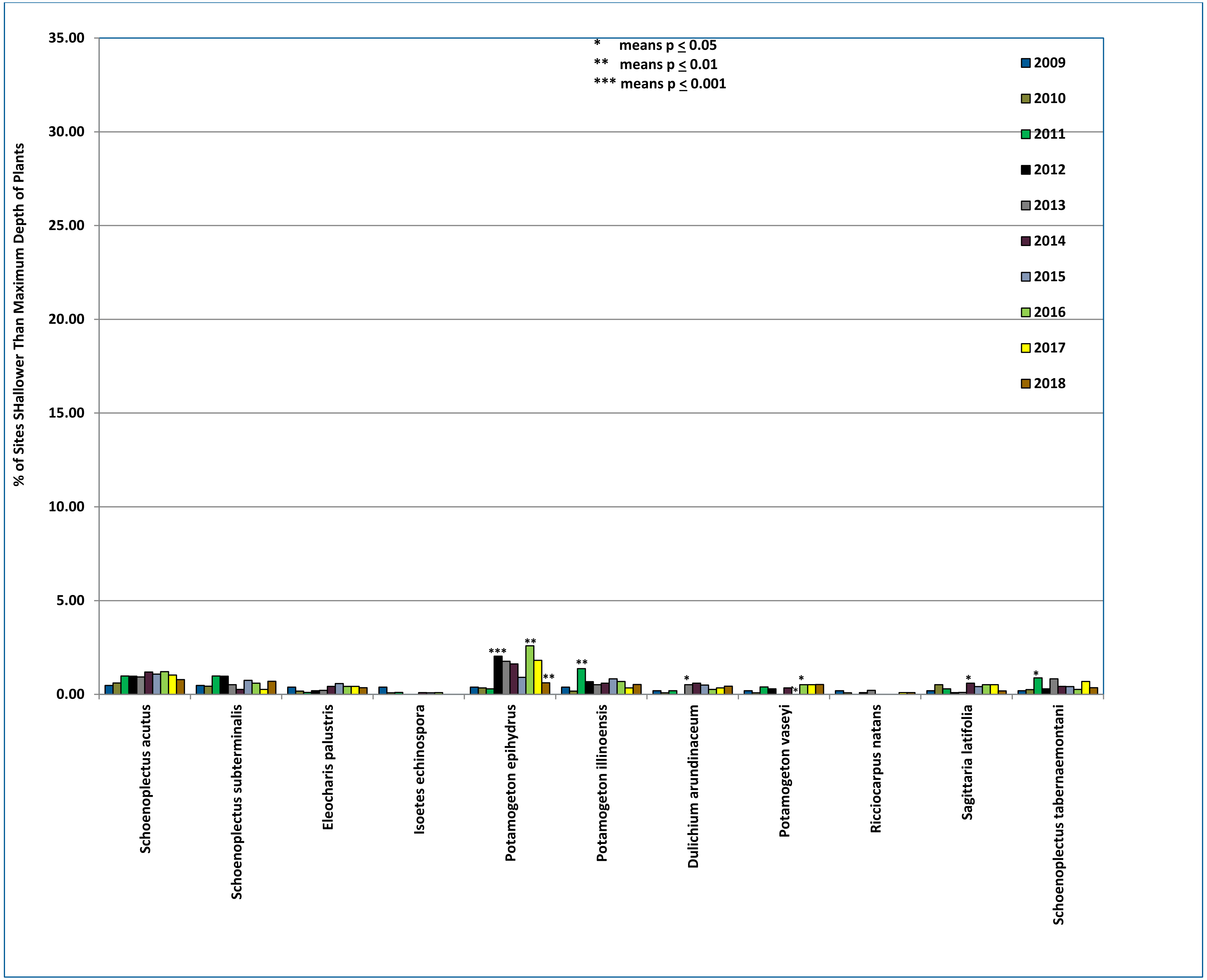


Figure 8-4 2009-2018 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

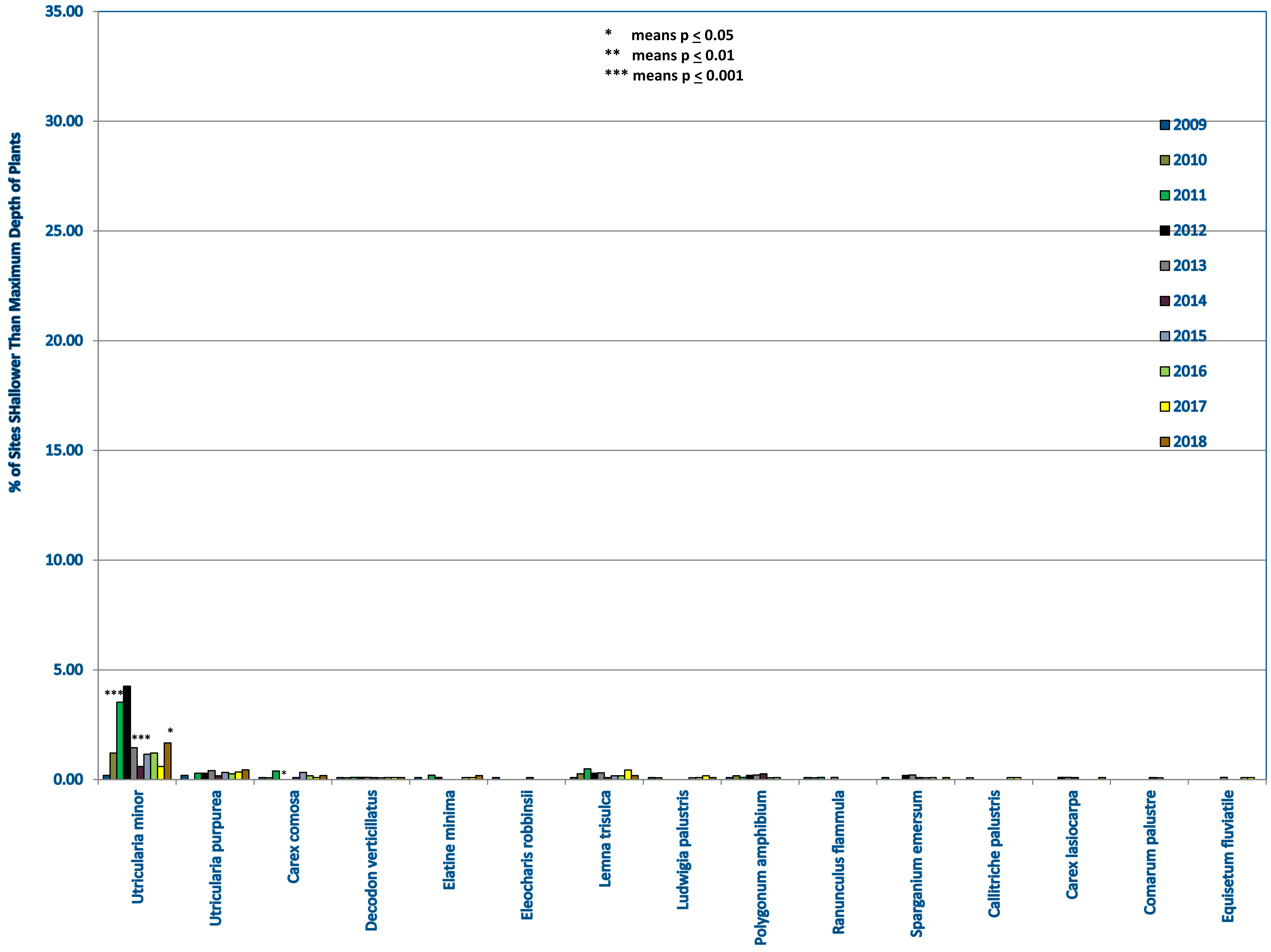


Figure 8-5 2009-2018 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

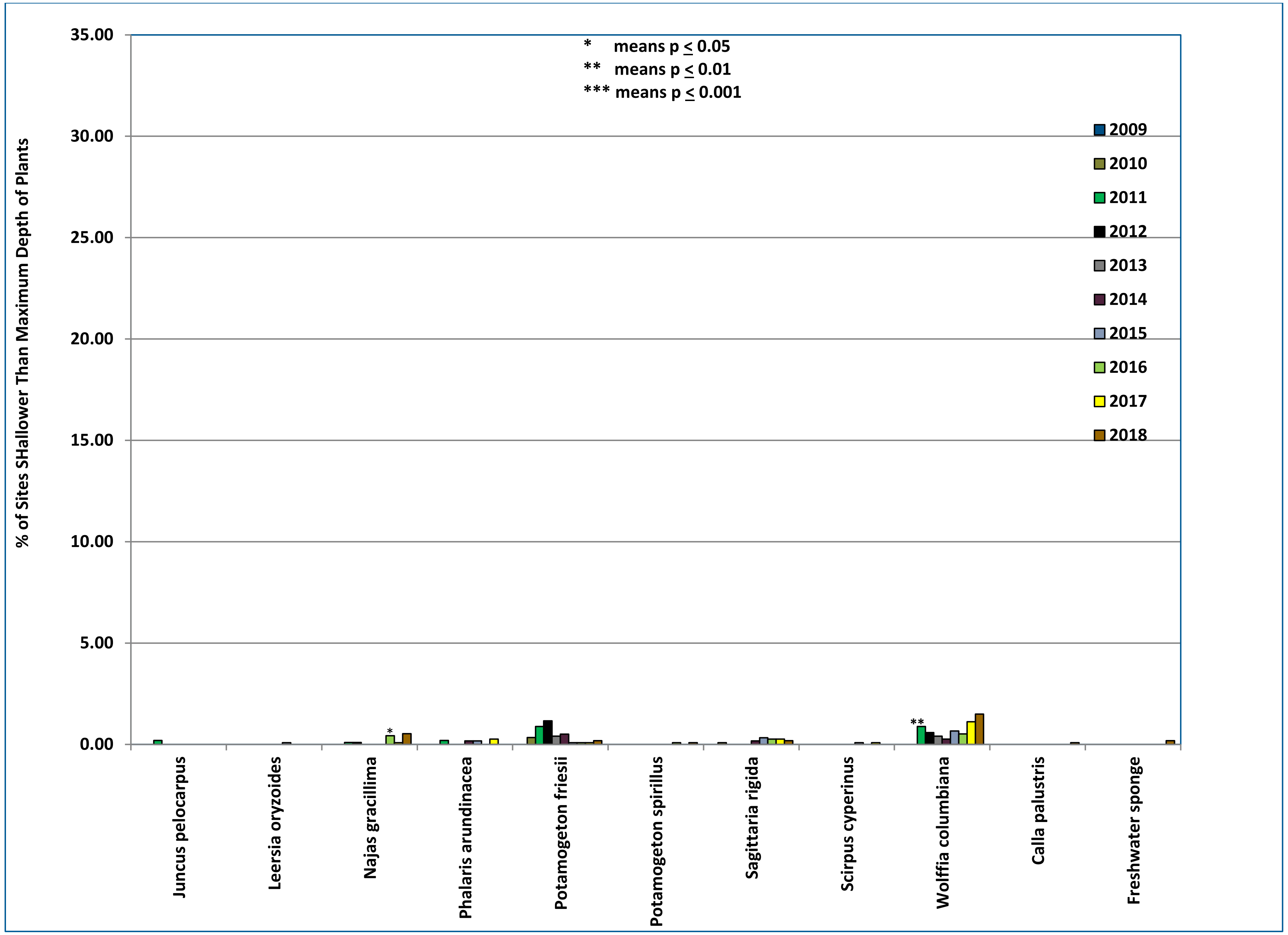


Figure 8-6 2009-2018 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

Table 8-2 2017-2018 Statistically Significant Changes in Frequency of Occurrence of Plant Species in Beaver Dam Lake

Species (Scientific Name)	Species (Common Name)	Beaver Dam Lake	West Lake	Williams Bay	Rabbit Island Bay	Library Lake	Cemetery Bay	City Bay	East Lake	Norwegian Bay
Bidens beckii	water marigold	* (+)				* (+)				
Ceratophyllum demersum	coontail									* (-)
Chara sp.	muskgrasses						* (-)	* (-)		
Elodea canadensis	common waterweed	*** (-)	* (-)				*** (-)	*** (-)	** (-)	*** (-)
Filamentous algae	filamentous algae	** (-)				* (-)				*** (-)
Heteranthera dubia	water-stargrass			* (+)			*** (-)	* (-)		
Najas flexilis	slender naiad		*** (+)							
Nitella sp.	nitella	*** (-)	* (-)			*** (-)	** (-)	** (-)		* (-)
Pontederia cordata	Pickerelweed	* (+)				** (+)				
Potamogeton amplifolius	Large-leaf pondweed			* (+)						
Potamogeton crispus	curly-leaf pondweed	* (-)								
Potamogeton epihydrus	ribbon-leaf pondweed	** (-)						** (-)		* (-)
Potamogeton gramineus	variable pondweed	* (-)				** (+)		*** (-)		
Potamogeton pusillus	small pondweed		* (+)					* (-)		
Potamogeton richardsonii	clasping-leaf pondweed	*** (-)	*** (-)	** (-)				** (-)		** (-)
Potamogeton robbinsii	fern pondweed	** (+)					** (+)			
Potamogeton zosteriformis	flat-stem pondweed							** (-)		** (-)
Riccia fluitans	slender riccia					* (-)				
Utricularia gibba	creeping bladderwort							* (+)		
Utricularia minor	small bladderwort	* (+)				** (+)				
Utricularia vulgaris	common bladderwort					** (+)				

* means $p \le 0.05$

** means $p \le 0.01$

*** means $p \le 0.001$

(+) Statistically significant Increase between 2017 and 2018

(-) Statistically significant decrease between 2017 and 2018

8.1 West Lake

West Lake has a surface area of 582 acres and a maximum depth of 106 feet. The lake is characterized by sharp drop offs and a very narrow littoral area. West Lake has excellent water quality, noting a trophic status of oligotrophic. During 2009 through 2017, the lake had excellent water transparency, noting Secchi disc depths ranging from 12.0 feet to 27.5 feet.

The water quality of West Lake, pictured above, is oligotrophic (excellent) and its aquatic plant community is of very high quality.

In 2018, the maximum and average depths of plant growth were relatively similar to previous years. The maximum depth of plant growth has ranged from 18.5 feet to 26.5 feet, and was 22.0 feet in 2018. The average depth of plant growth has ranged from 6.39 feet to 7.82 feet, and was 6.92 feet in 2018 (Table 8-3).

The 2018 plant survey results indicated the plant community in West Lake was very healthy and of high quality. The number of species (including visuals and boat surveys) in West Lake was similar to previous years—46 in 2018 compared with 44 to 55 during 2009 through 2017. In 2018, the number of species in West Lake was more than triple the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2018, the quality of the plant community, measured by FQI, was similar to previous years—38.00 in 2018 compared with 33.23 to 42.28 during 2009 through 2017. West Lake FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). Diversity, measured by Simpson Diversity Index, was at the top of the range observed in previous years—0.93 in 2018 compared with 0.91 to 0.93 in 2009 through 2017 (Table 8-3).

In 2018, plant frequency and the average number of native plant species per sample location were similar to previous years. During 2009 through 2017, the plant frequency of occurrence at sites shallower than the maximum depth of plants ranged from a low of 54 percent in 2015 to a high of 84 percent in 2012, and was 69 percent in 2018. More than 1 native species has generally been found at each West Lake sample location. The average number of native plant species at each sample location ranged from a low of 1.18 in 2015 to a high of 2.10 in 2012, and was 1.72 in 2018 (Table 8-3).

During 2009 through 2018, plant species abundance was balanced between many different types and no single plant species dominated the plant community. In 2018, 83 percent of West Lake plant species had a frequency of less than 10 percent. The most prevalent native plant species in West Lake in 2018, ranging from 12 to 23 percent, were muskgrasses (*Chara sp.*), fern pondweed (*Potamogeton robbinsii*), variable pondweed (*Potamogeton gramineus*), slender naiad (*Najas flexilis*), coontail (*Ceratophyllum demersum*), white-stem pondweed (*Potamogeton praelongus*), and wild celery (*Vallisneria americana*) (Figure 8-7).

Significant frequency changes have occurred in a third of the lake's native species since 2009 (Figure 8-7 through Figure 8-10.

17 of the lake's 51 native species collected on the sampling rake have significantly changed in a year-over-year frequency on at least one occasion since 2009.

- 10 native species have both significantly declined and significantly increased in a year-over-ear frequency since 2009
- 0 native species have significantly increased in a year-over-year frequency since 2009.
- 7 native species have significantly decreased in a year-over-year frequency since 2009.

Significant frequency changes of native species in 2018 were documented by a Chi Squared analysis of 2017 and 2018 data. There were 2 significant decreases and 2 significant increases in native species frequency in 2018 (Table 8-2 and Figure 8-7 through Figure 8-10.

Table 8-3 2009-2018 West Lake Summary Statistics

SUMMARY STATS:	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/16/12-7/17/12	7/17/13-7/19/13	7/14/14-7/15/14	7/14-15/15 & 7/17-20/15	7/22/16-7/23/16	7/20/17-7/23/17	7/24/18-7/25/18
Total number of points sampled	439	439	439	439	439	439	439	439	439	439
Total number of sites with vegetation	250	262	227	241	236	229	169	205	202	209
Total number of sites shallower than maximum depth of plants	352	321	292	287	298	318	314	318	323	304
Frequency of occurrence of all species at sites shallower than maximum depth of plants	71.02	81.62	77.74	83.97	79.19	72.01	53.82	64.47	62.54	68.75
Simpson Diversity Index	0.92	0.91	0.93	0.93	0.92	0.93	0.92	0.93	0.93	0.93
Maximum depth of plants (ft)	26.50	25.00	20.50	18.50	20.50	23.00	23.50	23.00	24.50	22.00
Average number of all species per site (shallower than max depth)	1.93	1.86	2.15	2.20	2.12	2.00	1.18	1.67	1.62	1.74
Average number of all species per site (veg. sites only)	2.72	2.28	2.77	2.61	2.67	2.78	2.20	2.59	2.59	2.53
Average number of native species per site (shallower than max depth)	1.80	1.76	2.08	2.10	2.06	1.94	1.18	1.64	1.60	1.72
Average number of native species per site (veg. sites only)	2.61	2.17	2.69	2.53	2.62	2.71	2.19	2.56	2.56	2.50
Species Richness	43	42	44	43	40	40	32	38	41	36
Species Richness (including visuals)	45	44	45	43	44	42	37	48	44	42
Species Richness (including visuals and boat survey)	45	44	45	46	48	48	44	55	48	46
Mean depth of plants (ft)	6.89	7.82	7.06	6.39	7.02	7.16	7.38	7.15	7.85	6.92
Median depth of plants (ft)	6.00	7.50	7.00	6.00	7.00	7.00	7.00	7.00	7.50	6.50
Mean rake fullness (veg. sites only)		1.84	1.99	1.80	1.72	1.69	1.62	1.70	1.73	1.67
Mean C	6.46	6.43	6.52	6.39	6.37	6.50	5.97	6.24	6.13	6.33
FQI	41.39	40.64	42.28	40.92	39.26	40.07	33.23	38.45	38.74	38.00

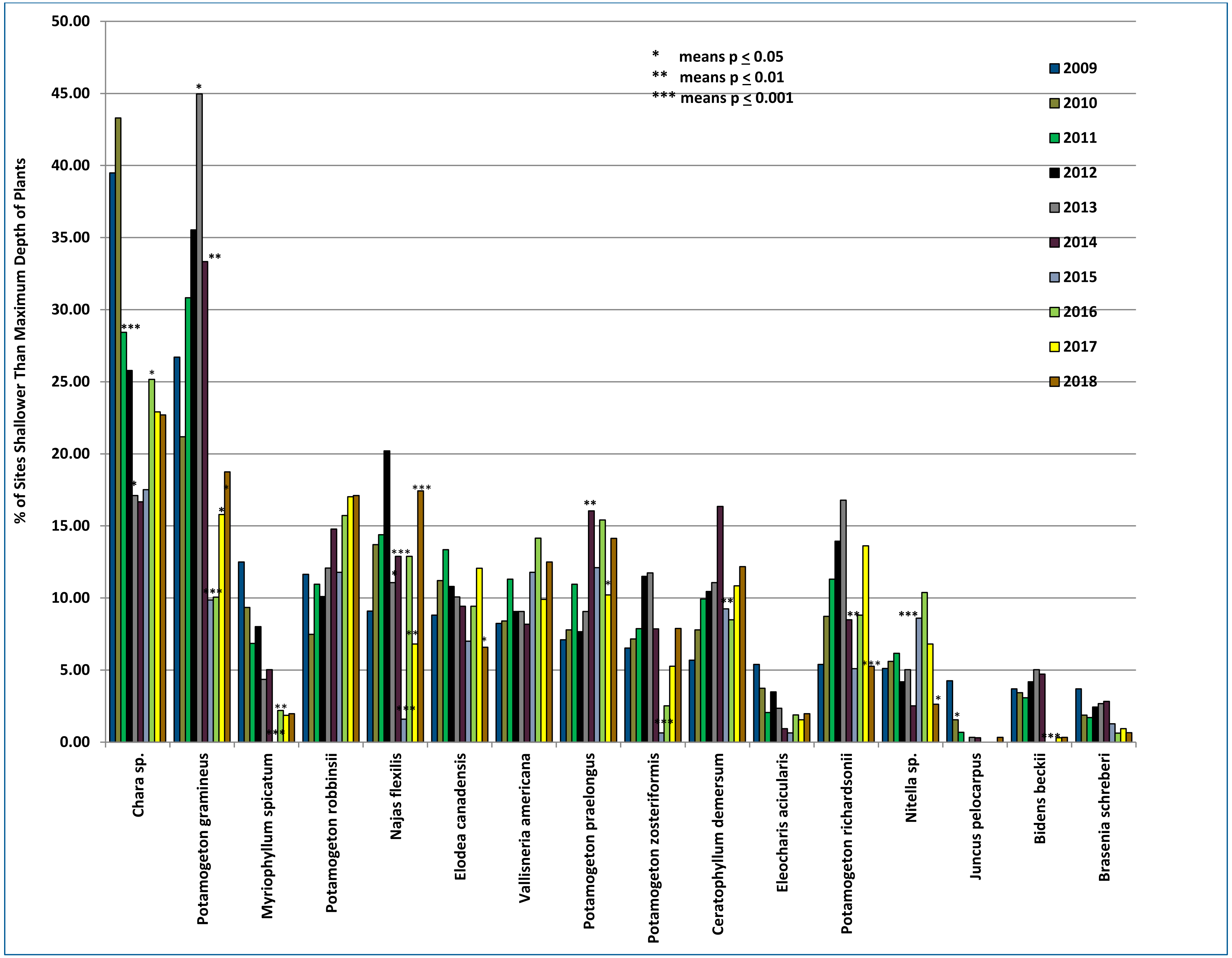


Figure 8-7 2009-2018 West Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

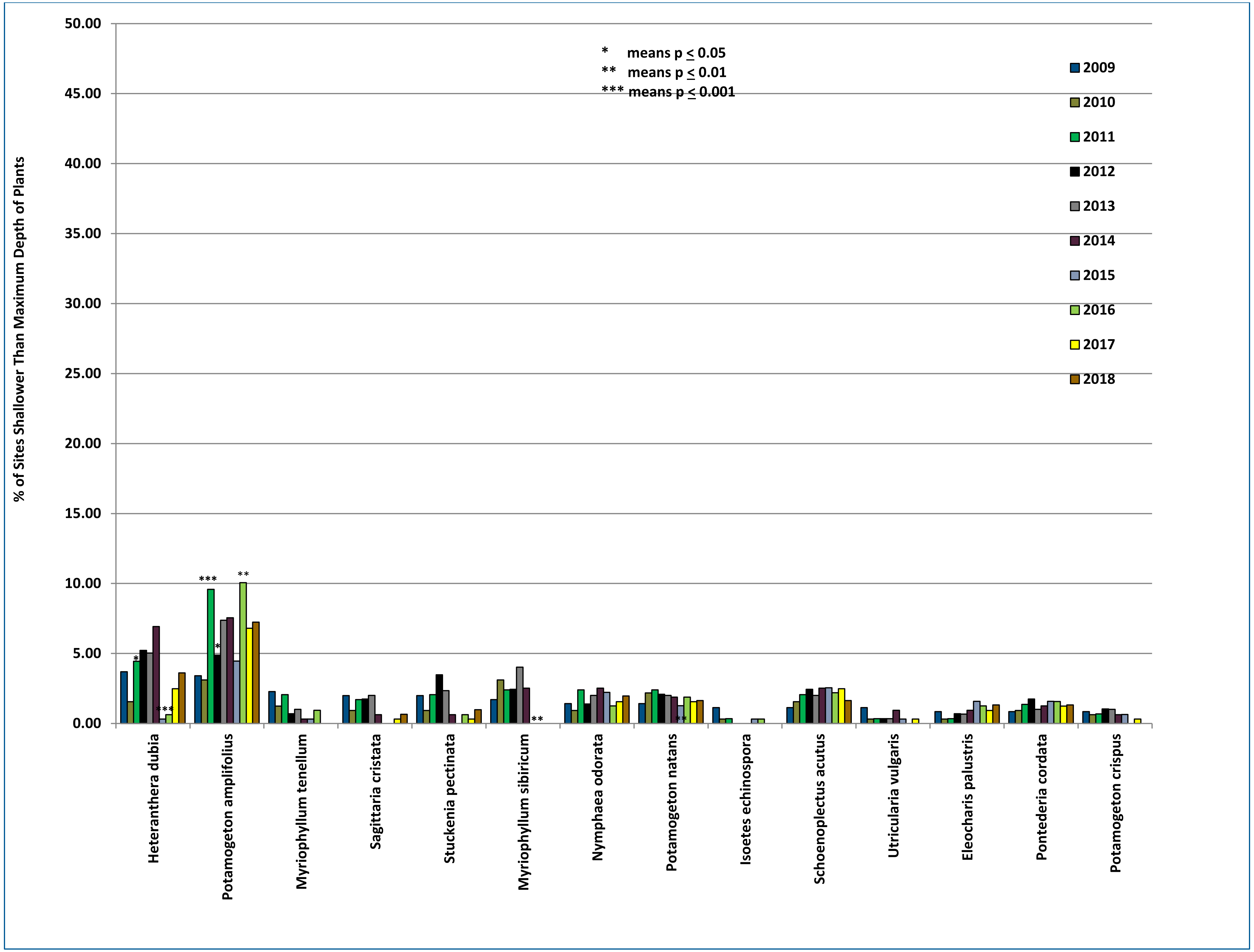


Figure 8-8 2009-2018 West Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

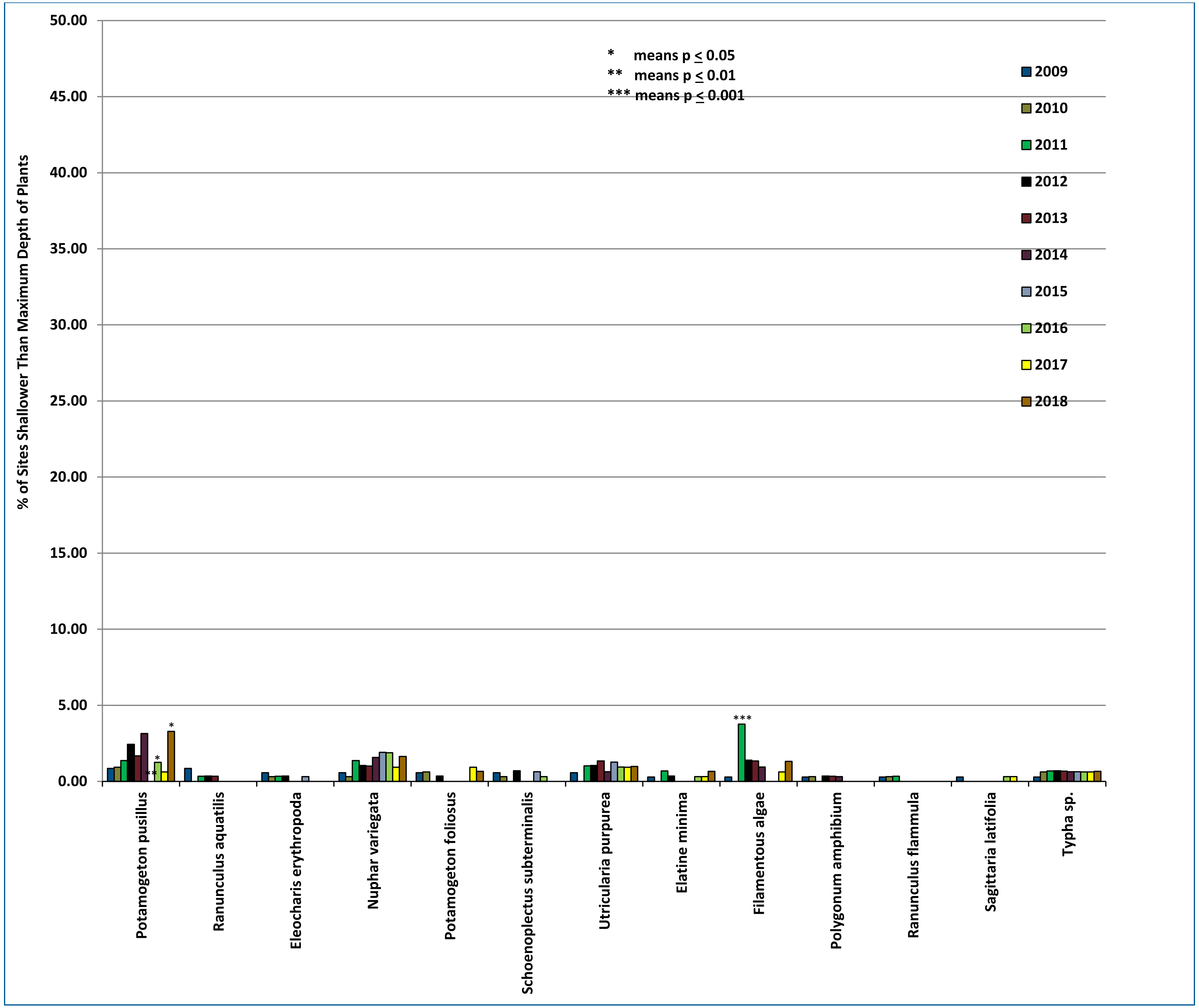


Figure 8-9 2009-2018 West Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

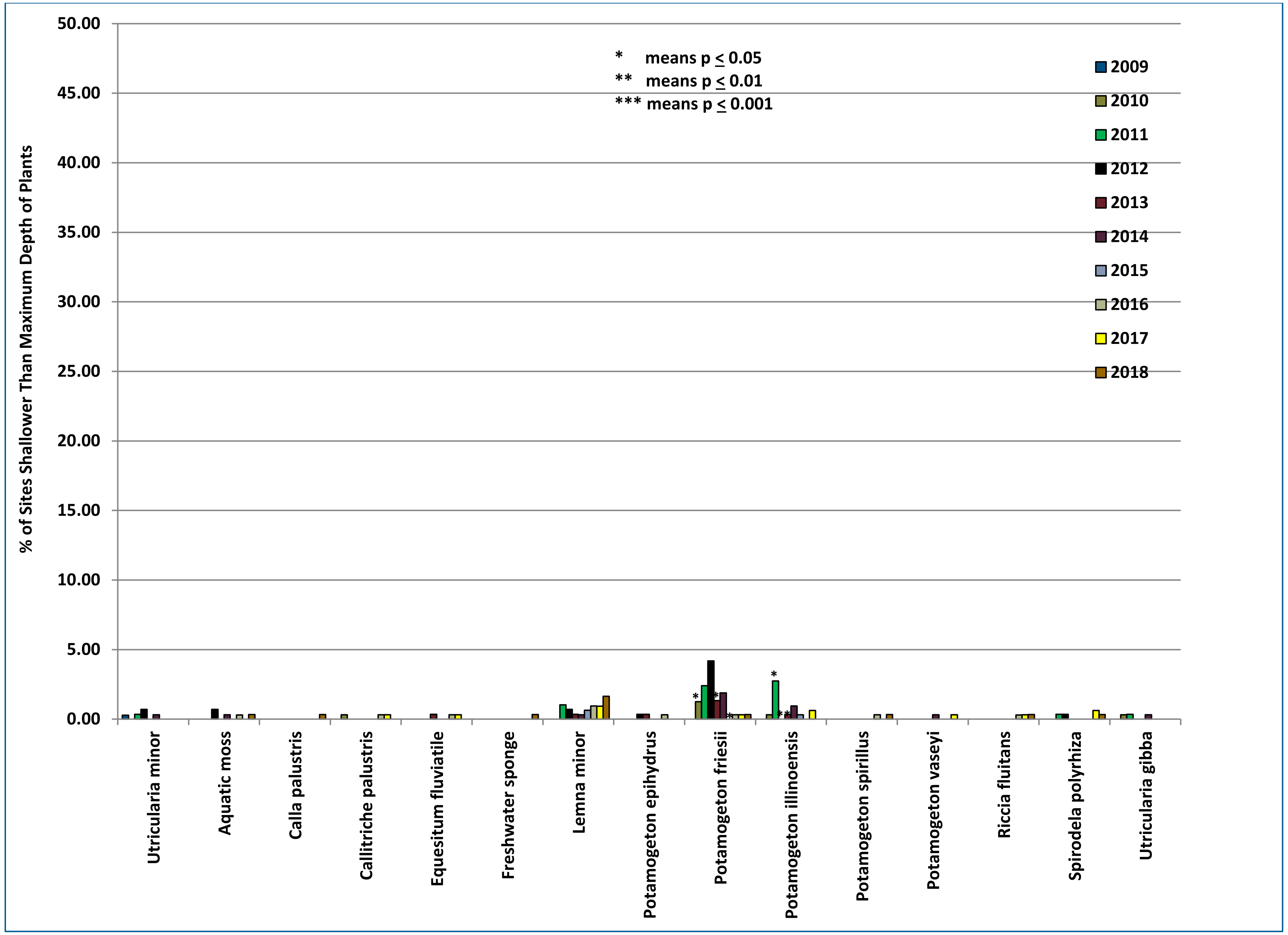


Figure 8-10 **2009-2018 West Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)**

8.2 Williams Bay

Williams Bay has a surface area of 155 acres and a maximum depth of 90 feet. The bay is characterized by sharp drop offs and a narrow littoral area. Williams Bay has excellent to good water quality, noting a trophic status ranging from oligotrophic to mesotrophic. During 2009 through 2017, the lake had excellent to good water transparency, noting Secchi disc depths ranging from 11 feet to 26 feet.

