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THE HISTORY AND AQUATIC FLORA OF SILVER LAKE, PORTER COUNTY, INDIANA, WITH COMMENTS ON THE ADEQUACY OF FLORISTIC QUALITY ASSESSMENT FOR LAKES

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ABSTRACT. During the growing season of 2004, floristic inventories were conducted on Silver Lake, Porter County, Indiana to quantitatively describe the aquatic flora. A modified point intercept technique was used to determine the frequency and relative frequency of each taxon from a total of 41 sampling points. Measurements of physical and chemical water parameters were taken from a random subsample of these points. Floristic inventories resulted in the documentation of 42 taxa in 32 genera from 23 families. Families exhibiting the greatest richness were the Lemnaceae and Potamogetonaceae. *Nuphar advena* had the highest frequency of occurrence (>75%). Chemical and physical evidence indicates that Silver Lake is a circumneutral water body prone to acidification because of its shallow depth, poor buffering capacity, and the presence of remnant peat deposits. The floristic and natural area quality of the lake proper was evaluated using the Floristic Quality Assessment (FQA) methodology of Swink & Wilhelm (1994). The floristic quality index (I) and mean coefficient of conservatism (C_{mean}) were calculated from two sources of C values (i.e., Indiana and the Chicago region), which have overlapping geographical ranges. A comparison of C values for the Silver Lake aquatic vascular plant taxa indicated that Indiana C values were at least one unit lower than those from the Chicago region. Although the use of Indiana C values resulted in lower values of C_{mean} and I, values of C_{mean} calculated from both sets of C values indicated that Silver Lake was high in natural area quality. However, the presence of a shallow lake basin, coupled with anthropogenic disturbance and drought-induced drawdowns, has contributed to a frequent and substantial loss of littoral zone, which has negatively impacted the lake's ability to sustain floristically significant submerged aquatic taxa. We recognize that problems exist with standard FQA methodology when applied to lake ecosystems and suggest ways to improve the diagnostic resolution of the FQA metrics.

Keywords: Floristic quality assessment, Indiana flora, Silver Lake, aquatic macrophytes, C values, I_{nni}

Silver Lake is one of only two small natural lakes located inside the city limits of Valparaiso, Indiana. Much of the property surrounding the lake is under private ownership; however, the southern shore is owned by the City of Valparaiso and has been selected as a project site for a road extension. The road extension has been permitted by the United States Army Corps of Engineers and the Indiana Department of Environmental Management and will be constructed through two small wetland areas. It has been determined that this project will impact an area of <0.04 ha. Many local conservationists believe the future ecological health and floristic quality of the lake and its surrounding wetlands will be diminished, or at least compromised, by the construction and use of this thoroughfare. Unfortunately, there are limited baseline data on the quality of this lake, rendering any scientific comparison of before and after conditions almost futile. These genuine concerns provided the impetus for us to conduct this study.

The main objectives of this study were (1) to quantitatively document the aquatic macrophytes within Silver Lake, (2) to measure physical and chemical habitat parameters often used in the characterization of aquatic macrophyte communities, and (3) to determine and evaluate the floristic and natural quality of the lake proper by using the Floristic Quality Assessment (FQA) methodology developed by Swink & Wilhelm (1994). Data on the habitat parameters provided here and used in conjunction with results from the floristic analysis will serve as a benchmark for the future monitoring of Silver Lake. We also provide suggestions on how to maintain, if not enhance, the floristic quality of this Lake.

A secondary objective of the Silver Lake analysis was to compare the Indiana coefficients of conservatism (*C* values) with those of the Chicago region (Swink & Wilhelm 1994) for the aquatic vascular plants at this site and determine which source was more appropriate for the FQA of Silver Lake. Because of its uncomplicated methodology, FQA is one of the most appealing diagnostic tools for evaluating habitat, given that one possesses sufficient taxonomic skills to correctly identify vascular plants. However, there are problems with the application of FQA to lake ecosystems. Therefore, we also examine some of the current problems with the use of FQA in the context of a lake ecosystem and provide suggestions on how to improve the adequacy of the FQA metrics.

METHODS

Study site.—Silver Lake is located in the northern portion of the City of Valparaiso in Porter County, Indiana (41°29′43″N, 87°03′34″W) directly northeast of Valparaiso High School and is situated between Campbell Street and Valparaiso Street (Fig. 1). This body of water is extremely shallow (*ca.* mean depth 0.6 m) and small (*ca.* 10.5 ha) and is the southern most lake of 13 lakes found in the Valparaiso Lakes Area watershed, which expands across 1085 ha. Much of the surface area of Silver Lake is dominated by spatterdock (*Nuphar advena*) and the majority of its shoreline is composed of cat-tails, sedges, and smartweeds. Due to its small size, shallow depth, and extensive emergent zone, Silver Lake is more reminiscent of a basin marsh than a lake. Although much of its shoreline is privately owned and no public access currently exists on this lake, the property adjacent to its south shore is owned by the City of Valparaiso and has been selected as the site for the extension of Vale Park Road to Campbell Street (Fig. 1).

