Memorandum

To: Beaver Dam Lake Management District (Board of Commissioners)
From: Barr Engineering Company (Meg Rattei)
Subject: Beaver Dam Lake: Native Plants
Date: December 5 2014
Project: 49030011.14

The purpose of this memorandum is to present the native plant data collected from Beaver Dam Lake in 2014 as well as historical native plant data collected since 2009. Significant changes in plant frequency between 2013 and 2014 are presented as well as significant year to year changes in frequency since 2009.

1.0 Beaver Dam Lake Native Plant Community

Summer plant surveys during 2009 through 2014 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 to 70 (Table 1). The number of species in Beaver Dam Lake is about 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 46 to 48 (Table 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, and (3) the lake has high water quality.

The 2009-2014 plant community in Beaver Dam Lake, pictured above, was very healthy and of very high quality. Photo Credit: Endangered Resource Services, LLC.

Simpson's Diversity Index was used to assess the overall health of the lake's plant community by measuring plant diversity. The index considers both the number of species present and the evenness of species distribution. The index scores range from 0 to 1. The scores represent the probability that two individual plants randomly selected from the lake will belong to different species. Higher scores indicate a more diverse plant community and a higher probability that two individuals randomly selected from the lake will represent different species. Diversity scores in Beaver Dam Lake were have ranged from 0.94 to 0.95 during 2009 through 2014 (Table 1). The scores indicate there would be a 94 to 95 percent chance that two plants selected from the lake at random would represent different species. The index values indicate Beaver Dam Lake is a healthy ecosystem with a high degree of diversity.

During 2009 through 2014, plants were observed at 74 to 88 percent of the sample locations shallower than the maximum depth at which plants were found to grow (20.5 to 26.5 feet). Although plants were found as deep as 26.5 feet, the average depth of plant growth ranged from a low of 5.3 feet to a high of 6.1 feet. More than one native species was generally found at Beaver Dam Lake sample locations. The average number of native plant species at each sample location ranged from a low of 1.7 in 2010 to a high of 2.6 in 2012 (Table 1).

Plant species abundance was very balanced between many different types and no single plant dominated the plant community. Hence, more than 80 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 during 2009 through 2014 were common waterweed (*Elodea canadensis*), found at a frequency of 21 to 30 percent, and coontail (*Ceratophyllum demersum*), found at a frequency of 12 to 25 percent (Figure 1). Other prevalent native species include muskgrasses (*Chara sp.*), variable pondweed (*Potamogeton gramineus*), white water lily (*Nymphaea odorata*), slender naiad (*Najas flexilis*), watershield (*Braseni schreberi*) fern pondweed (*Potamogeton robbinsii*), nitella (*Nitella sp.*), common bladderwort (*Utricularia vulgaris*), and creeping bladderwort (*Utricularia gibba*) (Figure 1).

White water lily, pictured above in Norwegian Bay, was a prevalent native species occurring in more than 10 percent of sample locations in Beaver Dam Lake. Photo Credit: Endangered Resource Services, LLC.

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. Three Species of Special Concern have been found in Beaver Dam Lake: *Potamogeton vasey* (Vasey's pondweed), *Eleocharis robbinsii* (Robbin's spikerush), and *Utricularia purpurea* (purple bladderwort) (Figures 2 and 3). All three species were present in 2014. Information about the location and population size of these species was reported to the Natural Heritage Inventory Division of WDNR.

Figures 1 through 3 show the significant changes in frequency of occurrence of the native plants within Beaver Dam Lake. During 2009 through 2014, a total of 37 native species experienced a significant change in frequency of occurrence - 18 native species experienced fluctuations that included both a significant decline and a significant increase, 12 native species experienced a significant increase, and 7 species experienced a significant decrease (Figures 1 through 3).

In 2014, 3 native species (*Nitella sp., Potamogeton praelongus, Sagittaria latifolia*) experienced significant increases in frequency and 5 native species experienced significant declines (*Eleocharis acicularis*, Filamentous algae, *Potamogeton gramineus, Potamogeton richardsonii*, and *Utricularia gibba)* (Table 2). The unusually long winter, late spring, and higher water levels from the wet weather in 2014 may have caused significant changes in the Beaver Dam Lake plant community.

Twelve native species experienced a significant increase in frequency of occurrence during 2009 through 2014, including white stem pondweed (*Potamogeton praelongus*) pictured above in Rabbit Island Bay. Photo Credit: Endangered Resource Services, LLC.

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. Hence, the lake's plant management program treats each entity as if it was a separate lake and manages each lake based upon its unique management needs. For this reason, the plant community in each of the eight 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. The four areas in the eastern basin – Cemetery Bay, City Bay, East Lake, and Norwegian Bay – are then discussed.

Table 1 2009-2014 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
Total number of points sampled	1,339	1,339	1,339	1,340	1,339	1339
Total number of sites with vegetation	844	867	849	864	849	864
Total number of sites shallower than maximum depth of plants	1,052	1,159	1,020	1,033	968	1175
Frequency of occurrence at sites shallower than maximum depth of plants	80.23	74.81	83.24	83.64	87.71	73.53
Simpson Diversity Index	0.94	0.94	0.95	0.95	0.95	0.94
Maximum depth of plants (ft)	26.50	25.00	22.00	21.00	20.50	25.00
Average number of all species per site (shallower than max depth)	2.31	1.82	2.59	2.73	2.40	2.10
Average number of all species per site (veg. sites only)	2.89	2.44	3.11	3.27	2.83	2.85
Average number of native species per site (shallower than max depth)	2.10	1.70	2.37	2.57	2.32	2.06
Average number of native species per site (veg. sites only)	2.69	2.34	2.93	3.10	2.76	2.81
Species Richness	59	59	59	55	56	61
Species Richness (including visuals)	62	61	60	56	61	61
Species Richness (including visuals and boat survey)	70	69	63	61	65	70
Mean depth of plants (ft)	5.37	6.09	5.72	5.26	5.55	5.72
Median depth of plants (ft)	4.50	5.50	5.50	5.00	5.00	5.00
Mean Rake fullness (veg. sites only)		2.01	2.15	2.11	1.93	1.85
Mean C	6.38	6.46	6.51	6.41	6.42	6.46
FQI	47.33	48.37	48.27	45.79	46.32	47.49