The water quality of Williams Bay, pictured above, is oligotrophic (excellent). The quality of the plant community, measured by FQI, is higher than the median value for lakes in the same eco-region.

In 2018, the maximum and depth of plant growth in Williams Bay was relatively similar to previous years. During 2009 through 2017 the maximum depth of plant growth ranged from 17.5 feet to 25.0 feet, and was 22.0 feet in 2018. The average depth of plant growth was a little higher in 2018 than previous years. During 2009 through 2017, the average depth of plant growth ranged from 7.51 feet to 9.48 feet, and was 9.54 feet in 2018 (Table 8-4).

The 2018 plant survey results indicated the plant community in Williams Bay was very healthy and of high quality. In 2018, the number of species (including visuals and boat surveys) in Williams Bay was similar to previous years—37 in 2018 compared with 20 to 41 during 2009 through 2017. The number of species in Williams Bay in 2018 was more than double the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2018, the quality of the plant community, measured by FQI, was similar to previous years—29.40 in 2018 compared with 26.16 to 31.57 during 2009 through 2017. Williams Bay FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). Diversity, measured by Simpson Diversity Index, was at the top of the range observed in previous years—0.93 in 2018 compared with 0.88 to 0.93 in 2009 through 2017 (Table 8-4).

In 2018, plant frequency and the average number of native plant species per sample location were similar to previous years. During 2009 through 2017, the plant frequency of occurrence at sites shallower than the maximum depth of plants ranged from a low of 56 percent in 2015 to a high of 80 percent in 2009, and was 67 percent in 2018. More than 1 native species has generally been found at each Williams Bay sample location. The average number of native plant species at each sample location ranged from a low of 1.17 in 2015 to a high of 1.83 in 2012, and was 1.71 in 2018 (Table 8-4).

During 2009 through 2018, plant species abundance was very balanced between many different types and no single plant species dominated the plant community. In 2018, 75 percent of Williams Bay plant species had a frequency of less than 10 percent. The most prevalent native plant species in Williams Bay in 2018, ranging from 10 to 20 percent, were wild celery (*Vallisneria americana*), slender naiad (*Najas flexilis*), nitella (*Nitella sp.*), flat-stem pondweed (*Potamogeton zosteriformis*), fern pondweed (*Potamogeton robbinsii*), coontail (*Ceratophyllum demersum*), and white-stem pondweed (*Potamogeton praelongus)* (Figure 8-11) .

Significant frequency changes have occurred in nearly a quarter of the lake's native species since 2009 (Figure 8-11 and Figure 8-12).

- 10 of the lake's 37 native species that were collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 5 native species have both significantly declined and significantly increased in a year-over-year frequency since 2009.
- 4 native species have significantly increased in a year-over-year frequency since 2009.
- 1 native species has significantly decreased in a year-over-year frequency since 2009.

Significant frequency changes of native species in 2018 were documented by a Chi Squared analysis of 2017 and 2018 data. In 2018, there was 1 significant decrease and 2 significant increases in native species frequency (Table 8-2 and Figure 8-11).

Table 8-4 2009-2018 Williams Bay Summary Statistics

SUMMARY STATS:	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/17/12	7/18/13	7/15/2014	7/17/2015	7/22/16-7/23/16	7/20/17	7/24/18
Total number of points sampled	130	130	130	130	130	130	130	130	130	130
Total number of sites with vegetation	72	71	64	72	67	58	59	74	61	64
Total number of sites shallower than maximum depth of plants	90	100	84	94	92	88	106	103	99	96
Frequency of occurrence of all species at sites shallower than maximum depth of plants	80.00	71.00	76.19	76.60	72.83	65.91	55.66*	71.84	61.62	66.67
Simpson Diversity Index	0.92	0.88	0.93	0.92	0.91	0.92	0.90	0.92	0.93	0.93
Maximum depth of plants (ft)	18.50	24.00	19.50	21.00	20.00	17.50	25.00	23.00	22.50	22.00
Average number of all species per site (shallower than max depth)	2.00	1.39	1.92	1.89	1.61	1.67	1.17	1.66	1.63	1.72
Average number of all species per site (veg. sites only)	2.50	1.96	2.52	2.47	2.21	2.53	2.10	2.31	2.64	2.58
Average number of native species per site (shallower than max depth)	1.76	1.34	1.76	1.83	1.60	1.66	1.17*	1.64	1.59	1.71
Average number of native species per site (veg. sites only)	2.29	1.91	2.35	2.39	2.19	2.52	2.10	2.28	2.57	2.56
Species Richness	28	20	24	27	25	25	20	25	25	26
Species Richness (including visuals)	30	20	24	27	28	28	23	32	31	28
Species Richness (including visuals and boat survey)	30	20	24	27	29	36	31	40	41	37
Mean depth of plants (ft)	7.51	8.94	7.66	7.81	8.63	8.28	9.48	9.36	9.48	9.54
Median depth of plants (ft)	7.50	8.50	7.75	8.00	8.50	8.25	9.00	9.00	9.00	9.00
Mean rake fullness (veg. sites only)		1.76	2.05	2.01	1.88	1.81	1.53*	1.95	1.80	1.81
Mean C	6.19	6.28	6.14	6.08	5.88	5.88	5.85	5.91	5.91	5.88
FQI	31.57	26.63	28.78	30.40	28.78	28.78	26.16	28.36	28.36	29.40

*Low plant frequency and low numbers and density of native plants at depths greater than 17.5 feet skewed the 2015 data lower. When computations were performed using the depth range at which plant growth was observed in 2014, 0 to 17.5-foot depth, (1) plant frequency was 64.20 percent in 2015, (2) average number of native species per site was 1.42 in 2015; and (3) mean rake fullness at vegetated sites was 1.58 in 2015. Because few plants were found at depths deeper than 17.5 feet during 2015, the frequency, and average number of native species, and mean rake fullness at vegetated sites statistics for the 0- to 17.5-foot depth range are more representative than the corresponding statistics for the 0- to 25-foot depth range shown in this table.

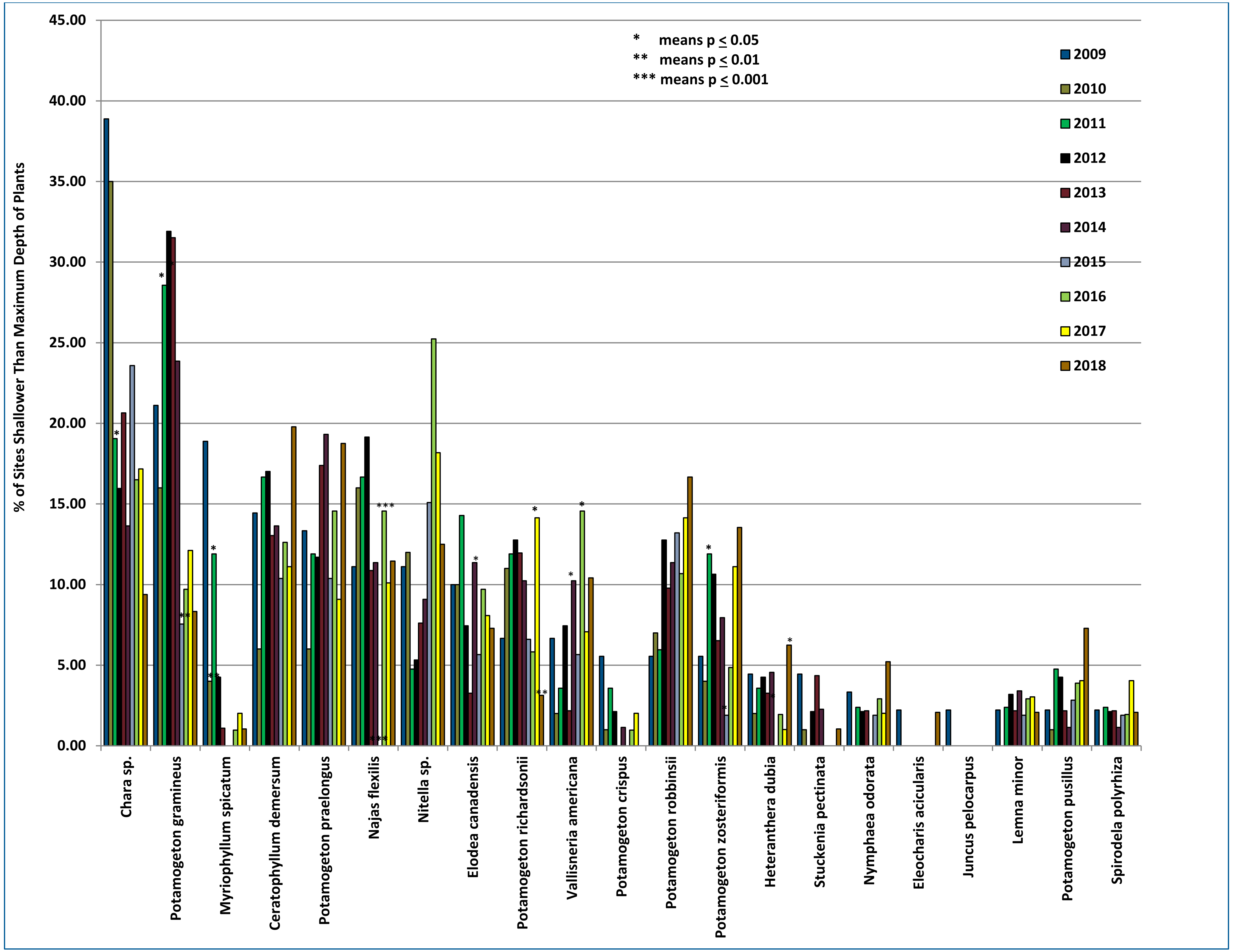


Figure 8-11 2009-2018 Williams Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

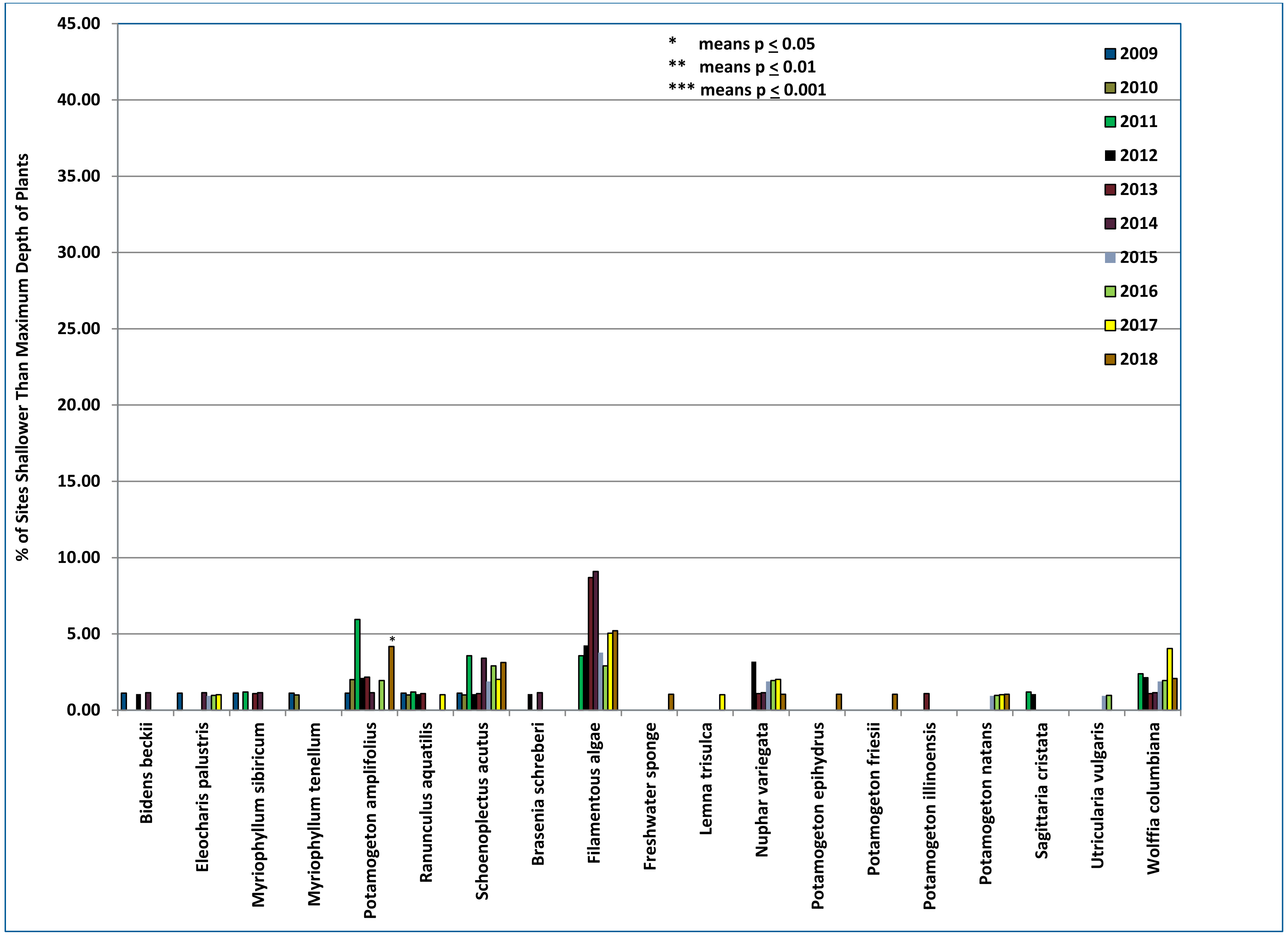


Figure 8-12 2009-2018 Williams Bay Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

8.3 Rabbit Island Bay

Rabbit Island Bay has a surface area of 94 acres and a maximum depth of 50 feet. The bay has excellent to good water quality, noting a trophic status ranging from oligotrophic to mesotrophic. During 2009 through 2017, the lake had excellent water transparency, noting Secchi disc depths ranging from 11 feet to 21 feet.

From 38 to 44 species of plants were observed in Rabbit Island Bay, pictured above, during 2009 through 2018. The quality of the plant community, measured by FQI, is higher than the median value for lakes in the same eco-region.

In 2018, the maximum and average depths of plant growth in Rabbit Island Bay were relatively similar to previous years. During 2009 through 2018, the maximum depth of plant growth ranged from 16.5 feet to 28.0 feet, and was 23.0 feet in 2018. During 2009 through 2018, the average depth of plant growth ranged from 5.16 feet to 6.01 feet, and was 5.59 feet in 2018 (Table 8-5)

The 2018 plant survey results indicated the plant community in Rabbit Island Bay was very healthy and of high quality. The number of species (including visuals and boat surveys) in Rabbit Island Bay was relatively similar to previous years—43 in 2018 compared with 38 to 44 during 2009 through 2017. The number of species in Rabbit Island Bay in 2018 was more than triple the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2018, the quality of the plant community, measured by FQI, was similar to previous years—37.81 in 2018 compared with 33.96 to 38.75 during 2009 through 2017. Rabbit Island Bay FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). Diversity, measured by Simpson Diversity Index, was within the range observed in previous years—0.94 in 2018 compared with 0.93 to 0.95 in 2009 through 2017 (Table 8-5).

In 2018, plant frequency and the average number of native plant species per sample location were similar to previous years. During 2009 through 2017, the plant frequency of occurrence at sites shallower than the maximum depth of plants ranged from a low of 88 percent in 2015 to a high of 96 percent in 2012, and was 91 percent in 2018. More than 2 native species have generally been found at each Rabbit Island Bay sample location. The average number of native plant species at each sample location ranged from a low of 2.46 in 2010 to a high of 3.57 in 2012, and was 3.34 in 2018 (Table 8-5).

During 2009 through 2018, plant species abundance was generally balanced between many different types. In 2018, 62 percent of Rabbit Island Bay plant species had a frequency of less than 10 percent. The most prevalent native plant species in Rabbit Island Bay in 2018, ranging from 11 to 43 percent, were fern pondweed (*Potamogeton robbinsii*), common waterweed (*Elodea canadensis*), muskgrasses (*Chara sp.*) coontail (*Ceratophyllum demersum*), slender naiad (*Najas flexilis*), white-stem pondweed (*Potamogeton praelongus*), variable pondweed (*Potamogeton gramineus*), white water lily (*Nymphaea odorata*), floating-leaf pondweed (*Potamogeton natans*), clasping-leaf pondweed (*Potamogeton richardsonii*), and wild celery (Vallisneria americana) (Figure 8-13 and Figure 8-14).

Plant species in Rabbit Island Bay, pictured above, were balanced between many different types and no single plant species dominated the plant community.

The decline in Eurasian watermilfoil in Rabbit Island Bay since 2009 has coincided with increasing frequency of fern pondweed. Eurasian watermilfoil frequency declined from 18 percent in 2009 to 2 percent in 2012, around 1 percent in 2013, 2014, and 2016, and was not observed in Rabbit Island Bay during the July survey in 2015, 2017, and 2018. During this period, Fern pondweed frequency increased from 16 percent in 2009 to 33 percent in 2012 to 43 percent in 2018.

Significant frequency changes have occurred in nearly a quarter of the lake's native species since 2009 (Figure 8-13 and Figure 8-14):

- 13 of the lake's 50 native species collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 3 native species have both significantly declined and significantly increased in year-over-year frequency since 2009.
- 5 native species have significantly increased in year-over-year frequency since 2009.
- 5 native species have significantly decreased in year-over-year frequency since 2009.

A Chi Squared analysis of 2017 and 2018 data documented there were no significant increases or decreases in frequency of native species y during 2018 (Table 8-2 and Figure 8-13 through Figure 8-16).

Table 8-5 2009-2018 Rabbit Island Bay Summary Statistics

SUMMARY STATS:	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/17/12	7/18/13	7/16/2014	7/17/2015	7/23/16-7/24/16	7/22/17	7/24/2018
Total number of points sampled	122	122	122	122	122	122	122	122	122	122
Total number of sites with vegetation	101	102	108	103	107	109	106	104	108	106
Total number of sites shallower than maximum depth of plants	108	112	113	107	113	115	120	112	119	116
Frequency of occurrence of all species at sites shallower than maximum depth of plants	93.52	91.07	95.58	96.26	94.69	94.78	88.33*	92.86	90.76	91.38
Simpson Diversity Index	0.94	0.94	0.95	0.94	0.94	0.94	0.93	0.95	0.94	0.94
Maximum depth of plants (ft)	17.00	20.50	22.00	16.50	20.00	22.00	28.00	21.50	24.00	23.00
Average number of all species per site (shallower than max depth)	3.34	2.59	3.19	3.61	3.02	3.20	2.83	2.94	2.96	3.36
Average number of all species per site (veg. sites only)	3.57	2.84	3.34	3.75	3.19	3.38	3.20	3.16	3.26	3.68
Average number of native species per site (shallower than max depth)	3.07	2.46	3.10	3.57	3.00	3.17	2.80*	2.92	2.93	3.34
Average number of native species per site (veg. sites only)	3.29	2.70	3.24	3.71	3.17	3.35	3.17	3.14	3.23	3.66
Species Richness	37	36	40	37	36	38	35	37	33	37
Species Richness (including visuals)	40	38	42	39	38	40	38	40	37	41
Species Richness (including visuals and boat survey)	40	38	42	39	38	44	43	43	42	43
Mean depth of plants (ft)	5.16	5.89	6.01	5.18	5.55	5.70	5.61	5.68	5.97	5.59
Median depth of plants (ft)	4.50	4.50	5.00	4.50	4.50	4.50	4.50	4.50	5.00	4.50
Mean rake fullness (veg. sites only)		2.08	2.26	2.27	1.93	1.88	1.93	2.12	1.99	1.79
Mean C	6.51	6.14	6.21	6.39	6.29	6.31	5.82	5.92	6.03	6.22
FQI	38.54	36.34	38.75	38.33	37.19	37.83	33.96	35.50	34.12	37.81

*Although the depth at which plants were found increased from 22 feet in 2014 to 28 feet in 2015, plants between 22 and 28 feet solely consisted of 1 plant species, *Potamogeton robbinsii*, found at one sample location at the 28 foot depth. This low plant frequency and low number of native plants at depths greater than 22 feet skewed the 2015 data lower. When computations were performed using the depth range at which plant growth was observed in 2009 through 2014, 0 to 22 foot depth, (1) plant frequency was 98 percent in 2015 which is greater than plant frequencies during 2009 through 2014 and (2) average number of native species per site was 3.13 in 2015 which is within the 2009 through 2014 range of values.. Because plants were only found at one location deeper than 22 feet during 2015, the frequency and average number of native species statistics for the 0- to 22-foot depth range are more representative than the corresponding statistics for the 0- to 28-foot depth range shown in this table.

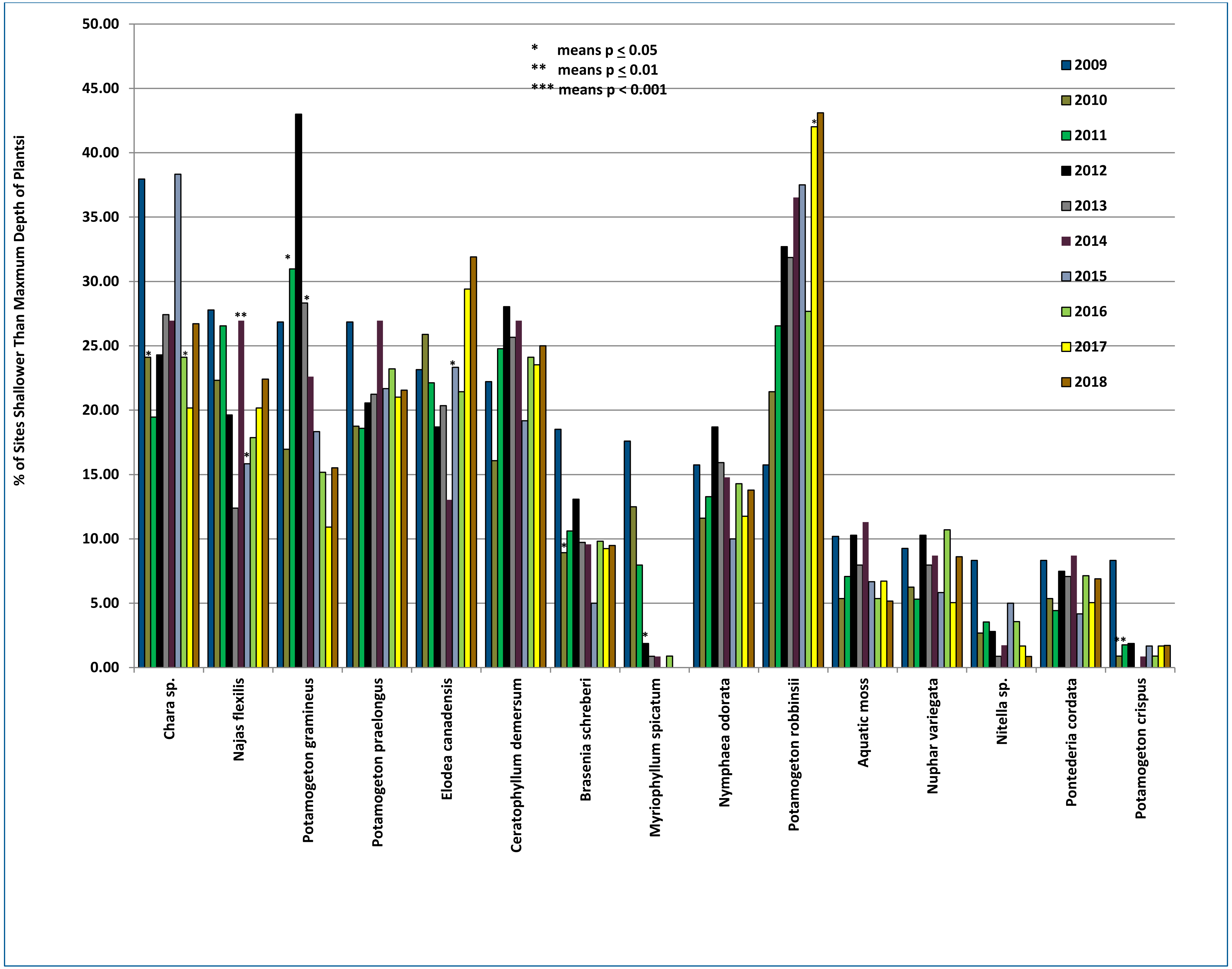


Figure 8-13 2009-2018 Rabbit Island Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

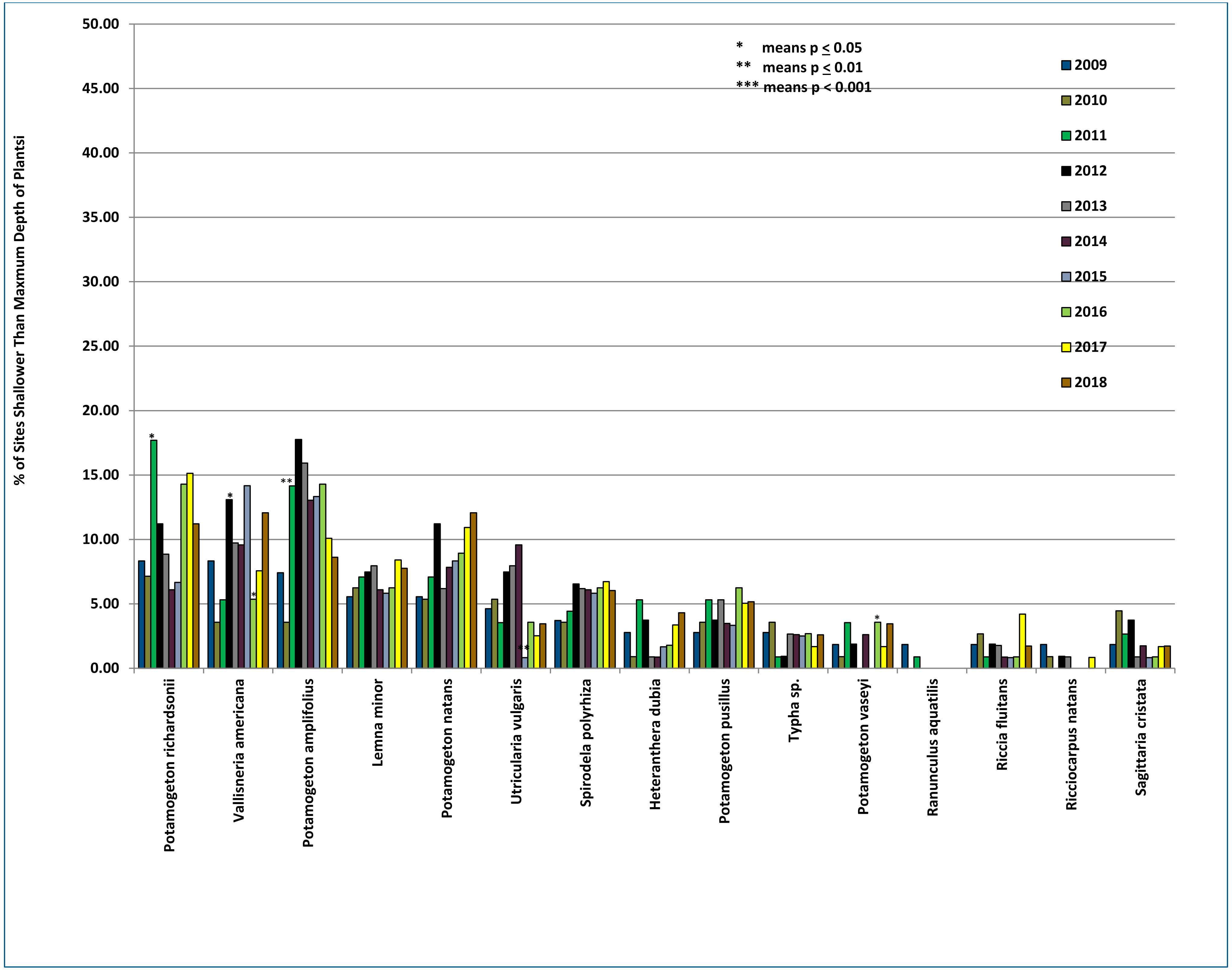


Figure 8-14 **2009-2018 Rabbit Island Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)**