Silver Lake lies within the Valparaiso Moraine Section of the Northwestern Morainal Natural Region (Homoya et al. 1985). This natural region is known for its dunes, glacial ridges, and diversity of wetland types (Post 1997). The Valparaiso Moraine Section topographically divides the Lake Michigan basin from the Kankakee River basin in northwest Indiana. Water from Silver Lake drains from an outlet located on its southeast corner (Fig. 1) to a ditch and water control structure, and then travels east through a ditch perpendicular and beneath Valparaiso Street, proceeding northward to Flint Lake, the largest lake in the Valparaiso Lakes Area watershed.

Silver Lake is found in Soil Region 7 characterized by the Blount-Morely-Pewamo association (Franzmeier 1997). These soil types are plentiful in the Valaparaiso Lakes Area watershed and were primarily formed from clayey glacial till after the retreat of the Wisconsinan glacier. With the exception of the western shore, which consists of Morely silt loam, much of the soil surrounding the immediate portions of Silver Lake, including the project site for the road extension, is Pewamo silty clay loam (Furr 1981). This very poorly-drained soil is commonly found in depressional areas and till plains in the Valparaiso Moraine Section. According to Furr (1981), this soil has severe limitations for building sites and roads because of its moderately slow permeability, which contributes to the accumulation of surface waters and its susceptibility to frost action potential; however, it is well-suited for water-tolerant vegetation.

The sediments of Silver Lake are composed of muck along the near shore areas, though remnants of peat occur in a few isolated areas especially toward the center of the lake. According to Joe Clifford (pers. comm.), a resident and property owner of land bordering the lake since the 1950s, Silver Lake was once an oak-hickory forest, having trees with diameter at breast heights (DBHs) of up to approximately 60 cm and an understory dominated by sassafras. Aerial photography from 1938 clearly shows that the current lake basin was a forested area (Fig. 2). In early November of 1953, the peat and sphagnum subsurface was ignited from a fire used to burn brush and debris from the clearing of land on the west side of the lake (Anonymous 1953a, 1953b, 1953c, 1953d). The peat burned down to the clay bottom of the original lake basin (Fig. 3) to a maximum depth of approximately 1 m, exposing the roots of the trees, which subsequently toppled over. Although some of the tree stumps and logs remain in the lake to this day, many were hauled out and chopped into firewood. The ultimate effect of this fire was to expose what likely represents the original post-glacial clay-lined lake basin. This basin, like many of those found in the northern United States, was probably originally formed as