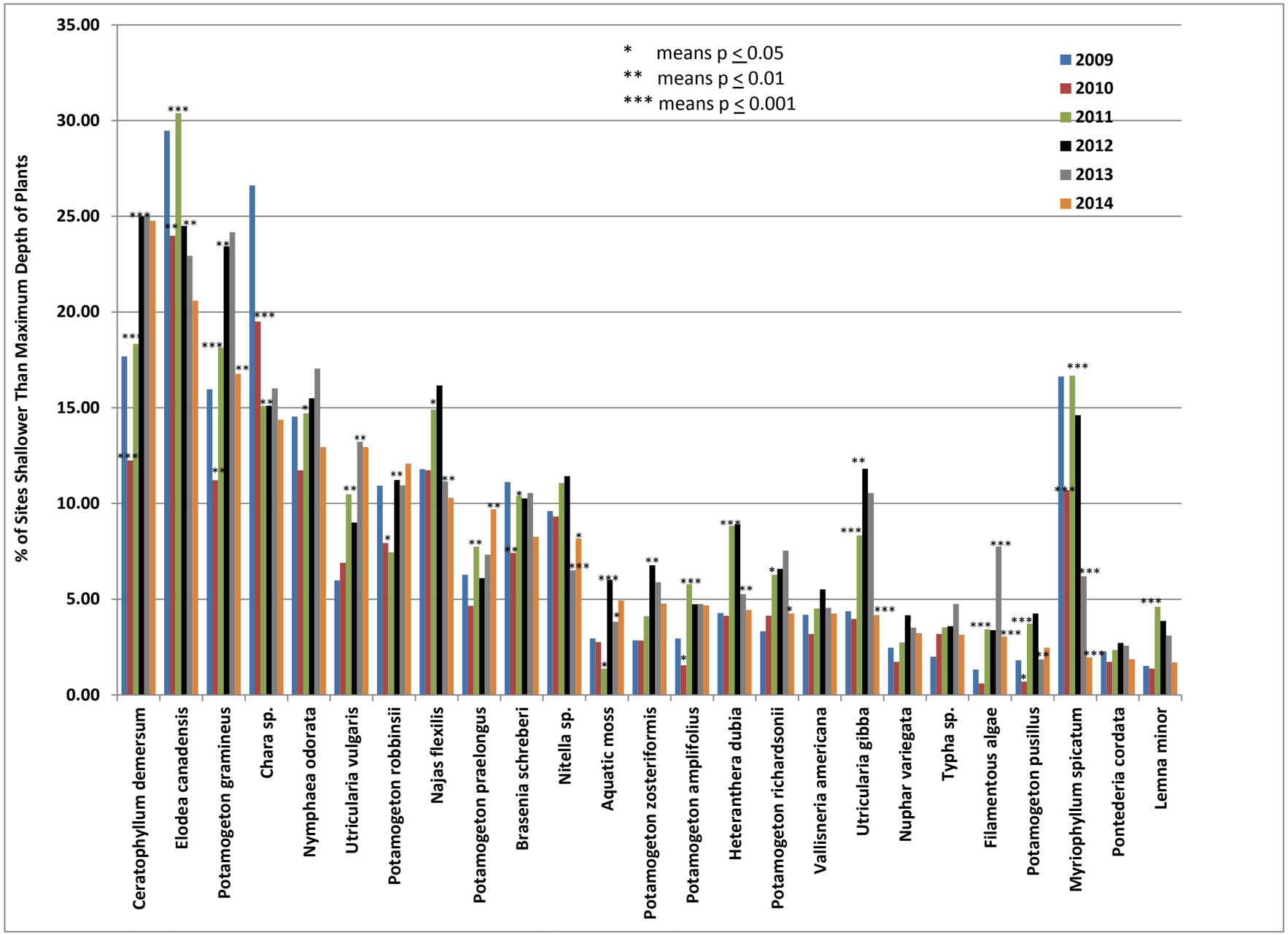

Figure 1 2009-2014 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

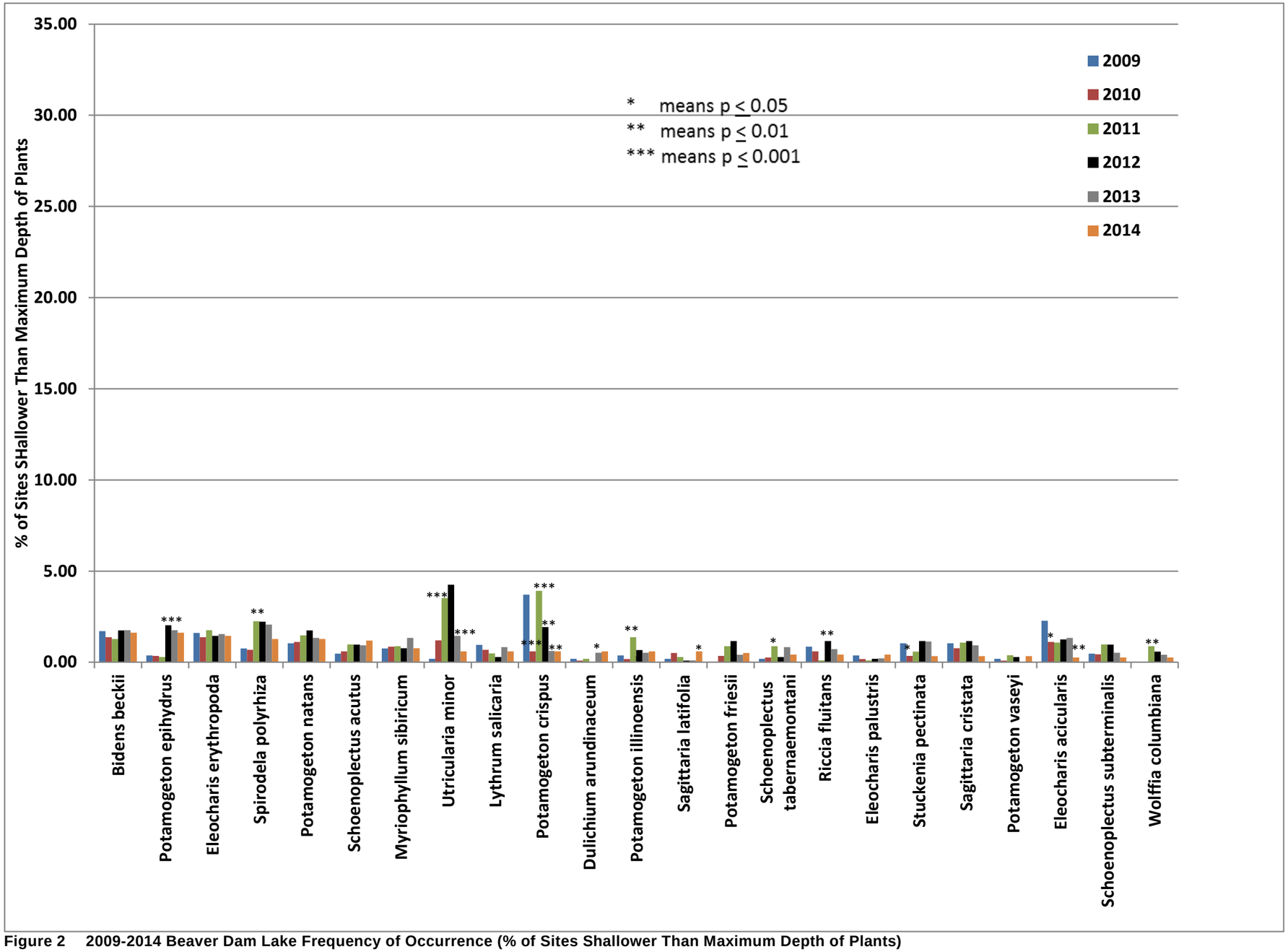

Figure 2 2009-2014 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

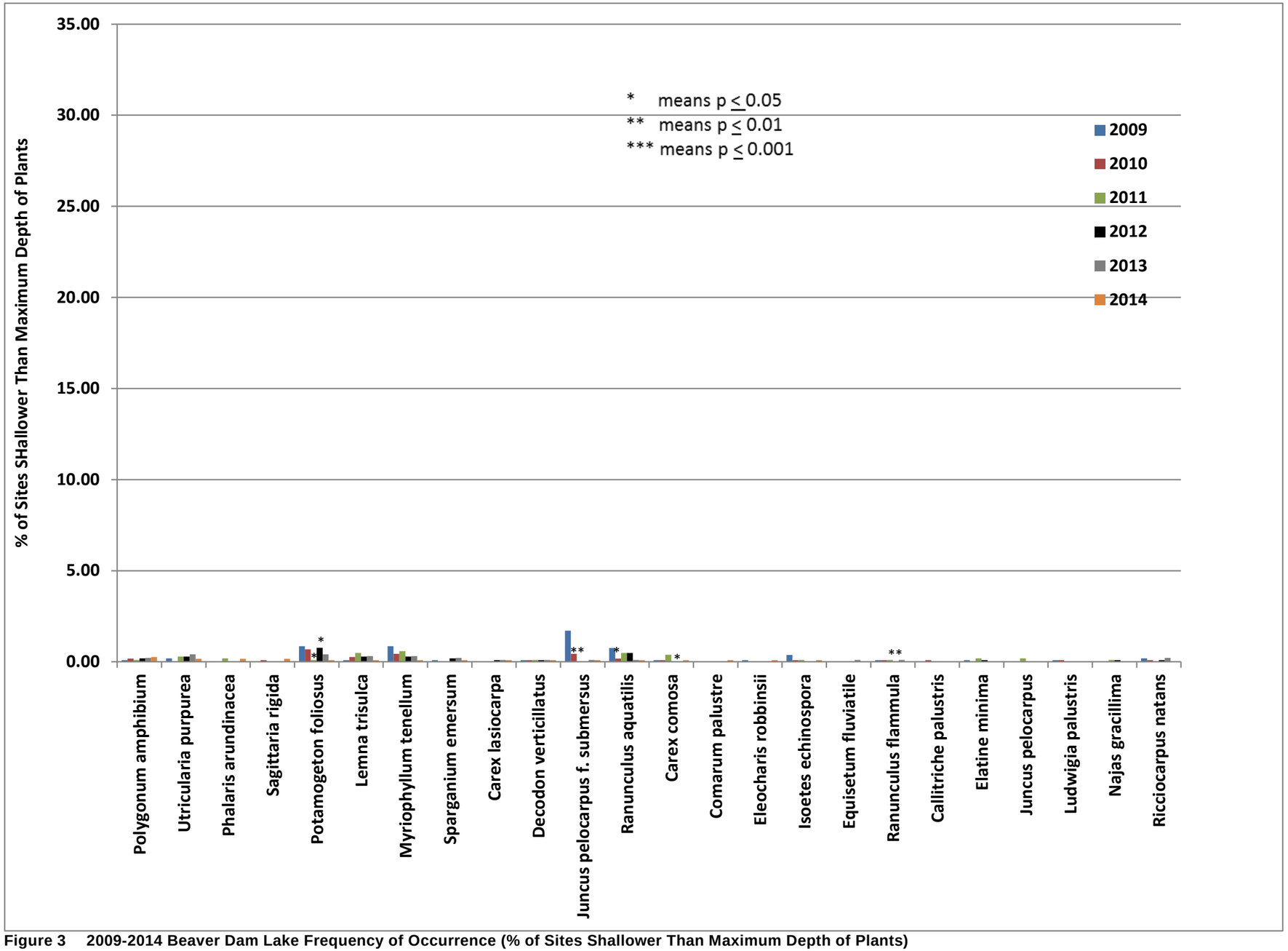

Figure 3 2009-2014 Beaver Dam Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

Table 2 2013-2014 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 Lake	Rabbit Island Bay	Library Lake	Cemetery Bay	City Bay	East Lake	Norwegian Bay
Bidens beckii	water marigold								* (+)	
Ceratophyllum demersum	coontail						** (+)			
Chara sp.	muskgrass						* (+)	* (+)		
Eleocharis acicularis	needle spikerush	** (-)				* (-)				
Elodea canadensis	common waterweed			* (+)			* (+)			
Filamentous algae	filamentous algae	*** (-)				** (+)	* (-)	*** (-)		*** (-)
Heteranthera dubia	water star-grass						* (+)			
Lemna minor	small duckweed					* (-)				
Myriophyllum spicatum	Eurasian watermilfoil	*** (-)						*** (-)		
Najas flexilis	slender naiad				** (+)				*** (-)	
Nitella sp.	nitella	* (+)							* (+)	** (+)
Nymphaea odorata	white water lily						* (-)			
Pontedora cordata	pickerelweed					* (-)				
Potamogeton amplifolius	large-leaf pondweed							* (+)		
Potamogeton gramineus	variable pondweed	** (-)	** (-)							
Potamogeton praelongus	white-stem pondweed	** (+)	** (+)							
Potamogeton pusillus	small pondweed							* (+)		
Potamogeton richardsonii	claspingleaf pondweed	* (-)	** (-)							
Sagittaria latifolia	common arrowhead	* (+)				* (+)				
Utricularia gibba	creeping bladderwort	*** (-)				** (-)		*** (-)		* (-)
Utricularia minor	small bladderwort					* (-)				
Vallisneria americana	wild celery			* (+)						

* means p ≤ 0.05 ** means p ≤ 0.01 *** means p ≤ 0.001
(+) Statistically significant increase between 2013 and 2014 (-) Statistically significant decrease between 2013 and 2014

1.1 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 2013, the lake experienced excellent water transparency, noting Secchi disc water transparency ranging from 12.5 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.

During 2009 through 2014, the maximum depth of plant growth ranged from a low of 18.5 feet in 2012 to a high of 26.5 feet in 2009. The lake's diverse and high quality plant community is consistent with its excellent water quality. From 44 to 48 species were observed during 2009 through 2014. The FQI in West Lake during 2009 to 2014 ranged from 39.3 to 42.3 and was approximately double the median value for lakes in the same eco-region, which is 20.9 (Nichols, 1999). Diversity, measured by the Simpson Diversity Index, was near the top of the 0 to 1 scale, ranging from 0.91 to 0.93. Plants were found at 71 to 84 percent of the sites shallower than the maximum depth of plant growth. On average, from 1.8 to 2.1 native plant species were found at each sample location (Table 3).

The most prevalent native species during 2009 through 2014 were muskgrasses (*Chara sp.*) and variable pondweed (*Potamogeton gramineus*). Other prevalent species include slender naiad (*Najas flexilis*), common waterweed (*Elodea canadensis*), clasping-leaf pondweed (*Potamogeton richardsonii)*, wild celery (*Valisneria americana*), white-stem pondweed (*Potamogeton praelongus*), fern pondweed (*Potamogeton robbinsii*), flat-stem pondweed (*Potamogeton zosteriformis*), and coontail (*Ceratophyllum demersum*) (Figure 4).

During 2009 through 2014, a total of 11 of the lake's native species experienced a significant change in frequency of occurrence. Four native species experienced fluctuations that included both significant declines and significant increases, 3 native species experienced a significant increase, and 4 species experienced a significant decrease (Figures 4 and 5). An assessment of the 11 species experiencing a significant change indicates 9 species observed a higher frequency of occurrence in 2014 than 2009 (Figures 4 and 5).

In 2014, the lake's plant community was relatively stable and only 3 native species experienced significant changes in frequency. One native species (*Potamogeton praelongus*) experienced a significant increase in frequency and 2 native species (*Potamogeton gramineus and Potamogeton richardsonii*) experienced significant declines (Table 2 and Figures 4 and 5).

Table 3 2009-2014 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
Total number of points sampled	439	439	439	439	439	439
Total number of sites with vegetation	250	262	227	241	236	229
Total number of sites shallower than maximum depth of plants	352	321	292	287	298	318
Frequency of occurrence at sites shallower than maximum depth of plants	71.02	81.62	77.74	83.97	79.19	72.01
Simpson Diversity Index	0.92	0.91	0.93	0.93	0.92	0.93
Maximum depth of plants (ft)	26.50	25.00	20.50	18.50	20.50	23.00
Average number of all species per site (shallower than max depth)	1.93	1.86	2.15	2.20	2.12	2.00
Average number of all species per site (veg. sites only)	2.72	2.28	2.77	2.61	2.67	2.78
Average number of native species per site (shallower than max depth)	1.80	1.76	2.08	2.10	2.06	1.94
Average number of native species per site (veg. sites only)	2.61	2.17	2.69	2.53	2.62	2.71
Species Richness	43	42	44	43	40	40
Species Richness (including visuals)	45	44	45	43	44	42
Species Richness (including visuals and boat survey)	45	44	45	46	48	48
Mean depth of plants (ft)	6.89	7.82	7.06	6.39	7.02	7.16
Median depth of plants (ft)	6.00	7.50	7.00	6.00	7.00	7.00
Mean rake fullness (veg. sites only)		1.84	1.99	1.80	1.72	1.69
Mean C	6.46	6.43	6.52	6.39	6.37	6.50
FQI	41.39	40.64	42.28	40.92	39.26	40.07

