Guidelines for sampling floating-leaf emergent plants in Indiana lakes

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Abstract

A sampling method designed to delineate and characterize the species composition of floating-leaf emergent plant beds, primarily spatterdock *Nuphar variegate* and white water lily *Nymphaea odorata*, was developed and field-tested by the Indiana Division of Fish and Wildlife at two natural lakes in northeast Indiana. Beds were delineated with a Global Positioning System (GPS) unit and rangefinder, while beds were characterized based on the dominance of floating-leaf species along transects within the beds. Supplemental data was also obtained on the presence of shallow-water emergent plants associated with floating-leaf beds. Twenty-four beds totaling 6.03 acres and 25 small patches of floating-leaf plants were delineated in Skinner Lake and 12 beds totaling 7.23 acres and 10 patches were delineated in Cree Lake. Bed coverage represented 5% of the total surface area at Skinner Lake and 13% at Cree Lake, excluding man-made residential channels. Ratios of lakeward perimeter bed length to shoreline length were 0.24:1 at Skinner Lake and 0.98:1 at Cree Lake. Of 109 transects examined in beds at Skinner Lake, 82% contained spatterdock and 30% contained water lilies. Spatterdock was the dominant plant in 18 beds totaling 5.29 acres and water lily was the dominant plant in four beds totaling 0.47 acres. Two beds contained a mixed ratio of spatterdock and water lily. At Cree Lake, 29% of 92 transects within floating-leaf beds contained spatterdock and 92% contained water lilies. Spatterdock was the dominant plant in two beds totaling 0.44 acres and water lily was the dominant plant in nine beds totaling 6.11 acres. Six other shallow-water emergent species were associated with beds at Skinner Lake and eight other shallow-water species associated with floating-leaf beds at Cree Lake.

Floating-leaf emergent aquatic plants have large leaves that float or extend slightly above the water surface and are usually found at depths greater than 2 feet (Borman et. al. 1999). They exist within a transition zone between shallow-water emergent plants and submersed plants. In Indiana, the most common floating-leaf emergents are spatterdock *Nuphar variegate* and white water lily *Nymphaea odorata*. Yellow pond lily *Nuphar advena* and American lotus *Nelumbo lutea* are less common. Some emergent plants, such as soft-stem bulrush *Scirpus validus*, can grow in water deeper than 2 feet but lack floating leaves. Other emergents are normally restricted to shallow wetland margins of lakes, such as arrow arum *Peltandra virginica*, arrowhead *Sagittaria latifolia*, pickerelweed *Pontederia cordata*, cattails (Genus *Typha*), sedges (Genus *Carex*) and spikerushes (Genus *Eleocharis*). Floating-leaf plants do not include submersed species with leaves that float on the surface or form surface canopies, such as *Potamogeton spp*.

The distinction between floating-leaf emergents and shallow-water emergents is arbitrary but can be useful for sampling and lake management purposes. Sampling floating-leaf emergents from a boat can be relatively easy but sampling shallow-water plants may require a different approach where boat access is difficult. Floating-leaf emergents generally provide habitat for fish and other aquatic wildlife, while shallow-water plants provide habitat for mammals, birds and other wetland wildlife. Both groups help protect the shore from erosion, add natural beauty and character to a lake, but floating-leaf emergents usually grow lakeward of the shoreline and are more likely to interfere with swimming, boating and other recreational uses. Shallow-water emergents usually grow at the water's edge and are more likely to limit lake access or viewing. In Indiana, management of floating-leaf emergents falls primarily under authority of the Department of Natural Resources in public freshwater lakes (Indiana Code 14-26-2) or lakes containing state-owned fish (Indiana Code 14-22-9-10). Shallow-water wetland plants lakeward of the shoreline are also under state control but those landward of the shoreline are not.

Little is known about the historical composition and extent of coverage of floating-leaf emergent beds in Indiana lakes (Alix and Scribailo 1998). As a result, changes in emergent plant communities have not been widely documented. The general perception among lake managers is that Indiana natural lakes have lost much of their once-flourishing floating-leaf flora, while Indiana reservoirs rarely contained floating-leaf emergents. Emergent plants in natural lakes have been removed physically, mechanically and chemically as a result of construction of piers, seawalls, beaches and lakebed dredging associated with residential development. Other factors related to boating, such as disturbance from wave energy, destruction by propellers, and encroachment within shallow sensitive areas, are believed to be contributing to the loss of floating-leaf plants (Indiana Lakes Management Workgroup 1999). Emergent plants in reservoirs are typically limited by water level fluctuations, turbidity and other environmental factors.