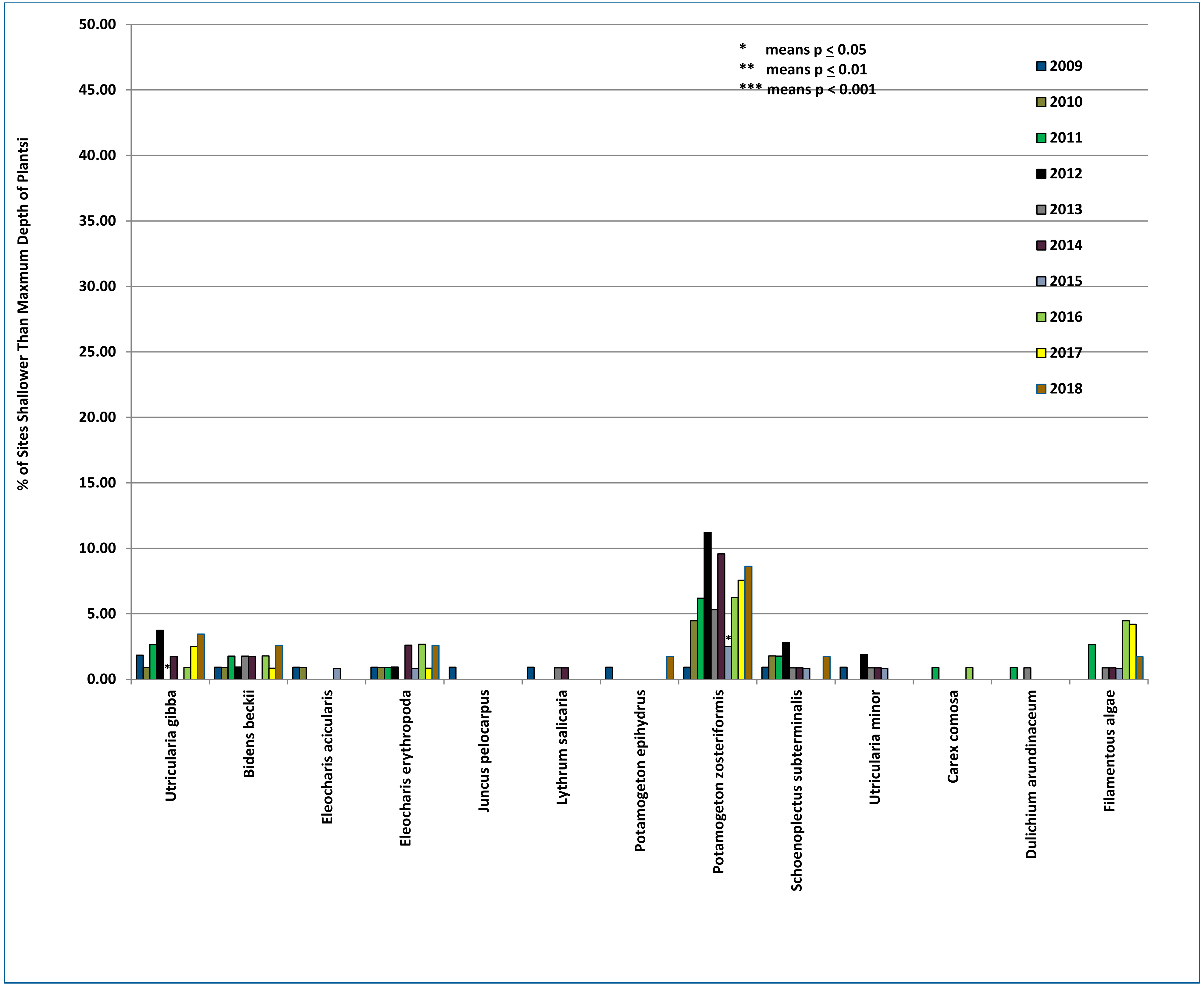


Figure 8-15 2009-2018 Rabbit Island Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

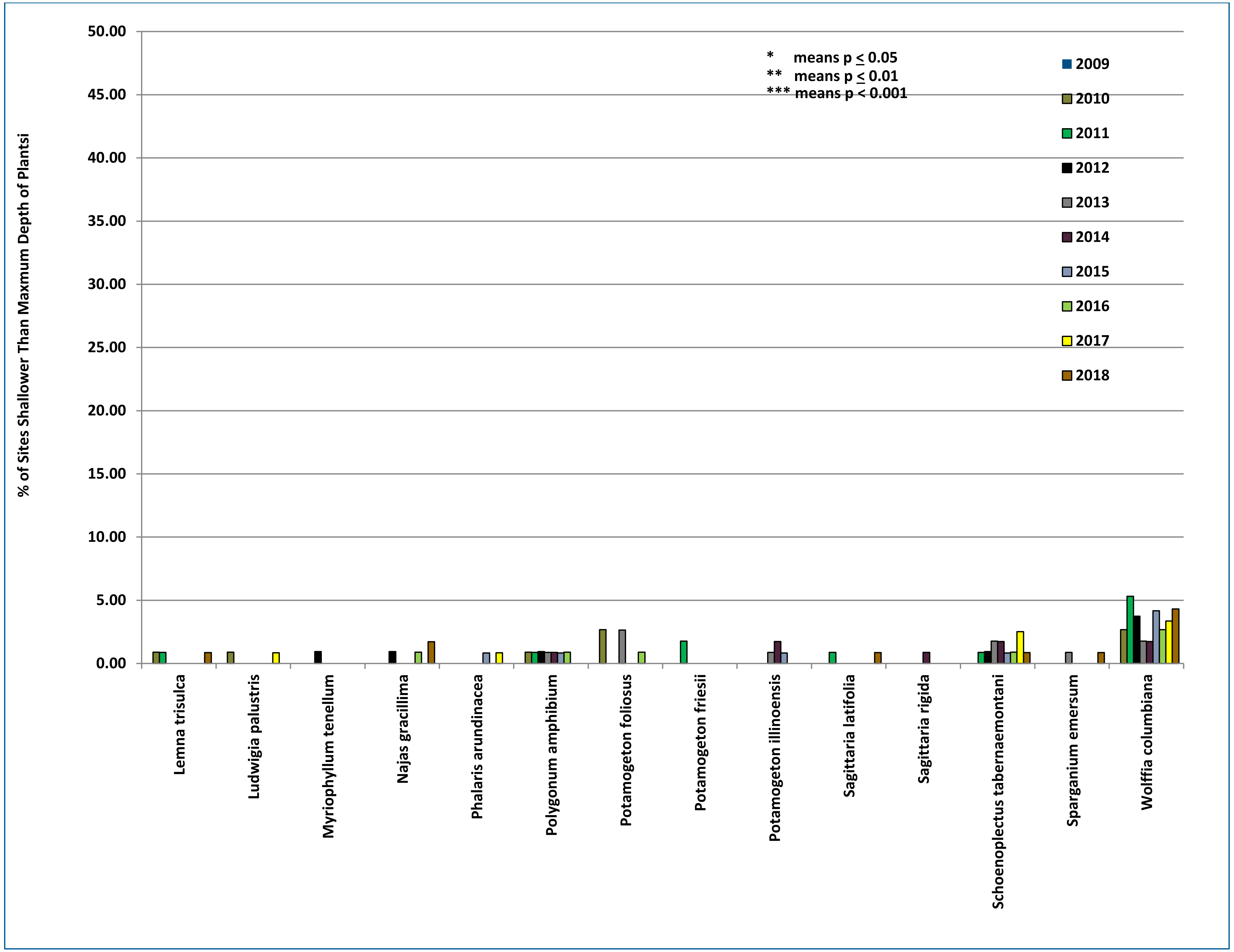


Figure 8-16 2009-2018 Rabbit Island Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

8.4 Library Lake

Library Lake has a surface area of 14 acres and a maximum depth of 20 feet. During 2009 through 2017, the lake had good to poor water transparency, noting Secchi disc water transparency ranging from 5.6 feet to 13.1 feet.

From 35 to 49 plant species were observed in Library Lake, pictured above, during 2009 through 2018. Photo Credit: Endangered Resource Services, LLC.

In 2018, the maximum and average depths of plant growth in Library Lake were relatively similar to previous years. During 2009 through 2017, the maximum depth of plant growth ranged from 15.0 feet to 20.0 feet, and was 18.0 feet in 2018. During 2009 through 2017, the average depth of plant growth ranged from 2.47 feet to 3.32 feet, and was 2.50 feet in 2018 (Table 8-6).

The 2018 plant survey results indicated the plant community in Library Lake was very healthy and of high quality. The number of species (including visuals and boat surveys) in Library Lake in 2018 was at the top of the 2009 through 2017 range—49 in 2018 compared with 35 to 49 during 2009 through 2017. In 2018, the number of species was three and a half times the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2018, the quality of the plant community, measured by FQI, was similar to previous years—37.63 in 2018 compared with 31.95 to 38.11 during 2009 through 2017. Library Lake FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). In 2018, diversity, measured by Simpson Diversity Index, was at the top of the range observed in previous years—0.94 in 2018 compared with 0.91 to 0.94 in 2009 through 2017 (Table 8-6).

In 2018, plant frequency was similar to previous years. During 2009 through 2017, the plant frequency of occurrence at sites shallower than the maximum depth of plants ranged from a low of 90 percent in 2015 to a high of 100 percent in 2012, and was 97 percent in 2018.

In 2018, the average number of plant species found at each sample location was the highest observed to date. More than 3 native species have consistently been found at each Library Lake sample location. During 2009 through 2017, the average number of native plant species at each sample location ranged from a low of 3.24 in 2010 to a high of 4.77 in 2012 compared. In 2018, the average number of native plant species at each sample location was 5.00 in (Table 8-6).

During 2009 through 2018, plant species abundance was balanced between many different types and no single plant species dominated the plant community. In 2018, 61 percent of Library Lake plant species had a frequency of less than 10 percent. The most prevalent native plant species in Library Lake in 2018, ranging from 11 to 59 percent, were white water lily (*Nymphaea odorata*), watershield (*Brasenia schreberi*), creeping bladderwort (*Utricularia gibba*), coontail (*Ceratophyllum demersum*), common bladderwort (*Utricularia vulgaris*), common waterweed (*Elodea canadensis*), hybrid cattail (*Typha glauca.*), flat-stem pondweed *(Potamogeton zosteriformis*), spadderdock (*Nuphar variegata*), variable pondweed (*Potamogeton gramineus*), small duckweed (*Lemna* minor), pickerelweed (*Pontederia cordata*, small pondweed (*Potamogeton pusillus*), small bladderwort (*Utricularia minor*), fern pondweed (*Potamogeton robbinsii*), water star-grass (*Heteranthera dubia*), and aquatic moss (Figure 8-17 through Figure 8-20).

Significant frequency changes have occurred in more than a third of the lake's native species since 2009 (Figure 8-17 through Figure 8-20).

- 19 of the lake's 49 native species collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 10 native species have both significantly declined and significantly increased in year-over-year frequency since 2009.
- 7 native species have significantly increased in year-over-year frequency since 2009.
- 2 native species have significantly decreased in year-over-year frequency since 2009.

Significant frequency changes of native species in 2018 were documented by a Chi Squared analysis of 2017 and 2018 data. There was one significant decrease and 5 significant increases in native species frequency in 2018 (Table 8-2 and Figure 8-17 through Figure 8-20).

Table 8-6 2009-2018 Library Lake Summary Statistics

SUMMARY STATS:	7/18/2009	7/18/2010	7/19/11-7/20/11	7/20/12	7/21/13	7/16/2014	7/20/2015	7/24/16	7/22/17	7/25/18
Total number of points sampled	139	139	139	139	139	139	139	139	139	139
Total number of sites with vegetation	116	121	115	116	123	119	119	123	117	117
Total number of sites shallower than maximum depth of plants	120	130	118	116	125	121	132	130	123	121
Frequency of occurrence of all species at sites shallower than maximum depth of plants	96.67	93.08	97.46	100.00	98.40	98.35	90.15*	94.62	95.12	96.69
Simpson Diversity Index	0.91	0.92	0.93	0.93	0.92	0.91	0.94	0.93	0.94	0.94
Maximum depth of plants (ft)	15.50	19.50	15.00	15.00	18.50	17.00	20.00	19.50	18.50	18.00
Average number of all species per site (shallower than max depth)	3.64	3.31	4.68	4.83	3.74	3.31	3.69	3.95	4.39	5.10
Average number of all species per site (veg. sites only)	3.77	3.55	4.80	4.83	3.80	3.36	4.09	4.17	4.62	5.27
Average number of native species per site (shallower than max depth)	3.46	3.24	4.57	4.77	3.66	3.25	3.57*	3.88	4.32	5.00
Average number of native species per site (veg. sites only)	3.58	3.51	4.69	4.77	3.72	3.30	3.99	4.11	4.54	5.17
Species Richness	34	32	34	33	32	35	44	39	42	41
Species Richness (including visuals)	36	35	35	36	37	36	45	45	47	43
Species Richness (including visuals and boat survey)	36	35	35	37	39	38	47	49	48	49
Mean depth of plants (ft)	2.63	3.32	2.57	2.47	3.04	2.68	3.04	3.31	2.69	2.50
Median depth of plants (ft)	1.50	2.00	2.00	2.00	1.50	2.00	2.00	2.00	2.00	1.50
Mean rake fullness (veg. sites only)		2.88	3.00	2.98	2.85	2.61	2.54*	2.80	2.87	2.83
Mean C	5.83	6.00	6.06	6.10	5.97	6.09	5.98	6.10	6.00	6.03
FQI	31.95	33.41	34.29	33.95	33.23	34.99	37.79	38.11	37.49	37.63

*Low plant frequency and low numbers and density of native plants at depths greater than 17 feet skewed the 2015 data lower. When computations were performed using the depth range at which plant growth was observed in 2014, 0- to 17-foot depth, (1) plant frequency was 97.5 percent in 2015, (2) average number of native species per site was 3.71 in 2015; and (3) mean rake fullness at vegetated sites was 2.94 in 2015. Because few plants were found at depths deeper than 17 feet during 2015, the frequency, and average number of native species, and mean rake fullness at vegetated sites statistics for the 0- to 17-foot depth range are more representative than the corresponding statistics for the 0- to 20-foot depth range shown in this table. When the plant frequency and mean rake fullness were computed using only native species, (1) native plant frequency was 98 percent in 2014 and 84 percent in 2015 and (2) native mean rake fullness was 2.61 in 2014 and 2.94 in 2015.

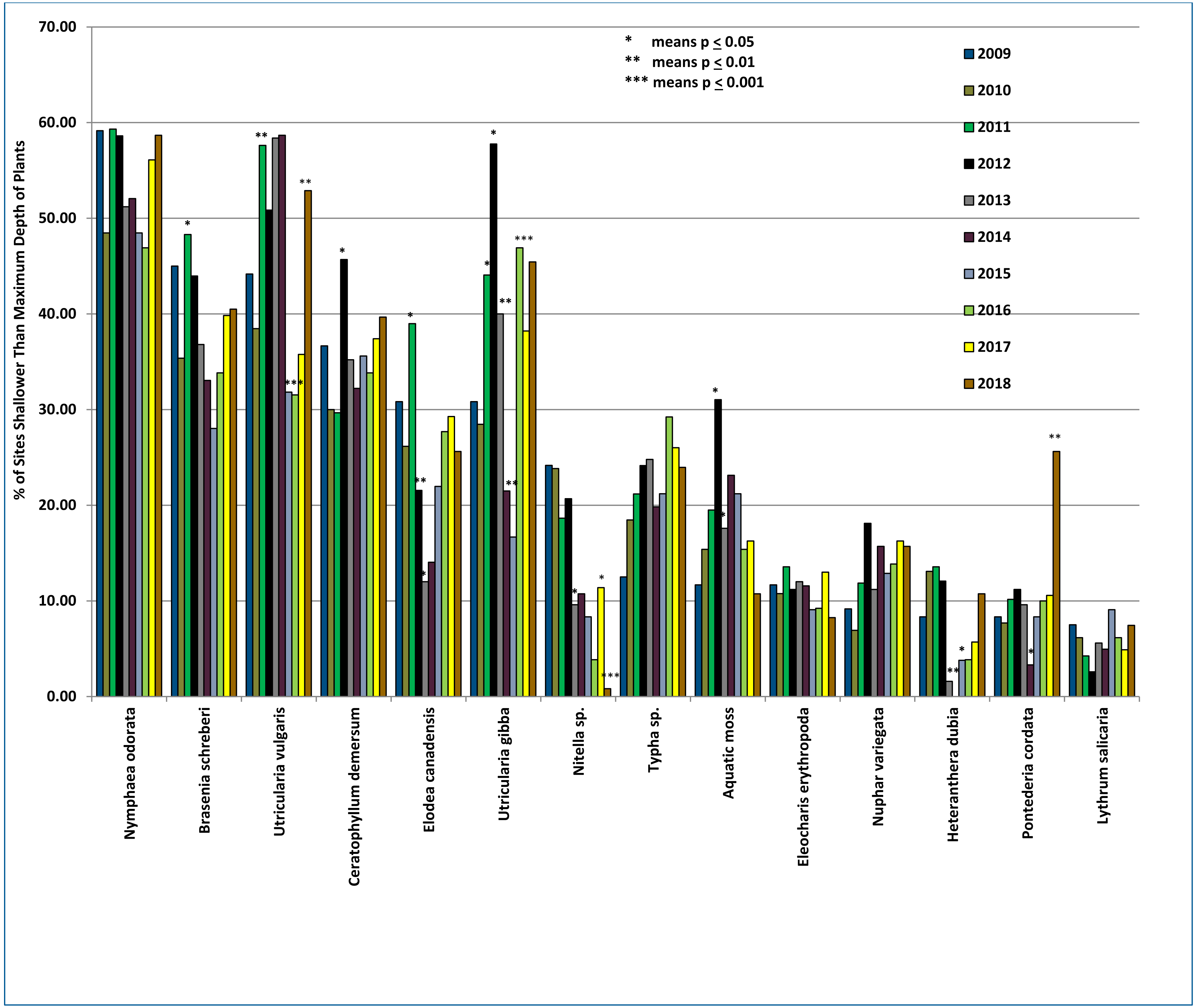


Figure 8-17 2009-2018 Library Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

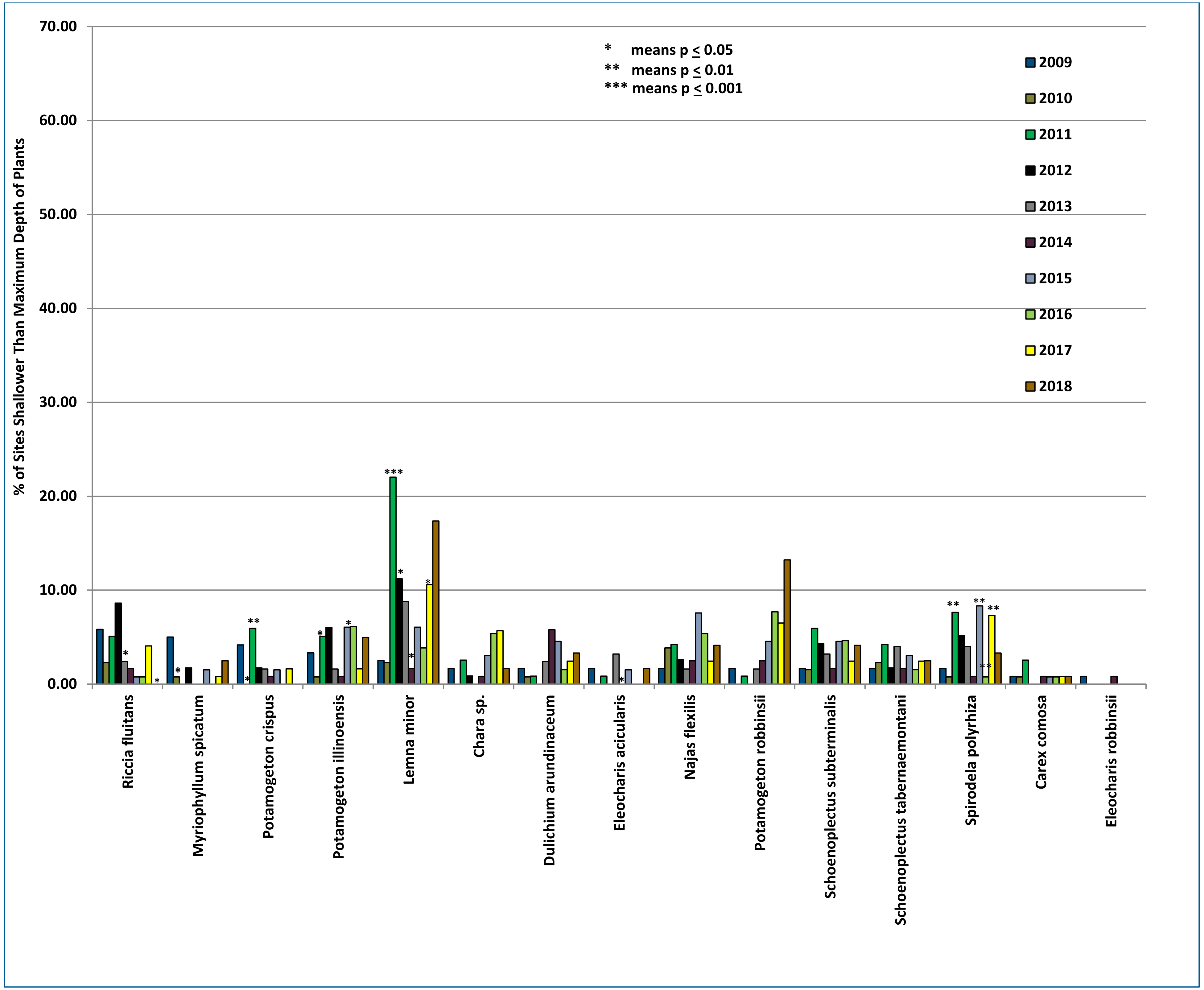


Figure 8-18 2009-2018 Library Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

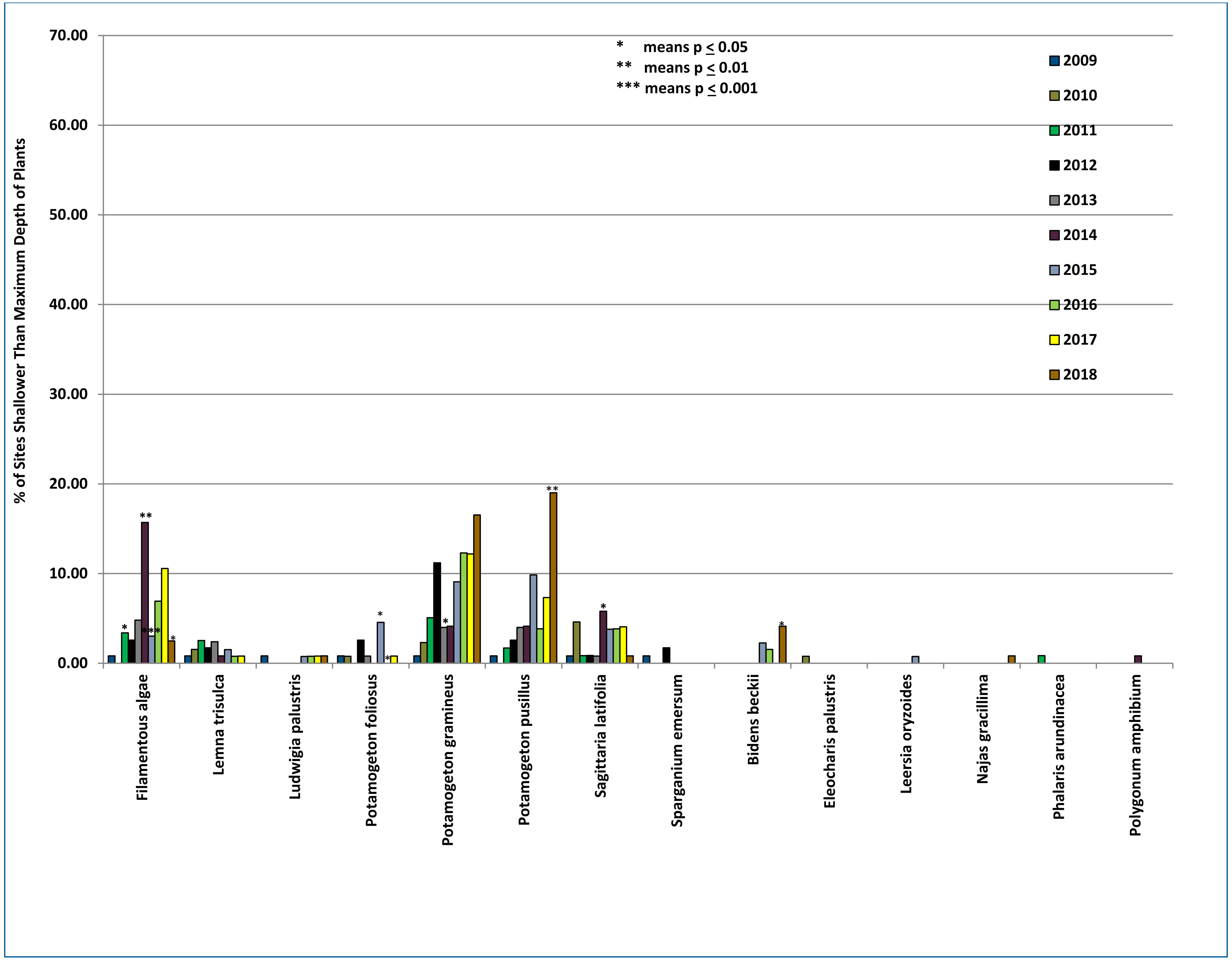


Figure 8-19 2009-2018 Library Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

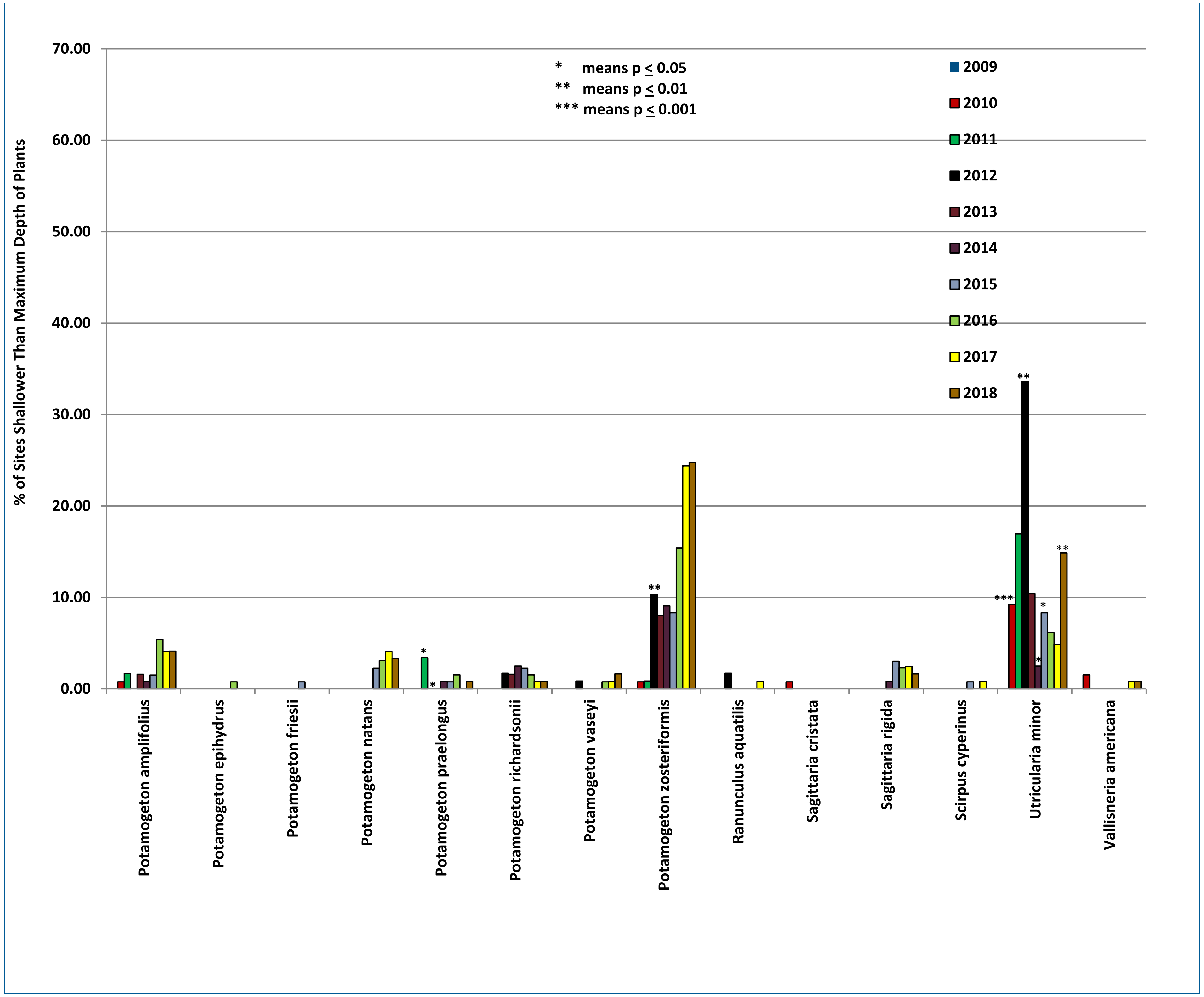


Figure 8-20 2009-2018 Library Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

8.5 Cemetery Bay

Cemetery Bay has a surface area of 53 acres and a maximum depth of 7 feet. The bay has had poor water quality, noting a trophic status ranging from eutrophic to hypereutrophic. The most recent water quality data are Secchi disc measurements during 2012 that ranged from 2 to 5 feet. A 2007 water quality study concluded that internal loading plays a major role in causing the bay's poor water quality. Historically, Cemetery Bay received discharges from the City of Cumberland wastewater treatment facility for a period of time (Short Elliot Hendrickson Inc., 1995). The discharges contributed toward the nutrient rich sediments in the bay that continue to impact water quality through internal loading.

The plant community in Cemetery Bay, pictured above, has improved since 2009. Photo Credit: Endangered Resource Services, LLC.

The lake's variable water quality impacts the maximum depth at which plants may grow. During 2009 to 2018, the maximum depth of plant growth has ranged from a low of 6.0 feet in 2013, a wet year, to a high of 9.5 feet in 2009, a dry year. In 2018, the maximum depth of plant growth was 7.5 feet.

The plant community within Cemetery Bay is consistent with its water quality and poorer than plant communities found in the lake's western basins that have much better water quality. Nonetheless, the Cemetery Bay plant community has greatly improved in number of species, plant frequency, number of native species per site, quality of the plant community, and diversity since 2009.

- The number of species has quadrupled since 2009—from 6 in 2009 to 24 in 2018.
- Plant frequency has more than quadrupled since 2009—from 24 percent in 2009 to 97 percent in 2018.
- The number of native species per site has increased by more than an order of magnitude since 2009—from 0.22 in 2009 to 2.67 in 2017.
- The FQI, a measure of plant community quality, has more than doubled—from a low of 9.80 in 2010 to a high of 27.10 in 2016 and was 25.24 in 2018.
- Diversity, measured by the Simpson Diversity Index, has increased by 83 percent since 2009—from 0.47 in 2009 to 0.86 in 2018 (Table 8-7).
- Mean depth of plants has increased—from a low of 3.87 in 2010 to 4.61 in 2018.

During 2009 through 2018, plant prevalence and the number of species in Cemetery Bay greatly increased. In 2018, four plant species dominated the plant community, ranging in frequency from

20 to 66 percent—coontail (*Ceratophyllum demersum)*, fern pondweed (*Potamogeton* robbinsii), common waterweed (*Elodea canadensis*), and white water lily (*Nymphaea odorata*. Other prevalent plant species in 2018, ranging in frequency from 10 to 15 percent, were large-leaf pondweed (*Potamogeton amplifolius*), variable pondweed (*Potamogeton gramineus*), white stem pondweed (*Potamogeton praelongus*), and slender naiad (*Najas flexilis*) (Figure 8-21).

In 2018, 40 percent of the plant species had a frequency of 10 percent or greater and 60 percent of the plant species had a frequency of less than 10 percent.

Significant frequency changes have occurred in more than half of the lake's native species since 2009 (Figure 8-21 and Figure 8-22):

- 15 of the lake's 24 native species that collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 5 native species have both significantly declined and significantly increased in year-over-year frequency since 2009.
- 8 native species have significantly increased in year-over-year frequency since 2009.
- 2 native species has significantly decreased in year-over-year frequency since 2009.

Significant frequency changes of native species in 2018 were documented by a Chi Squared analysis of 2017 and 2018 data. In 2018, a total of 1 native species significantly increased in frequency and 4 native species significantly decreased in frequency (Table 8-2 and Figure 8-21 and Figure 8-22).