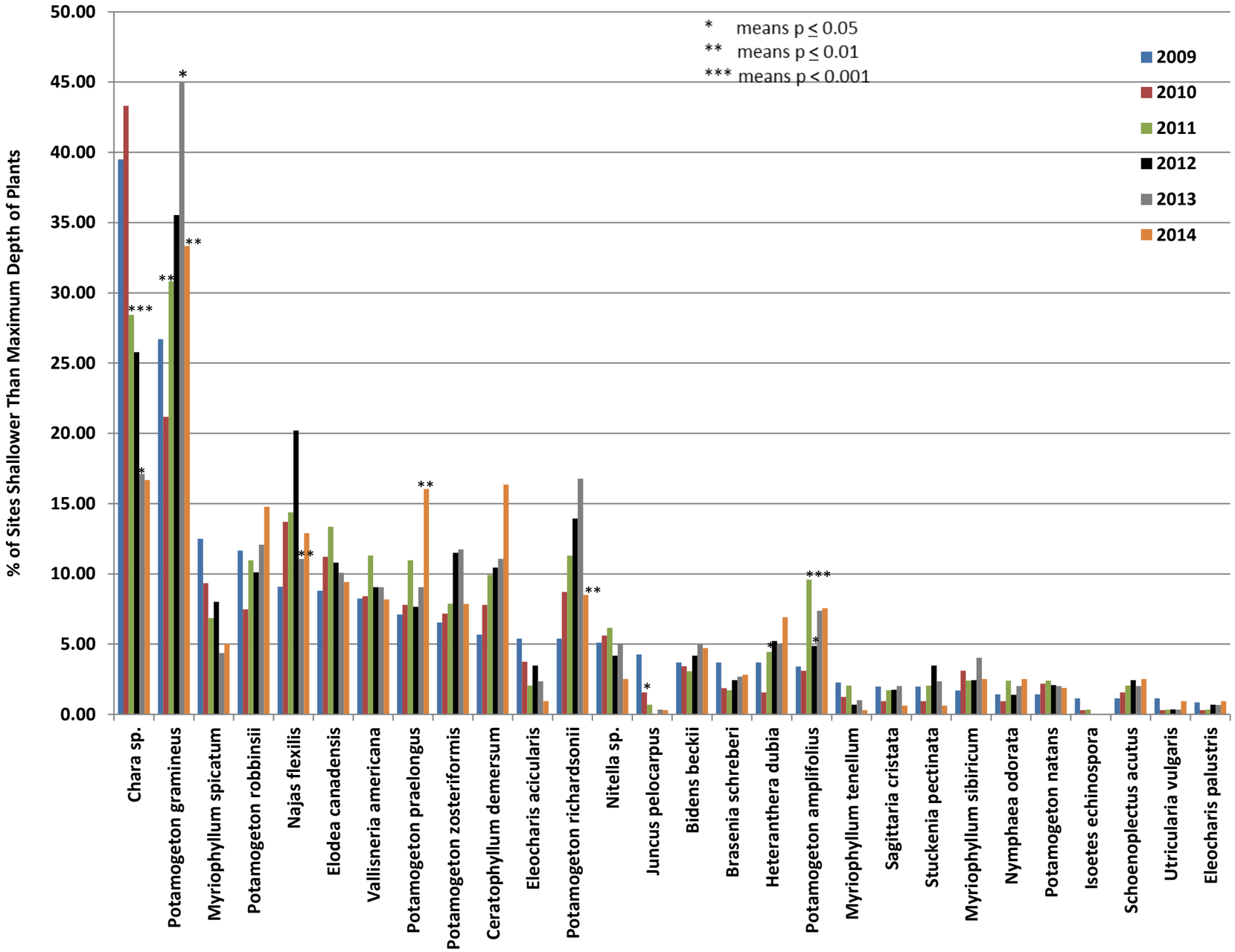

Figure 4 2009-2014 West Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

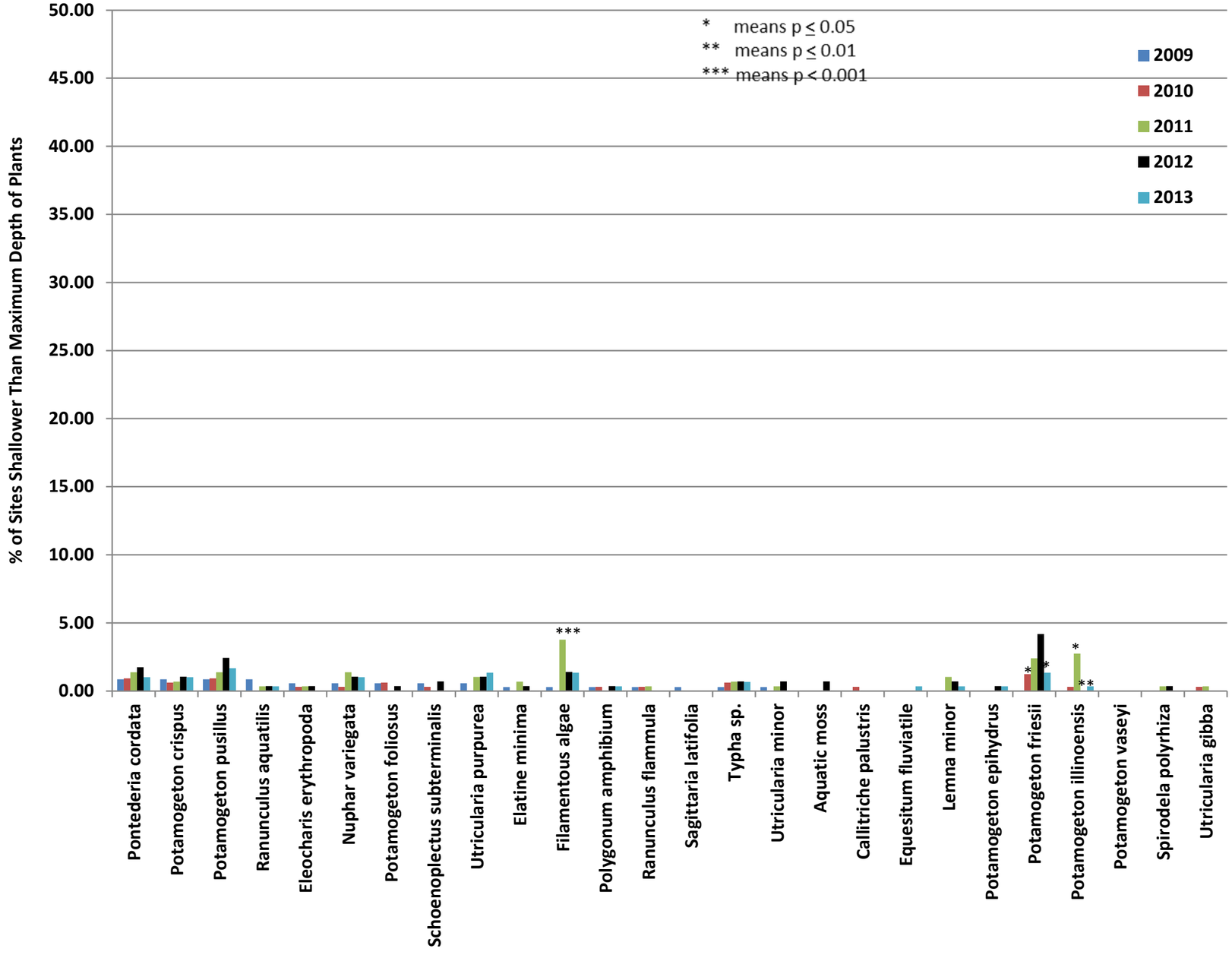

Figure 5 2009-2014 West Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

1.2 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 2014, the lake experienced excellent to good water transparency, noting Secchi disc water transparency ranging from 12 feet to 18 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.

During 2009 through 2014, the maximum depth of plant growth ranged from a low of 17.5 feet in 2014 to a high of 24 feet in 2010. The lake's diverse and high quality plant community is consistent with its excellent water quality. From 20 to 36 species were observed during 2009 through 2014. The FQI in Williams Bay during 2009 to 2014 ranged from 26.6 to 31.6 which was greater than the median value for lakes in the same eco-region (20.9) (Nichols, 1999). Diversity, measured by the Simpson Diversity Index, was high and ranged from 0.88 to 0.93 during 2009 through 2014. Plants were found at 66 to 80 percent of the sites shallower than the maximum depth of plant growth. On average, 1.3 to 1.8 native plant species were found at each sample location (Table 3). During 2009 through 2014, the most prevalent native species were variable pondweed (*Potamogeton gramineus*) and muskgrasses (*Chara sp*.). Other prevalent species included coontail (*Ceratophyllum demersum*), slender naiad (*Najas flexilis*), common waterweed (*Elodea canadensis*), white-stem pondweed (*Potamogeton praelongus*), clasping-leaf pondweed (*Potamogeton richardsonii*), nitella (*Nitella sp*.), wild celery (*Vallisneria americana)*, fern pondweed (*Potamogeton robbinsii)*, and flat-stem pondweed (*Potamogeton zosteriformis*) (Figure 6).

During 2009 through 2014, a total of 6 native species experienced a significant change in frequency of occurrence. Five native species experienced a significant increase and 1 species experienced a significant decrease (Figure 6). In 2014, two native species significantly increased in frequency of occurrence (Table 2 and Figure 6).

Table 4 2009-2014 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
Total number of points sampled	130	130	130	130	130	130
Total number of sites with vegetation	72	71	64	72	67	58
Total number of sites shallower than maximum depth of plants	90	100	84	94	92	88
Frequency of occurrence at sites shallower than maximum depth of plants	80.00	71.00	76.19	76.60	72.83	65.91
Simpson Diversity Index	0.92	0.88	0.93	0.92	0.91	0.92
Maximum depth of plants (ft)	18.50	24.00	19.50	21.00	20.00	17.50
Average number of all species per site (shallower than max depth)	2.00	1.39	1.92	1.89	1.61	1.67
Average number of all species per site (veg. sites only)	2.50	1.96	2.52	2.47	2.21	2.53
Average number of native species per site (shallower than max depth)	1.76	1.34	1.76	1.83	1.60	1.66
Average number of native species per site (veg. sites only)	2.29	1.91	2.35	2.39	2.19	2.52
Species Richness	28	20	24	27	25	25
Species Richness (including visuals)	30	20	24	27	28	28
Species Richness (including visuals and boat survey)	30	20	24	27	29	36
Mean depth of plants (ft)	7.51	8.94	7.66	7.81	8.63	8.28
Median depth of plants (ft)	7.50	8.50	7.75	8.00	8.50	8.25
Mean rake fullness (veg. sites only)		1.76	2.05	2.01	1.88	1.81
Mean C	6.19	6.28	6.14	6.08	5.88	5.88
FQI	31.57	26.63	28.78	30.40	28.78	28.78

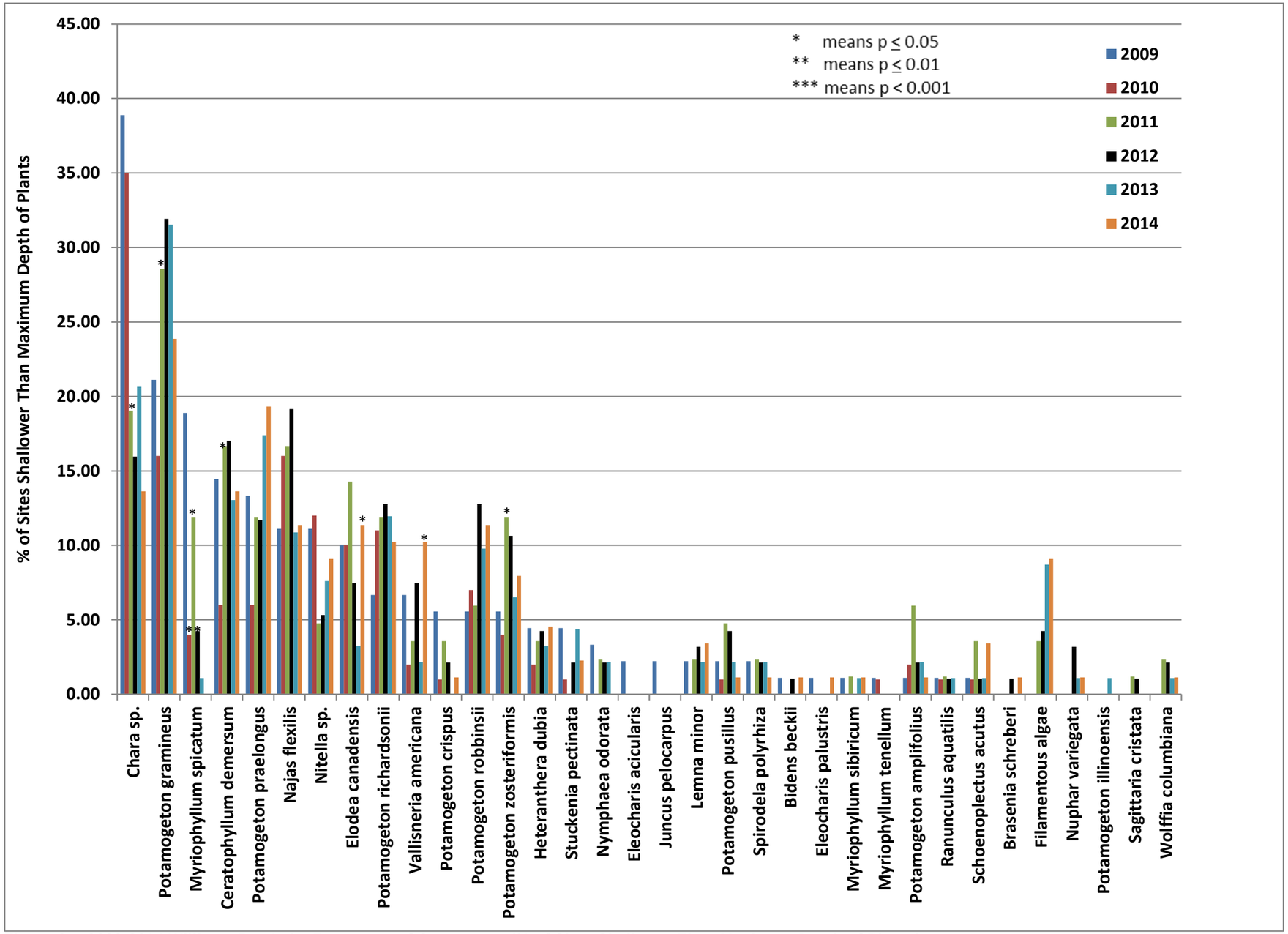

Figure 6 2009-2014 Williams Bay Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