Although the Indiana Department of Natural Resources has some recent information on floating-leaf emergent plant beds, the data is not quantitative or based on standardized sampling procedures. Species lists and hand-sketched maps of beds noted during fish population surveys are on file with the Division of Fish and Wildlife. Other records include surveys and maps generated from diagnostic studies partially funded through the Division of Soil Conservation. The Division of Water has files with photographs and comments pertaining to environmental reviews of requests for shoreline or lakebed alteration permits at specific sites. However, none of these records provide sufficient comparative data to monitor changes in emergent plant communities or provide adequate information to assess the impacts of changes on lake ecology. Consequently, the purpose of this paper is to describe a sampling method that is capable of locating, delineating and characterizing floating-leaf emergent aquatic plant beds in Indiana lakes. It follows an earlier paper that described techniques for sampling submersed aquatic plants (Pearson 2004).

Sampling Method

The advent of Global Positioning System (GPS) equipment and personal computer mapping technology has opened new opportunities for lake managers to delineate, quantify and present data on aquatic plant resources. Prior to GPS technology, plant surveys conducted by Indiana fisheries biologists were either not geo-referenced or were based on a limited transect technique that did not provide estimates of the extent of area coverage (Shipman 2000). At the same time, comprehensive surveys of floating-leaf emergents based on labor-intensive transect methods, random plot design, aerial photography, or hydro-acoustic technology (Aquatic Control, Inc. 2004) were considered outside the limits of cost and manpower. As a result, our efforts were directed at developing a low-cost, standard sampling technique centered on using a GPS unit, a rangefinder, and mapping software to delineate the shape of plant beds and record the frequency of occurrence of various species along a series of transects corresponding to each GPS coordinate. We did not quantify plant density based on a percentage scale within an established field of view because most floating-leaf emergent beds, by definition, had distinct edges and typically occupied more than 60% of the area where present (Yin et al 2000, Hoffman 2003 unpublished).

As we developed the technique, it became apparent that specific terminology was needed to adequately describe the procedure, record the data in a standard format, and summarize the results. A “bed” was defined as a geo-referenced polygon with distinct edges enclosing a contiguous stand of floating-leaf emergents plants (primarily spatterdock and lily). To conform to rules adopted for permit assessments under Indiana Administrative Code 312, beds were generally greater than 625 square feet in size, more than 25 feet in length, and/or separated by similar plants by 25 feet or more. Smaller isolated stands of floating-leaf emergents or individual plants were defined as “patches”.

Various parameters were used to describe bed dimensions. Widths were measured landward at each GPS coordinate (Garmin® *GPS III Plus*) with an optical rangefinder (Ben Meadows® *M100*). Perimeter length was calculated by summing linear distances between GPS points along the lakeward edge of the bed. Bed coverage area was estimated as the sum of a series of consecutive polygons based on the average widths of two adjacent transects within a bed multiplied by the linear distance between their lakeward GPS points. This method did not require mapping software to estimate bed area. To map the various beds, we imported GPS coordinates into software (DeLorme® *StreetAtlas* or ESRI® *ArcGIS*), drew line segments perpendicular to shore corresponding to bed width at each coordinate, then digitized the resulting polygon created by the ends of all segments.

As we developed the procedure, we eventually adopted the following standard technique and tested it at two lakes. We sampled on calm days in August but sampling could be done from mid-June to mid-September. We used a two-person crew, one logging GPS waypoints and measuring bed width while the other recorded data. We boated counterclockwise along the lakeward edge of a bed, stopping first at the edge of each bed as close to shore as possible where we recorded the site number, the letter “S” symbolizing the start of the bed, and logged the GPS waypoint. We then stopped at various points along the bed where substantial changes in direction or shape of the bed occurred. At the lakeward end of each bed, we recorded the letter “E”. At each GPS coordinate, bed width was measured on a visual straight-line perpendicular transect to shore. For offshore beds, additional landward points were recorded at the edge for bed delineation but were assigned no widths because widths were always measured from lakeward positions. Due to inherent variability in size and orientation of the beds based on lake contour and shape, sample points theoretically approached a random design. We also occasionally recorded water depth to establish the maximum depth of the floating-leaf plants.