Table 8-7 2009-2018 Cemetery Bay Summary Statistics

SUMMARY STATS:	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/15/12	7/16/13	7/12/14	7/14/15	7/20/16	7/19/17	7/24/18
Total number of points sampled	89	89	89	89	89	89	89	89	89	89
Total number of sites with vegetation	21	23	40	35	52	67	88	89	87	86
Total number of sites shallower than maximum depth of plants	89	84	89	89	84	87	89	89	89	89
Frequency of occurrence of all species at sites shallower than maximum depth of plants	23.60	27.38	44.94	39.33	61.90	77.01	98.88	100.00	97.75	96.63
Simpson Diversity Index	0.47	0.56	0.75	0.79	0.63	0.70	0.77	0.85	0.87	0.86
Maximum depth of plants (ft)	9.50	6.50	7.00	7.50	6.00	6.50	6.50	7.00	7.50	7.50
Average number of all species per site (shallower than max depth)	0.24	0.31	0.63	0.69	1.02	1.38	2.11	2.84	3.11	2.67
Average number of all species per site (veg. sites only)	1.00	1.13	1.40	1.74	1.65	1.79	2.14	2.84	3.18	2.77
Average number of native species per site (shallower than max depth)	0.22	0.31	0.51	0.66	1.02	1.38	2.06	2.81	3.11	2.67
Average number of native species per site (veg. sites only)	1.00	1.13	1.32	1.69	1.65	1.79	2.08	2.81	3.18	2.77
Species Richness	6	6	10	14	8	13	21	22	18	19
Species Richness (including visuals)	6	6	10	15	9	15	22	23	19	20
Species Richness (including visuals and boat survey)	6	6	10	17	12	18	23	24	22	24
Mean depth of plants (ft)	4.14	3.87	4.71	3.93	4.36	4.78	4.88	4.92	4.95	4.61
Median depth of plants (ft)	4.00	4.00	5.00	4.00	4.50	5.00	5.00	5.00	5.00	4.50
Mean rake fullness (veg. sites only)		2.22	1.90	2.03	1.62	1.81	2.22	2.00	1.85	1.92
Mean C	5.80	4.00	5.13	5.77	5.50	5.77	6.05	6.10	5.80	5.80
FQI	12.97	9.80	14.50	20.80	15.56	20.80	27.06	27.10	24.70	25.24

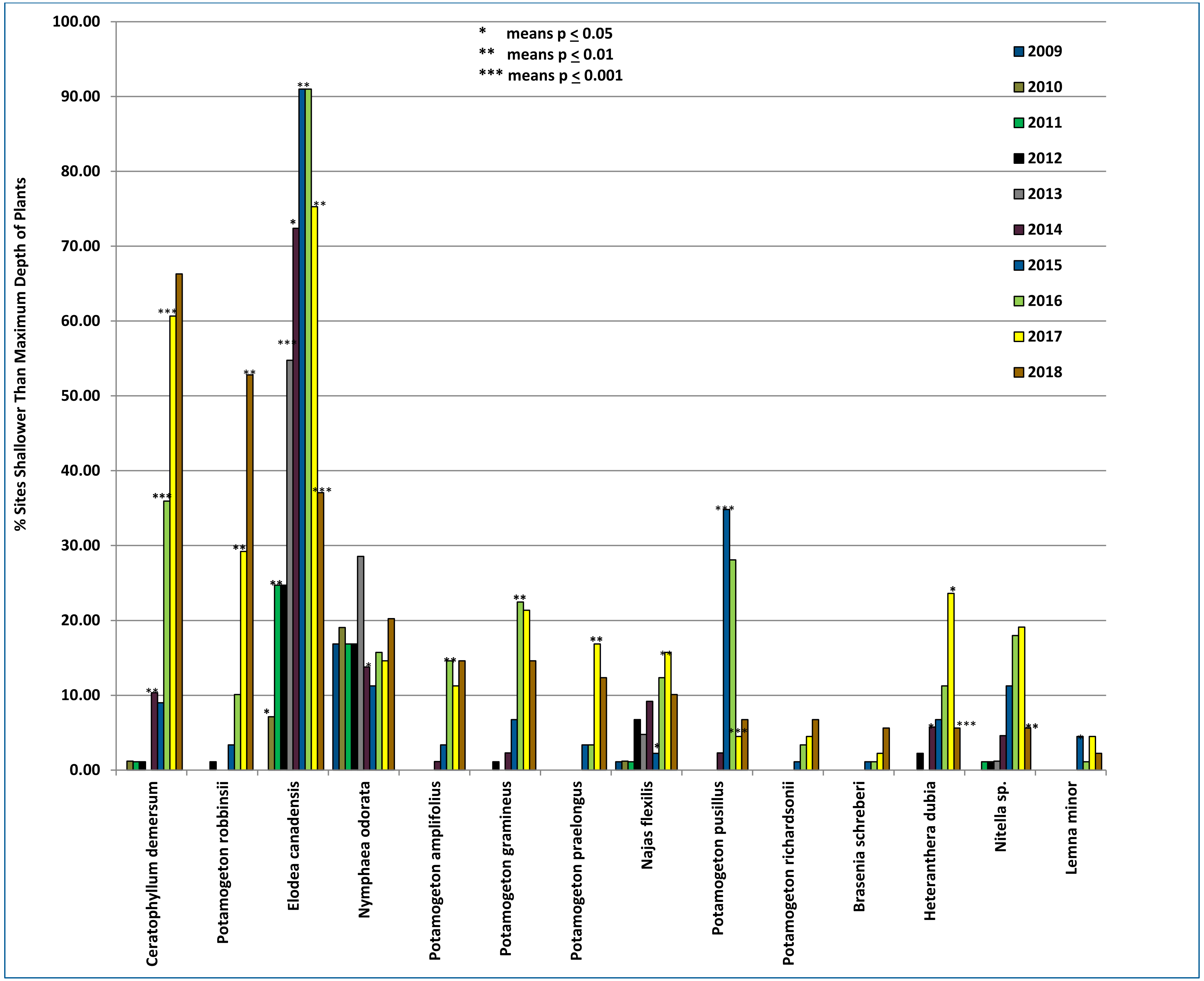


Figure 8-21 2009-2018 Cemetery Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants

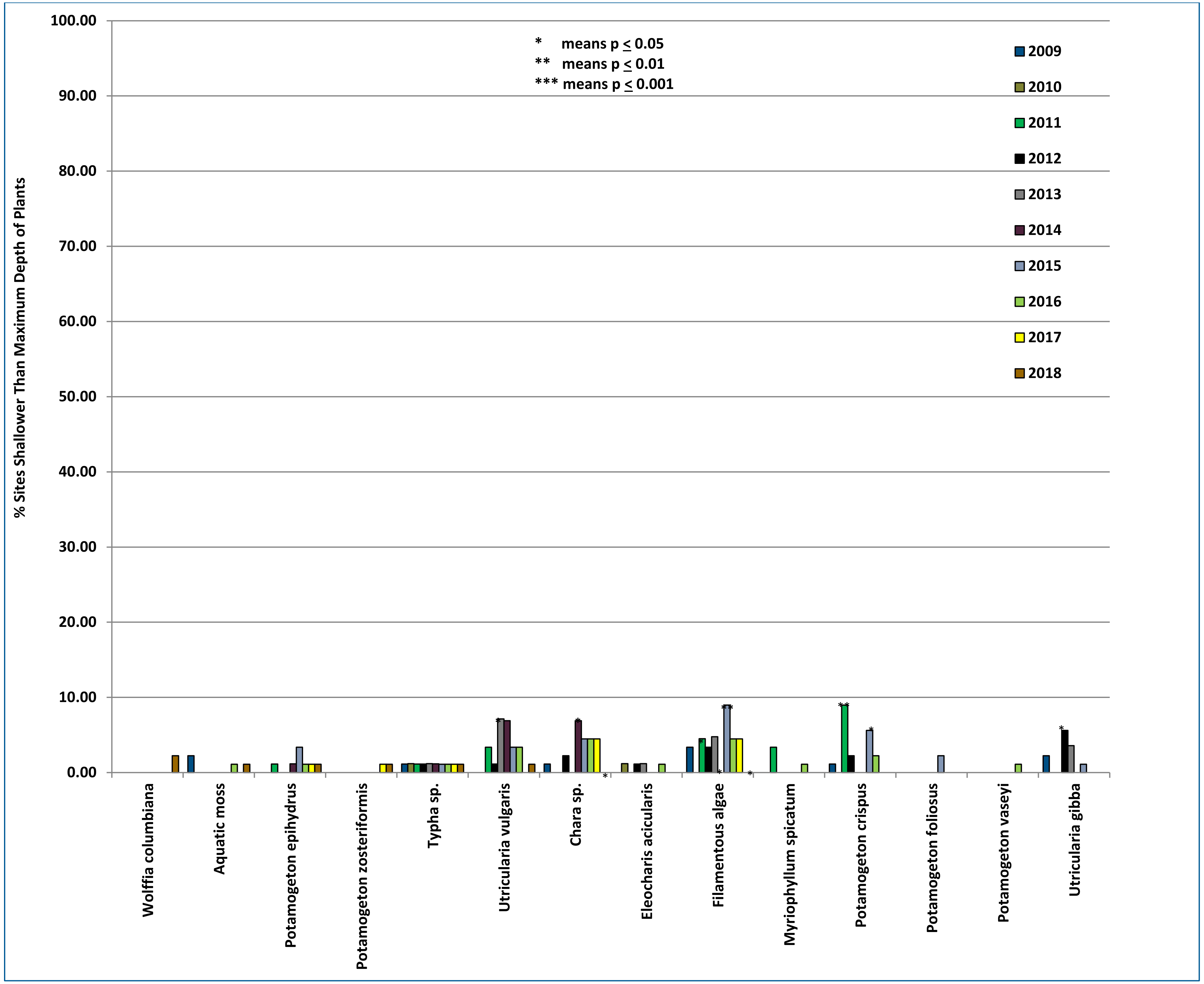


Figure 8-22 2009-2018 Cemetery Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

8.6 City Bay

City Bay has a surface area of 102 acres and a maximum depth of 18 feet. The most recent water quality data from City Bay are Secchi disc measurements during the 1990s which ranged from 5 feet to 15 feet.

From 28 to 45 plant species were observed in City Bay, pictured above, during 2009 through 2018. The quality of the plant community, measured by FQI, is higher than the median value for lakes in the same eco-region. Photo Credit: Endangered Resource Services, LLC.

In 2018, the maximum and average depths of plant growth in City Bay were relatively similar to previous years. During 2009 through 2017, the maximum depth of plant growth ranged from 8 feet to 20 feet, and was 12.5 feet in 2018. During 2009 through 2017, the average depth of plant growth ranged from 4.25 feet to 4.98 feet, and was 4.33 feet in 2018 (Table 8-8).

The 2018 plant survey results indicated the plant community in City Bay was very healthy and of high quality. The number of species (including visuals and boat surveys) in City Bay was relatively similar to previous years—38 in 2018 compared with 28 to 45 during 2009 through 2017. The number of species in City Bay in 2018 was more than double the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2018, the quality of the plant community, measured by FQI, was similar to previous years—33.96 in 2018 compared with 30.40 to 37.02 during 2009 through 2017. City Bay FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). Diversity, measured by Simpson Diversity Index, was below the range observed in previous years—0.86 in 2018 compared with 0.88 to 0.92 in 2009 through 2017 (Table 8-8).

In 2018, plant frequency was higher than previous years. During 2009 through 2017, the plant frequency of occurrence at sites shallower than the maximum depth of plants ranged from a low of 84.36 percent in 2015 to a high of 98.86 percent in 2017, and was 98.88 percent in 2018.

In 2018, the average number of native plant species per sample location was similar to previous years. More than 2 native species have generally been found at each City Bay sample location. During 2009 through 2017, the average number of native plant species at each sample location ranged from a low of 2.01 in 2010 to a high of 3.33 in 2017 and was 2.32 in 2018 (Table 8-8).

In 2018, the City Bay plant community was dominated by fern pondweed (*Potamogeton robbinsii*). Fern pondweed frequency has steadily increased as Eurasian watermilfoil frequency has declined over the past several years. Eurasian watermilfoil frequency declined from 49 percent in 2011 to 0 percent (not observed) in July of 2015. Eurasian watermilfoil was then observed at a frequency around 1 percent in 2016 and 2017 and was not observed in July of 2018. During this period of time, fern pondweed increased in frequency by more than an order of magnitude from 5 percent in 2011 to 78 percent in 2018 (Figure 8-23).

Significant frequency changes have occurred in more than a third of the lake's native species since 2009 (Figure 8-23 through Figure 8-25):

- 19 of the lake's 44 native species collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 17 native species have both significantly declined and significantly increased in year-over-year frequency since 2009.
- 2 native species have significantly increased in year-over-year frequency since 2009.
- 0 native species has significantly decreased in year-over-year frequency since 2009.

Significant frequency changes of native species in 2018 were documented by a Chi Squared analysis of 2017 and 2018 data. In 2018, 9 native species significantly decreased in frequency and 1 native species significantly increased in frequency (Table 8-2 and Figure 8-23 through Figure 8-25):

The significant declines in frequency of 9 native species may be an indication of adverse impact from the spring treatment to control Eurasian watermilfoil. The 2,4-D dose used for the 2018 whole bay treatment of City Bay was higher than the doses used in previous years. The higher dose resulted in excellent control of Eurasian watermilfoil, but may have adversely impacted some native plant species. Eight of the nine native plant species that significantly declined in frequency in City Bay in 2018 have significantly declined following 2,4-D treatments in one or more Wisconsin lakes. These eight species are listed below together with the other Wisconsin lakes in which they significantly declined following a 2,4-D treatment:

- Muskgrasses (*Chara sp.*) – Wilson Lake and South Twin Lake (2009)[3]
- Common waterweed (*Elodea canadensis*) – Tomahawk Lake and South Twin Lake (2010)[1]
- Water stargrass (*Heteranthera dubia*) – South Twin Lake (2009-2010)[1]
- Ribbon-leaf pondweed (*Potamogeton epihydrus*) – Kathan Lake[1]
- Variable-leaf pondweed (*Potamogeton gramineus*) – Sandbar and South Twin Lake (2010)[1]
- Small pondweed (*Potamogeton pusillus*) – Sandbar Lake, Tomahawk Lake, Kathan Lake, and South Twin Lake (2009-2010)[1]
- Flat-stem pondweed (*Potamogeton zosteriformis*) – Berry Lake and South Twin Lake (2010)[1]
- Nitella (*Nitella sp.)* – Tomahawk Lake and Kathan Lake[1]

Two species increased in frequency in City Bay following the 2018 2,4-D treatment, although not significantly, but significantly decreased in frequency following 2,4-D treatments of other Wisconsin lakes.

---

[3] Nault, Michelle and John Skogerboe. 2014. Scientific Evaluation of Efficacy and Selectivity of Herbicide Treatments in Wisconsin Lakes. Presented at UMISC Conference, Duluth, MN, October 20-22, 2014.

Coontail, a dicot, would be expected to be more vulnerable to harm by 2,4-D than monocots since 2,4-D is specific to dicots. However, coontail increased in frequency in City Bay during 2018, although not significantly. The response of coontail to the City Bay 2,4-D treatment was in stark contrast to its response to 2,4-D treatment of Wilson Lake where it significantly decreased in frequency. The dominant species in City Bay, fern pondweed, increased, in frequency in 2018, although not significantly, but significantly declined following 2,4-D herbicide treatments of Tomahawk Lake and Wilson Lake.[1]

One species that significantly declined in City Bay in 2018, clasping-leaf pondweed (*Potamogeton richardsonii)*, significantly increased following a 2,4-D treatment of South Twin Lake (2009).[1]

Despite some anomalies in response of City Bay species to the 2018 2,4-D herbicide treatment when compared with other Wisconsin lakes that received 2,4-D treatments, the data support a conclusion that the higher dose of 2,4-D used in 2018 caused a significant decline in frequency of multiple native species. The declines are expected to be a temporary impact. The species that declined in frequency during 2018 are expected to increase in frequency in subsequent years to attain pre-treatment frequencies in City Bay. Despite declines in frequency of several native plant species, the City Bay plant community remained healthy in 2018 and, as detailed above, a diverse community of high quality plants were documented in 2018. In addition, City Bay noted an overall plant frequency in 2018 that was slightly higher than the overall plant frequency noted in previous years. Hence, changes in some native plant frequencies did not reduce overall plant frequency in City Bay.

The 2018 plant community of City Bay, pictured above, included a diverse assemblage of native pondweeds

Table 8-8 2009-2018 City Bay Summary Statistics

SUMMARY STATS:	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/15/12-7/16/12	7/16/13-7/17/13	7/12/2014	7/14/2015	7/19/16-7/20/16	7/19/17	7/24/18
Total number of points sampled	180	180	180	181	180	180	180	180	180	180
Total number of sites with vegetation	162	167	171	173	163	171	151	171	174	176
Total number of sites shallower than maximum depth of plants	175	176	176	177	175	180	179	175	176	178
Frequency of occurrence of all species at sites shallower than maximum depth of plants	92.57	94.89	97.16	97.74	93.14	95.00	84.36	97.71	98.86	98.88
Simpson Diversity Index	0.90	0.88	0.91	0.92	0.91	0.91	0.92	0.92	0.90	0.86
Maximum depth of plants (ft)	8.00	10.00	10.00	9.00	8.00	20.00	14.50	9.00	10.50	12.50
Average number of all species per site (shallower than max depth)	2.79	2.22	3.16	3.41	2.71	2.74	2.06	2.82	3.33	2.32
Average number of all species per site (veg. sites only)	3.01	2.34	3.25	3.49	2.91	2.88	2.44	2.89	3.37	2.35
Average number of native species per site (shallower than max depth)	2.44	2.01	2.59	3.01	2.50	2.72	2.05	2.82	3.30	2.32
Average number of native species per site (veg. sites only)	2.74	2.22	2.77	3.20	2.70	2.88	2.43	2.88	3.34	2.35
Species Richness	28	25	38	32	26	31	27	34	33	29
Species Richness (including visuals)	28	28	39	32	32	32	30	36	38	37
Species Richness (including visuals and boat survey)	28	28	39	32	33	38	33	45	41	38
Mean depth of plants (ft)	4.25	4.75	4.98	4.64	4.60	4.85	4.48	4.72	4.76	4.33
Median depth of plants (ft)	4.75	5.50	5.50	5.00	5.00	5.00	5.00	5.00	5.00	4.50
Mean rake fullness (veg. sites only)		1.96	2.28	2.2	1.93	1.70	1.58	2.11	2.40	2.12
Mean C	6.23	6.46	6.26	6.23	6.08	6.43	6.07	6.09	6.19	6.20
FQI	31.77	31.64	37.02	34.14	30.40	35.24	31.56	35.50	34.48	33.96

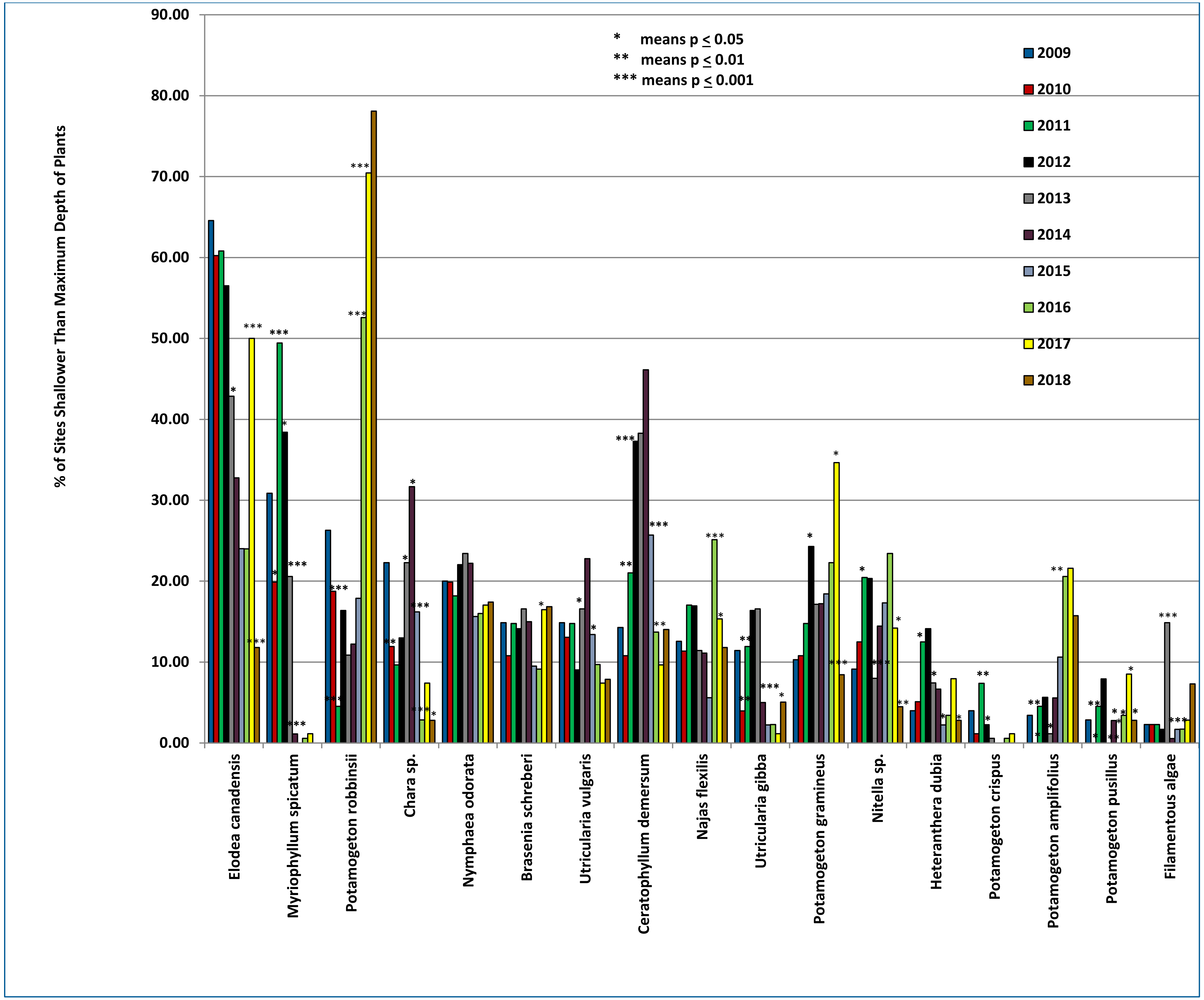


Figure 8-23 2009-2018 City Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

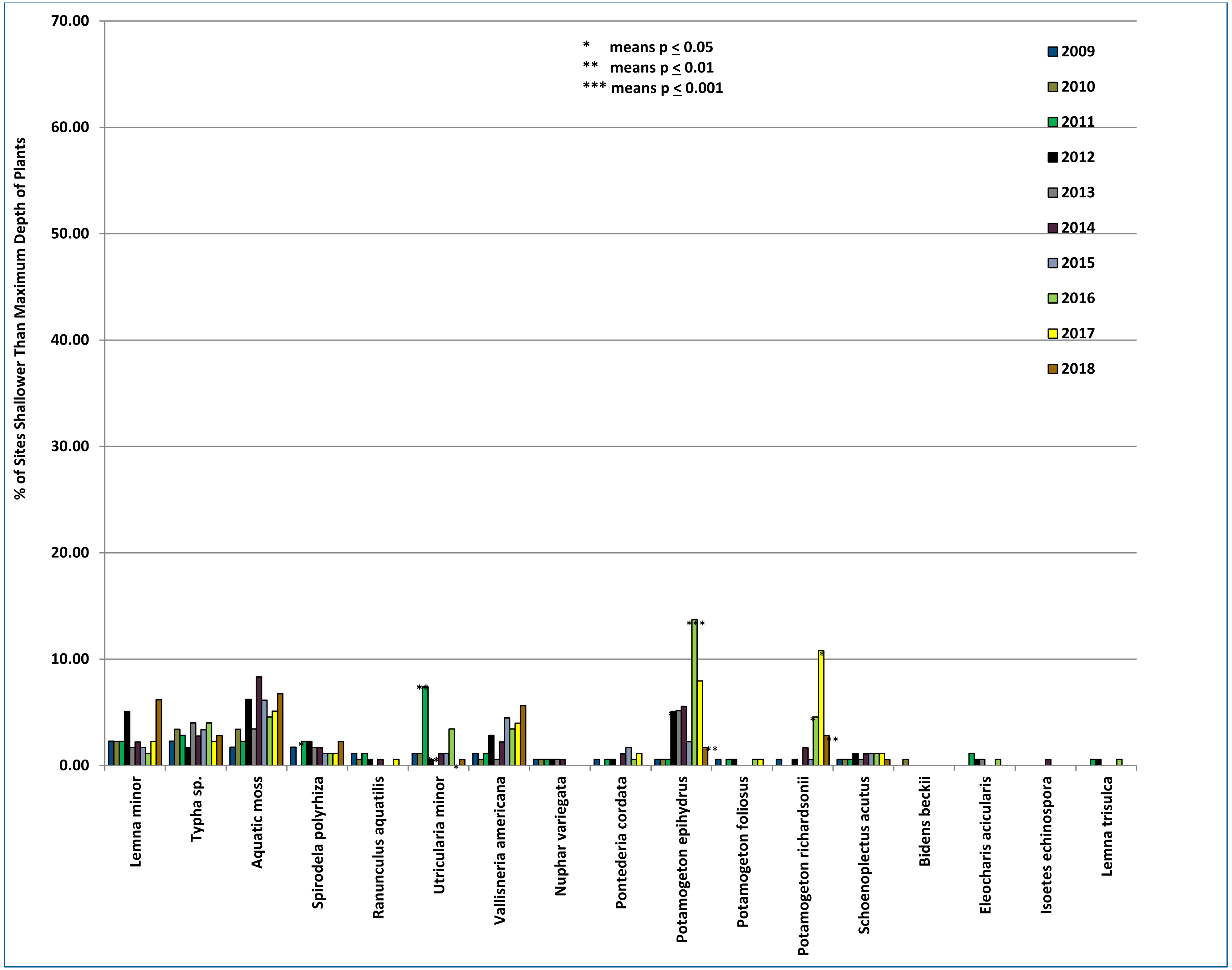


Figure 8-24 2009-2018 City Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

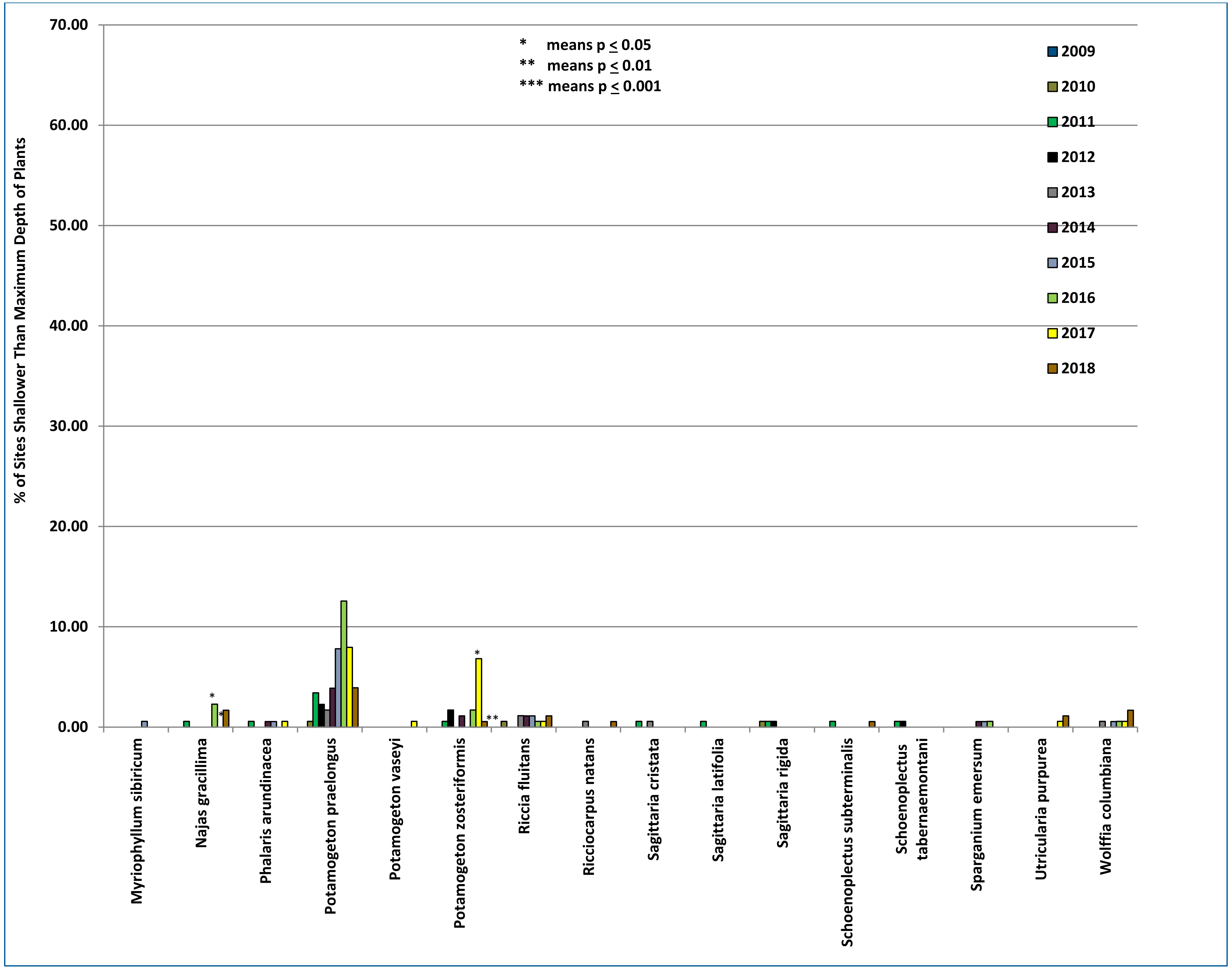


Figure 8-25 2009-2018 City Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants

8.7 East Lake

East Lake has a surface area of 147 acres and a maximum depth of 90 feet. The most recent water quality data are Secchi disc measurements during 2012 that ranged from 4 to 10 feet. The measurements indicate lake water transparency ranged from good to poor.

From 15 to 23 plant species were observed in East Lake, pictured above, during 2009 through 2018. The quality of the plant community, measured by FQI, is higher than the median value for lakes in the same eco-region.

In 2018, the maximum and average depths of plant growth in East Lake were relatively similar to previous years. During 2009 through 2017, the maximum depth of plant growth ranged from 13.0 feet to 26.5 feet, and was 22.0 feet in 2018. During 2009 through 2017, the average depth of plant growth ranged from 6.33 feet to 8.72 feet, and was 8.18 feet in 2018 Table 8-9.

The 2018 plant survey results indicated the plant community in East Lake was very healthy and of high quality. In 2018, the number of species (including visuals and boat surveys) was similar to previous years—20 in 2018 compared with 15 to 23 during 2009 through 2017. The number of species in East Lake in 2018 was greater than the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2018, the quality of the plant community, measured by FQI, was within the range observed in previous years—22.98 in 2018 compared with 22.45 to 28.17 during 2009 through 2017. East Lake FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999).

In 2018, plant frequency and the average number of native plant species per sample location were similar to previous years. During 2009 through 2017, the plant frequency of occurrence at sites shallower than the maximum depth of plants ranged from a low of 28 percent in 2015 to a high of 76 percent in 2011, and was 50 percent in 2018. The average number of native plant species at each sample location shallower than the maximum depth of plant growth ranged from a low of 0.54 in 2015 to a high of 1.59 in 2009, and was 0.82 in 2018 (Table 8-9).

In 2018, the East Lake plant community was dominated by fern pondweed (*Potamogeton robbinsii*). Fern pondweed was not observed in East Lake during 2011 when Eurasian watermilfoil frequency was 42 percent. A decline in Eurasian watermilfoil frequency to 23 percent in 2012 coincided with the appearance of fern pondweed (frequency of 10 percent). Eurasian watermilfoil has not been observed during the July plant surveys performed during 2015 through 2018 and fern pondweed frequency has steadily increased during this period of time. In 2018, fern pondweed frequency was 37 percent and the only plant species with a frequency greater than 10 percent. (Figure 8-26).

East Lake noted a decline in diversity as measured by Simpson Diversity Index in 2018 - was 0.76 in 2018 compared with 0.81 to 0.90 during 2009 through 2017 (Table 8-9). The Simpson Diversity Index indicates the probability that two individual plants randomly selected from the lake will belong to different species. In 2018, this probability was 76 percent in East Lake compared with 81 to 90 percent in previous years. East Lake was not treated with herbicide during 2018 and its change in diversity is, hence, due to natural causes. Increased frequency of fern pondweed is the likely cause of the decline in diversity in East Lake in 2018. Increased frequency of fern pondweed has decreased the probability that two individual plants randomly selected from the lake belong to different species.

Significant frequency changes have occurred in more than a third of the lake's native species since 2009 (Figure 8-26 and Figure 8-27).

- 9 of the lake's 24 native species collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 3 native species have both significantly declined and significantly increased in year-over-year frequency since 2009.
- 2 native species have significantly increased in year-over-year frequency since 2009.
- 4 native species have significantly decreased in year-over-year frequency since 2009.