1.3 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 2013, the lake experienced excellent water transparency, noting Secchi disc water transparency ranging from 12 feet to 21 feet.

From 38 to 44 species of plants were observed in Rabbit Island Bay, pictured above, during 2009 through 2014. The quality of the plant community, measured by FQI, is higher than the median value for lakes in the same eco-region.

During 2009 through 2014, the maximum depth of plant growth ranged from a low of 16.5 feet in 2012 to a high of 22 feet in both 2011 and 2014. The lake's diverse and high quality plant community is consistent with its excellent water quality. From 38 to 44 species were observed during 2009 through 2014. The FQI in Rabbit Island Bay during 2009 to 2014 ranged from 36.3 to 38.8 which was greater than the median value for lakes in the same eco-region (20.9) (Nichols, 1999). Diversity, measured by the Simpson Diversity Index, was near the top of the 0 to 1 scale, ranging from 0.94 to 0.95. Plants were found at 91 to 96 percent of sample sites shallower than the maximum depth of plants. On average, 2.5 to 3.6 native plant species were generally found at each sample location (Table 5). The most prevalent native species during 2009 through 2014 were variable pondweed (*Potamogeton gramineus*), slender naiad (*Najas flexilis*), fern pondweed (*Potamogeton robbinsii*), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), muskgrasses (*Chara sp.*), and white-stem pondweed (*Potamogeton praelongus*), (Figure 7).

During 2009 through 2014, a total of 8 native species experienced a significant change in frequency of occurrence. Four native species experienced a significant increase, 3 species experienced a significant decrease, and 1 species experienced fluctuations that included both a significant increase and significant decrease (Figures 7 and 8).

In 2014, 1 native species, slender naiad (*Najas flexilis*) experienced a significant increase in frequency (Table 2 and Figures 7 and 8).

Table 5 2009-2014 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
Total number of points sampled	122	122	122	122	122	122
Total number of sites with vegetation	101	102	108	103	107	109
Total number of sites shallower than maximum depth of plants	108	112	113	107	113	115
Frequency of occurrence at sites shallower than maximum depth of plants	93.52	91.07	95.58	96.26	94.69	94.78
Simpson Diversity Index	0.94	0.94	0.95	0.94	0.94	0.94
Maximum depth of plants (ft)	17.00	20.50	22.00	16.50	20.00	22
Average number of all species per site (shallower than max depth)	3.34	2.59	3.19	3.61	3.02	3.20
Average number of all species per site (veg. sites only)	3.57	2.84	3.34	3.75	3.19	3.38
Average number of native species per site (shallower than max depth)	3.07	2.46	3.10	3.57	3.00	3.17
Average number of native species per site (veg. sites only)	3.29	2.70	3.24	3.71	3.17	3.35
Species Richness	37	36	40	37	36	38
Species Richness (including visuals)	40	38	42	39	38	40
Species Richness (including visuals and boat survey)	40	38	42	39	38	44
Mean depth of plants (ft)	5.16	5.89	6.01	5.18	5.55	5.70
Median depth of plants (ft)	4.50	4.50	5.00	4.50	4.50	4.50
Mean rake fullness (veg. sites only)		2.08	2.26	2.27	1.93	1.88
Mean C	6.51	6.14	6.21	6.39	6.29	6.31
FQI	38.54	36.34	38.75	38.33	37.19	37.83

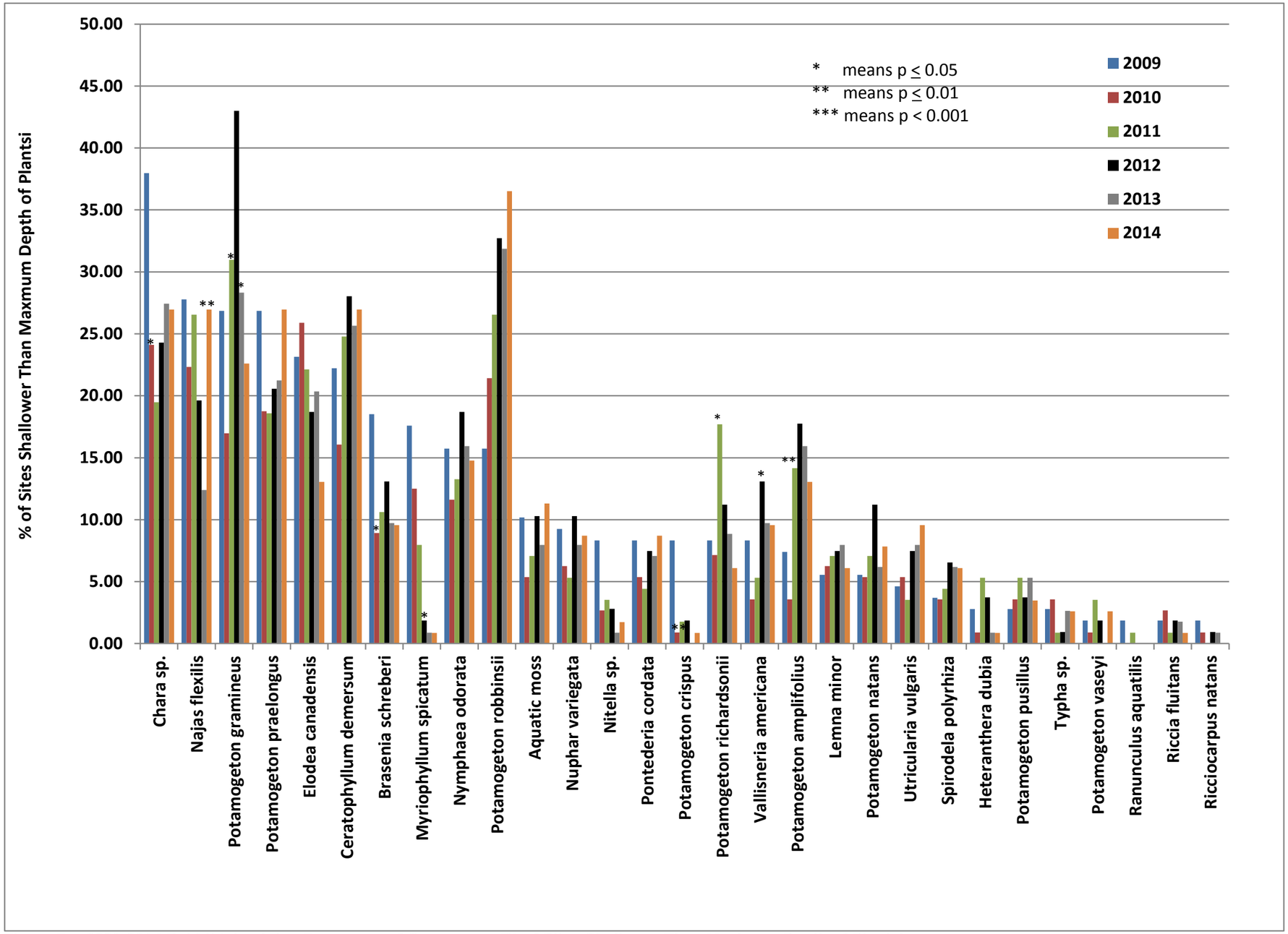

Figure 7 2009-2014 Rabbit Island Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

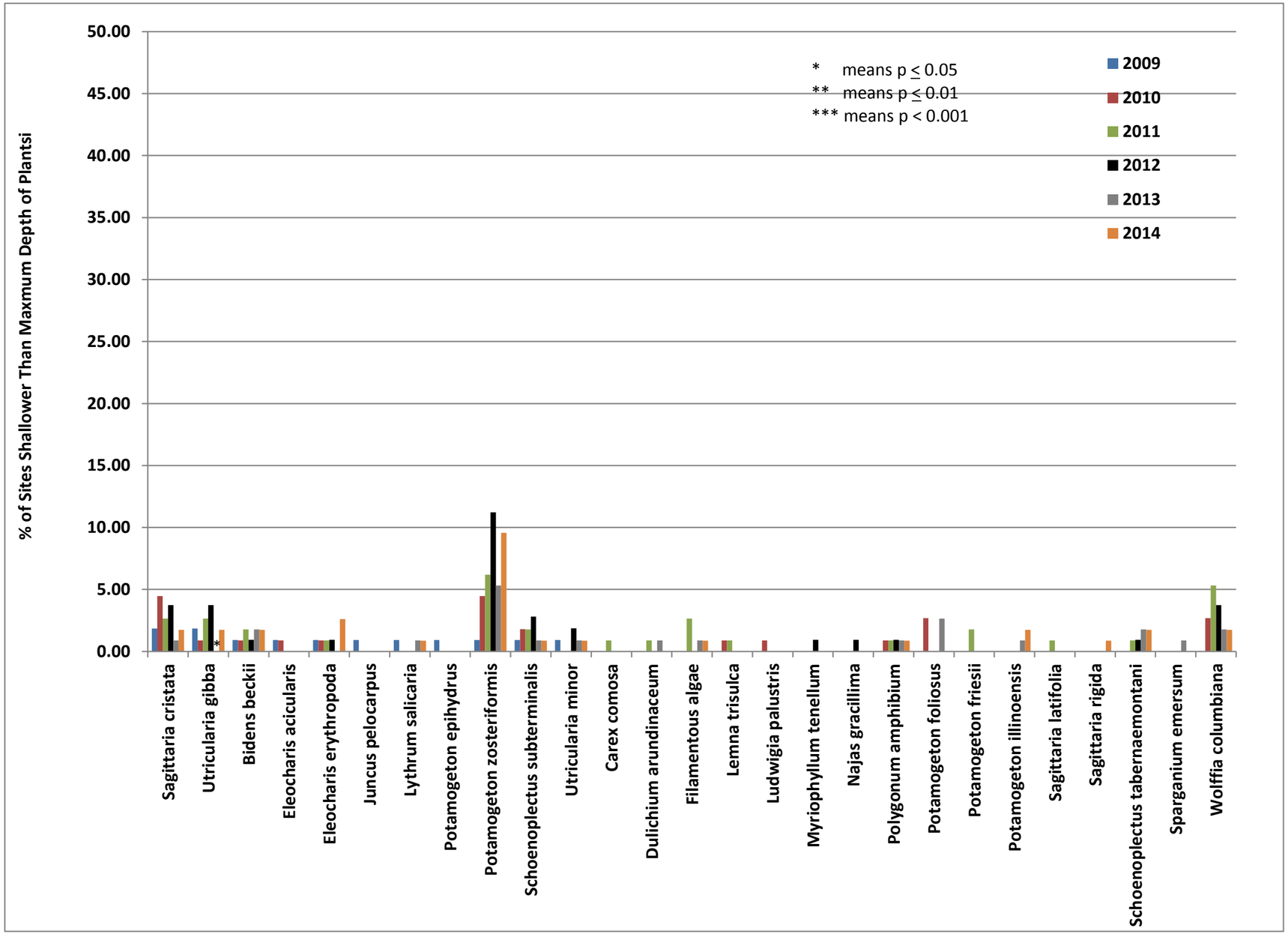

Figure 8 2009-2014 Rabbit Island Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

1.4 Library Lake

Library Lake has a surface area of 14 acres and a maximum depth of 20 feet. During 2009 through 2013, the lake experienced good to poor water transparency, noting Secchi disc water transparency ranging from 6 feet to 10 feet.