Although our primary purpose was to sample floating-leaf emergents, we also noted the presence of other emergents when we recorded data. At each GPS point, we assigned a score of "1" for any emergent species encountered in the immediate area (less than 10-ft by 10-ft square) of the surveyor. We then noted the presence of other floating-leaf and shallow-water emergent plants along the transect extending toward shore and assigned a default score of "9" for each observed species. The field of view along each transect was limited to a width of 10 feet. Where floating-leaf patches were encountered, we recorded site number, labeled the site "P", and scored a "1" for each species observed within the patch.

In addition to generating maps showing the location, shape and size of each bed, various summary statistics were calculated to describe bed characteristics. Mean width of each bed was determined by averaging bed widths at each GPS coordinate. The percentage of total surface area covered by floating-leaf emergent beds was determined by dividing estimated bed size by lake area, excluding man-made channels dug for residential development where no emergent sampling was conducted. Floating-leaf bed area was also calculated as a fraction of the lake area less than 10 feet deep. We compared total lakeward perimeter lengths of beds to measurements of shoreline length (excluding channels) to calculate a bed-length:shoreline-length ratio. To describe the species composition of the floating-leaf beds, as well as shallow-water plants associated with them, we determined the frequency of occurrence of all emergent species observed along the transects at each bed. Floating-leaf beds were also characterized on the basis of their dominant species. Where the ratio of spatterdock occurrence to other floating-leaf species within the bed was 2:1 or greater, the bed was labeled a "spatterdock bed". Where lilies occurred twice as often as spatterdock along transects, the bed was labeled a "lily bed". Ratios less than 2:1 were labeled "mixed beds".

The sampling guidelines were tested on August 24 at Skinner Lake, a 122-acre natural lake near Albion, and August 30 at Cree Lake, a 76-acre natural lake near Kendallville. At Skinner Lake, 24 emergent beds and 25 patches were delineated with 134 GPS points. At Cree Lake, 12 beds and 10 patches were located with 102 GPS points. Sampling was done by a two-person crew at an average rate of one site per minute, although boating through dense chara stands next to floating-leaf plant beds at Cree Lake required more sampling time and effort.

The *M100* rangefinder proved to be inaccurate over the range of widths we encountered among various beds. Based on three repeated tests with known distances, measurements beyond 10 feet were consistently less than true distances and inaccuracy increased with greater distances. To compensate for the inaccuracy, we developed an equation to correct for discrepancies between true distances (D_t) and estimated distances (D_e) where: $D_t = ((D_e - 1.779)/0.87)$. Bed acreages (BA) were calculated from: $BA = 3((G_i - G_{i+1})*((W_i + W_{i+1})/2))$ where $(G_i - G_{i+1})$ represents the linear distance in feet between two consecutive GPS positions and $(W_i + W_{i+1})$ represents successive corrected bed widths. The formula we used for calculating linear distance in feet between GPS points was $(G_i - G_{i+1}) = SQRT(((367560* (Lat_i - Lat_{i+1}))*(367560*(Lat_i - Lat_{i+1})))+((274500*(Lon_i - Lon_{i+1}))*(274500*(Lon_i - Lon_{i+1}))))$ where Lat_i represents latitude in degrees and Lon_i represents longitude in degrees using NAD83 map datum.

The *M100* rangefinder at times also proved difficult to use on the water because distinct edges of lilies or spatterdock plants could not be clearly focused upon at greater distances. In addition, floating-leaf plants often blended with shallow-water emergent edges or shifted with only the slightest wind or waves. Beds with distinct edges along seawalls and other structures were discerned more easily.

Results

Twenty-four floating-leaf emergent beds were delineated within Skinner Lake. They ranged in size from 0.01 to 1.54 acres and totaled 6.03 acres (*Appendix 1*). Overall mean bed width was 46 feet (*SD*=23) and mean width per bed was 42 feet (*SD*=16). Their coverage area represented 5% of the total lake surface and 13% of the lake area within the 10-foot depth contour. Their lakeward perimeter extended for 1.03 miles for a bed-length:shoreline-length ratio of 0.24:1. Twenty-five patches of floating-leaf emergents were also located.