Significant frequency changes of native species in 2017 were documented by a Chi Squared analysis of 2016 and 2017 data. In 2018, there was 1 significant decrease in native plant frequency and no native species significantly increased in frequency (Table 8-2 and Figure 8-26 and Figure 8-27).

Table 8-9 2009-2018 East Lake Summary Statistics

SUMMARY STATS:	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/15/12	7/16/13	7/13/14	7/18/15	7/20/16-7/21/16	7/20/17	7/23/18
Total number of points sampled	172	172	172	172	172	172	172	172	172	172
Total number of sites with vegetation	67	62	63	59	43	51	42	57	63	65
Total number of sites shallower than maximum depth of plants	95	87	83	97	82	143	149	139	139	130
Frequency of occurrence of all species at sites shallower than maximum depth of plants	70.53	71.26	75.90	60.82	52.44	35.66*	28.19*	41.01	45.32	50.00
Simpson Diversity Index	0.85	0.86	0.86	0.90	0.86	0.85*	0.81*	0.81	0.83	0.76
Maximum depth of plants (ft)	14.50	14.50	13.00	15.00	13.00	25.00	26.50	24.00	24.00	22.00
Average number of all species per site (shallower than max depth)	1.79	1.41	1.86	1.70	1.06	0.58	0.54	0.77	0.86	0.82
Average number of all species per site (veg. sites only)	2.54	1.98	2.44	2.80	2.02	1.63	1.90	1.88	1.90	1.63
Average number of native species per site (shallower than max depth)	1.59	1.10	1.41	1.46	1.01	0.57*	0.54*	0.77	0.86	0.82
Average number of native species per site (veg. sites only)	2.29	1.85	2.05	2.45	2.02	1.61	1.90	1.88	1.92	1.63
Species Richness	18	15	20	22	15	15	16	13	18	14
Species Richness (including visuals)	20	15	22	22	16	16	16	16	20	15
Species Richness (including visuals and boat survey)	20	15	22	23	17	18	20	19	21	20
Mean depth of plants (ft)	6.55	7.15	7.25	6.33	6.42	8.72	7.18	7.54	7.13	8.18
Median depth of plants (ft)	7.00	7.50	7.50	6.50	6.50	7.00	6.50	7.50	7.00	7.50
Mean rake fullness (veg. sites only)		1.52	1.76	1.46	1.16	1.22	1.51	1.61	1.67	7.50
Mean C	6.31	6.00	6.28	6.30	6.29	6.29	6.19	6.23	6.24	6.14
FQI	25.25	22.45	26.63	28.17	23.52	23.52	24.75	22.47	25.71	22.98

*Low plant frequency and low numbers of native plants at depths greater than 15 feet skewed the 2014 and 2015 data lower. When computations were performed using the depth range at which plant growth was observed in 2009 through 2013, 0- to 15-foot depth, (1) plant frequency was 57 percent in 2014 and 52 percent in 2015, (2) diversity was 0.87 in 2014 and 0.82 in 2015, and (3) average number of native species per site was 0.97 in 2014 and 1.01 in 2015. Because only a few plants were found at depths deeper than 15 feet during 2014 and 2015, the frequency, diversity, and average number of native species statistics for the 0- to 15-foot depth range are more representative than the corresponding statistics for the 0- to 25- or 26.5-foot depth ranges shown in this table.

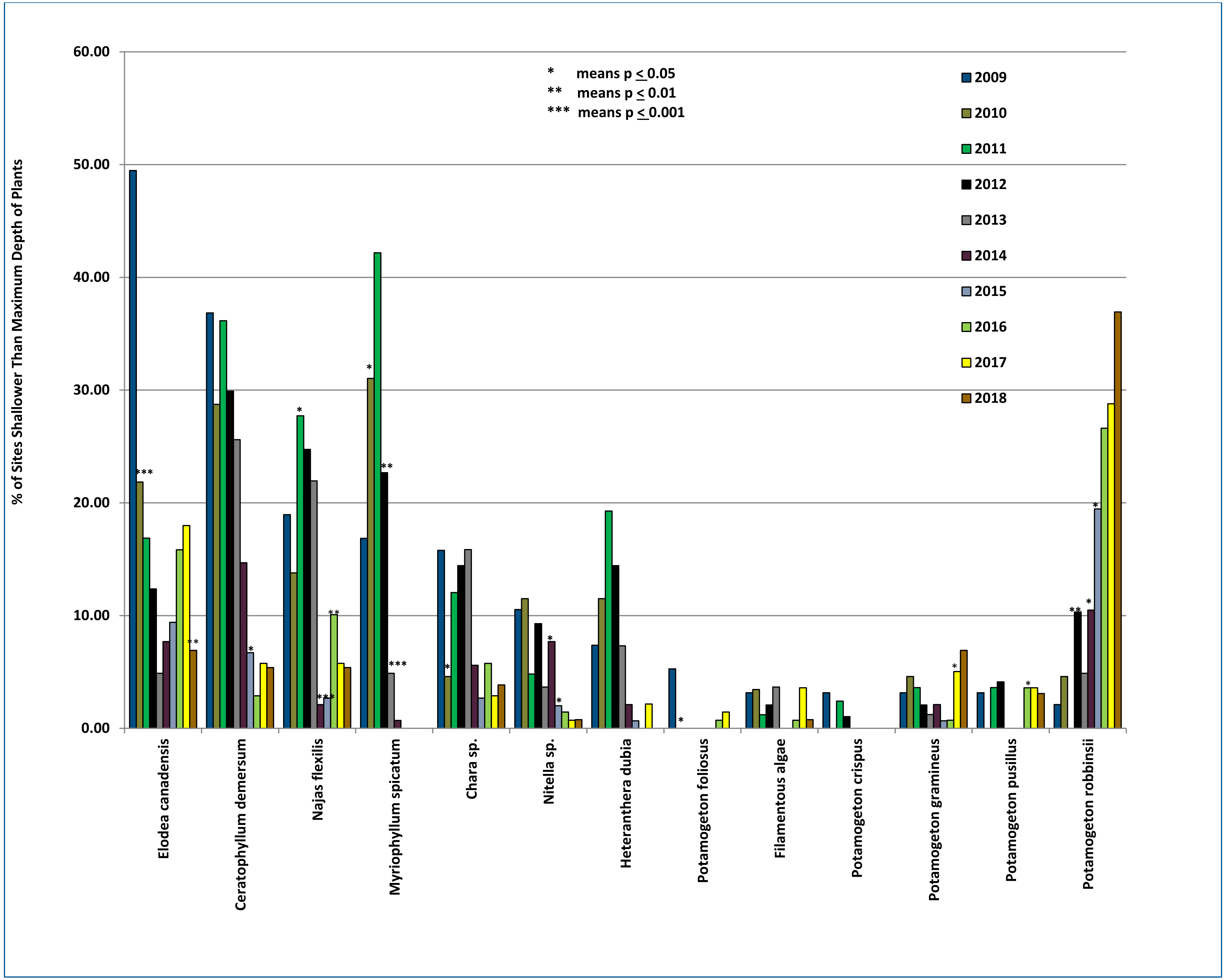


Figure 8-26 2009-2018 East Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

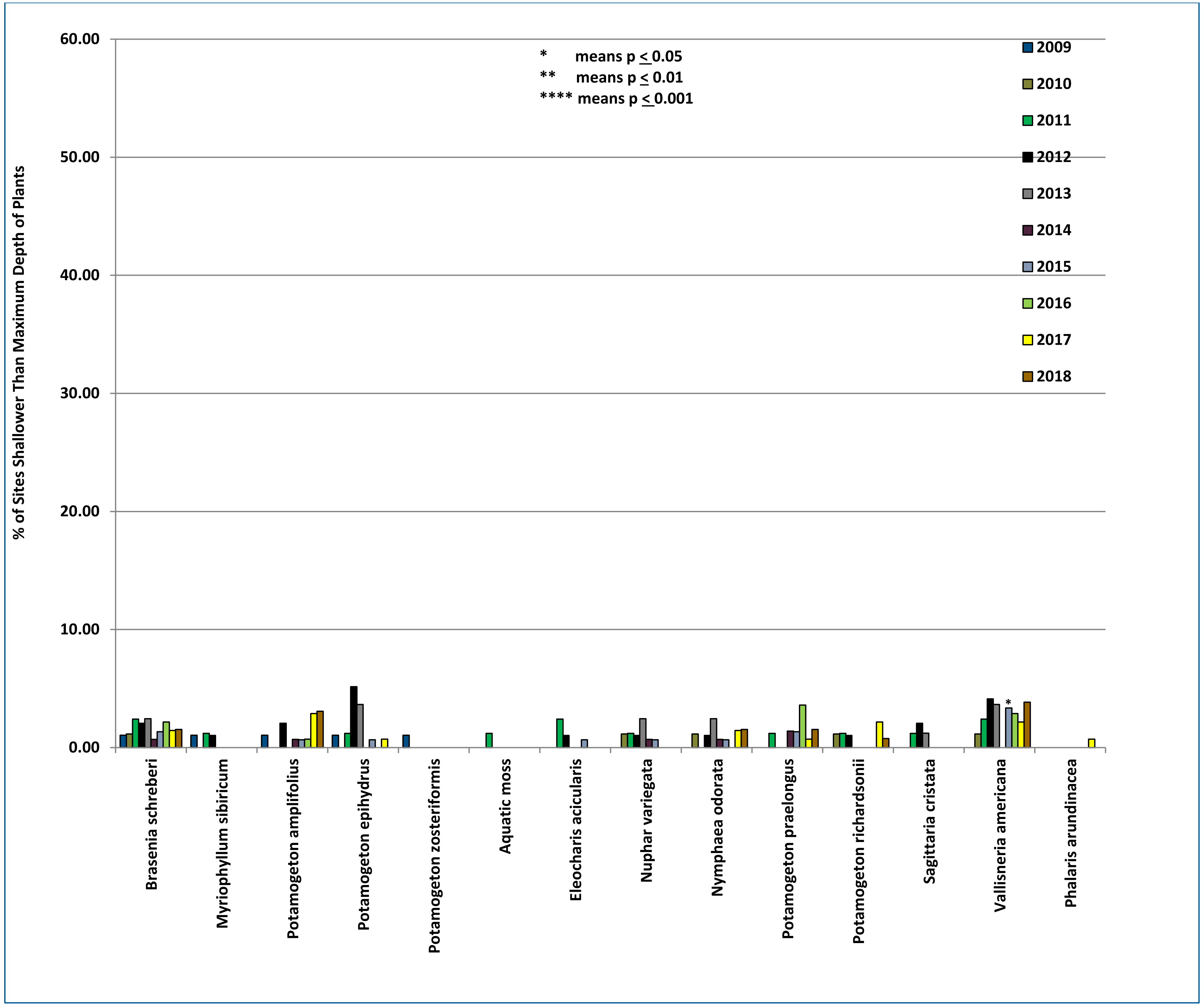


Figure 8-27 2009-2018 East Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

8.8 Norwegian Bay

Norwegian Bay has a surface area of 38 acres and a maximum depth of 18 feet. Water quality data are not available for Norwegian Bay.

The quality of the plant community, measured by FQI, in Norwegian Bay, pictured above, was higher than the median value for lakes in the same eco-region.

In 2018, the maximum and average depths of plant growth in Norwegian Bay were relatively similar to previous years. During 2009 through 2017, the maximum depth of plant growth ranged from 7.0 feet to 12.0 feet, and was 9.0 feet in 2018. During 2009 through 2017, the average depth of plant growth ranged from 4.08 feet to 5.18 feet, and was 4.40 feet in 2018 (Table 8-10).

The 2018 plant survey results indicated the plant community in Norwegian Bay was very healthy and of high quality. The number of species (including visuals and boat surveys) in Norwegian Bay in 2018 was relatively similar to previous years—36 in 2018 compared with 23 to 44 during 2009 through 2017. The number of species in Norwegian Bay in 2018 was more than double the median value for lakes in the same eco-region (median value of North Central Hardwood Forests is 14) (Nichols, 1999). In 2018, the quality of the plant community, measured by FQI, was similar to previous years—30.79 in 2018 compared with 23.28 to 33.05 during 2009 through 2017. Norwegian Bay FQI has been consistently higher than the median value for lakes in the same eco-region (i.e., 20.9) (Nichols, 1999). Diversity, measured by Simpson Diversity Index, was relatively similar to previous years—0.85 in 2018 compared with 0.84 to 0.92 in 2009 through 2017 (Table 8-10).

In 2018, plant frequency and the average number of native plant species per sample location were relatively similar to previous years. During 2009 through 2017, the plant frequency of occurrence at sites shallower than the maximum depth of plants ranged from a low of 88 percent in 2009 and 2010 to a high of 100 percent in 2016, and was 100 percent in 2018. More than 1 native species has consistently been found at each Norwegian Bay sample location. The average number of native plant species at each sample location ranged from a low of 1.52 in 2010 to a high of 3.62 in 2017 and was 2.36 in 2018 (Table 8-10).

In 2018, the Norwegian Bay plant community was dominated by fern pondweed (*Potamogeton robbinsii*). Fern pondweed frequency has steadily increased as Eurasian watermilfoil frequency has declined over the past several years. Eurasian watermilfoil frequency declined from 45 percent in 2013 to 0 percent (not observed) in July of 2015. Eurasian watermilfoil was then observed at a frequency around 2 to 5 percent in 2016 and 2017 and was not observed in July of 2018. Fern pondweed was not observed in 2013, but was observed at a 5 percent frequency in 2014. During 2014 through 2018, fern pondweed frequency increased by more than an order of magnitude to a frequency of 84 percent in 2018. Figure 8-28).

Significant frequency changes have occurred in more than a third of the lake's native species since 2009 (Figure 8-28 through Figure 8-31):

- 17 of the lake's 44 native species collected on the sampling rake have significantly changed in year-over-year frequency on at least one occasion since 2009.
- 6 native species have both significantly declined and significantly increased in year-over-year frequency since 2009.
- 7 native species have significantly increased in year-over-year frequency since 2009.
- 4 native species have significantly decreased in year-over-year frequency since 2009.

Significant frequency changes of native species in 2018 were documented by a Chi Squared analysis of 2017 and 2018 data. In 2018, 6 native species significantly decreased in frequency and no native species significantly increased in frequency (Table 8-2 and Figure 8-28 through Figure 8-31). The significant declines in frequency of 6 native species may be an indication of adverse impact from the spring treatment to control Eurasian watermilfoil. The 2,4-D dose used for the 2018 whole bay treatment of Norwegian Bay was higher than the doses used in previous years. The higher dose resulted in excellent control of Eurasian watermilfoil, but may have adversely impacted some native plant species. Five of the six native plant species that significantly declined in frequency in Norwegian Bay in 2018 have significantly declined following 2,4-D treatments in one or more Wisconsin lakes. These five species are listed below together with the other Wisconsin lakes in which they significantly declined following a 2,4-D treatment:

- Coontail (*Ceratophyllum demersum*) – Wilson Lake[1]
- Common waterweed (*Elodea canadensis*) – Tomahawk Lake and South Twin Lake (2010)[1]
- Ribbon-leaf pondweed (*Potamogeton epihydrus*) – Kathan Lake[1]
- Flat-stem pondweed (*Potamogeton zosteriformis*) – Berry Lake and South Twin Lake (2010)[1]
- Nitella (*Nitella sp.*) – Tomahawk Lake and Kathan Lake[1]

One species that significantly declined in Norwegian Bay in 2018, clasping-leaf pondweed (Potamogeton richardsonii), significantly increased following a 2,4-D treatment of South Twin Lake (2009).[1] The dominant species in Norwegian Bay, fern pondweed, increased, in frequency in 2018, although not significantly, but significantly declined following herbicide treatment in Tomahawk Lake and Wilson Lake.[1]

Despite some anomalies in response of Norwegian Bay species to the 2,4-D herbicide treatment, the data support a conclusion that the higher dose of 2,4-D used in 2018 caused a significant decline in frequency of multiple native species. Despite these declines, the Norwegian Bay plant community remained healthy in 2018 and, as detailed above, had a diverse community of high quality plants. In 2018, the overall plant frequency in Norwegian Bay was 100 percent, which is at the top of its 2009 through 2018 range. Hence, changes in some native plant frequencies did not reduce overall plant frequency in the Norwegian Bay.

Table 8-10 2009-2018 Norwegian Bay Summary Statistics

SUMMARY STATS:	7/15/09-7/18/09	7/15/10-7/18/10	7/16/11-7/19/11	7/15/12	7/16/13	7/13/14	7/18/15	7/21/16	7/20/17	7/23/18
Total number of points sampled	68	68	68	68	68	68	68	68	68	68
Total number of sites with vegetation	57	58	61	65	58	60	57	64	64	64
Total number of sites shallower than maximum depth of plants	65	66	66	66	63	66	61	64	66	64
Frequency of occurrence of all species at sites shallower than maximum depth of plants	87.69	87.88	92.42	98.48	92.06	90.91	93.44	100.00	96.97	100.00
Simpson Diversity Index	0.86	0.84	0.89	0.91	0.90	0.90	0.89	0.91	0.92	0.85
Maximum depth of plants (ft)	9.50	11.50	12.00	11.00	8.50	11.50	7.00	9.50	11.00	9.00
Average number of all species per site (shallower than max depth)	2.51	1.73	2.65	3.64	2.71	3.26	2.44	3.36	3.70	2.38
Average number of all species per site (veg. sites only)	2.86	1.97	2.87	3.69	2.95	3.58	2.61	3.36	3.81	2.38
Average number of native species per site (shallower than max depth)	2.12	1.52	2.52	3.12	2.63	3.17	2.43	3.30	3.62	2.36
Average number of native species per site (veg. sites only)	2.42	1.79	2.77	3.17	2.91	3.48	2.60	3.30	3.73	2.36
Species Richness	24	20	23	26	25	33	27	32	36	29
Species Richness (including visuals)	28	23	24	29	28	35	35	41	40	34
Species Richness (including visuals and boat survey)	28	23	24	30	29	36	39	44	41	36
Mean depth of plants (ft)	4.08	4.60	5.18	4.70	4.34	4.81	4.25	4.69	4.75	4.40
Median depth of plants (ft)	4.00	4.50	5.50	4.50	4.50	4.75	4.50	5.00	5.00	4.50
Mean rake fullness (veg. sites only)		1.71	2.07	2.02	1.74	1.87	1.58	1.98	2.41	2.22
Mean C	6.33	5.65	6.00	6.05	6.09	6.00	6.00	6.14	6.35	6.04
FQI	29.02	23.28	26.83	28.36	28.57	31.18	29.39	33.05	37.04	30.79

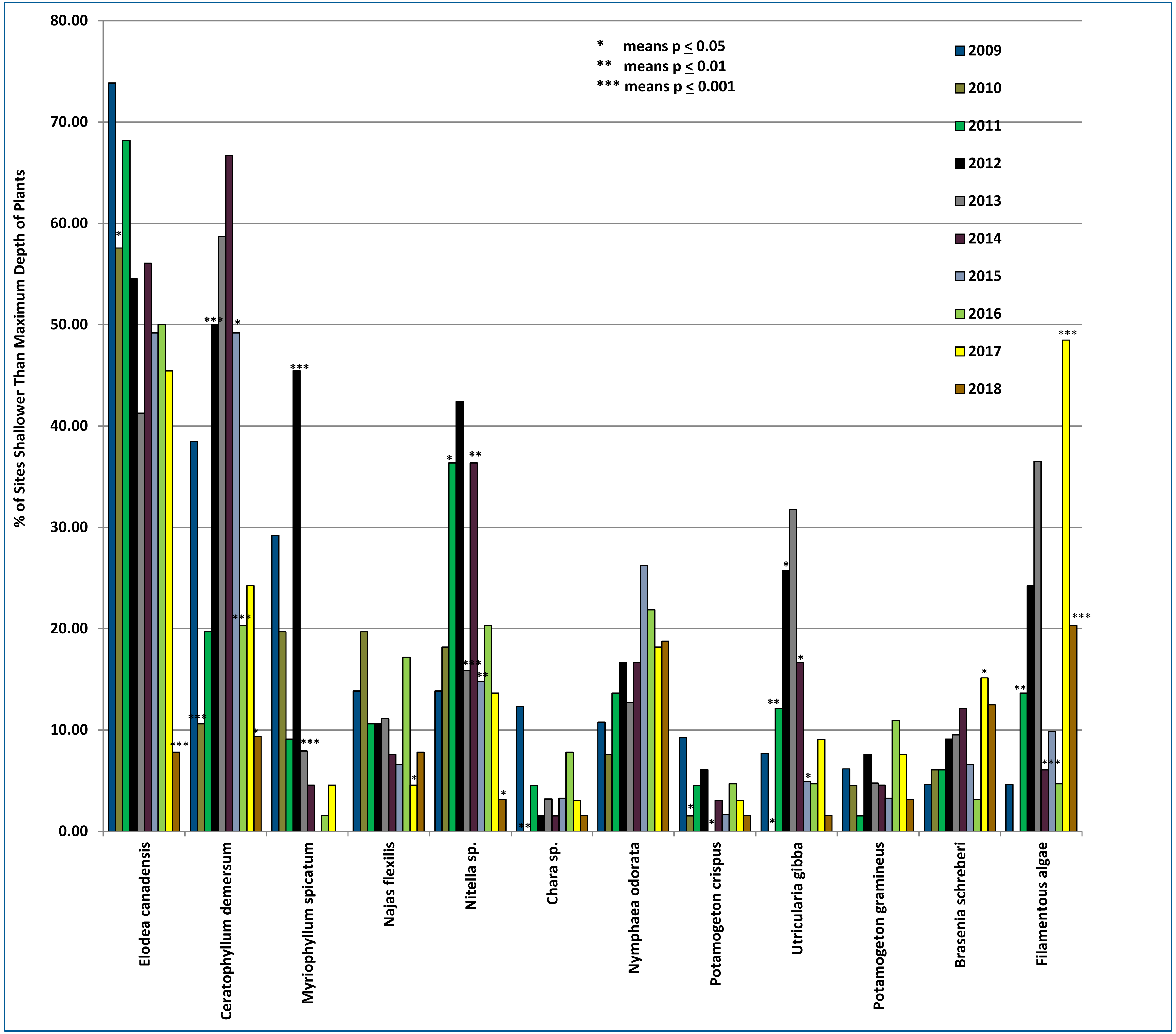


Figure 8-28 2009-2018 Norwegian Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

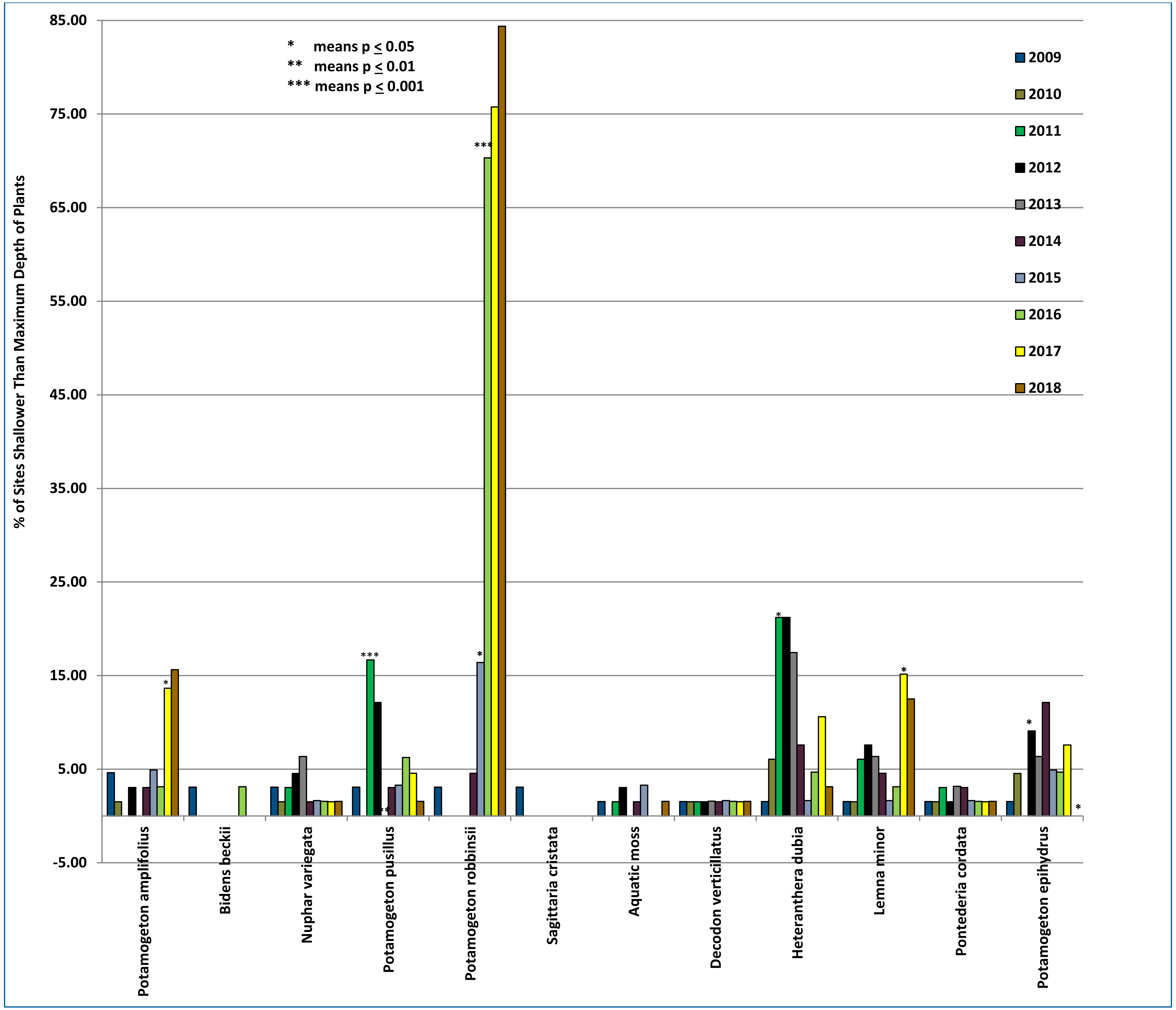


Figure 8-29 **2009-2018 Norwegian Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)**

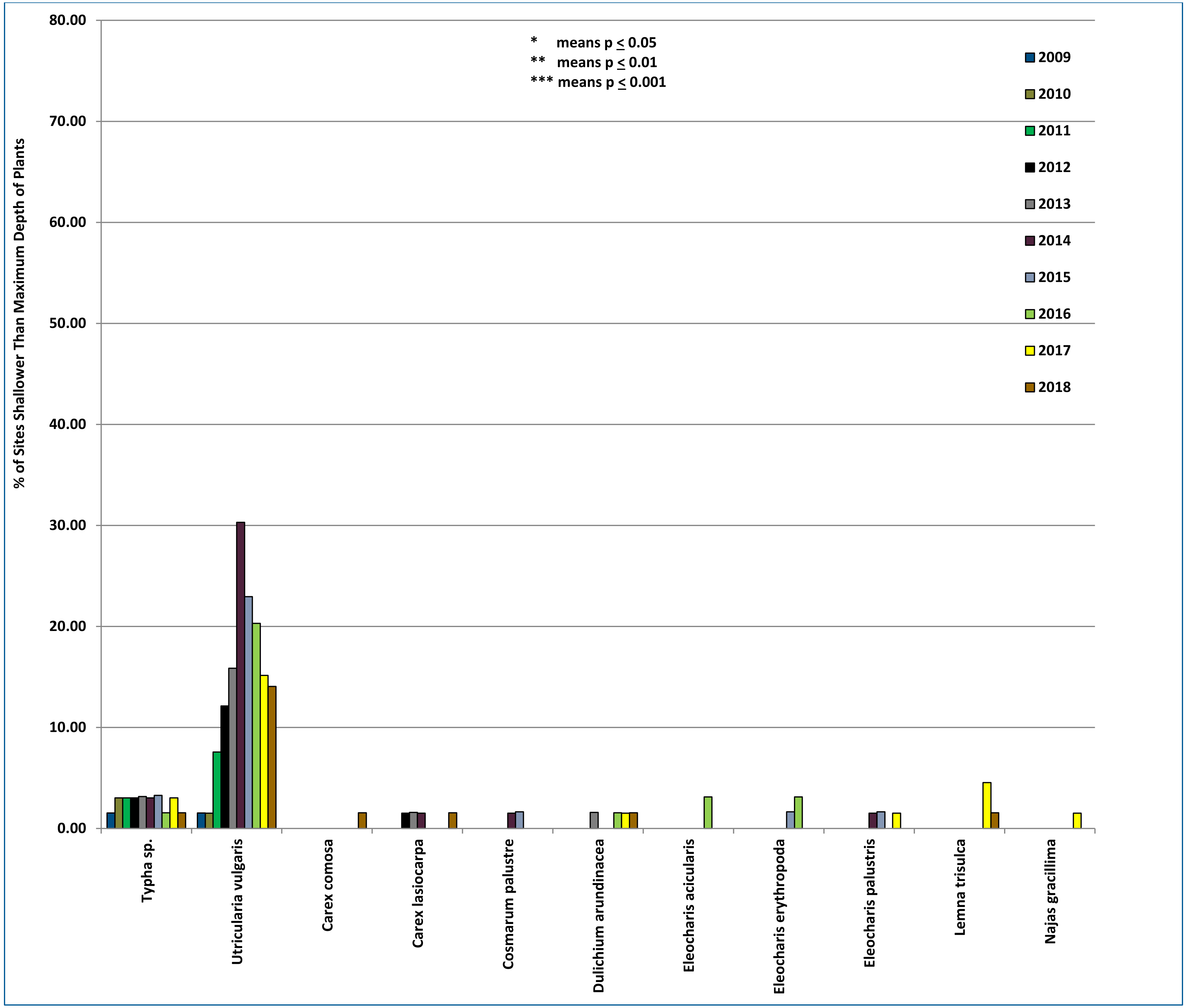


Figure 8-30 2009-2018 Norwegian Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

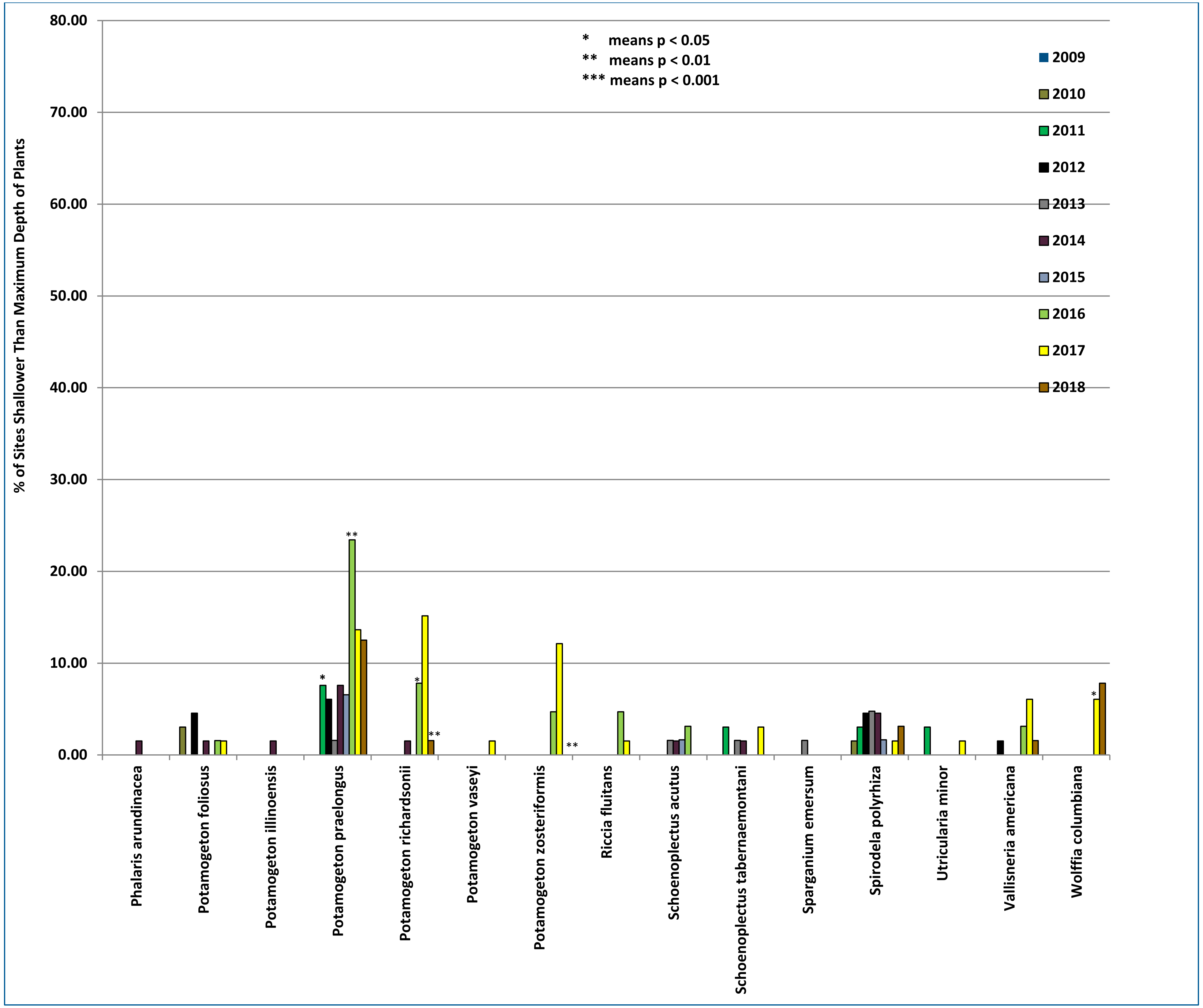


Figure 8-31 2009-2018 Norwegian Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

8.9 Summary

In 2018, the Beaver Dam Lake plant community was healthy and of very high quality. The plant community in Beaver Dam Lake as a whole and in three of the eight individual basins – West Lake, Rabbit Island Bay, and Cemetery Bay – was stable and all 2018 metrics were within the range of previous years. Three individual basins noted a positive change in the plant community during 2018:

- **Williams Bay** – the average depth of plant growth was a little higher in 2018 (9.54 feet) than had been observed during 2009 through 2017 (7.51 to 9.4 feet)
- **Library Lake** – the average number of plant species found at each sample location was higher in 2018 (5.00) than had been observed during 2009 through 2017 (3.24 to 4.77 feet)
- **City Bay** – overall plant frequency was slightly higher in 2018 (98.88 percent) than had been observed during 2009 through 2017 (84.36 to 98.86 percent).