From 35 to 39 plant species were observed in Library Lake, pictured above, during 2009 through 2014. Photo Credit: Endangered Resource Services, LLC.

During 2009 through 2013, the maximum depth of plant growth ranged from a low of 15 feet in 2011 and 2012 to a high of 19.5 feet in 2010. A diverse and high quality plant community comprised of from 35 to 39 species was observed in the lake during 2009 through 2014. The FQI in Library Lake during 2009 to 2014 ranged from 32.0 to 35.0 which was greater than the median value for lakes in the same eco-region (20.9) (Nichols, 1999). Diversity, measured by the Simpson Diversity Index, was near the top of the 0 to 1 scale, ranging from 0.91 to 0.93. Plants were found at 93 to 100 percent of sample sites shallower than the maximum depth of plants. On average, 3.2 to 4.8 native plant species were generally found at each sample location (Table 6). The most prevalent native species during 2009 through 2014 were white water lily (*Nymphaea odorata*), common bladderwort (*Utricularia vulgaris*), watershield (*Brasenia schreberi*), creeping bladderwort (*Utricularia gibba*), common waterweed (*Elodea canadensis*), and coontail (*Ceratophyllum demersum*) (Figure 9).

During 2009 through 2014, a total of 20 native species experienced a significant change in frequency of occurrence. Six native species experienced fluctuations that included both a significant decline and a significant increase, 6 native species experienced a significant decrease in frequency, and 8 native species experienced a significant increase in frequency (Figures 9 and 10).

In 2014, 5 native species experienced significant declines in frequency and 2 native species experienced significant increases in frequency (Table 2 and Figures 9 and 10).

Table 6 2009-2014 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
Total number of points sampled	139	139	139	139	139	139
Total number of sites with vegetation	116	121	115	116	123	119
Total number of sites shallower than maximum depth of plants	120	130	118	116	125	121
Frequency of occurrence at sites shallower than maximum depth of plants	96.67	93.08	97.46	100.00	98.40	98.35
Simpson Diversity Index	0.91	0.92	0.93	0.93	0.92	0.91
Maximum depth of plants (ft)	15.50	19.50	15.00	15.00	18.50	17.00
Average number of all species per site (shallower than max depth)	3.64	3.31	4.68	4.83	3.74	3.31
Average number of all species per site (veg. sites only)	3.77	3.55	4.80	4.83	3.80	3.36
Average number of native species per site (shallower than max depth)	3.46	3.24	4.57	4.77	3.66	3.25
Average number of native species per site (veg. sites only)	3.58	3.51	4.69	4.77	3.72	3.30
Species Richness	34	32	34	33	32	35
Species Richness (including visuals)	36	35	35	36	37	36
Species Richness (including visuals and boat survey)	36	35	35	37	39	38
Mean depth of plants (ft)	2.63	3.32	2.57	2.47	3.04	2.68
Median depth of plants (ft)	1.50	2.00	2.00	2.00	1.50	2.00
Mean rake fullness (veg. sites only)		2.88	3.00	2.98	2.85	2.61
Mean C	5.83	6.00	6.06	6.10	5.97	6.09
FQI	31.95	33.41	34.29	33.95	33.23	34.99

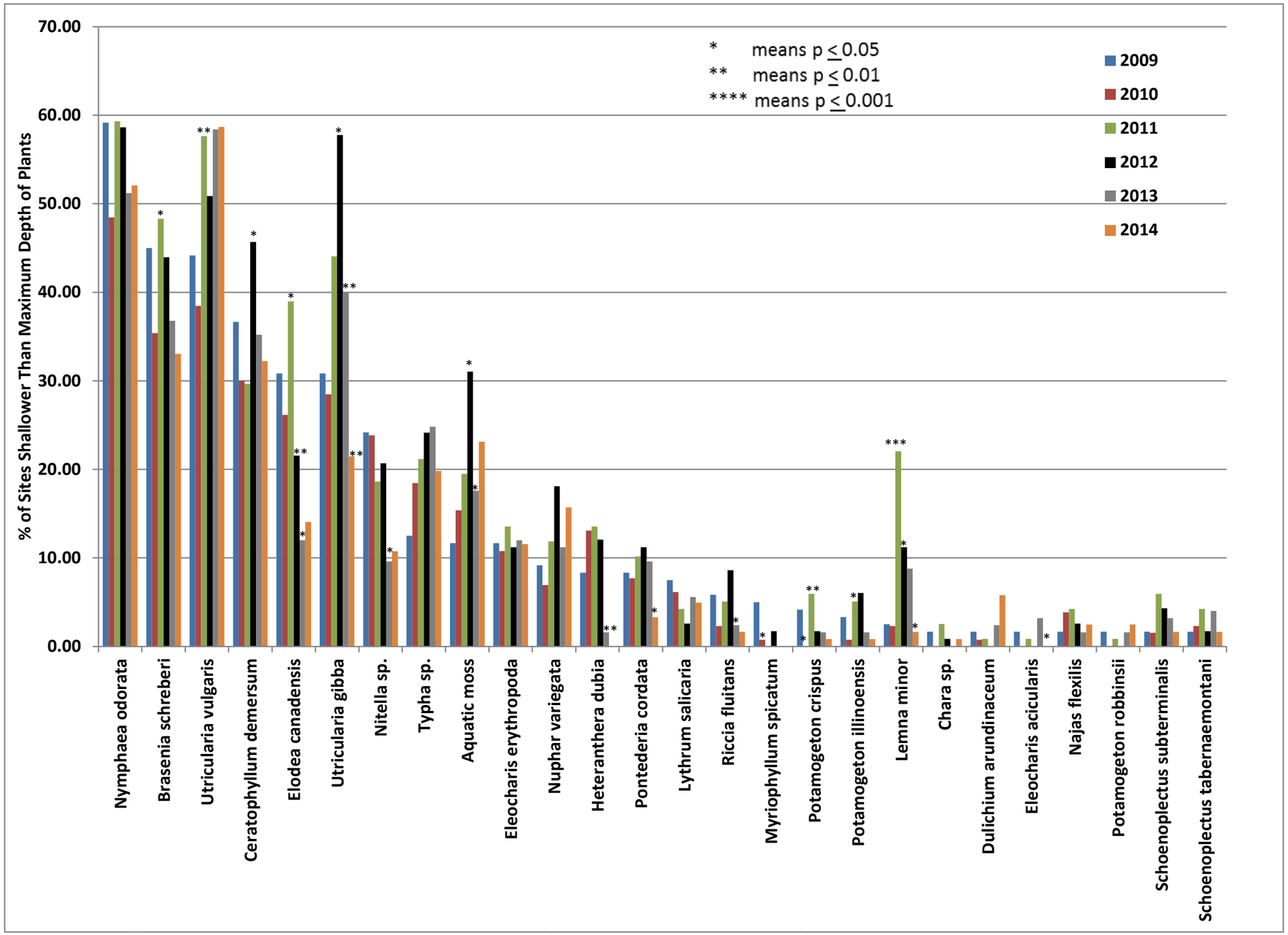

Figure 9 2009-2014Library Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

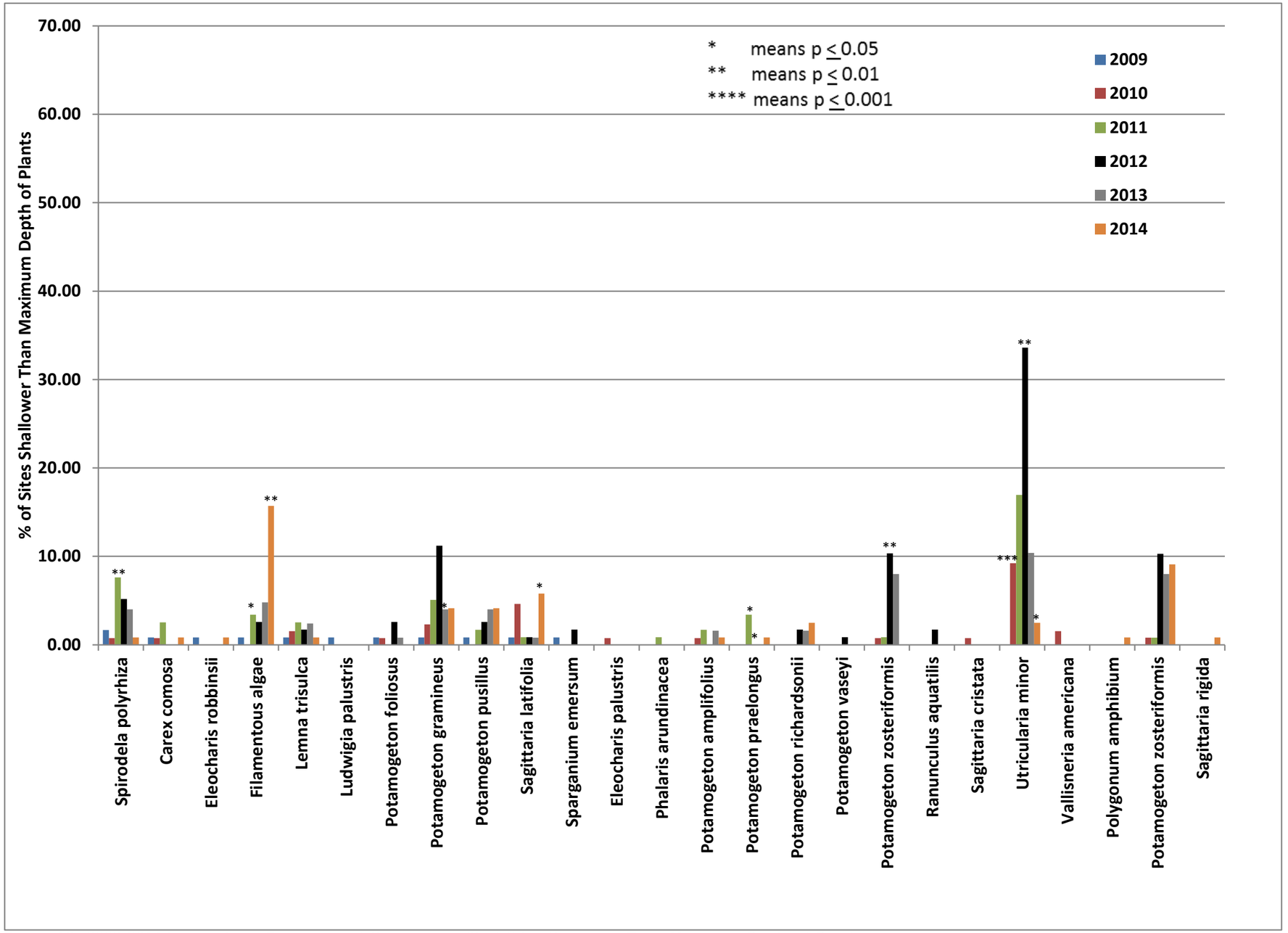

Figure 10 2009-2014 Library Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

1.5 Cemetery Bay

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

Cemetery Bay has a surface area of 53 acres and a maximum depth of 7 feet. The bay has experienced poor water quality, noting a trophic status ranging from eutrophic to hypereutrophic. In 2012, the lake experienced Secchi disc water transparency ranging 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.