Spatterdock and white water lily were the only floating-leaf emergents plants identified at Skinner Lake, although six other shallow-water emergent species were associated with the floating-leaf beds. The mean number of emergent species encountered per transect, including floating leaf plants, was 1.94 and varied from 1.00-3.25 (*SD*=0.93), while the mean number of species per bed was 2.9 (*SD*=1.3). Spatterdock was present in 21 of the 24 beds and water lilies were present in 10. Arrow arum was present in 21, swamp loosestrife and cattails were present in six beds, pickerelweed was present in four, while soft-stem bulrush and purple loosestrife were each present in one bed.

Of the 109 transects examined during the survey, 82% contained spatterdock and 30% contained water lilies. In beds where spatterdock was present, it occurred at frequencies that varied from 40-100% and averaged 90%. In beds where water lilies were present, they occurred at 14-100% of the transects and averaged 71%. Spatterdock was the dominant floating-leaf emergent in 18 beds totaling 5.29 acres, while water lily was the dominant emergent in four beds totaling 0.47 acres. Fifteen beds contained spatterdock throughout the bed and six beds had lilies throughout. Two beds totaling 0.27 acres contained a mixed ratio of spatterdock and water lily. Lilies also occurred within 68% of the 25 patches and spatterdock was present within 36%.

Floating-leaf emergent beds in Skinner Lake were generally scattered along the shore except on the west side, midway along the south shore, and around a public beach on the north shore (*Figure 1*). Bed continuity was interrupted in several areas by piers. The largest beds, those exceeding 0.5 acres, were present along undeveloped shoreline sections located in the southeast corner (#5 and #6) and the northeast corner (#13) of the lake. The largest bed was located in the northwest corner (#19). Isolated patches were primarily located midway along the south shore adjacent to the mouth of the main inlet (Rimmell Ditch) and in the area between the beach and the northeast corner.

Twelve floating-leaf emergent beds were delineated in Cree Lake. They ranged in size from 0.09-2.38 acres and totaled 7.23 acres (*Appendix 2*). Overall mean bed width was 50 feet (SD=27), while mean width per bed was 49 feet (SD=10). Their coverage area represented 13% of the lake surface (excluding 18 acres of man-made channels on the east side) and 40% of the surface area within the 10-foot depth contour. Their lakeward perimeter extended for 1.29 miles for a bed-length:shoreline-length ratio of 0.98:1. Ten patches of floating-leaf emergents were also noted.

Spatterdock and white water lily were present in the floating-leaf beds at Cree Lake. Eight other species of emergent plants were also associated with the beds. The mean number of emergent species, including floating-leaf plants, encountered per transect was 2.26 and varied from 1.67-3.60 (SD=0.97), while the mean number of species per bed was 5.1 (*SD*=2.0). Spatterdock was present in nine of the 12 beds and water lilies were present in all 12. Arrow arum was present in 11 beds, cattails were present at 10, followed by soft-stem bulrush at five, purple loosestrife at four, with arrowhead and smartweed at three. Swamp loosestrife and pickerelweed were present at two beds.

Of the 92 transects examined at Cree Lake, 29% contained spatterdock and 92% contained water lilies. In beds where spatterdock was present, it occurred at frequencies that varied from 20-100% and averaged 47%. In beds where lilies were present, they also occurred at 20-100% of the transects but averaged 88%. Spatterdock was the dominant floating-leaf emergent in two beds totaling 0.44 acres, while lilies were the dominant floating-leaf emergents in nine beds totaling 6.11 acres. Only one bed contained spatterdock throughout the bed and eight beds contained lilies throughout. A 0.68-acre bed contained a mixed ratio of spatterdock and water lily. Ten patches consisting entirely of lilies were noted.