Increasing frequency of fern pondweed in East Lake resulted in a decline in diversity as measured by Simpson Diversity Index in 2018 - was 0.76 in 2018 compared with 0.81 to 0.90 during 2009 through 2017. The Simpson Diversity Index indicates the probability that two individual plants randomly selected from the lake will belong to different species. In 2018, this probability was 76 percent in East Lake compared with 81 to 90 percent in previous years. East Lake was not treated with herbicide during 2018 and its change in diversity is, hence, due to natural causes. Increased frequency of fern pondweed is the likely cause of the decline in diversity in East Lake in 2018. Increased fern pondweed frequency decreased the probability that two individual plants randomly selected from the lake belong to different species.

The whole bay 2,4-D treatments of City Bay and Norwegian Bay at higher doses than had been used previously appears to be the cause of a significant reduction in frequency of multiple native species. In City Bay, 9 native species observed a significant reduction in frequency during 2018. In Norwegian Bay, 5 native species observed a significant reduction in frequency. The declines are expected to be a temporary impact. The species that declined in frequency during 2018 are expected to increase in frequency in subsequent years to attain pre-treatment frequencies in both bays. Despite the reductions in frequency of some native plant species, the plant communities of City Bay and Norwegian Bay remained healthy in 2018 and their overall plant frequency was either higher or at the top of the range observed in previous years. As noted above, City Bay observed an overall plant frequency in 2018 that was slightly higher than the overall plant frequency observed since 2009. In 2018, plant frequency in Norwegian Bay was 100 percent – plants were observed at all monitoring locations – which was at the top of the range observed since 2009.

9.0 Citizen Survey and Results

An aquatic plant management citizen survey was prepared by the Beaver Dam Lake Management District, with assistance from the citizen advisory committee on aquatic plant management, and mailed to the 1,150 residents of the Beaver Dam Lake Management District during August of 2011. The survey provided an opportunity for citizen input to the Aquatic Plant Management Plan. The survey asked questions about lake use, the impact of aquatic plants on lake use, and citizen opinions on management of aquatic plants in Beaver Dam Lake. The District received 189 completed surveys which is a 16.4 percent return rate. The survey questions and a tabulation of the responses are found in Appendix G and discussed in the following paragraphs.

As shown in Figure 9-1, 83 percent of survey respondents were citizens living on Beaver Dam Lake and 45 percent of survey respondents were citizens who reported at least a 20-year residency.

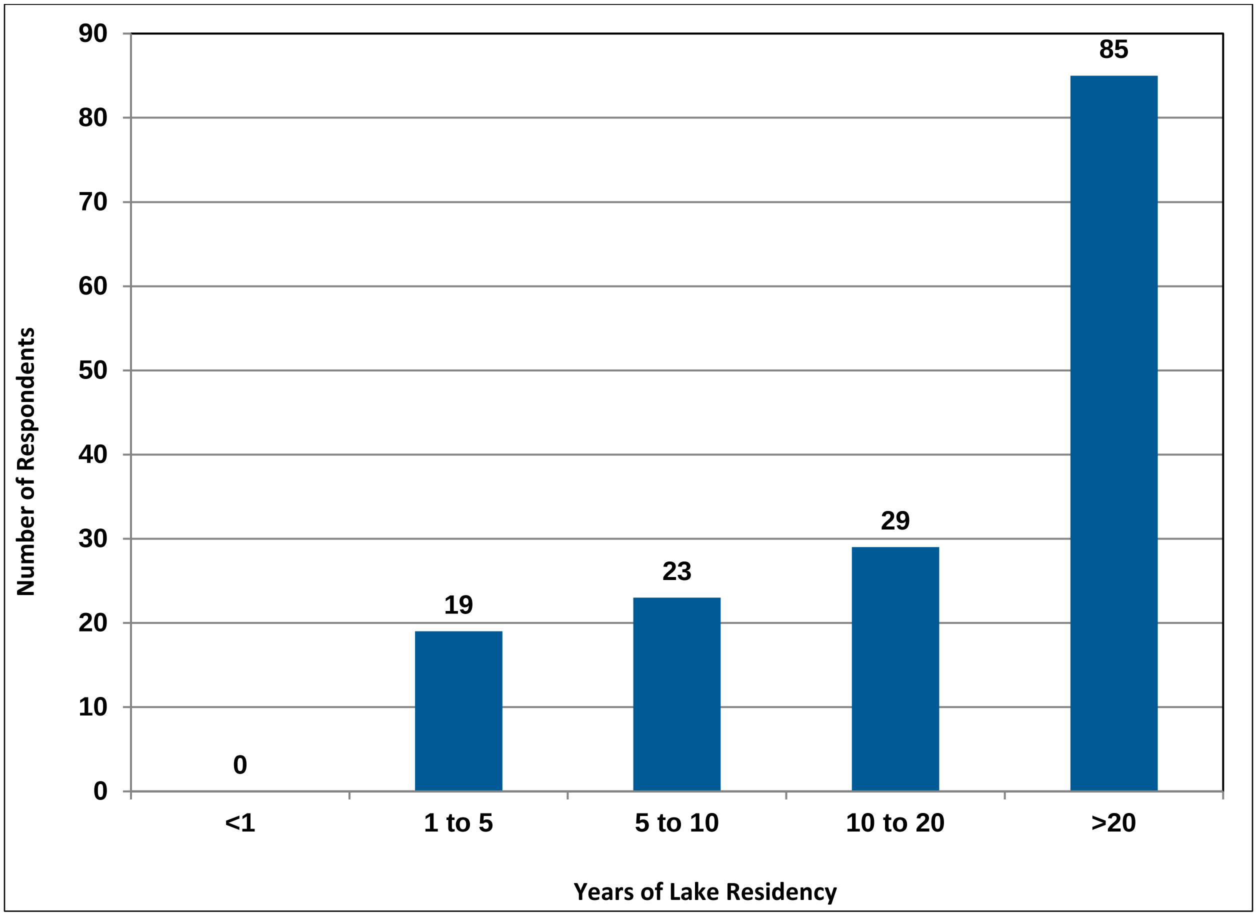


Figure 9-1 Years of Lake Residency Reported by Survey Respondents

Respondents indicated Beaver Dam Lake is a busy lake with broad recreational use. The highest uses of the lake are motor boating, enjoying the view, swimming, fishing, observing waterfowl/wildlife, and pontooning (Figure 9-2).

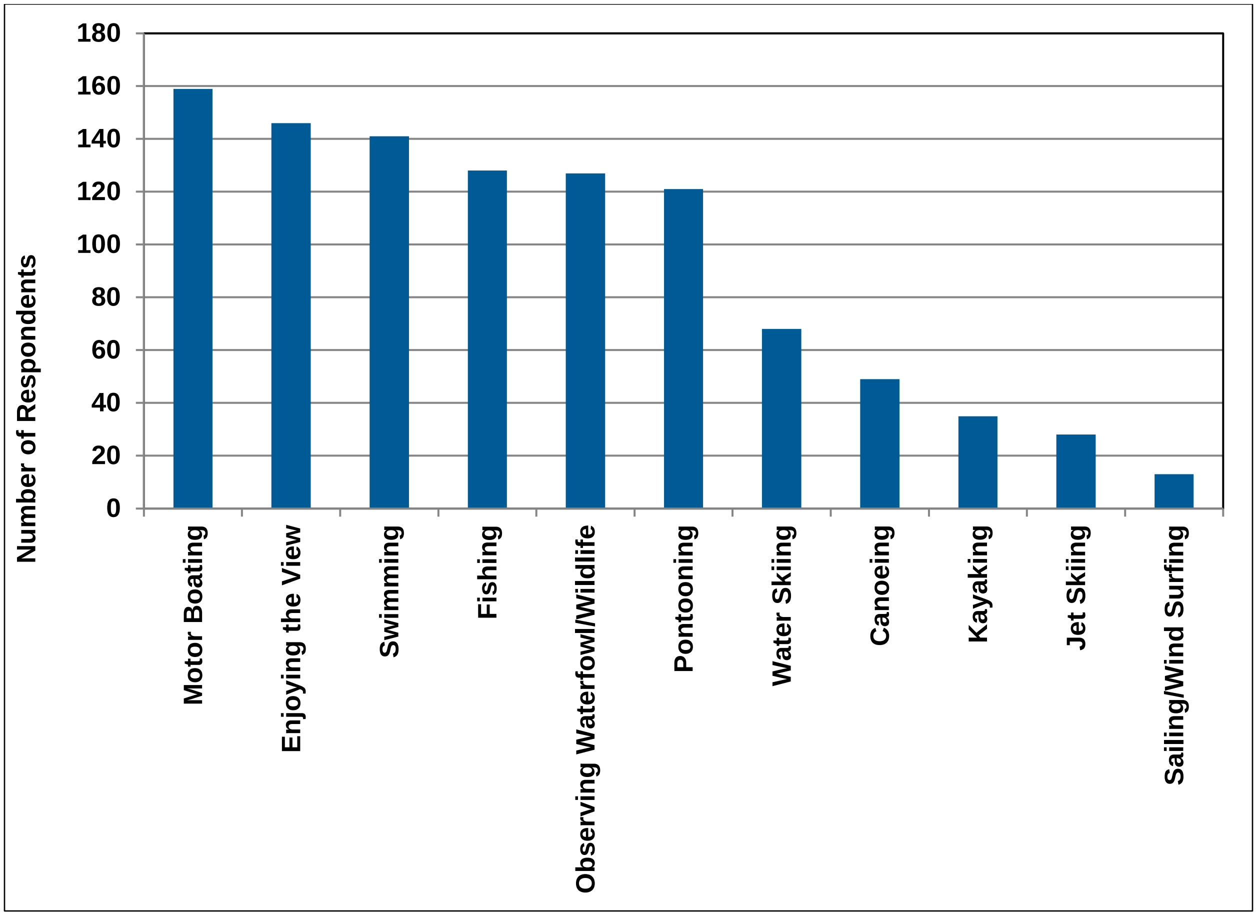


Figure 9-2 Lake Uses Reported by Survey Respondents

About 60 percent of respondents feel their activities are negatively affected by aquatic plants. Lake uses most negatively affected by aquatic plants are swimming, fishing, and pontooning followed closely by motor boating and enjoying the view Figure 9-3.

More than 50 percent believed the amount of vegetation in the lake had increased in the last 5 years (i.e., 2006 to 2011). It should be noted that the survey was taken during August of 2011 when EWM extent was rapidly increasing in the eastern basin of the lake. As shown on Table 7-4, EWM covered a larger area in the eastern basin during the fall of 2011 than the previous 5 years. When asked to rank the degree of impact that invasive species has on use or enjoyment of the lake, more than half of the respondents selected high impact Figure 9-4.

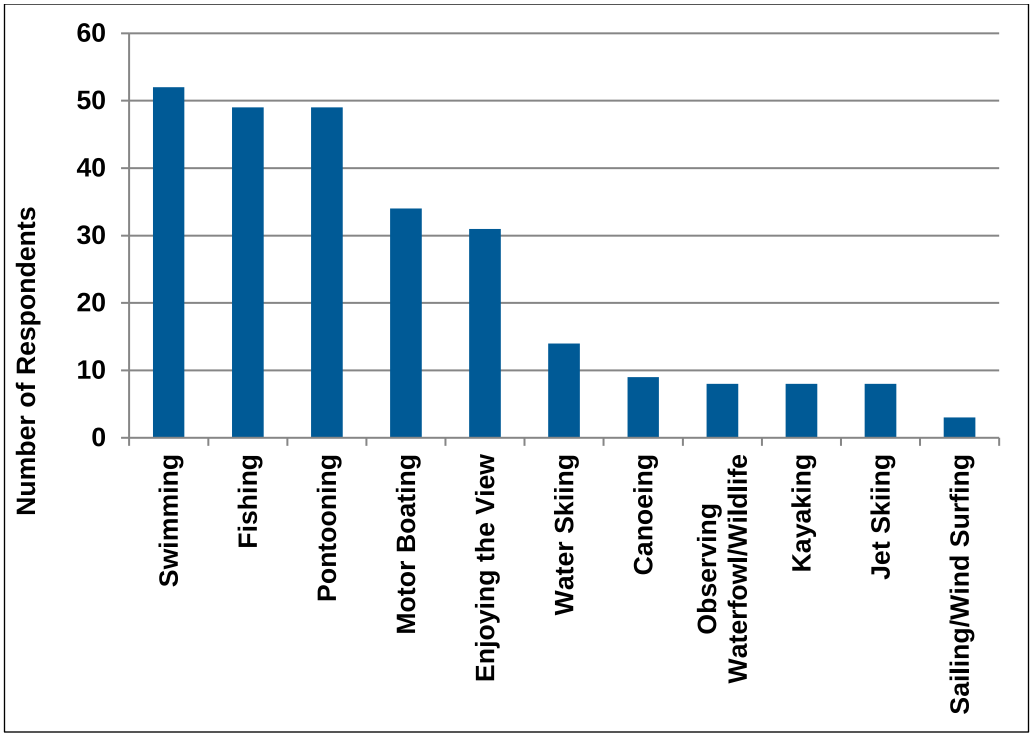


Figure 9-3 Lake Uses Impaired by Plant Growth

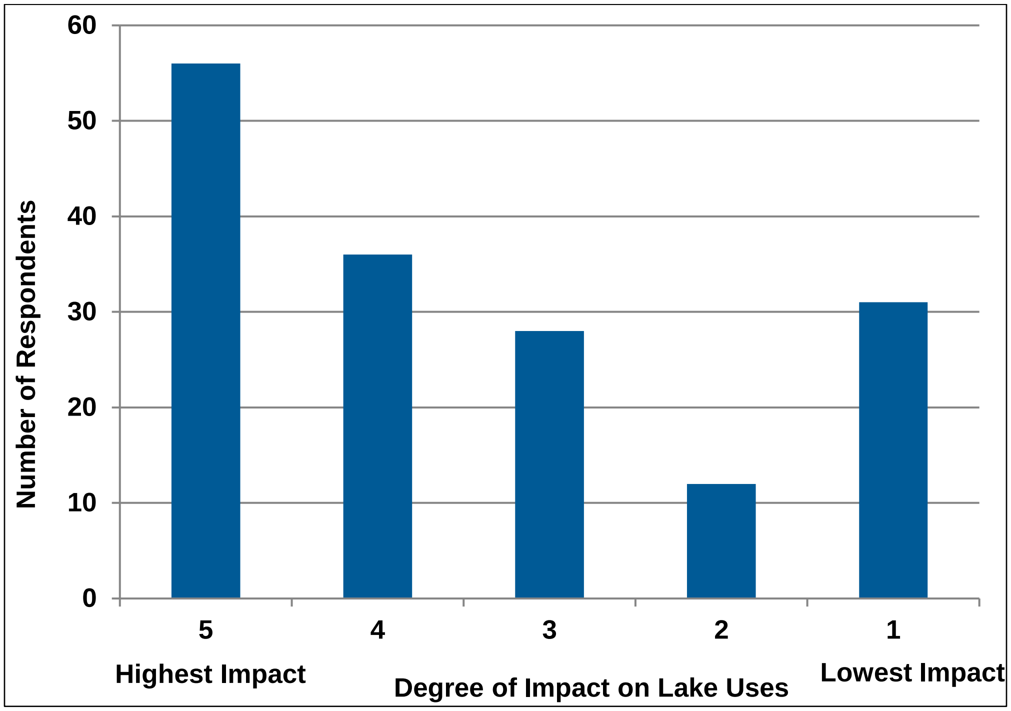


Figure 9-4 Degree of Impact by Invasive Plant Species on Use or Enjoyment of the Lake

Most respondents (57 percent) didn't know whether the "types" of plants in the lake had changed in the last 5 years. A huge majority (15:1) support the use of herbicides to remove plants that are not native to Wisconsin lakes. The majority of respondents (71 percent) support the former EWM goal of 5 percent or less and 23 percent would support more control (Note: the goal established in this APMP is 7 percent). A large majority (83 percent) support reducing the amount of CLP in the lake. A third of respondents indicated native plants had a high impact on use or enjoyment of the lake. A huge majority (93 percent) support removing native plants in navigation channels if they interfere with boat navigation. A huge majority (96.5 percent) support the City of Cumberland boat inspection program or increasing the program. Approximately 50 percent of respondents have cleared their beaches and 21 percent have used private herbicide treatment. The majority (72 percent) would consider approved private herbicide treatment. Fish stocking was supported by over 90 percent of respondents. The citizens expressed their support of the work of the Beaver Dam Lake Management District and were complimentary with numerous comments like "keep up the good work."

A huge majority of survey respondents supported the use of herbicides to remove plants that are not native to Wisconsin lakes. Removing non-native plants, such as EWM, from Beaver Dam Lake supports its beneficial uses, such as swimming at the public beach area, pictured above.

10.0 Problem

EWM, pictured above, was introduced to Beaver Dam Lake in 1991 and rapidly spread throughout the lake. Photo Credit: Endangered Resource Services, LLC.

Beaver Dam Lake has a diverse and high quality aquatic plant community. However, EWM poses a threat to the lake's native community and has prevented the lake from fully supporting recreational uses such as motor boating, swimming, and fishing. EWM was introduced to the lake in 1991 and was allowed to grow and spread without management during 1991 through 1999. From a 1999 plant survey, it was estimated that 73 percent of the lake's littoral area was infested with EWM (Barr, 2012a). Herbicide treatment of EWM reduced the area of infestation to 47 percent of the lake's littoral area by 2005 (Barr, 2012a). Herbicide treatment during 2006 through 2018 reduced the area of EWM infestation to 18 acres by 2018, which is 3 percent of the 530-acre littoral area (Table 7-4, Table 7-5, and Figure 7-5). During the past 9 years, EWM extent in Beaver Dam Lake has been reduced by 90 percent—from 176 acres in 2008 to 18 acres in 2018 (Table 7-4).

Despite the effectiveness of previous control efforts, continued EWM management is necessary to prevent the spread of EWM in the lake. It is well documented that EWM in Beaver Dam Lake is a rapidly expanding population, curtailed only by annual herbicide treatments or manual removal. Annual point intercept plant surveys during July and October have documented the rapid expansion of EWM between summer and fall. As shown in Table 7-3 and Table 7-4, EWM lake-wide frequency of occurrence increased by more than four-fold and extent by more than six-fold between summer and fall of 2014. During 2015, the untreated EWM in Cemetery Bay increased by more than an order of magnitude—from 2 acres to 32 acres. During 2015, the untreated EWM in Library Lake more than doubled, from 0.7 acres in summer to 1.9 acres in fall. During 2016, the unmanaged EWM in West Lake nearly tripled, from 6.8 acres in summer to 20.6 acres in fall. The District EWM goal of reducing EWM to no more than seven percent of the littoral zone was attained in both 2017 and 2018. Although the District goal has been attained, the District plans to continue EWM management in an attempt to reduce EWM to the lowest possible extent and to prevent a return of EWM to pre-management conditions.

Further reduction of EWM in Beaver Dam Lake will reduce the likelihood that Beaver Dam Lake will continue to be a source of infestation to other lakes. Beaver Dam Lake receives significant use by boaters and is the likely source of EWM infestation of several neighboring lakes that observed infestations of EWM following its introduction to Beaver Dam Lake (e.g., Sand Lake and Echo Lake). Continued efforts to reduce EWM infestation as well as continued watercraft inspections of boats leaving the lake will help protect neighboring lakes not yet infested with EWM (e.g., Kirby Lake, Dummy Lakes).

Problematic growths of EWM have prevented Beaver Dam Lake from fully supporting recreational activities. A survey of lake residents found that about 60 percent feel their activities are negatively affected by aquatic plants. Lake uses most negatively affected by aquatic plants are swimming, fishing and pontooning followed closely by motor boating and enjoying the view. When asked to rank the degree of impact that invasive species has on use or enjoyment of the lake, more than half of survey respondents selected high impact.

Management of EWM is necessary to reduce the area of EWM infestation, support recreational use of the lake, and protect and, whenever possible, improve the native plant community in Beaver Dam Lake.

Plant surveys of Beaver Dam Lake have documented the very diverse and high quality native plant community in the lake. In 2018, the lake's FQI was 47.19 which is more than double the Ecoregion median FQI of 20.9. In addition, three NHI species of concern were observed in Beaver Dam Lake during 2009 through 2018, *Potamogeton vasey* (Vasey's pondweed), *Eleocharis robbinsii* (Robbin's spikerush), and *Utricularia purpurea* (purple bladderwort). Control of EWM is necessary to protect the high quality native plant community of Beaver Dam Lake, including the NHI species of concern that currently reside in the lake.

Fishery surveys have documented the high quality fishery in the lake. Because EWM can aggressively displace native species that provide necessary habitat for the lake's fishery, control of EWM is necessary to protect the lake's high quality fishery.

The presence of CLP, pictured above, in Beaver Dam Lake poses a threat to the lake's native plant community.

While EWM is the primary invasive species of concern, the presence of CLP in the lake also poses a threat to the lake's native plant community. Limited management of CLP during 2006 through 2013 consistently controlled CLP (Table 7-1 and Table 7-2 and Figure 7-4) and no management was needed in 2014 through 2018. While treatment has consistently controlled CLP, evidence of CLP spread in the absence of treatment has been documented. The area of the lake infested with CLP was reduced from 16 acres in 2009 to one acre in 2010. No CLP treatment occurred in 2011 and rapid spread of CLP increased the area of CLP infestation from one acre in 2010 to 19 acres in 2011. Management of CLP in 2012 and 2013 reduced CLP levels to low levels and no management was required in 2014 through 2018. Although CLP currently occupies less than seven percent of the lake's littoral zone and seems to be a latent problem, ongoing management of CLP may be needed to contain it to a low occurrence (i.e., less than 7 percent of the littoral zone) and prevent the accumulation of turions (i.e., similar to seeds).

Problematic growths of invasive plant species have prevented the lake from fully supporting recreational activities. A survey of lake residents found that about 60 percent feel their activities are negatively affected by aquatic plants. Lake uses most negatively affected by aquatic plants are swimming, fishing and pontooning followed closely by motor boating and enjoying the view. When asked to rank the degree of impact that invasive species has on use or enjoyment of the lake, more than half of respondents selected high impact (Figure 9-4).

The negative impact to the lake's plant community caused by the accidental introduction of EWM clearly shows the vulnerability of the ecosystem to harmful introductions of invasive species. Beaver Dam Lake is a busy lake and, hence, vulnerable to the accidental introduction of additional invasive species. In 2011, a boat monitor found and removed a zebra mussel shell from one of the boats about to enter the lake (Hardie, 2012). The discovery and removal of the zebra mussel in 2011 clearly illustrates the vulnerability of Beaver Dam Lake to invasion by additional species. Hence, a preventative program to protect the lake from the introduction of additional invasive species is crucial to the protection of the lake.

Problematic growths of native plants interfere with use or enjoyment of the lake. About one third of survey respondents indicated native plants had a high impact on use or enjoyment of the lake. A huge majority (93 percent) support removing native plants in navigation channels if they interfere with boat navigation. One long-time Norwegian Bay resident indicated he was unable to enjoy boating on the lake during 2008 through 2011 because plant growth was so dense that he was not able to navigate from his residence to the open water areas of the lake. An analysis of the 2011 summer plant community within 300 feet of his residence indicated a dense growth of native species prevented navigation to open waters and use of the lake during the 2011 growing season (Barr, 2011b found in Appendix H). An annual summer navigation survey of the lake is important to identify navigation problems when they occur and to determine appropriate management measures when needed.

11.0 Consider all Techniques

Following a consideration of all possible management alternatives, a management plan was identified for Beaver Dam Lake. A detailed discussion of management alternatives and the rationale for the selection of herbicide treatment for control of EWM and CLP as well as treatment of navigation channels in Beaver Dam Lake is found in Appendix I as well as the previous aquatic plant management plans (Barr, 2000; Barr, 2006; Barr, 2012d; Barr 2014a; Barr, 2014b; and Barr, 2016).

12.0 Goals, Objectives, Strategies, and Measurements for the Beaver Dam Lake Aquatic Plant Management Plan

The Citizen Aquatic Plant Management Advisory Committee met on September 27, 2011 and prepared six draft goals for aquatic plant management of Beaver Dam Lake. In formulating the goals, the committee reviewed the results of the citizen survey, the goals from the previous Beaver Dam Lake APM Plan, and reviewed several WDNR approved APM Plans prepared by other Wisconsin lake organizations. After formulating draft goals, the committee presented them to the District Board at the October 26, 2011 meeting. A representative from WDNR attended the meeting and joined the Board in the discussion of the draft goals. Warranted changes to the goals were made during the discussion and the Board approved the finalized goals at the October 26, 2011 meeting. Following WDNR review of the APM Plan and a discussion with WDNR staff of comments to APM Plan goals, the Board changed the EWM and CLP goal from 5 percent to 10 percent at its October 24, 2012 meeting. Due to EWM reductions in the lake, the Board changed the goal to 7 percent at its November 20, 2014 meeting. Hence, the current EWM and CLP goal is 7 percent. The six goals selected for the APM Plan are shown on Figure 12-1.

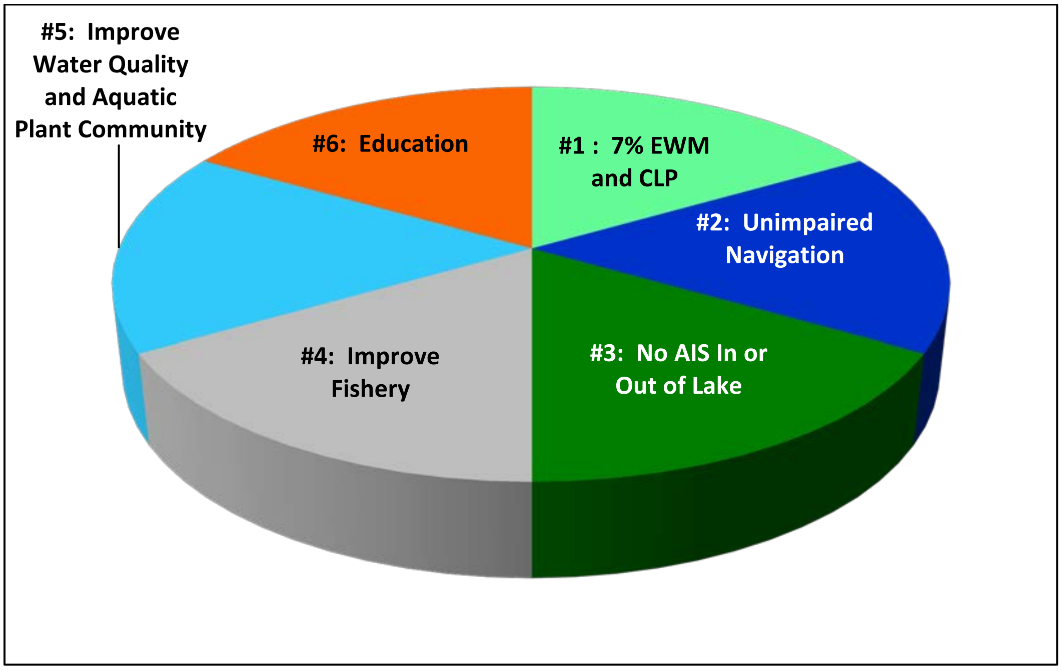


Figure 12-1 Beaver Dam Lake APM Plan Goals

This section of the report discusses the APM Plan goals, objectives, strategies, and measurements. Goals are broad statements of what the District intends to accomplish. Objectives are supporting statements and clarifications of the goals that provide reasons why the goals are important. Strategies are action steps to attain the goals. Measurements show how we know whether the strategy was successful. The goals, objectives, strategies, and measurements for the Beaver Dam Lake APM Plan are shown in Table 12-1 through Table 12-6, and discussed in the following paragraphs.