During 2009 to 2014, the maximum depth of plant growth 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. The lake's plant community is consistent with its poor water quality and has differed greatly from the plant communities observed in the western bays of the lake. Improvements in the plant community were observed during 2009 through 2014. The number of species tripled during 2009 through 2014, from 6 in 2009 to 18 in 2014. The FQI in Cemetery Bay more than doubled during 2009 to 2014, from 9.8 in 2010 to 20.8 in 2012 and 2014. Diversity, measured by the Simpson Diversity Index, improved from 0.47 in 2009 to 0.79 in 2012. Diversity in 2014 was 0.70 (Table 7). The data indicate the plant community in Cemetery Bay has improved since 2009.

Although plants have consistently been observed less frequently in Cemetery Bay than in other areas of Beaver Dam Lake, frequency has increased since 2009. Plants were found at a frequency of 24 percent in 2009 and a frequency of 77 percent in 2014. The number of native species found at sample locations shallower than the maximum depth of plant growth increased seven-fold, from 0.2 in 2009 to 1.4 in 2014 (Table 7). The most prevalent native species during 2009 through 2014 were common waterweed (*Elodea canadensis*) and white water lily (*Nymphaea odorata*). Filamentous algae were present during 2009 and 2011 through 2014 (Figure 11).

During 2009 through 2014, a total of 6 native species experienced a significant increase in frequency of occurrence and 2 native species experienced a significant decrease in frequency of occurrence (Figure 11). In 2014, 4 native species experienced significant increases in frequency and 2 native species experienced significant decreases in frequency (Table 2 and Figure 11).

Table 7 2009-2014 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
Total number of points sampled	89	89	89	89	89	89
Total number of sites with vegetation	21	23	40	35	52	67
Total number of sites shallower than maximum depth of plants	89	84	89	89	84	87
Frequency of occurrence at sites shallower than maximum depth of plants	23.60	27.38	44.94	39.33	61.90	77.01
Simpson Diversity Index	0.47	0.56	0.75	0.79	0.63	0.70
Maximum depth of plants (ft)	9.50	6.50	7.00	7.50	6.00	6.50
Average number of all species per site (shallower than max depth)	0.24	0.31	0.63	0.69	1.02	1.38
Average number of all species per site (veg. sites only)	1.00	1.13	1.40	1.74	1.65	1.79
Average number of native species per site (shallower than max depth)	0.22	0.31	0.51	0.66	1.02	1.38
Average number of native species per site (veg. sites only)	1.00	1.13	1.32	1.69	1.65	1.79
Species Richness	6	6	10	14	8	13
Species Richness (including visuals)	6	6	10	15	9	15
Species Richness (including visuals and boat survey)	6	6	10	17	12	18
Mean depth of plants (ft)	4.14	3.87	4.71	3.93	4.36	4.78
Median depth of plants (ft)	4.00	4.00	5.00	4.00	4.50	5.00
Mean rake fullness (veg. sites only)		2.22	1.90	2.03	1.62	1.81
Mean C	5.80	4.00	5.13	5.77	5.50	5.77
FQI	12.97	9.80	14.50	20.80	15.56	20.80

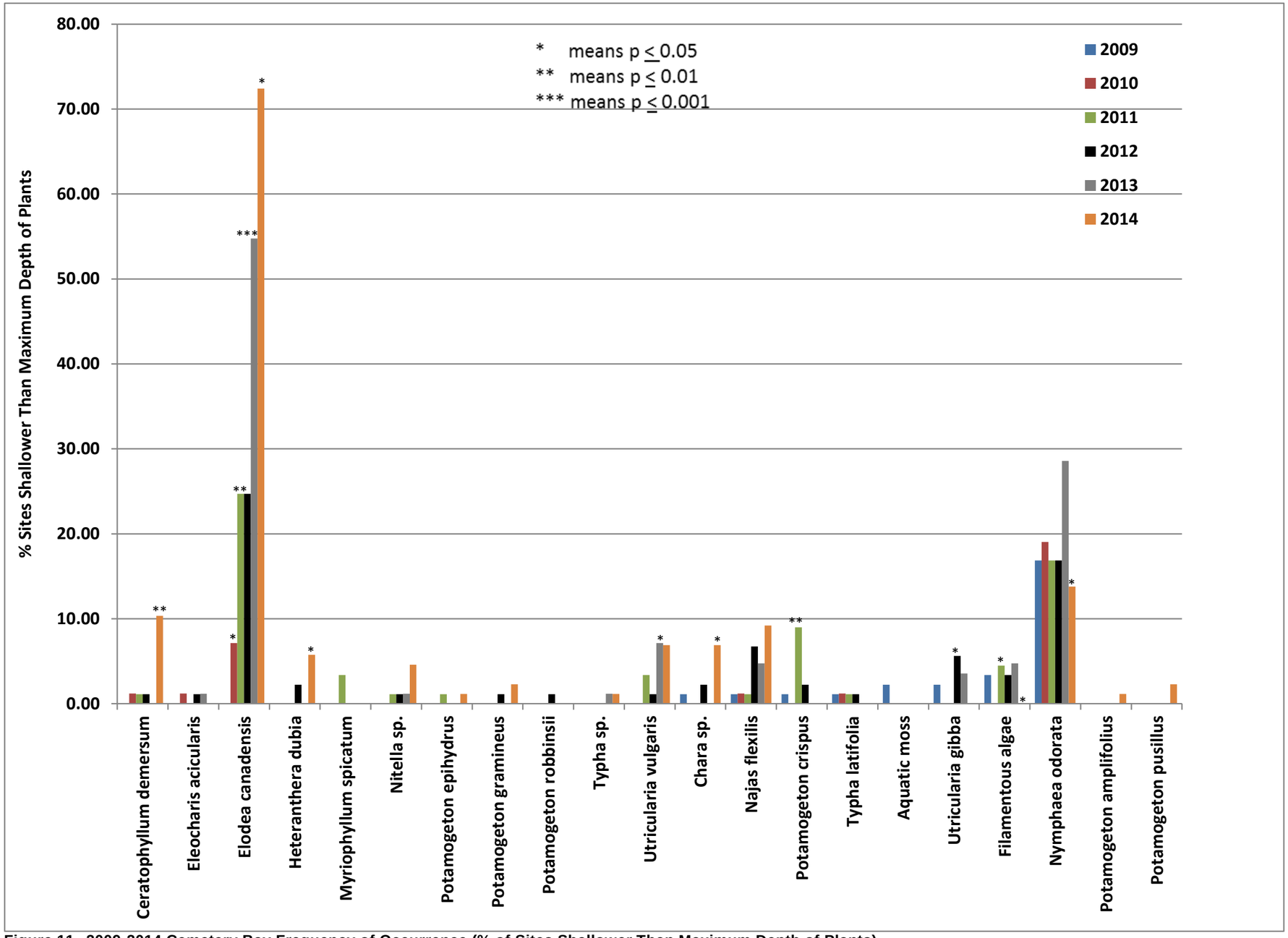

Figure 11 2009-2014 Cemetery Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

1.6 City Bay

From 28 to 39 plant species were observed in City Bay, pictured above, during 2009 through 2013. 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.

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.

During 2009 to 2014, the maximum depth of plant growth ranged from 8 to 20 feet. From 28 to 39 species were observed during 2009 through 2014. The FQI in City Bay during 2009 to 2014 ranged from 30.4 to 37.0 which was greater than the median value for lakes in the same eco-region (20.9) (Nichols, 1999). Diversity, measured by the Simpson Diversity Index, was high and ranged from 0.88 to 0.92. Plants were found at 93 to 98 percent of sample sites shallower than the maximum depth of plants. On average, 2.0 to 3.0 native plant species were found at each sample location shallower than the maximum depth of plant growth (Table 8). The most prevalent native species during 2009 through 2014 were common waterweed (*Elodea canadensis*) and coontail (*Ceratophyllum demersum*). Other prevalent native species included nitella (*Nitella sp*.), white water lily (*Nymphaea odorata*), slender naiad (*Najas flexilis*), watershield (*Brasenia schreberi*), variable pondweed (*Potamogeton gramineus*), fern pondweed (*Potamogeton robbinsii*), muskgrasses (*Chara sp*.), and common bladderwort (*Utricularia vulgaris*) (Figures 12 and 13).

During 2009 through 2014, a total of 15 native species experienced a significant change in frequency of occurrence. Nine native species experienced fluctuations that included declines and increases, 5 native species experienced a significant increase, and 1 species experienced a significant decrease (Figures 12 and 13).

In 2014, 5 native species experienced a significant change in frequency of occurrence (Table 8 and Figures 12 and 13). Three native species experienced a significant increase in frequency (*Chara sp., Potamogeton amplifolius*, and *Potamogeton pusillus*) and 2 native species experienced a significant decrease in frequency (*Utricularia gibba* and filamentous algae) (Table 2 and Figures 12 and 13).

Table 8 2009-2014 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
Total number of points sampled	180	180	180	181	180	180
Total number of sites with vegetation	162	167	171	173	163	171
Total number of sites shallower than maximum depth of plants	175	176	176	177	175	180
Frequency of occurrence at sites shallower than maximum depth of plants	92.57	94.89	97.16	97.74	93.14	95.00
Simpson Diversity Index	0.90	0.88	0.91	0.92	0.91	0.91
Maximum depth of plants (ft)	8.00	10.00	10.00	9.00	8.00	20.00
Average number of all species per site (shallower than max depth)	2.79	2.22	3.16	3.41	2.71	2.74
Average number of all species per site (veg. sites only)	3.01	2.34	3.25	3.49	2.91	2.88
Average number of native species per site (shallower than max depth)	2.44	2.01	2.59	3.01	2.50	2.72
Average number of native species per site (veg. sites only)	2.74	2.22	2.77	3.20	2.70	2.88
Species Richness	28	25	38	32	26	31
Species Richness (including visuals)	28	28	39	32	32	32
Species Richness (including visuals and boat survey)	28	28	39	32	33	38
Mean depth of plants (ft)	4.25	4.75	4.98	4.64	4.60	4.85
Median depth of plants (ft)	4.75	5.50	5.50	5.00	5.00	5.00
Mean rake fullness (veg. sites only)		1.96	2.28	2.2	1.93	1.70
Mean C	6.23	6.46	6.26	6.23	6.08	6.43
FQI	31.77	31.64	37.02	34.14	30.40	35.24