Floating-leaf emergent beds were present throughout most of Cree Lake's shore, although bed continuity was interrupted slightly by piers (*Figure 2*). The largest beds, those exceeding 0.5 acres, were present along the west side (#2 and #3), midway on the east shore (#8), and on the north end (#11 and #12). The largest bed (bed #4) rimmed the south shore. Although lily-dominated beds were located throughout the lake margin, spatterdock-dominated beds were present only in the southeast corner near the mouth of an extensive manmade channel system. Patches were located primarily midway along the east shore.

Implications

The sampling procedures presented in this report appeared to adequately characterize the location, shape, size and species composition of floating-leaf emergent plant beds in two Indiana natural lakes. In addition, the technique generated supplemental data on the presence of floating-leaf emergent patches as well as data on the presence of shallow-water emergent species associated with each floating-leaf bed. Sampling did not take an inordinate amount of time or involve the use of expensive survey equipment, although use of a laser rangefinder might improve accuracy when measuring bed width.

Data collected using these procedures can be summarized with most spreadsheet applications. As more surveys are conducted, the information should be stored in a format capable of generating standard output reports and enable investigators to query the data for use with geographic information systems. Even without sophisticated software, data obtained by these procedures can be analyzed and presented in a way that may be useful for anglers, lake residents and others interested in lake management. Although we used only one method to calculate bed coverage area, estimates of bed size can also be generated from the digitized maps.

Coupled with standardized sampling techniques developed for submersed aquatic plants, the information obtained on floating-leaf emergents based on these guidelines can provide a more complete assessment of botanical resources in Indiana lakes. Trying to sample both groups of plants at the same time, however, might prove troublesome. The submersed plant sampling technique is based on a random design and does not include bed area delineation, while the sampling procedure described here for floating-leaf plants is targeted at specific locations for purposes of bed delineation and mapping. Calculations of floating-leaf bed size are based on successive GPS coordinates that could be more difficult to track if recorded at the same time as submersed plant sampling sites.

No single aquatic plant sampling technique fits all needs. Additional effort or an alternative technique would be required to more fully assess shallow-water vegetation where no floating-leaf emergents are presently located. A procedure similar to the one described here could be developed that incorporates random or targeted transects for evaluating the presence of emergent species along the entire shoreline. Other more sophisticated techniques linking GPS with digital photography could be developed for shallow-water emergent sampling that would have even broader application for whole-lake plant assessments, permit reviews, and environmental law enforcement.

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Figure 1. Locations of floating-leaf emergent plant beds in Skinner Lake, August 24, 2004.