12.1 Goal 1: 7% EWM and CLP

Goal 1: ***Reduce Eurasian watermilfoil and curly-leaf pondweed levels to seven percent of the littoral zone area while minimizing harm to native aquatic plants.***

Objectives: *(1) Protect the lake's ability to support recreational uses such as boating, fishing, swimming, and enjoying the view; (2) Protect fisheries habitat and the overall health of the lake; (3) Prevent CLP dominance and the subsequent long-term annual control to hold the plant back from a resurgence to dominance; (4) Reduce the annual EWM and CLP management cost.*

Table 12-1 Goal 1 Strategies and Measurements

Strategies	Measurements	
	Yes	No
Strategy 1: Fall whole lake point intercept plant survey completed to determine EWM and CLP locations		
Strategy 2: Planning meeting completed to determine Treatment/Manual Removal Plans for Subsequent Year		
Strategy 3: Amended APM Plan completed		
Strategy 4: Amended APM Plan adopted at public noticed Board meeting and submitted to WDNR		
Strategy 5: Application for permits completed and submitted to WDNR		
Strategy 6 (Optional): Pre-treatment spring CLP delineation completed		
Strategy 7: Permitted EWM and/or CLP management completed		
Strategy 8: Herbicide residue monitoring program completed when required by WDNR as a permitting condition		
Strategy 9 (Optional): June post-treatment survey to assess CLP treatment results completed		
Strategy 10: Summer whole lake point intercept survey of all plants completed		
Strategy 11: Summer plant survey data assessed to verify need for Treatments/Manual Removal		
Strategy 12: EWM Management Plan Updated as Needed from Summer Plant Survey Data and Adopted at Public Noticed Board Meeting		
Strategy 13: Updated EWM Management Plan and Permit Applications Submitted to WDNR		
Strategy 14: Permitted Treatment/Manual Removal Completed		

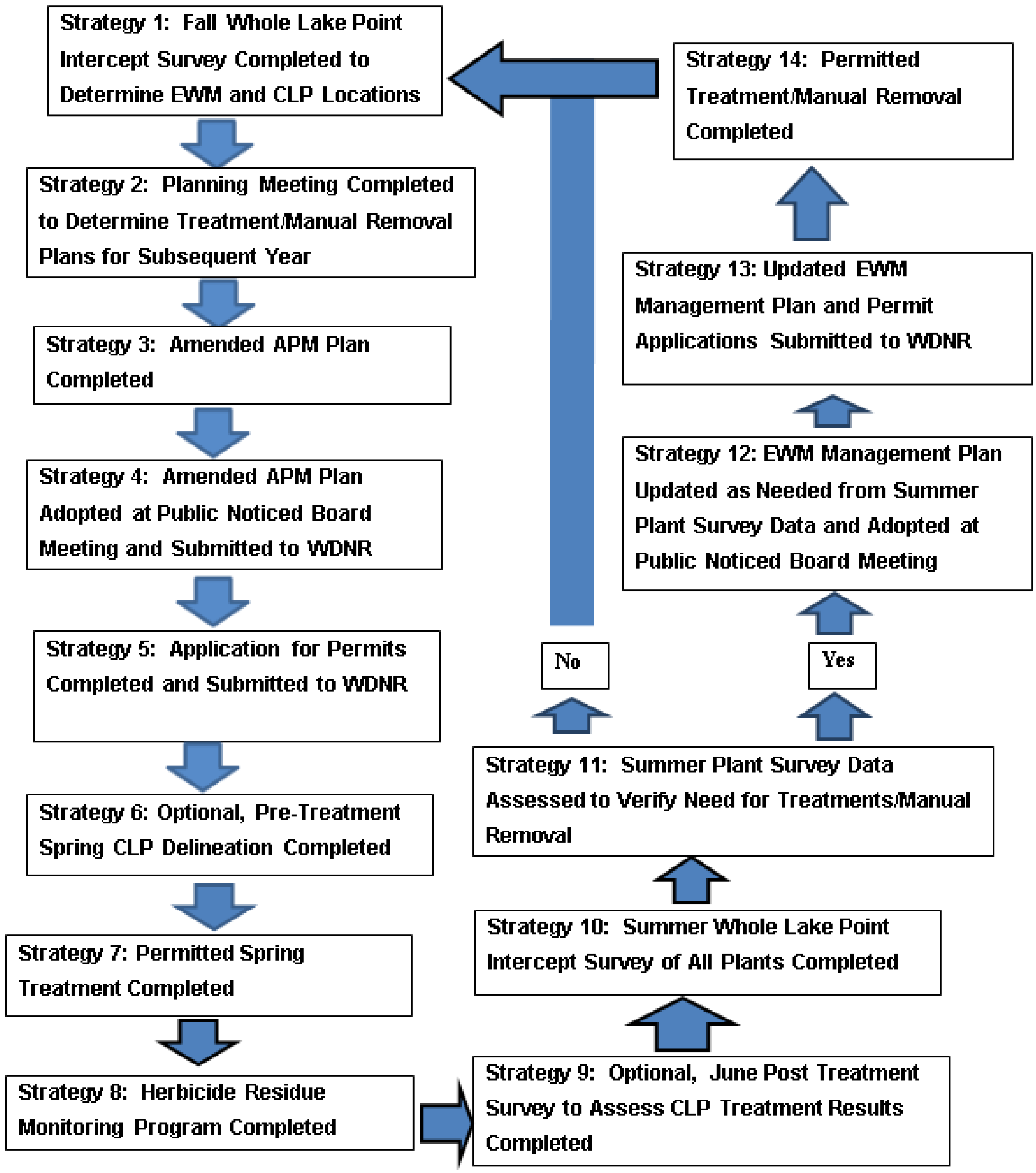


Figure 12-2 7% EWM and CLP Strategies for Beaver Dam Lake

12.1.1 7% EWM Strategies 2 and 12: Treatment/Manual Removal Plans

The following paragraphs detail the approach and strategies to create treatment/manual removal plans (Strategies 2 and 12 of Figure 12-2 to attain the 7 percent EWM goal.

Beaver Dam Lake is a complex system. The lake is divided into two separate basins, East Lake and West Lake, separated by U.S. 63. Each basin is further subdivided into four sub basins or bays. Each of the eight sub basins or bays in Beaver Dam Lake is managed as if it were a separate lake. This approach insures that the unique characteristics of each sub basin or bay area are considered when selecting a treatment/manual removal plan to manage EWM. The approach also considers the unique plant community within each sub basin or bay area. Finally, the approach assesses the impacts of treatment/manual removal within each sub basin or bay area on EWM as well as the native species. Treatment/manual removal results and the response of the native plant community within each treatment area are used to plan the subsequent year's treatment. The lake's eight sub basins/bays are shown in Figure 1-2.

The EWM management plans for Beaver Dam Lake use either herbicide treatment or manual removal to manage EWM. When herbicide treatment is used, herbicide, dose, and application methods within each treatment area are selected to attain EWM control per past experience with EWM herbicide treatments of Beaver Dam Lake and the latest research studies. The herbicide most frequently used for treatments during 2000 through 2018 was 2,4-D. In 2017 through 2018, diquat was successfully used for spot treatments of a few areas. In 2019, four herbicides will be used for treatment of EWM – 2,4-D, diquat, Aquastrike, and ProcellaCOR. Additional EWM management options may be available in the future. The District will select the best available management techniques to effectively manage EWM in Beaver Dam Lake.

In 2015, the EWM management program was expanded to include manual removal of EWM in summer. In 2015, manual removal of EWM occurred in Norwegian Bay, Cemetery Bay, and Library Lake during late July and in Library Lake and Norwegian Bay in late August. In 2016, manual removal of EWM occurred in Rabbit Island Bay, the channel between Rabbit Island Bay and Library Lake, Cemetery Bay, City Bay, and Norwegian Bay during late August. In 2017, manual removal of EWM occurred in Library Lake during July. In 2018, a manual removal of EWM occurred in the west canal of Rabbit Island Bay in July. Beginning in 2019, Diver Assisted Suction Harvesting (DASH) will be used for removal of EWM at 4.46 acres while either DASH or rake removal of EWM will occur at an additional 4.13 acres. Any EWM documented by the July plant survey that is suitable for manual removal will be removed by DASH whenever feasible and by rake removal whenever DASH is not appropriate.

The 2018 herbicide treatment reduced EWM to the lowest extent to date—3 percent of the littoral area. However, EWM management in all basins infested with EWM is expected to continue annually provided WDNR permits the management activities. The District will use the best available management techniques to manage EWM in the lake. Current management options are herbicide treatment or manual removal. Additional management options could become available in the future.

12.1.2 7% CLP Strategy 2: Spring Treatment Plan

The following paragraphs detail the approach and strategies to create a spring treatment plan (Strategy 2 of Figure 12-2) to continue attainment of the 7 percent CLP goal whenever plant survey data indicate treatment is needed.

CLP in Beaver Dam Lake occupies less than 7 percent of the lake's littoral zone and seems to be a latent problem. The management goal for CLP is to contain it to a low occurrence (i.e., less than 7 percent of the littoral zone). Periodic treatments of CLP will occur to not only contain CLP, but to prevent accumulation of turions. Turions are CLP winter buds that act like seeds. Each CLP plant can produce up to 900 turions annually and each turion can grow into a new CLP plant. The turions can remain viable for several years. Controlling CLP with early spring treatment not only removes CLP plants from the lake, but also prevents the plants from producing turions. This approach prevents CLP dominance and the subsequent required long-term annual control to hold the plant back from a resurgence to dominance. It appears that many aquatic invasive species, including CLP, may languish at a low level until a favorable environmental circumstance happens that allows it to expand rapidly. This seems to fit the theoretical concept that an organism can make itself established and then only needs the right trigger to expand into a problem. Consistent management of CLP to contain it to the low levels in the lake will prevent its rapid expansion to problematic conditions.

The management of CLP in Beaver Dam Lake is intended to avoid the CLP expansion that occurred in Kohlman Lake, located in Maplewood, Minnesota. A whole lake point intercept survey in June of 2001 indicated CLP was present at 1.5 percent of sample locations (Barr, 2008b). Unmanaged, CLP rapidly expanded during 2002 through 2006 and was found at 73 percent of sample locations during June of 2006 (Barr, 2008b). Large scale treatment to control CLP during 2008 through 2011 reduced CLP to 3 percent of sample locations (Barr, 2012b). Although no treatment occurred in 2012, a spot treatment occurred in 2013 and CLP was not observed after the treatment. The large number of turions deposited during the years in which CLP was unmanaged and allowed to expand annually replenished CLP in Kohlman Lake and, hence, caused the presence of CLP in the lake during the 2008 through 2013 treatment period. The Beaver Dam Lake Management District recognizes that the small investment to control CLP while it is at low levels will avoid the larger investment required to control a large scale infestation resulting from a rapid expansion of CLP. Hence, the District strategy for CLP management is to consistently manage CLP when needed to prevent rapid expansion to problematic conditions.

CLP presence in the lake is currently monitored annually in fall (October). Because CLP begins its annual growing cycle in late summer, it is present in fall when the District conducts the annual EWM survey to determine spring management program. Although the District recognizes that CLP is at its peak growth stage in June, monitoring CLP during the fall EWM plant survey is a cost effective means of monitoring changes in CLP coverage. Monitoring results detect CLP expansion and, hence, indicate when CLP treatment may be warranted. If a rapid expansion or problematic changes in CLP growth are detected in the fall survey, a CLP survey will be completed during the following June to define CLP coverage when CLP is at its peak growth stage. June CLP coverage would determine whether or not treatment during the following spring is necessary.

Whenever problematic CLP growths are identified, a June survey to define the CLP problem will occur and a CLP management plan will be prepared based upon survey results whenever management is needed. Manual removal using either DASH or rake removal will occur whenever feasible. Herbicide treatment will occur whenever needed and feasible. The feasibility of herbicide treatment will be based upon the likelihood that treating the areas infested with CLP at the allowed herbicide dose would result in the concentration and contact time needed to attain control of CLP in the treatment area. Whenever herbicide treatment is warranted and control is likely to be attained, herbicide treatment will occur. Herbicide treatment will not occur whenever dilution by untreated waters is expected to prevent control of CLP in the treatment areas. When manual removal and/or herbicide treatment is planned, a permit will be obtained from WDNR. Prior to implementation of the permitted CLP management program, a spring survey would be completed to accurately define the boundaries of the management area.

12.1.3 EWM 7% Strategy 11: Fall Treatment

Historically, a fall treatment has been occasionally used to control EWM in selected areas of Beaver Dam Lake when spring treatments were unsuccessful at attaining EWM control. The following paragraphs detail a history of the use of fall treatments to control EWM in Beaver Dam Lake.

12.1.3.1 Beaver Dam Lake Fall Treatment History

Fall treatment was used to control EWM at the Eagle Point boat landing area, the Tourist Park boat landing area, Library Lake, and Norwegian Bay during 2006 through 2010. Details follow.

Eagle Point Boat Landing Area – High Traffic Area and Located Near Deep Basins: The area near the Eagle Point Boat Landing (Figure 6-1) was treated during both spring and fall of 2006 through 2010 because previous treatment efforts were unsuccessful in reducing EWM coverage and density due to high boat traffic and dilution from adjacent deep basins. Treating this area both during spring and fall during 2006 through 2010 reduced the area infested with EWM from 35 acres in 2006 to less than 8 acres in 2011.

Tourist Park Boat Landing Area – High Traffic Area and Treatment Areas Receiving High Flow Volumes: The area near the Tourist Park Boat Landing (Figure 6-1) was treated during both the spring and fall of 2008 through 2009 because previous treatment efforts were unsuccessful in reducing EWM coverage due to high boat traffic and dilution from flow from West Lake to East Lake through this area. Treating this area both during spring and fall during 2008 and 2009 reduced the area infested with EWM from 10.7 acres in 2008 to 0 acres (not present) in the fall of 2009. However, EWM has subsequently been observed in this area and spring treatments have occurred as needed.

Library Lake – Nearing Complete Control of EWM: Library Lake (Figure 1-2) was treated during the spring and fall of 2009 as well as the spring of 2010 and 2011. The fall treatment of 2009 occurred because nearly complete control of EWM had been attained by the spring treatment. The fall treatment was intended to expedite the process of attaining complete control of EWM. As shown in Table 7-4, the area of Library Lake infested with EWM decreased from 3.6 acres in the fall of 2008 to 0.4 acres after treatment in the spring of 2009. The fall 2009 treatment further reduced the area infested with EWM to 0.1 acres. The spring treatment in 2010 again reduced the area infested with EWM to 0.04 acres.

Treatment in the spring of 2011 attained control of EWM and it was not observed in Library Lake during the 2011 summer and fall plant surveys. Hence, Library Lake was not treated during 2012. However, low levels of EWM have subsequently been observed in the lake and spring treatments occurred in 2013, 2014, and 2016. A spring herbicide treatment is planned for 2019.

Norwegian Bay – High Traffic Area and Treatment Areas Receiving High Flow Volumes:
Norwegian Bay was treated during spring and fall of 2010 as well as spring of 2011. Challenges to controlling EWM in Norwegian Bay include a high traffic area near a boat landing and high flow from a 10,064-acre drainage area that is conveyed to Norwegian Bay via a drainage ditch. Treating this area both during spring and fall of 2010 reduced the area infested with EWM from 28 acres in fall of 2009 to 12 acres during summer of 2010 to 10 acres during fall of 2010. Spring treatment during 2011 further reduced the area in Norwegian Bay infested with EWM to 2 acres. Unfortunately, a rapid expansion of EWM increased the infested area by an order of magnitude to 20 acres by the fall of 2011. Because of the rapid expansion of EWM, the District applied for a fall treatment permit. However, a treatment permit was not issued by WDNR for a fall 2011 treatment and no treatment occurred. Since 2011, multiple spring treatments have reduced EWM extent to very low levels (e.g., 0.65 acres in fall of 2018). In the future, spring herbicide treatments or manual removal will occur as needed.

12.1.3.2 Fall Treatment Plan

During October of 2012, WDNR staff conveyed a change in WDNR policy relative to fall treatments. Although treatment in both spring and fall had been allowed for permitted areas in the past, only one herbicide treatment per year will be allowed in the future for each of the eight treatment zones within Beaver Dam Lake (Kevin Gauthier, 2012). The District may choose to treat either in the spring or in the fall, but not both. Because control of EWM in spring is challenging in areas receiving a large volume of flow from snowmelt runoff, a fall treatment may be preferable for some areas of the lake when a high volume of flow in spring dilutes herbicide concentrations to the point that treatment effectiveness is compromised. In general, flow is lower in fall and, hence, the risk of compromised treatment effectiveness due to dilution from inflowing waters is lower in fall. The District will annually evaluate spring treatment results following the summer and fall plant surveys and determine whether spring or fall treatment is the best option to control EWM in each area. If fall treatment is selected for a treatment area for the subsequent year, then no spring treatment will occur in that area. The treatment plans for the subsequent year, both spring and fall, will be prepared following completion of the fall plant survey. However, the fall treatment plan may be updated following the summer plant survey. If updated, the updated version of the fall treatment plan will be submitted to the WDNR for review and approval.

12.1.3.3 Evaluation of Fall Treatment Results

Following each fall treatment, the treatment results would be evaluated to determine whether the EWM infestation was reduced by the fall treatment. As shown in Figure 12-2, a whole lake point intercept survey of EWM and CLP occurs annually in the fall. The survey occurs about a month after a fall treatment would occur, and hence, would document the results of a fall treatment. Fall survey EWM results would be compared with summer EWM results to determine whether or not fall treatment reduced the area and/or frequency of EWM in treated areas. Fall treatment success would be defined as a reduction in frequency and/or area of EWM infestation in treated areas. Fall treatments would continue as deemed necessary as long as the program results in success defined as a reduction in the area and/or frequency of EWM in the treated areas.

12.1.4 Implementation of EWM and CLP Management Strategies

Implementation of the EWM and CLP Management Plan and management strategies are illustrated in the 2012 through 2019 EWM management plans found in Appendix J.

Annual EWM management is expected to occur as long as EWM is documented to be present in Beaver Dam Lake. Although the geographic locations of the EWM management areas and the method of EWM management used on the areas (herbicide treatment or manual removal) will vary annually, the future annual management plans will follow the format of the 2012 through 2019 EWM management plans. Each annual management plan is based upon the results of the preceding fall plant survey to determine EWM locations. Each plan divides the lake into the eight management areas shown on Figure 1-2 and shows specifics of EWM management within each area. When herbicide treatment is used, the type of herbicide and dose applied to each treatment polygon to control EWM is shown on the treatment map and described in the plans. When the treated area is large enough to attain a lake-wide impact, the expected "whole lake" concentration for each treated bay or basin is shown in the plan. When EWM is not observed in a bay/basin during the fall invasive species survey, no management will occur during the subsequent year. When EWM areas are small, manual removal or spot treatment with herbicide will be used to manage EWM.

The 2012 through 2019 EWM management plans detail the monitoring program used to assess management effectiveness and native plant response to annual management. Maps of management locations and a detailed description of the herbicide residue and plant surveys are detailed in the plans (Appendix J).

CLP management will occur as needed and, hence, may not occur every year. Whenever management is needed, manual removal will be used for CLP removal whenever feasible. When manual removal is not feasible, herbicide treatment will be used for CLP management. Although CLP management plans will vary, the future plans will follow the format of the 2013 CLP treatment plan whenever herbicide treatment is required. Each treatment plan is based upon the results of a spring pre-treatment survey. Each plan shows the treatment polygons within each treatment area, the herbicide and dose applied to each treatment polygon is shown on the plan. When the treated area is large enough to attain a lake-wide impact, the expected whole bay concentration following treatment is shown in the plan.

Beginning in 2015 the BDLMD began AIS surveillance of Beaver Dam Lake to assess locations and extent of EWM and CLP in the lake. During 2015, the BDLMD solicited and trained volunteers at a workshop conducted by Endangered Resource Services, LLC. In the future, volunteers intend to provide AIS surveillance of a particular stretch of Beaver Dam Lake shoreline (e.g., shoreline adjacent to volunteer's home) monthly during May through October. Volunteers intend to monitor for EWM during May through October and curly-leaf pondweed (CLP) during May through June. Volunteers intend to submit CLMN surveillance data to the Surface Water Integrated Monitoring System (SWIMS) database to document their AIS monitoring activity.

12.2 Goal 2: Unimpaired Navigation Channels

Goal 2: ***Maintain navigation channels that are not impaired by native plants and invasive plant growth.***

Objectives: *(1) Protect the lake's ability to support recreational uses such as boating, pontooning, and fishing; (2) Provide riparian owners with the ability to access the lake with their boats and pontoons.*

Table 12-2 Goal 2 Strategies and Measurements

Strategies	Measurements	
	Yes	No
Strategy 1: Navigation channels inspected annually during July by selected contractor and any impairment by plants documented		
Strategy 2: Impaired access corridors reported as impaired by riparian residents inspected annually in July by selected contractor and any impairment by plants documented		
Strategy 3: Permit application to treat impaired navigation channels and/or impaired access corridors completed by selected herbicide applicator and submitted to WDNR. Documentation of impairment submitted with permit application.		
Strategy 4: Permitted treatment completed		
Strategy 5: Whole lake point intercept summer survey completed and data assessed to evaluate plant community in treated areas		
Strategy 6: Treated navigation channel and access corridor areas mapped		
Strategy 7: Amended APM Plan completed and any needed changes to the unimpaired navigation channel program included		
Strategy 8: Amended APM Plan adopted at a public noticed Board meeting and submitted to WDNR		

The District understands the risk of AIS spread to navigation channels cleared by herbicide treatment. However, navigation channel treatment is sometimes necessary when plant growth prevents navigation in common navigation channels or prevents riparian access to the lake. One long-time Norwegian Bay resident indicated he had been unable to access the lake for several years due to dense vegetation. Navigation channel treatment in this APM Plan follows WDNR policy detailed in *Aquatic Plant Management Strategy Northern Region WDNR* (WDNR, 2007). When navigation channels impaired by plants are identified, the impairment will be documented as required by WDNR policy. Documentation of impairment of navigation will include:

a. Specific locations of navigation routes (preferably with GPS coordinates)

b. Specific dimensions in length, width, and depth

c. Specific times when plants cause problems and how long the problem persists

d. Adaptations or alternatives that have been considered by the lake shore user to avoid or lessen the problem.

e. The species of plant or plants creating the nuisance (documented with samples or from a Site inspection) (WDNR, 2007).

A resident of Norwegian Bay, pictured above, was unable to access the lake for several years due to impairment by dense vegetation. This APM Plan includes inspection of access corridors and navigation channels during the summer to identify impairment that meets WDNR policy for treatment. Photo Credit: Endangered Resource Services, LLC.

Documentation of nuisance conditions will include:

a. Specific periods of time when plants cause the problem (e.g., when does the problem start and when does it go away).

b. Photos of the nuisance are encouraged to help show what uses are limited and to show the severity of the problem.

c. Examples of specific activities that would normally be done when native plants occur naturally on a site but cannot occur because native plants have become a nuisance (WDNR, 2007).

The Beaver Dam Lake Management District will work with WDNR as needed to obtain treatment permits to attain Goal 2, unimpaired navigation channels. Each navigation channel and riparian corridor treatment area will be mapped annually and tracked for need of treatment in subsequent years. After a couple of years of documentation, these areas could be considered as planned annual treatments and may not need documentation.

The navigation channel and riparian corridor management strategies for Beaver Dam Lake are shown in Figure 12-3.

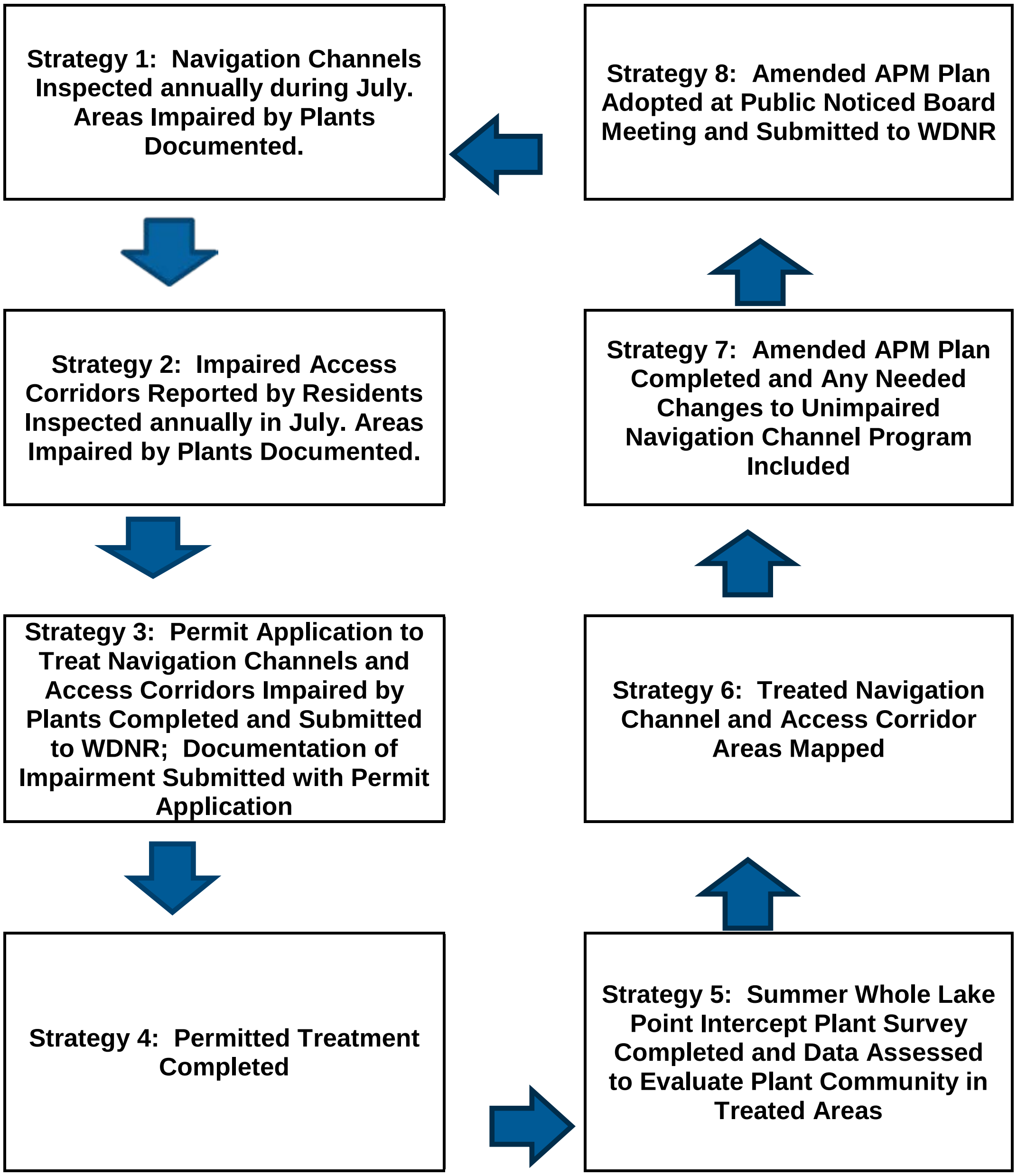


Figure 12-3 Unimpaired Navigation Channel Strategies for Beaver Dam Lake

12.3 Goal 3: No AIS In or Out of Lake

Goal 3: Prevent transfer of invasive plant and animal species both to and from Beaver Dam Lake.

Objectives: *(1) Protect the lake's ability to support recreational activities (2) Protect the lake's fishery (3) Containment of EWM and CLP to prevent the introduction of EWM and CLP to other lakes and prevent introduction of other invasive species to Beaver Dam Lake.*

Table 12-3 Goal 3 Strategies and Measurements

Strategies	Measurements	
	Yes	No
Strategy 1: The City of Cumberland's Clean Boats/Clean Waters boat inspection program fully funded if grant money not available. If grant money available to fund 75 percent of program cost, the 25 percent local cost share funded.		
Strategy 2: Educational material given to each lake user whose boat was inspected by the Clean Boats/Clean Waters program.		
Strategy 3: Sign placed at each boat landing educating boaters to clean boats and trailers of any plant materials before entering and leaving the lake.		
Strategy 4: Each newsletter contained information that educated readers to remove plants and animals from boats before entering or leaving the lake.		

The Clean Boats/Clean Waters program will annually hire four boat monitors to inspect boats entering the lake at three boat landings: (1) Eagle Point, (2) Tourist Park, and (3) City Bay (Figure 6-1). All boats entering and leaving the lake during noon to 8 PM each Friday, Saturday, and Sunday from Memorial Day weekend through Labor Day weekend will be inspected. A total of three boat monitors will work each weekend and the fourth monitor will have the weekend off. The results of the inspections will be recorded on forms provided by the WDNR and the information will then electronically be entered on the DNR on-line data base known as Surface Water Integrated Monitoring System.

Pictured above, a sign placed at a boat landing by the Beaver Dam Lake Management District educates boaters to clean boats and trailers of any plant materials.

The strategies to prevent transfer of invasive plant and animal species both to and from Beaver Dam Lake is shown on Figure 12-4.

The Wisconsin DNR updated Aquatic Invasive Species (AIS) boat landing signs with a new sign (updated in 2010). The Beaver Dam Lake Management District installed the new signs, pictured to the right, at all boat landings.

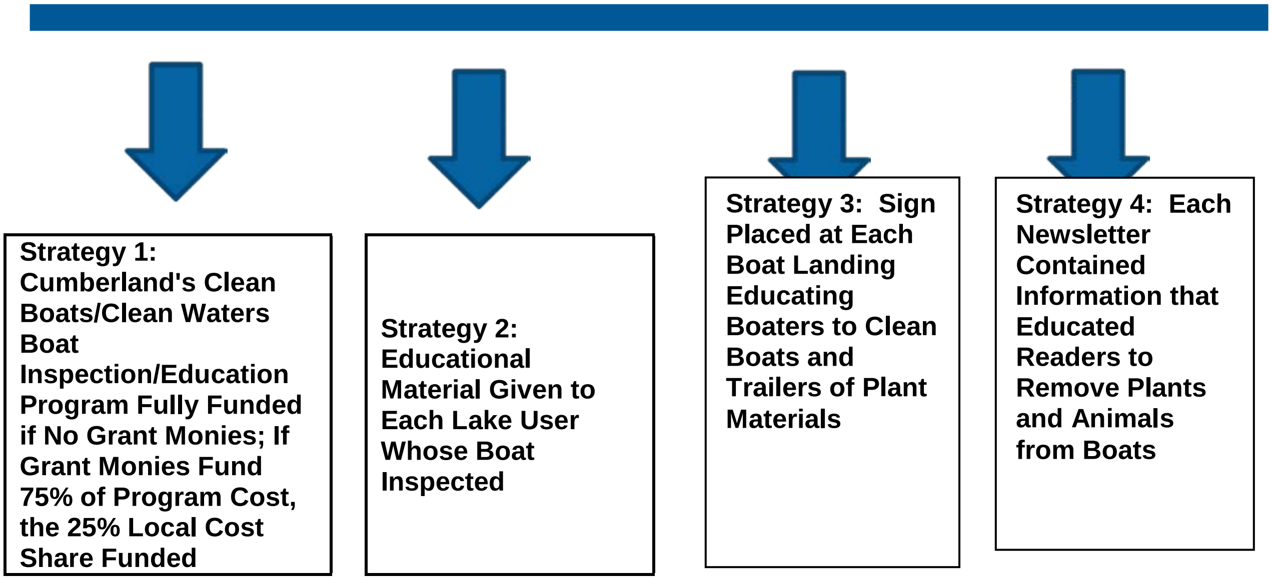


Figure 12-4 No AIS In or Out of Lake Strategies for Beaver Dam Lake

12.4 Goal 4: Improve Fishery

The northern pike, pictured above, was caught in a shallow vegetated area in Beaver Dam Lake. Aquatic plants are important to northern pike because they provide cover for young northern pike and their prey. Photo Credit: www.lake-link.com/lakes/lake.cfm?LakeID=128

Goal 4: Improve Fishery

Objectives*:* *(1) Improve fishery habitat through the reduction of EWM and CLP to 7 percent of the littoral area; (2) Protect fishery habitat by minimizing harm to the native plant community during the treatment of EWM and CLP; (3) Protect plants found in critical habitat areas of the lake because these plants are important to the lake's fishery; (4) Improve the fishery resource by controlling rainbow smelt, an invasive species, through the stocking of extended growth walleyes.*

Table 12-4 Goal 4 Strategies and Measurements

Strategies	Measurements	
	Yes	No
Strategy 1: Herbicide treatment of invasive species completed during spring or fall when native plants are seasonally suppressed.		
Strategy 2: Summer whole lake point intercept survey completed and data assessed to determine treatment effectiveness and native plant response to treatment.		
Strategy 3: When WDNR has completed the proposed critical habitat areas designation for Beaver Dam Lake, plant data collected from critical habitat areas during summer whole lake point intercept survey assessed to determine the condition of critical habitat areas. A subjective rating system annually tracked the status of critical habitat areas (e.g., "status-stable, improving, loss, threats present, or watch status"). Species involved in changing status noted.		
Strategy 4: Stock extended growth walleye every other year to increase predation on rainbow smelt to improve walleye natural reproduction, stock recruitment, and abundance.		

The strategies to improve fishery are shown on Figure 12-5.