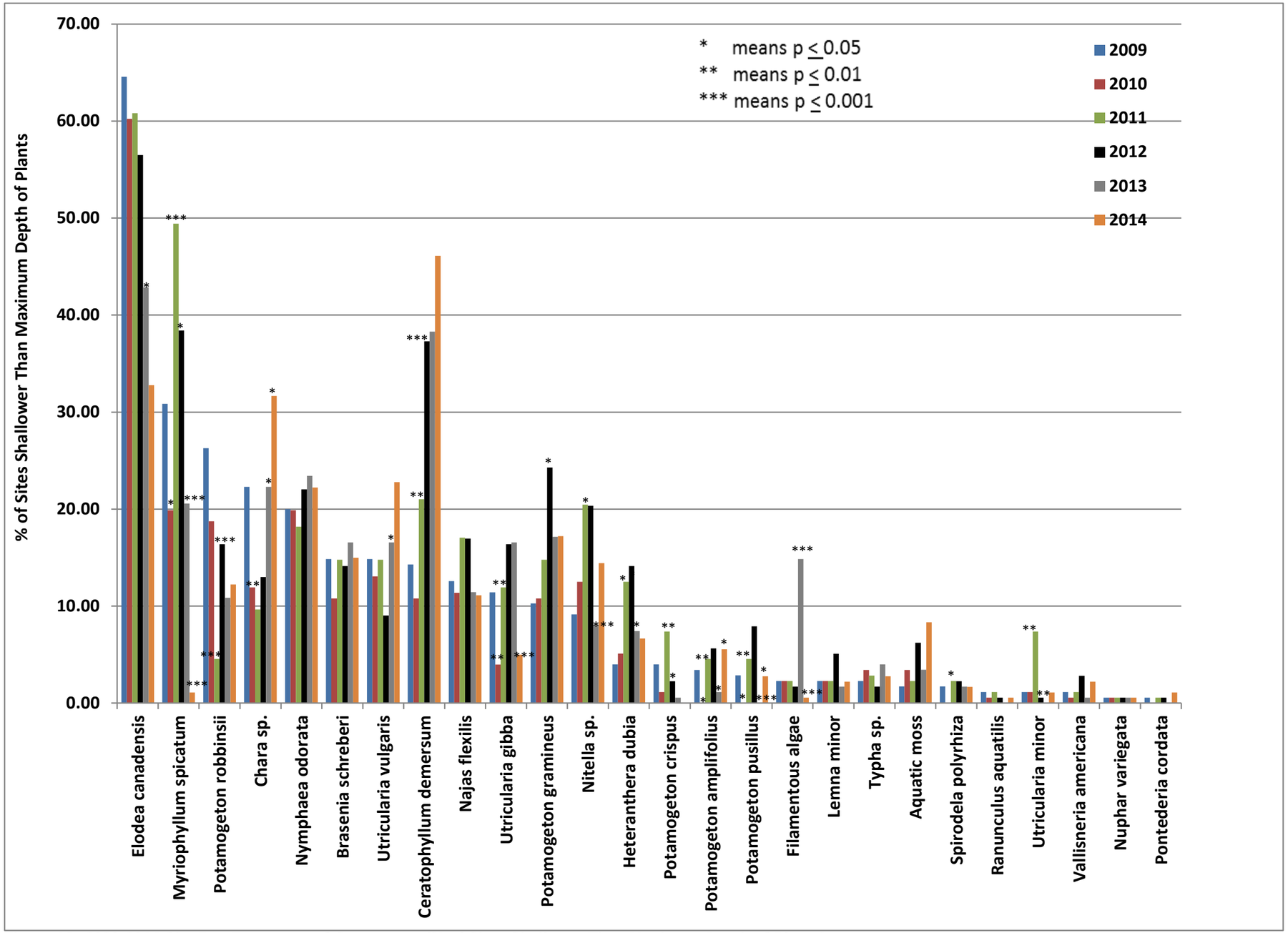

Figure 12 2009-2014 City Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

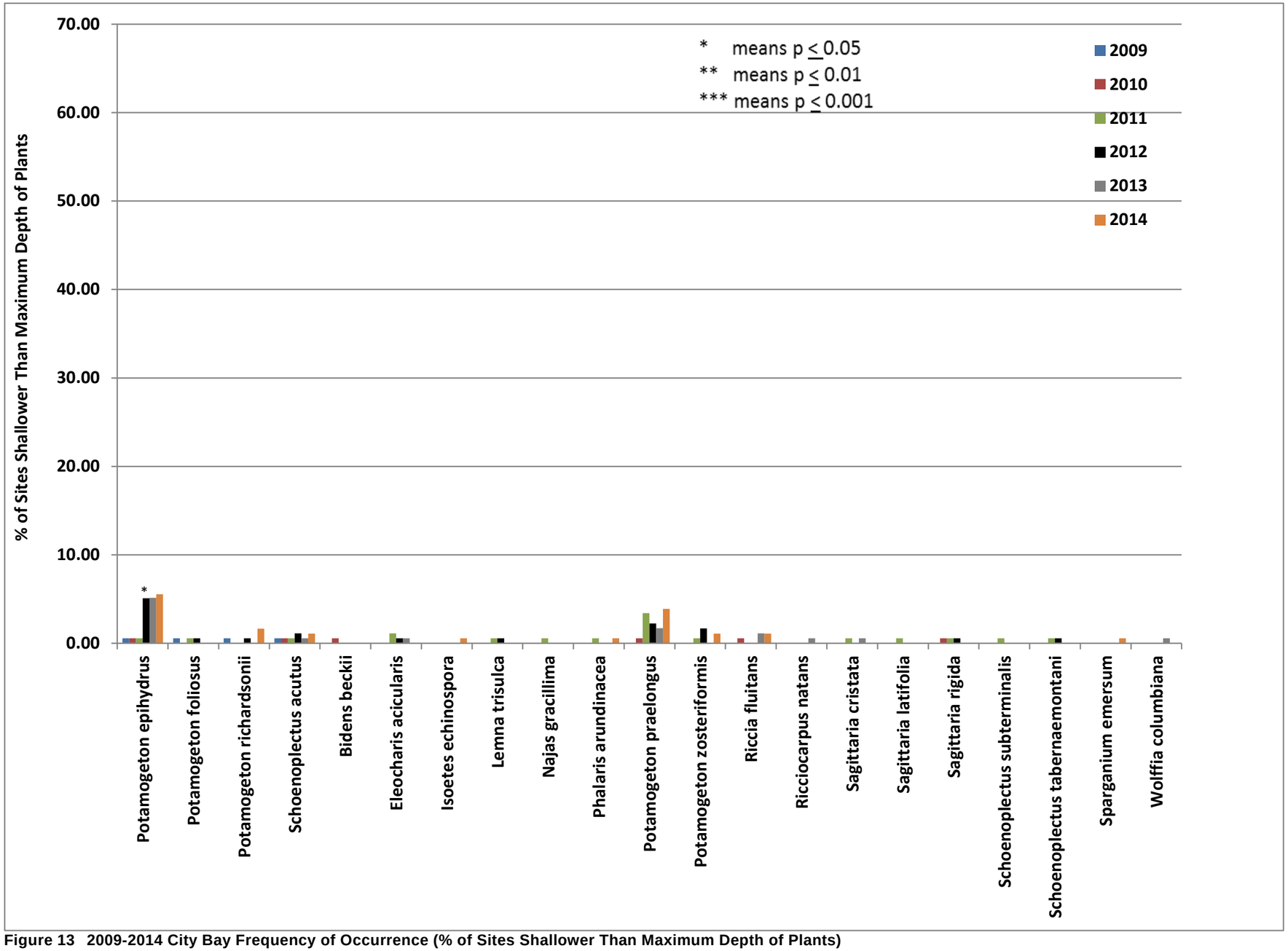

Figure 13 2009-2014 City Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

1.7 East Lake

East Lake has a surface area of 147 acres and a maximum depth of 90 feet. In 2012, the lake experienced good to poor water transparency noting Secchi disc water transparency ranging from 4 to 10 feet.

From 15 to 23 plant species were observed in East Lake, pictured above, during 2009 through 2014. The quality of the plant community, measured by FQI, is higher than the median value for lakes in the same eco-region.

During 2009 through 2014, the maximum depth of plant growth ranged from 13 feet to 25 feet. From 15 to 23 species were observed during 2009 through 2014. The FQI in East Lake during 2009 to 2014 ranged from 22.5 to 28.2 which was greater than the median value for lakes in the same eco-region (20.9) (Nichols, 1999). Diversity, measured by the Simpson Diversity Index, ranged from 0.85 to 0.90. Plants were found at 36 to 76 percent of sample sites shallower than the maximum depth of plants. On average, 0.6 to 1.6 native plant species were generally found at each sample location (Table 8). The most prevalent native species during 2009 through 2014 were coontail (*Ceratophyllum demersum*), slender naiad (*Najas flexilis*), water star-grass (*Heteranthera dubia*), common waterweed (*Elodea canadensis*), fern pondweed (*Potamogeton robbinsii*), nitella (*Nitella sp*.), and muskgrasses (*Chara sp.)* (Figure 14).

During 2009 through 2014, a total of 6 native species experienced a significant change in frequency of occurrence. Two native species experienced fluctuations that included both a significant decline and a significant increase, 1 native species experienced a significant increase, and 3 native species experienced a significant decrease (Figure 14). In 2014, 3 native species experienced a significant change in frequency of occurrence (Table 2 and Figure 14). Two native species experienced a significant increase in frequency (*Nitella sp*. and *Potamogeton robbinsii*) and 1 native species experienced a significant decrease in frequency (*Najas flexilis*) (Table 2 and Figure 14).

Table 8 2009-2014 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	7/13/2014
Total number of points sampled	172	172	172	172	172	172
Total number of sites with vegetation	67	62	63	59	43	51
Total number of sites shallower than maximum depth of plants	95	87	83	97	82	143
Frequency of occurrence at sites shallower than maximum depth of plants	70.53	71.26	75.90	60.82	52.44	35.66
Simpson Diversity Index	0.85	0.86	0.86	0.90	0.86	0.85
Maximum depth of plants (ft)	14.50	14.50	13.00	15.00	13.00	25.00
Average number of all species per site (shallower than max depth)	1.79	1.41	1.86	1.70	1.06	0.58
Average number of all species per site (veg. sites only)	2.54	1.98	2.44	2.80	2.02	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
Average number of native species per site (veg. sites only)	2.29	1.85	2.05	2.45	2.02	1.61
Species Richness	18	15	20	22	15	15
Species Richness (including visuals)	20	15	22	22	16	16
Species Richness (including visuals and boat survey)	20	15	22	23	17	18
Mean depth of plants (ft)	6.55	7.15	7.25	6.33	6.42	8.72
Median depth of plants (ft)	7.00	7.50	7.50	6.50	6.50	7.00
Mean rake fullness (veg. sites only)		1.52	1.76	1.46	1.16	1.22
Mean C	6.31	6.00	6.28	6.30	6.29	6.29
FQI	25.25	22.45	26.63	28.17	23.52	23.52

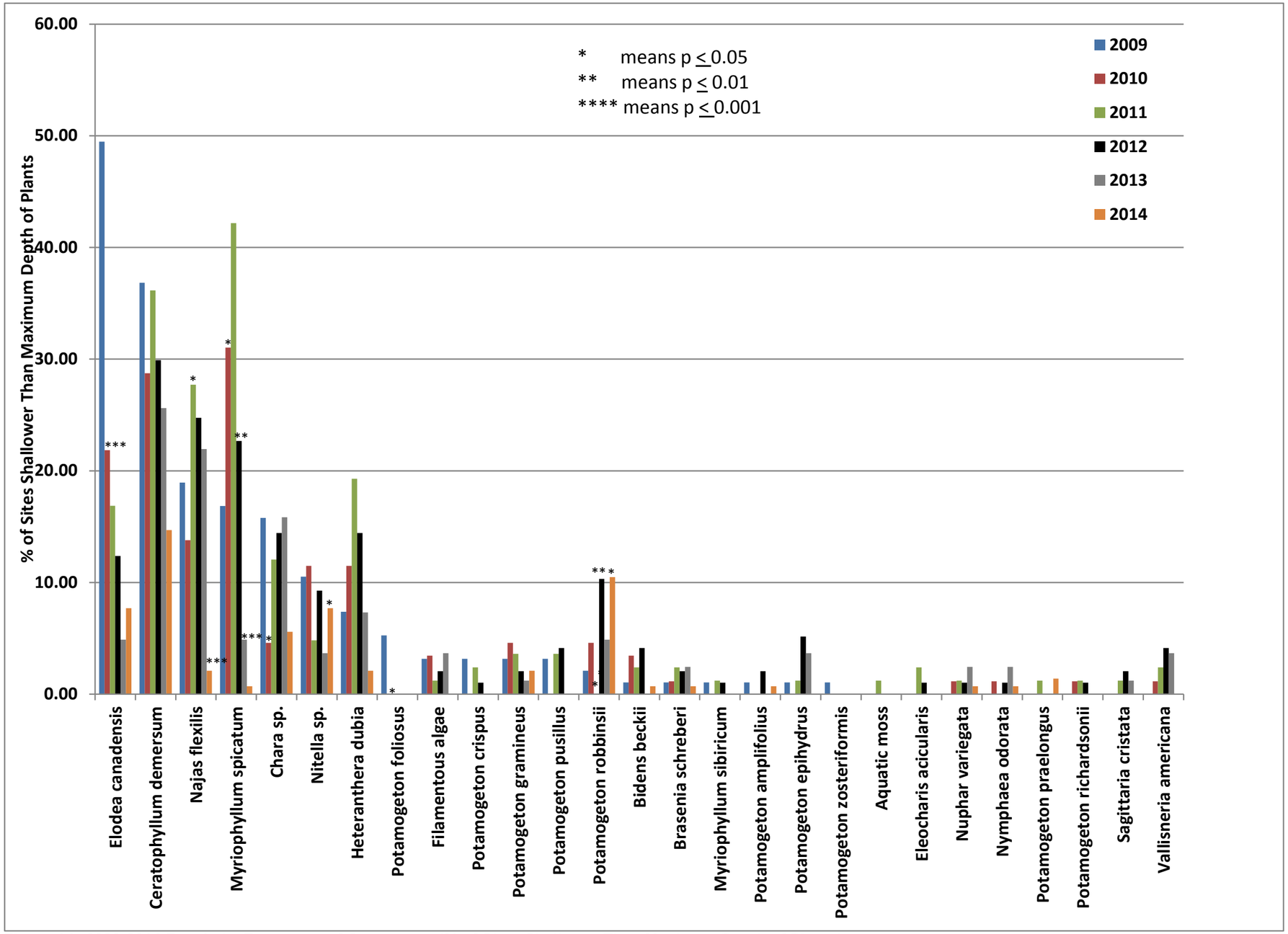

Figure 14 2009-2014 East Lake Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

1.8 Norwegian Bay

Norwegian Bay has a surface area of 38 acres and a maximum depth of 18 feet.