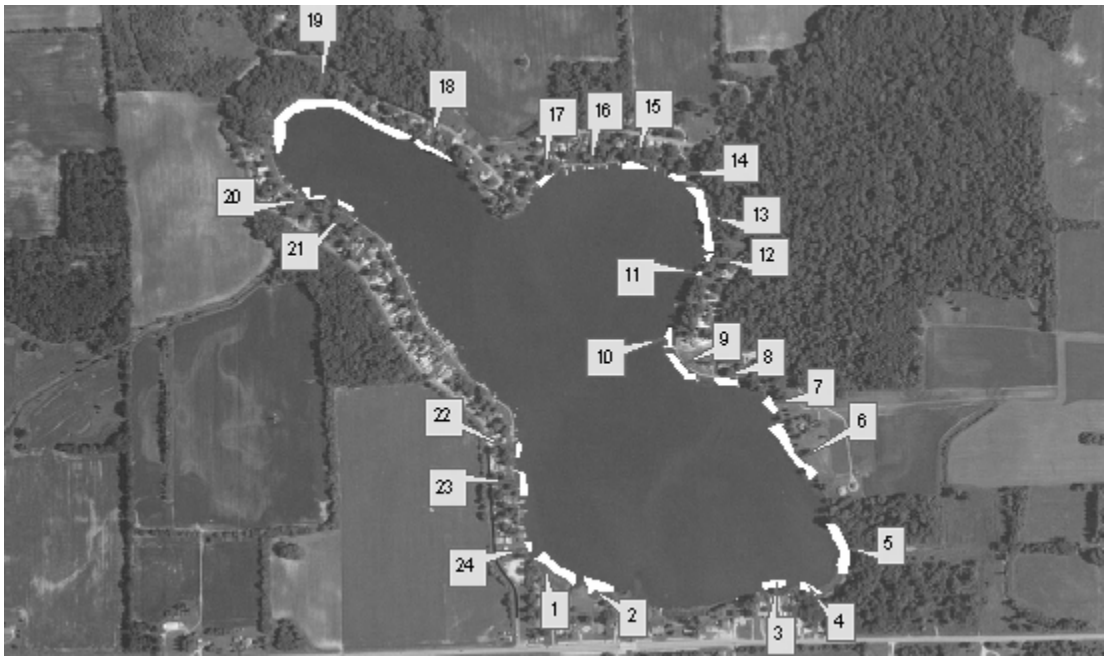
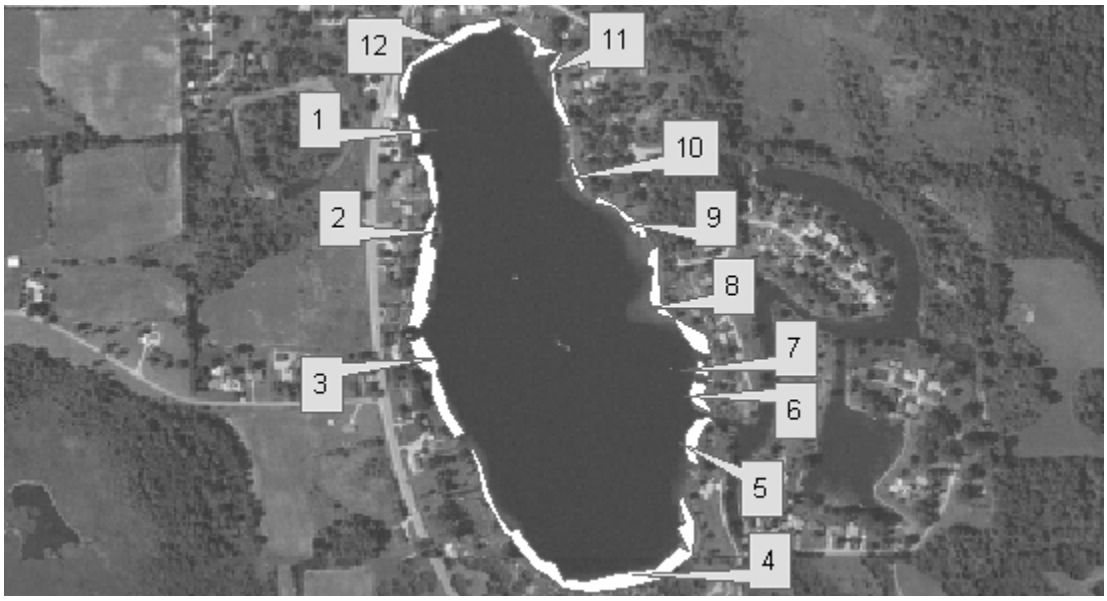


Figure 2. Locations of floating-leaf emergent plant beds in Cree Lake, August 30, 2004.



Appendix 1. Floating-leaf emergent plant bed size and species composition at Skinner Lake on August 24, 2004.