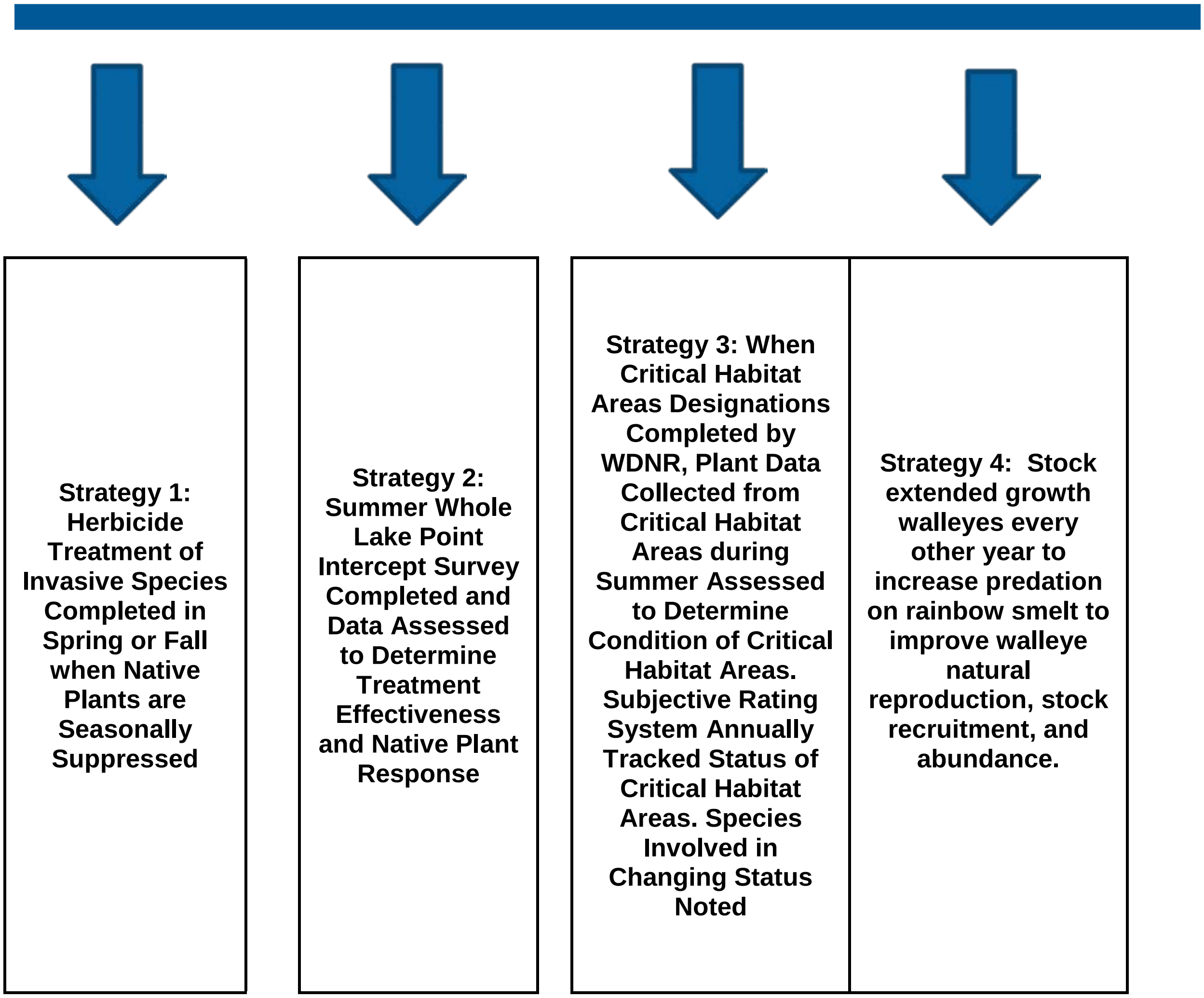


Figure 12-5 Improve Fishery Strategies for Beaver Dam Lake

12.5 Goal 5: Improve Water Quality and Aquatic Plant Community

Goal 5: ***Improve water quality and aquatic plant community through management of stormwater and riparian shoreline areas.***

Objectives*: (1) Improve the lake's ability to support recreational uses such as boating, fishing, swimming, and enjoying the view; (2) Improve fisheries and wildlife habitat and the overall health of the lake*

Table 12-5 Goal 5 Strategies and Measurements

Strategies	Measurements	
	Yes	No
Strategy 1: Supported City of Cumberland's efforts to implement the City of Cumberland Stormwater Management Plan		
Strategy 2: Constructed Library Lake wetland treatment cell and implemented additional stormwater treatment measures recommended in Library Lake Management Plan if funding became available		
Strategy 3: Provided information to help riparian residents voluntarily establish buffer areas.		

The District conducted a shoreline assessment of Beaver Dam Lake during September of 2012 to document the current status of the shoreline of Beaver Dam Lake (Evenson, 2012). The results of the survey will be used to aid the District in its education program to help riparian residents voluntarily establish buffer areas.

To support the efforts of residents to voluntarily establish shoreline buffers, the District has helped fund workshops to train area landscapers to install rainwater gardens and complete shoreline stabilization projects. The workshops were held at the UW campus in Rice Lake, WI on March 27 and April 17, 2012. Workshop topics included shoreline buffers, runoff mitigation, and shoreline stabilization.

The strategies to improve water quality and the aquatic plant community are shown on Figure 12-6.

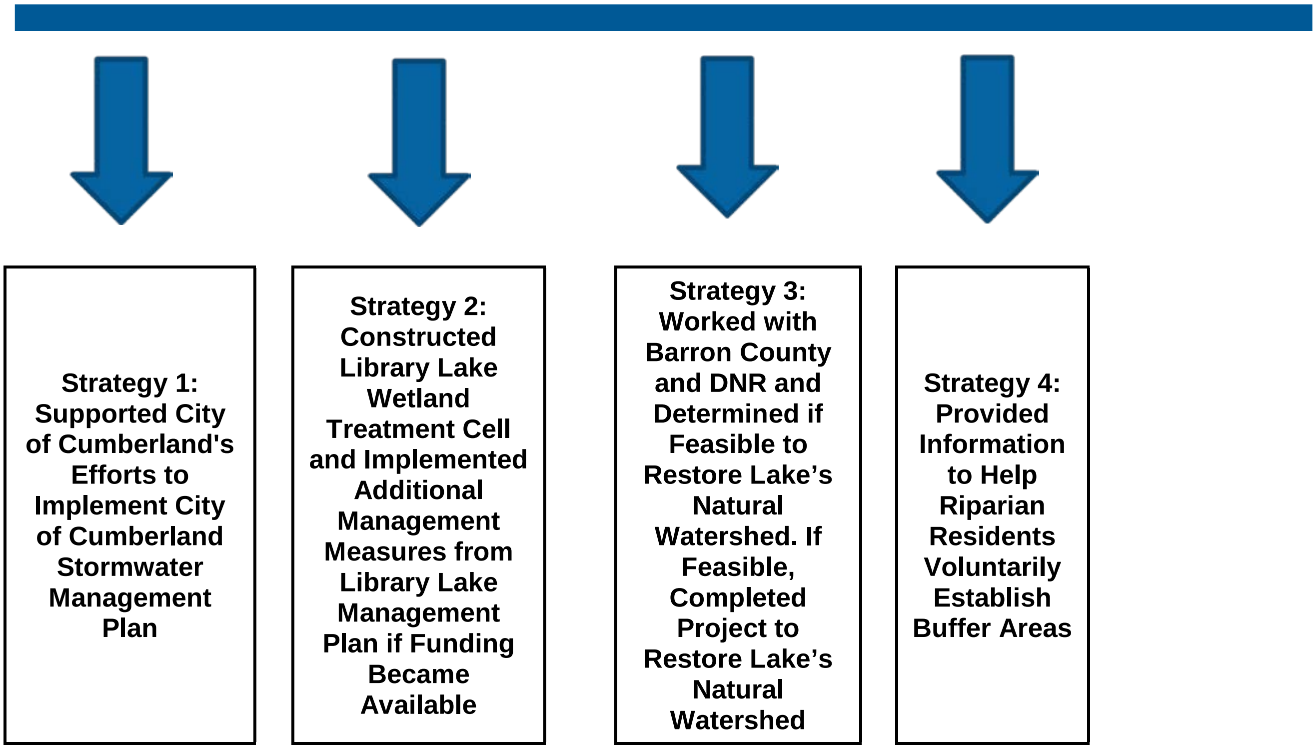


Figure 12-6 Improve Water Quality and Aquatic Plant Community Strategies for Beaver Dam Lake

12.6 Goal 6: Education

Goal 6: ***Provide stewardship educational materials to help area residents manage riparian land and water areas and educate the Public about progress on goals and strategies of the Beaver Dam Lake Management District.***

Objectives: *(1) Help residents protect the attributes of the lake they most enjoy; (2) Help residents protect fish and wildlife habitat and the overall health of the lake; (3) Keep the public informed about progress on attaining District goals and strategies.*

Table 12-6 Goal 6 Strategies and Measurements

Strategies	Measurements	
	Yes	No
Strategy 1: Provided education materials and reported progress on attaining District goals and strategies at annual meeting		
Strategy 2: Provided education materials and reported progress on attaining District goals and strategies in District newsletters and on District website		
Strategy 3: Used other media to provide education materials and report progress on attaining District goals and strategies		
Strategy 4: Provided education materials and reported progress on attaining District goals and strategies in amended APM Plan		

The program is a continuation of past District efforts to assist riparian owners in the important work of caring for the natural plant and animal community in the near shore and shoreline areas of the lake. District newsletters showing examples of past stewardship education are found in Appendix K.

In 2015, the District solicited volunteers to assist with hand-pulling EWM in Library Lake. The District has participated in a WDNR media campaign – "Protect WI Waters/It's the Law". Participation has included publishing articles in the local newspaper to inform the public of Beaver Dam Lake AIS management activities and other information about AIS and soliciting volunteers to participate in AIS surveillance and EWM hand-pulling. Other possible future activities include informing the public of AIS laws that protect WI waters and encouraging lake users to do their part to protect the lake from AIS.

The education strategies are shown on Figure 12-7.

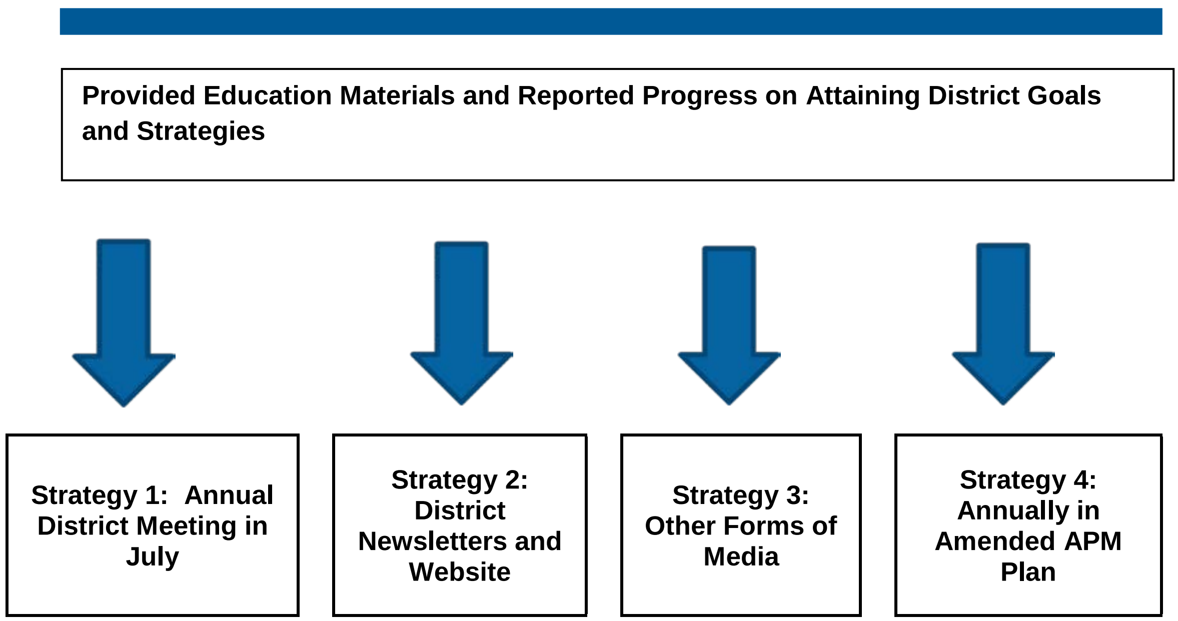


Figure 12-7 Education Strategies for Beaver Dam Lake

13.0 Annually Amended APM Plan

The Beaver Dam Lake Management District intends to continue AIS management in Beaver Dam Lake indefinitely. This APM Plan is not limited to a 5-year period. Up to this point, the District has funded all elements of the APM Plan implementation as needed, and intends to continue funding the implementation of the plan whenever grant money is not available. This APM Plan describes a framework for annual AIS control activities that include the required elements of an APM Plan. Those elements of an APM Plan that involve annual management activities are updated annually. Remaining elements that may remain relatively unchanged, such as watershed information, will be reviewed for new information and updated when new information becomes available. Herbicide treatment (and all attendant monitoring) is a critical element to be reviewed annually and will be used to plan and apply for each annual NR 107 permit. Updated as it is each year, the APM Plan fulfills the need of a long-term commitment to AIS management. Updated annually, it will include new technical developments for control of AIS. The annually amended APM Plan will be adopted at a public noticed Board meeting and then submitted to the WDNR. Table 13-1 compares the APM Plan elements with the elements that are updated annually.

Table 13-1 Comparison of Elements in an Aquatic Plant Management Plan with Elements Updated Annually

Aquatic Plant Management Plan Elements*	Updated Annually
Public Input	**
Water Quality Studies	**
Clean Boats/Clean Waters Boat Inspection Program	X
Invasive Species (Purple Loosestrife, CLP, and EWM)	X
Native Plant Community	X
Define Problem	X
Goals and Objectives	**
Aquatic Plant Management Plan	X
Lake and Watershed Information	**
Watershed Management	**
Shoreline, Fishery, and Wildlife Management	**

*Update required every 5 years
**Review for new information and update when new information becomes available

14.0 Potential Adverse Impacts on Non-Targeted Species

The aquatic plant management project detailed in this APM Plan involves herbicide treatment or manual removal of aquatic invasive species (EWM and CLP) as well as treatment of navigation channels and/or riparian corridors to support boating use of the lake whenever needed. The AIS management program is a continuation of a long-term management program. It is acknowledged that non-target species may be unintentionally harmed during the herbicide treatment of invasive species. However, long-term data collection of the ongoing invasive species treatment program has documented that the treatment program has resulted in a consistent decline of invasive species. The plant data indicate the treatment has benefited the ecosystem by reducing frequency and extent of invasive species.

A comparison of fishery data prior to herbicide treatment (1993 through 1994) and after several years of herbicide treatment (2006 through 2007 and 2013) documented that no adverse impact to the fishery has been documented from the treatment (Cole, 2015). The data indicate the treatment program proposed in the APM Plan is not expected to cause adverse impacts to the fishery.

Annual monitoring of the plant community would detect any adverse impacts caused by implementation of the APM Plan. This APM Plan will be updated annually. Hence, should any adverse impact be detected, the APM Plan has the flexibility to be changed annually to address the issue and prevent additional adverse impacts from occurring.

15.0 References

Aiken, S.G., P.R. Newroth, and I. Wile. 1979. "The Biology of Canadian Weeds. 34. *Myriophyllum spicatum* L." *Canadian Journal of Plant Science*. 59: 201-215.

Barr Engineering Co. 1994. *Trego Flowage Survey and Macrophyte Management Plan.* Prepared for NSP as Directed by Article 405 of its FERC Operating License for the Trego Hydro Project (FERC No. 2711). 34 p.

Barr Engineering Co. 1997. *Big Lake Macrophyte Survey and Management Plan.* Prepared for Church Pine, Round, and Big Lake Protection and Rehabilitation District. 53 p.

Barr Engineering Co. 2000. *Beaver Dam Lake (East and West) Macrophyte Surveys and Management Plan.* Prepared for Beaver Dam Lake Management District. 99 pp.

Barr Engineering Co. 2006. *Beaver Dam Lake Aquatic Plant Survey and Management Plan*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2007a. *2006 Beaver Dam Lake Report and Amended Aquatic Plant Management Plan*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2007b. *2007 Beaver Dam Lake Report and Amended Aquatic Plant Management Plan*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2008a. *2007 Beaver Dam Lake Water Quality Study*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2008b. *Kohlman Lake Aquatic Plant Management Plan*. Prepared for Ramsey-Washington Metro Watershed District.

Barr Engineering Co. 2009a. 2*008 Beaver Dam Lake Report and Amended Aquatic Plant Management Plan*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2009b. *2008 Kohlman Lake Aquatic Plant Management*. Prepared for Ramsey Washington Metro Watershed District.

Barr Engineering Co. 2010a. *2009 Beaver Dam Lake Report and Amended Aquatic Plant Management Plan*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2010b. *2009 Kohlman Lake Aquatic Plant Management*. Prepared for Ramsey Washington Metro Watershed District.

Barr Engineering Co. 2011a. *2010 Beaver Dam Lake Report and Amended Aquatic Plant Management Plan*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2011b. Norwegian Bay 2011 Plant Data. Memorandum to the Beaver Dam Lake Management District.

Barr Engineering Co. 2011c. Presentation to Beaver Dam Lake Management District Annual Meeting on July 26, 2011.

Barr Engineering Co. 2012a. Presentation to Beaver Dam Lake Management District Planning Meeting on January 11, 2012.

Barr Engineering Co. 2012b. *2011 Kohlman Lake Aquatic Plant Management*. Prepared for Ramsey Washington Metro Watershed District.

Barr Engineering Co. 2012c. *2011 Beaver Dam Lake Report*. Prepared for Beaver Dam Lake Management District.

Barr Engineering Co. 2012d. *Beaver Dam Lake Aquatic Plant Management Plan.* Prepared for Beaver Dam Lake Management District in December 2012.

Barr Engineering Co. 2014a. *Beaver Dam Lake Aquatic Plant Management Plan.* Prepared for Beaver Dam Lake Management District in January 2014.

Barr Engineering Co. 2014b. *Beaver Dam Lake Aquatic Plant Management Plan*. Prepared for Beaver Dam Lake Management District in December 2014.

Barr Engineering Co. 2016. *Beaver Dam Lake Aquatic Plant Management Plan*. Prepared for Beaver Dam Lake Management District in January 2016.

Beaver Dam Lake Management District. 2010. Minutes from Special Meeting on October 23, 2010.

Beaver Dam Lake Management District. 2011a. Minutes from Annual Meeting on July 26, 2011.

Beaver Dam Lake Management District. 2011b. Minutes from Board Meeting on August 3, 2011.

Beaver Dam Lake Management District. 2011c. Minutes from Board Meeting on October 26, 2011.

Beaver Dam Lake Management District. 2012a. Minutes from Board Meeting on April 25, 2012.

Beaver Dam Lake Management District. 2012b. Minutes from Public Hearing on May 23, 2012.

Beaver Dam Lake Management District. 2012c. Minutes from Annual Meeting on July 7, 2012.

Bernthal, T.W. *Wetland Monitoring Strategies: One Step at a Time.* Wisconsin Department of Natural Resources. Unpublished Report to EPA.

Bolduan, B.R., G.C. Van Eeckhout, H.W. Quade and J.E. Gannon. 1994. "*Potamogeton crispus* – the other invader." *Lake and Reservoir Management* 10(2):113-125.

Borman, S., R. Korth, and J. Temte. 1997. *Through the Looking Glass ... A Field Guide to Aquatic Plants.* Wisconsin Lakes Partnership, a division of the University of Wisconsin-Extension and the Wisconsin Department of Natural Resources. 248 pp.

Catling, P.M. and I. Dobson. 1985. "The Biology of Canadian Weeds. 69. *Potamogeton crispus L.*" *Canadian Journal of Plant Science* 65:655-668.

Cole, Aaron. 2015. E-mail communication on November 18, 2015.

Cooke, G.E., E.B. Welch, S.A. Peterson and P.R. Newroth. 1993. *Restoration and Management of Lakes and Reservoirs.* Second Edition. Lewis Publishers, Boca Raton. 548 pp.

Couch, R., and E. Nelson. 1985. "*Myriophyllum spicatum* in North America." The Aquatic Plant Management Society, Proceedings of the 1st International Symposium on watermilfoil (*Myriophyllum spicatum*) and related Haloragaceae species, Vicksburg, MS.

Creed, R. P. Jr. and S. P. Sheldon. 1995. "Weevils and Watermilfoil: Did a North American Herbivore Cause the Decline of an Exotic Plant." *Ecological Applications*, 0(0):1-6.

Cunningham, Paul. 2012. Email communication on April 2, 2012 re: status of Beaver Dam Lake Critical Habitat Areas Designation.

Deppe, E.R. and R. C. Lathrop. 1992. *A Comparison of Two Rake Sampling Techniques for Sampling Aquatic Macrophytes*. Research Management Findings, 32:1-4.

Ellitson, Richard A. and Kerry K. Steward. 1972. "The Response of Eurasian Watermilfoil to Various Concentrations and Exposure Periods of 2,4-D." *Hyacinth Control Journal/Journal of Aquatic Plant Management*. 10:38-40.

Emmons & Olivier Resources, Inc. 2010. *City of Cumberland Stormwater Management Plan – Phase 1*. Prepared for the City of Cumberland.

Engel, S. 1985. *Aquatic Community Interactions of Submerged Macrophytes*. Wisconsin Department of Natural Resources Technical Bulletin 156.

Engel, S. 1990. *Ecosystem Responses to Growth and Control of Submerged Macrophytes: A Literature Review*. Technical Bulletin No. 170. Department of Natural Resources, Madison, WI.

Engel, S. 1999. Correspondence/Memorandum: EWM in 1999 and Beyond. Wisconsin Department of Natural Resources.

Evenson, Dave. 2012. Personal Communication.

Gauthier, Kevin. 2012. Personal Communication at Meeting with Beaver Dam Lake Management District Board on October 11, 2012.

Gibbons, M.V. H.L. Gibbons, Jr., and M.D. Sytsma. 1994. *A Citizens Manual for Developing Integrated Aquatic Vegetation Management Plans*. No. 93-93. Washington Department of Ecology. 68 pp.

Gibbons, M.V., H.L. Gibbons, and R.E. Pine. 1987. *An Evaluation of a Floating Mechanical Rototiller for Eurasian Water Milfoil Control*. No. 87-17. Washington Department of Ecology.

Grace, J.B., and R.G. Wetzel. 1978. "The Production Biology of Eurasian Watermilfoil *(Myriophyllum spicatum L.):* A Review." *Journal of Aquatic Plant Management*. 16: 1-11.

Hardie, Keith. 2012. Personal Communication (Phone call on March 12, 2012).

Harmony Environmental and Emmons & Olivier Resources, Inc. 2010. *Library Lake: Lake Management Plan*. Prepared for the Library Lake Committee of the Beaver Dam Lake Management District in Conjunction with the City of Cumberland.

Hartleb, C.F., J.D, Madsen, and C.W. Boylen. 1993. *Environmental Factors Affecting Seed Germination in Myriophyllum spicatum L*. Aquatic Botany 45: 15-25.

Hutchinson, G. E. 1970. "The Ecology of Three Species of *Myriophyllum*." *Limnology and Oceanography*, 15:1-5.

Hutchinson, G.E. 1975. *A Treatise on Limnology, Vol III. Limnological Botany*. John Wiley & Sons, New York. 660 pp.

Jessen, R. and R. Lound. 1962. *An Evaluation of a Survey Technique for Submerged Aquatic Plants*. Game Investigational Report. Minnesota Department of Conversation.

Jester, L.L., M.A. Bozek, and D.R. Helsel. 1999. *Wisconsin Milfoil Weevil Project 1996-1998 Results*. Wisconsin Cooperative Fishery Research Unit, University of Wisconsin-Stevens Point. 27 pp.

Koshere, Frank. 2012. Personal Communication.

Little, E. C. S. 1968. "The Control of Water Weeds." *Weed Res.* 8(2):79-105.

Madsen, J. 1997b. "Seasonal Biomass and Carbohydrate Allocation in a Southern population of Eurasian Watermilfoil." *Journal of Aquatic Plant Management* 35:15-21.

Madsen, J. 2005. Presentation at 2005 Minnesota Department of Natural Resources Annual Aquatic Plant Meeting. Minneapolis, MN

Madsen, J. and D.H. Smith. 1997. "Vegetative Spread of Eurasian Watermilfoil Colonies." *Journal of Aquatic Plant Management* 35: 63-68.

Madsen, J. D., G. O. Dick, D. Honnell, J. Shearer, and R. M. Smart. 1994. *Ecological Assessment of Kirk Pond*. Miscellaneous Paper A-94-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Madsen, J.D. 1997a. "Method for Management of Nonindigenous Aquatic Plants." Chapter 12. *Assessment and Management of Plant Invasion.* J.O. Luken and J.W. Thieret, Ed., Springer, Hew York, 145-171.

Madsen, J.D. and J. A. Bloomfield. 1992. *Aquatic Vegetation Monitoring and Assessment Protocol Manual*. A report to the Finger Lakes Water Resources Board. 27 p.

Madsen, J.D., J.W. Sutherland, J.A. Bloomfield, L.W. Eichler, and C.W. Boylen. 1991. "The Decline of Native Vegetation Under Dense Eurasian Watermilfoil Canopies." *Journal of Aquatic Plant Management* 29: 94-99.

Marshall, D. 1990. *Managing Deep Water Stands of Eurasian Watermilfoil to Improve Fish Habitat and Boating Access: Small-scale Aquatic Plant Harvesting Demonstration*. Wisconsin Department of Natural Resources. Madison Area Office, Fitchburg. 7 pp.

Maxnuk, M. 1979. *Studies on Aquatic Macrophytes. Part XXII. Evaluation of Rotovating and Diver Dredging for Aquatic Weed Control in the Okanagan Valley*. Water Investigations Branch Rep. No. 2823, British Columbia Ministry of Environment.

Michels, Jay. 2011. Presentation at the Beaver Dam Lake Management District Annual Meeting on July 9, 2011.

Minnesota Department of Natural Resources. 1994. *A Guide to Aquatic Plants Identification and Management*. 52p.

Morgan, Kevin. 2012. *Wildlife on Beaver Dam Lake, City of Cumberland, Barron County, Wisconsin* DNR. Provided to the Beaver Dam Lake Management District by email on February 13, 2012.

Newman, R. M. and D. W. Ragsdale. 1995. *Evaluation of Biological Control Agents for Eurasian Watermilfoil: Final Report* submitted as deliverable D.2.6/D.2.7 prepared for Minnesota Department of Natural Resources.

Newman, R.M. 1999. *The Milfoil Weevil (Euhrychiopsis lecontei)*. Website @ http://www.fw.umn.edu/research/milfoil/milfoilbc/weevil.html

Newman, R.M. 2009. *Assessment of the Effects of Lake Drawdown on Curlyleaf Pondweed Turion Density and Viability.* Prepared for the Nine Mile Creek Watershed District. 7 pages.

Nichols, S.A. 1999. "Floristic Quality Assessment of Wisconsin Lake Plant Communities with Example Applications." *Journal of Lake and Reservoir Management* 15 (2): 133-141.

Nichols, S.A. and B.H. Shaw. 1986. "Ecological life histories of the three aquatic nuisance plants, *Myriophyllum spicatum,* Potamogeton crispus and Elodea canadensis." *Hydrobiologia* 131:3-21.

Patten, B.C., Jr. 1954. "The Status of Some American Species of *Myriophyllum* as Revealed by the Discovery of Intergrade Material Between *M. exalbescens Fern.* and *M. spicatum L* in New Jersey". *Rhodora*. 56:213-225.

Patten, B.C., Jr. 1955. "Germination of the Seed of *Myriophyllum spicatum L*." *Bulletin of the Torrey Botanical Club.* 82:50-56.

Patten. B.C., Jr. 1956. "Notes on the Biology of *Myriophyllum spicatum L*. in a New Jersey Lake." *Bulletin of the Torrey Botanical Club*. 83:5-18.

Perkins, M.A. and M.D. Sytsma. 1987. "Harvesting and Carbohydrate Accumulation in Eurasian Watermilfoil." *Journal of Aquatic Plant Management.* 25: 57-62.

Reed, C. F. 1977. "History and Distribution of Eurasian Watermilfoil in United States and Canada." *Phytologia* 36: 417-436.

Sales, M. 1997. *Tiny Weevil Shows Big Potential to Control Eurasian Watermilfoil*. Minnesota Sea Grant Seiche. 4pp.

Short Elliott Hendrickson, Inc. 1995. *Beaver Dam Lake Improvement and Protection Project 1994 Report.* Prepared for the Beaver Dam Lake Management District, Barron County Wisconsin. SHE No. A-Beave9402.00 67pp.

Short Elliott Hendrickson, Inc. 2006. *The City of Cumberland Comprehensive Plan.* Prepared for the City of Cumberland.

Simpson, W. 1949. "Measurement of Diversity." *Nature* 163:688.

Smart, R. M., R. D. Doyle, J. D. Madsen, and G. O. Dick. 1996. *Establishing Native Submersed Aquatic Plant Communities in Southern Reservoirs*. Technical Report A-96-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Smith, C.S., and J.W. Barko. 1990. "Ecology of Eurasian Watermilfoil." *Journal of Aquatic Plant Management*. 28: 55-64.

Smith, Ted R. 1990. *Water Quality Assessment – Beaver Dam Lake Diversion*. Wisconsin Department of Natural Resources Water Resources Management Unit – Spooner.

Solarz, S.L. and R.M. Newman. 1996. "Oviposition Specificity and Behavior of the Watermilfoil Specialist *Euhrychiopsis lecontei*." *Oecologia*. 106: 337-344.

Standifer N.E. and J.D. Madsen. 1997. "The Effect of Drying Period on the Germination of Eurasian Watermilfoil Seeds." *Journal of Aquatic Plant Management.* 35:35-36.

Stanley, R.A. 1976. "Response of Eurasian Watermilfoil to Subfreezing Temperature." *Journal of Aquatic Plant Management* 14: 36-39.

U.S. Forest Service Pacific Island Ecosystems at Risk (PIER). 2012. Potamogeton crispus L. Potamogetonaceae. Retrieved February 13, 2012 from: http://www.hear.org/Pier/species/Potamogeton_crispus.htm

UW Extension Lakes. Aquatic Plant Management in Wisconsin. Retrieved on February 17, 2012 from: http://www4.uwsp.edu/cnr/uwexlakes/ecology/APMguide.asp

Wehrmeister, John R. and Ronald L. Stuckey. 1992. "Life History of Potamogeton Crispus." *The Michigan Botanist.* 31:3-16

Wisconsin Department of Natural Resources. 2012a. "1992-2011 Beaver Dam Lake Data" from WDNR Citizen Monitoring Network. http://dnr.wi.gov/lakes/CLMN/Station.aspx?id=033131

Wisconsin Department of Natural Resources. 2012b. Aquatic Plant Curly-leaf Pondweed. Retrieved on February 13, 2012 from: http://dnr.wi.gov/topic/Invasives/documents/classification/Potamogeton%20crispus.pdf

Wisconsin Department of Natural Resources. 2012c. Aquatic Plant Eurasian Watermilfoil. Retrieved on February 13, 2012 from: http://dnr.wi.gov/topic/Invasives/documents/classification/Myriophyllum%20spicatum.pdf

Wisconsin Department of Natural Resources. 2012d. Eurasian Watermilfoil – Beaver Dam Lake. http://dnr.wi.gov/lakes/invasives/AISDetail.aspx?roiseq=1228

Wisconsin Department of Natural Resources. 2013. APM Plan Approval Letter to Dave Evenson, Beaver Dam Lake Management District from Alex Smith, WDNR Lake Biologist

Wisconsin Legislature. 1989. Chapter NR 107 Aquatic Plant Management. Retrieved on April 2, 2012 from https://docs.legis.wisconsin.gov/code/admin_code/nr/107/05/3/i

Wisconsin Legislature. 2005. Chapter NR 1.06 Identification of Public Rights Features. Retrieved on April 2, 2012 from http://docs.legis.wisconsin.gov/code/admin_code/nr/1/06

Wisconsin Legislature. 2009. Chapter NR 198 Aquatic Invasive Species Prevention and Control Grants. Retrieved on February 17, 2012 from http://docs.legis.wi.gov/code/admin_code/nr/198/Title

Wisconsin Legislature. 2011. Chapter NR 1.91 Public Boating Access Standards. Retrieved on February 17, 2012 from http://docs.legis.wi.gov/code/admin_code/nr/1/91

Appendices

Appendices

(located in stand-alone PDF files)

List of Appendices

Appendix A	Public Input
Appendix B	Clean Boats Clean Waters 2011-2012 Boat Inspection Data
Appendix C	2009-2018 Purple Loosestrife Locations
Appendix D	2006-2018 Curly-leaf Pondweed
Appendix E	Sample Points
Appendix F	2006-2018 EWM Extent
Appendix G	Citizen Survey Results
Appendix H	2011 Norwegian Bay Memo
Appendix I	Assessment of Management Techniques
Appendix J	2012-2019 Beaver Dam Lake EWM and CLP Treatment Plans
Appendix K	Beaver Dam Lake Management District Newsletters
Appendix L	2012-2013 CLP Survey Results
Appendix M	2006-2018 Herbicide Residue Data
Appendix N	2012 Riparian Owners' Summer EWM Treatment Areas