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.

During 2009 through 2014, the maximum depth of plant growth ranged from 8.5 feet to 12 feet. From 23 to 36 species were observed during 2009 through 2014. The FQI in Norwegian Bay during 2009 to 2014 ranged from 23.3 to 31.0 which was greater than the median value for lakes in the same eco-region (20.9) (Nichols, 1999). Diversity, measured by the Simpson Diversity Index, ranged from 0.84 to 0.91. Plants were found at 88 to 98 percent of sample sites shallower than the maximum depth of plants. On average, 1.5 to 3.2 native plant species were generally found at each sample location (Table 9). The most prevalent native species during 2009 through 2014 were coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), nitella (*Nitella sp.*), water star-grass (*Heteranthera dubia*), common bladderwort (*Utricularia gibba*), and creeping bladderwort (*Utricularia gibba*) (Figure 15). Filamentous algae were prevalent in 2011 through 2013, but were less prevalent in 2014 (Figure 15).

During 2009 through 2014, a total of 10 native species experienced a significant change in frequency of occurrence. Five native species experienced fluctuations that included declines and increases, 3 native species experienced a significant increase, and 2 native species experienced a significant decrease (Figures 15 and 16).

In 2014, 1 species experienced a significant increase in frequency (*Nitella sp.*) and 2 species experienced a significant decrease in frequency (*Utricularia gibba*. and filamentous algae) (Table 2 and Figures 15 and 16).

Table 9 2009-2014 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	7/13/2014
Total number of points sampled	68	68	68	68	68	68
Total number of sites with vegetation	57	58	61	65	58	60
Total number of sites shallower than maximum depth of plants	65	66	66	66	63	66
Frequency of occurrence at sites shallower than maximum depth of plants	87.69	87.88	92.42	98.48	92.06	90.91
Simpson Diversity Index	0.86	0.84	0.89	0.91	0.90	0.90
Maximum depth of plants (ft)	9.50	11.50	12.00	11.00	8.50	11.50
Average number of all species per site (shallower than max depth)	2.51	1.73	2.65	3.64	2.71	3.26
Average number of all species per site (veg. sites only)	2.86	1.97	2.87	3.69	2.95	3.58
Average number of native species per site (shallower than max depth)	2.12	1.52	2.52	3.12	2.63	3.17
Average number of native species per site (veg. sites only)	2.42	1.79	2.77	3.17	2.91	3.48
Species Richness	24	20	23	26	25	33
Species Richness (including visuals)	28	23	24	29	28	35
Species Richness (including visuals and boat survey)	28	23	24	30	29	36
Mean depth of plants (ft)	4.08	4.60	5.18	4.70	4.34	4.81
Median depth of plants (ft)	4.00	4.50	5.50	4.50	4.50	4.75
Mean rake fullness (veg. sites only)		1.71	2.07	2.02	1.74	1.87
Mean C	6.33	5.65	6.00	6.05	6.09	6.00
FQI	29.02	23.28	26.83	28.36	28.57	31.18

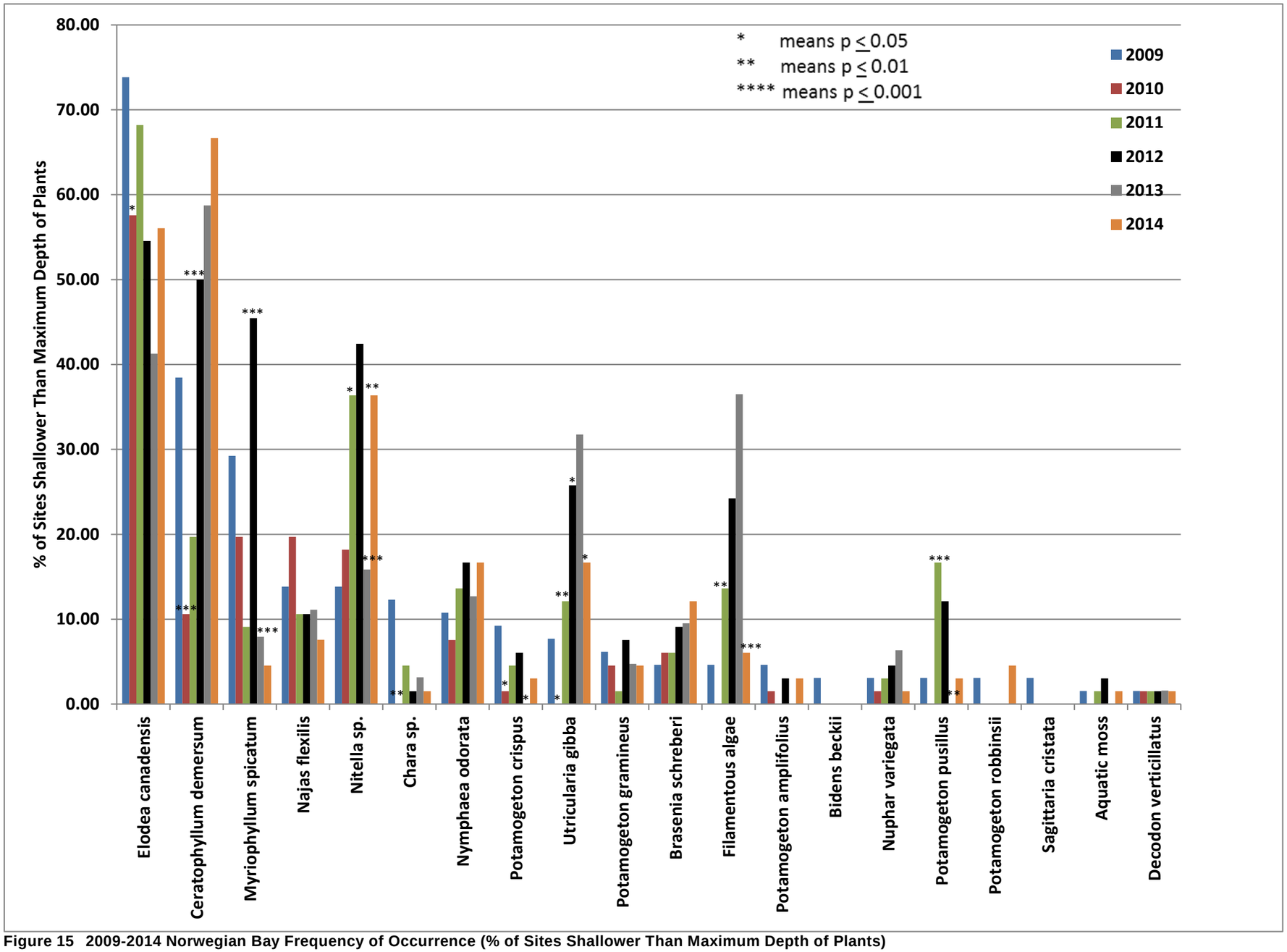

Figure 15 2009-2014 Norwegian Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)

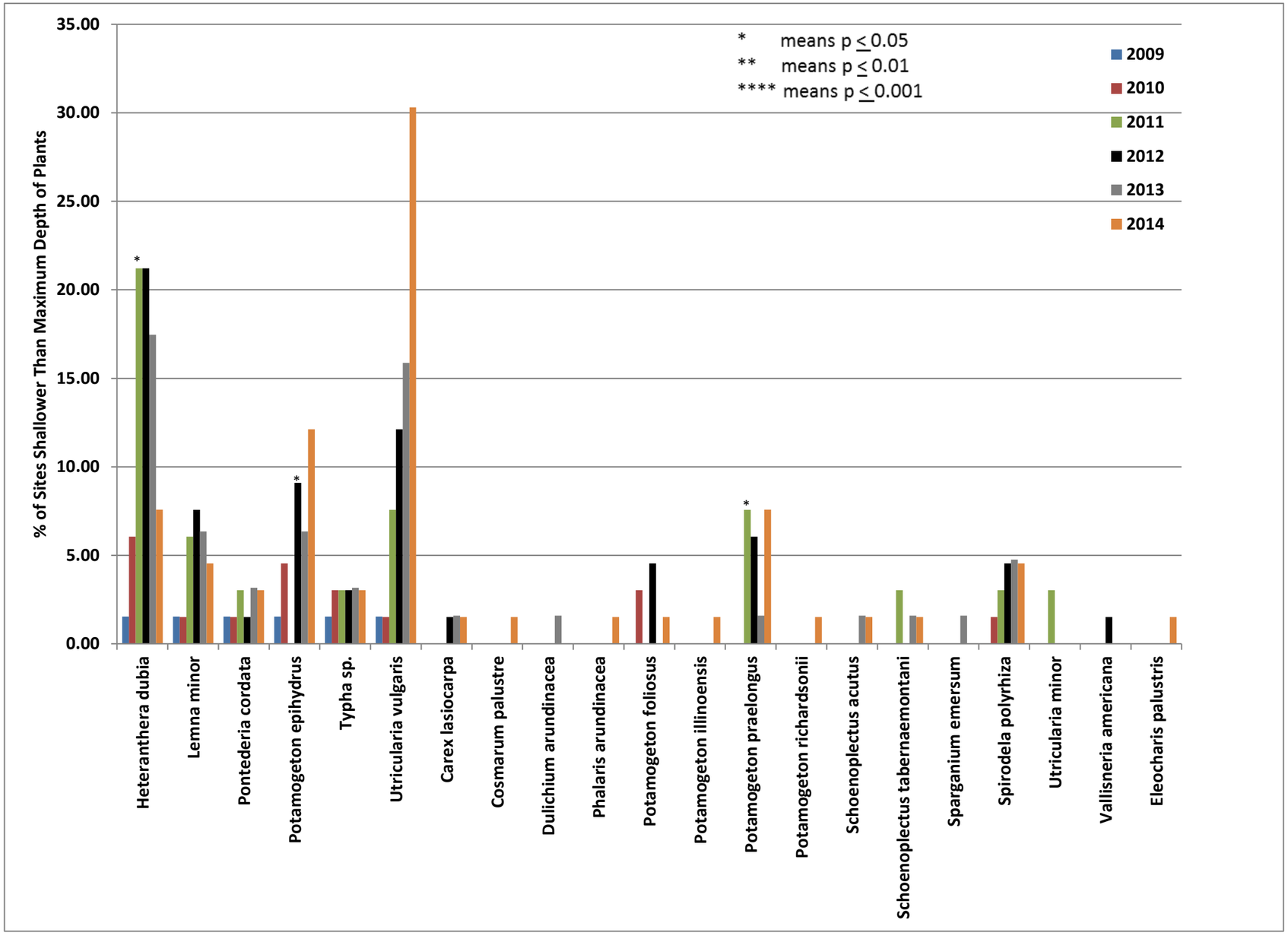

Figure 16 2009-2014 Norwegian Bay Frequency of Occurrence (% of Sites Shallower Than Maximum Depth of Plants)