			Mean	Species frequency of occurrence*									Species composition		
Bed	**Acres**	**Sites**	**Width**	**SPA**	**WAL**	**ARA**	**SWL**	**CAT**	**PIK**	**PRL**	**STB**	**ARH**	**N**	**N/site**	**Dominance**
All	6.03	109	46	81.7	30.3	52.3	11.0	10.1	7.3	0.9	0.9	0.0	8	1.94	Spatterdock
1	0.43	5	68	100.0		20.0	60.0						3	1.80	Spatterdock
2	0.31	8	52	100.0		37.5		50.0					3	1.88	Spatterdock
3	0.16	5	41	60.0	100.0								2	1.60	Mixed
4	0.13	4	40		100.0	25.0							2	1.25	Water lily
5	0.51	5	74	100.0		80.0	60.0	20.0	20.0				5	2.80	Spatterdock
6	0.61	7	63	100.0	14.3	14.3			28.6	14.3			5	1.71	Spatterdock
7	0.13	3	59	100.0	33.3	66.7							3	2.00	Spatterdock
8	0.16	5	42	40.0	100.0								2	1.40	Water lily
9	0.25	4	50	100.0		25.0							2	1.25	Spatterdock
10	0.10	5	29	100.0	20.0	20.0							3	1.40	Spatterdock
11	0.02	2	22	100.0									1	1.00	Spatterdock
12	0.04	3	36		100.0	66.7							2	1.67	Water lily
13	0.59	7	51	100.0		85.7	14.3						3	2.00	Spatterdock
14	0.11	4	44	75.0	100.0	50.0		50.0	50.0				5	3.25	Mixed
15	0.14	4	31		100.0	50.0							2	1.50	Water lily
16	0.01	2	12	100.0		50.0							2	1.50	Spatterdock
17	0.04	3	30	66.7		100.0		66.7					3	2.33	Spatterdock
18	0.24	4	36	100.0		100.0							2	2.00	Spatterdock
19	1.54	11	62	90.9	45.5	81.8	27.3	9.1	27.3				6	2.82	Spatterdock
20	0.11	5	33	100.0		100.0							2	2.00	Spatterdock
21	0.12	4	31	100.0		25.0	25.0						3	1.50	Spatterdock
22	0.06	3	22	66.7		100.0							2	1.67	Spatterdock
23	0.16	3	48	100.0		100.0							2	2.00	Spatterdock
24	0.06	3	35	100.0		66.7	33.3	33.3			33.3		5	2.67	Spatterdock
Mean	0.25	5	42	90.4	71.3	60.2	36.6	38.2	31.5	14.3	33.3	0.0	2.9	1.87	
Patches		25		36.0	68.0	12.0					4.0	4.0	5	1.18	

***Species present**

ARA *Arrow arum*
ARH *Arrowhead*
CAT *Cattail*
PIK *Pickerelweed*
PRL *Purple loosestrife*
SPA *Spatterdock*
STB *Soft-stem bulrush*
SWL *Swamp loosestrife*
WAL *Water lily*

Appendix 2. Floating-leaf emergent plant bed size and species composition at Cree Lake on August 31, 2004.

			Mean	Species frequency of occurrence*										Species composition		
Bed	**Acres**	**Sites**	**Width**	**SPA**	**WAL**	**ARA**	**SWL**	**CAT**	**PIK**	**PRL**	**STB**	**ARH**	**SMW**	**N**	**N/site**	**Dominance**
All	7.23	92	49.8	29.3	92.4	55.4	3.3	26.1	2.2	6.5	5.4	3.3	5.4	10	2.26	Water lily
1	0.19	5	40.8	40.0	100.0	40.0		20.0					40.0	5	2.40	Water lily
2	1.25	14	50.9		100.0	57.1		35.7						3	1.93	Water lily
3	0.52	7	52.3	28.6	100.0	57.1		28.6						4	2.14	Water lily
4	2.38	20	53.0	30.0	95.0	80.0		10.0		15.0				5	2.30	Water lily
5	0.35	5	59.8	80.0	20.0	80.0		40.0			20.0	20.0		6	2.40	Spatterdock
6	0.20	4	66.8	25.0	100.0	75.0		25.0		25.0				5	2.50	Water lily
7	0.09	2	53.5	100.0	50.0	50.0								3	2.00	Spatterdock
8	0.68	9	54.2	55.6	88.9	66.7	11.1	11.1	11.1	11.1		11.1		8	2.56	Mixed
9	0.23	5	40.0	20.0	100.0	80.0		60.0	20.0	20.0	20.0		40.0	8	3.60	Water lily
10	0.11	3	28.3		100.0	33.3					33.3			3	1.67	Water lily
11	0.51	10	42.0	40.0	100.0	20.0	20.0	20.0			10.0	10.0	10.0	8	2.20	Water lily
12	0.72	8	46.3		100.0			62.5			12.5			3	1.75	Water lily
Mean	0.60	8	49.0	46.6	87.8	58.1	15.6	31.3	15.6	17.8	19.2			5.1	2.29	
Patches			10		100.0								10.0	2	1.1	

***Species present**

ARA *Arrow arum*
ARH *Arrowhead*
CAT *Cattail*
CMR *Chairmaker's rush*
PIK *Pickerelweed*
PRL *Purple loosestrife*
SPA *Spatterdock*
SMW *Smartweed*
STB *Soft-stem bulrush*
SWL *Swamp loosestrife*
WAL *Water lily*