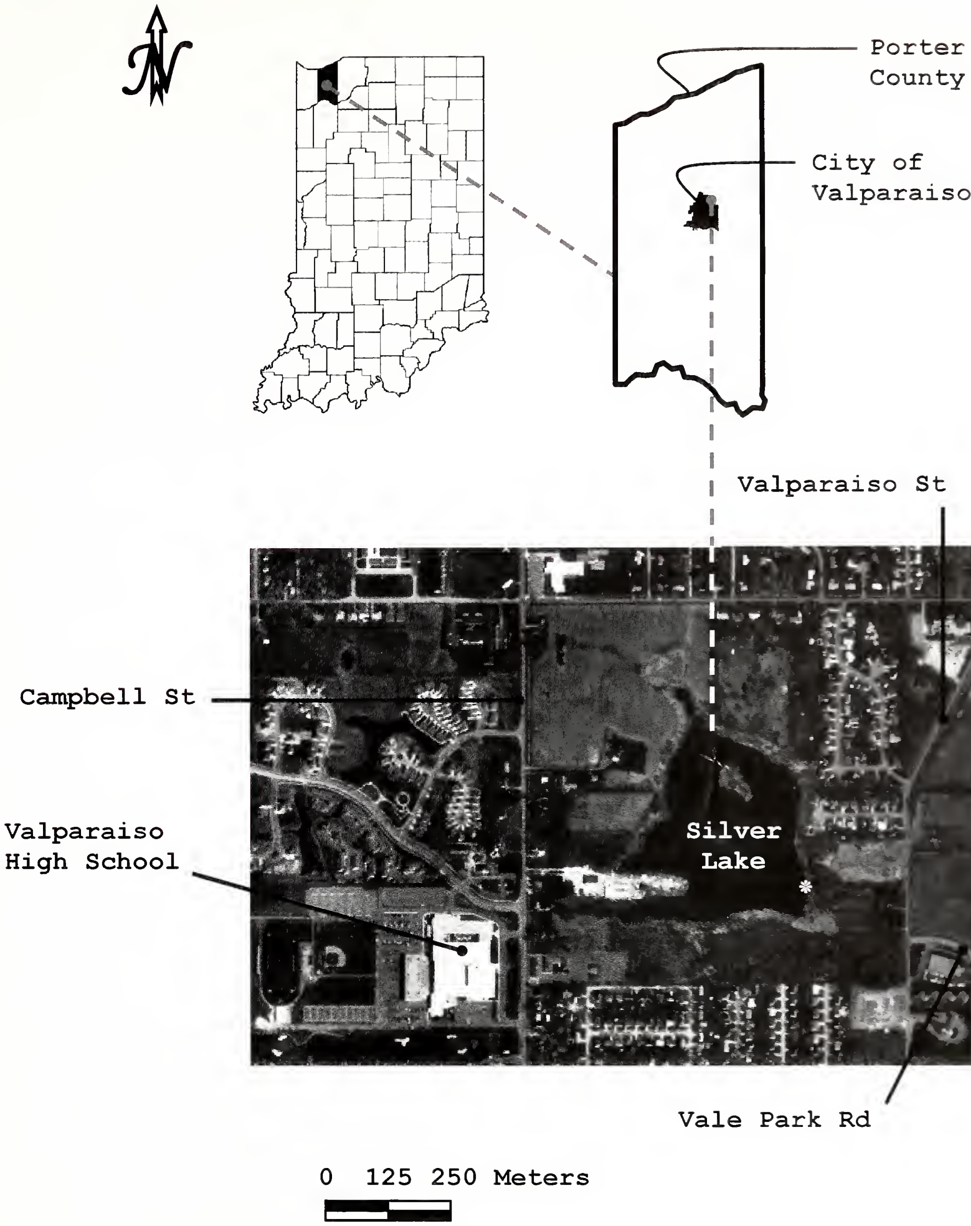
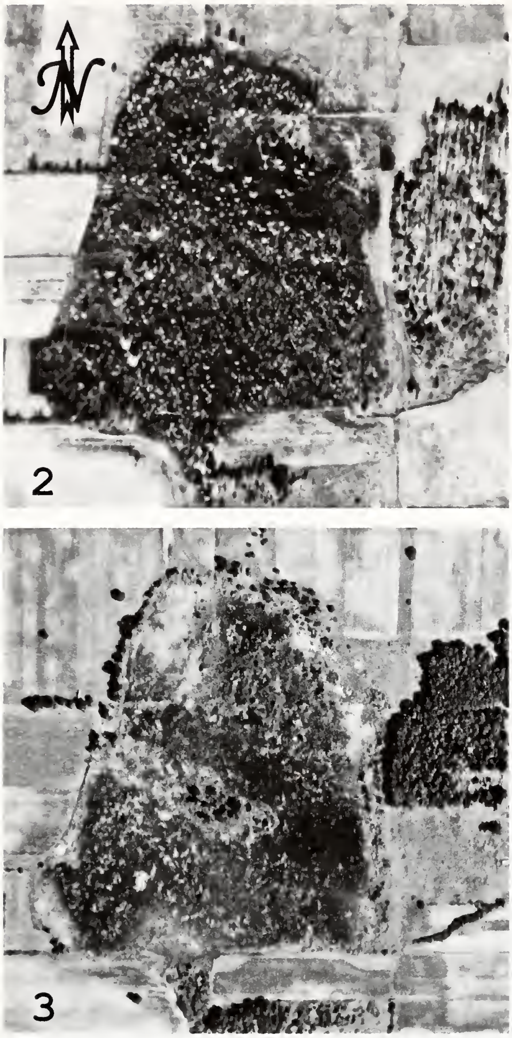


Figure 1.—Silver Lake, located in the City of Valparaiso in Porter County, Indiana. The white star at the southeast corner of the lake indicates the location of the outlet. (Orthophotograph courtesy of the United States Geological Survey.)

an ice block depression, which subsequently became a kettle hole lake following the last Wisconsinan glacial retreat. Although we believe it is not possible to accurately reconstruct the vegetational history of Silver Lake because of the loss of peat layers due to the fire, it is likely that the lake went through typical bog successional stages. It is somewhat ironic that the lake appears to have reverted back to earlier successional stages as a result of anthropogenic activity. Over the last 50 years, Silver Lake has slowly accumulated silt from runoff and organic matter from the growth of aquatic macrophytes, and is now largely covered by spatterdock.

Floristic survey and assessment.—In



Figures 2, 3.—Orthophotographs of Silver Lake area. 2. Pre-burn forested area in 1938; 3. Post-burn Silver Lake basin in 1954. (Orthophotographs courtesy of the United States Geological Survey.)

2004, field surveys were conducted during the months of May–August to inventory the aquatic flora of Silver Lake. One survey was made each month to minimize temporal effects and to ensure that diagnostic characters, such as flowers and fruits, were present for positive identifications of specimens. Areas were surveyed using a point intercept method modified from Madsen (1999), which consisted of recording the presence of species in a radial area encircling a pre-selected waypoint. This method utilized a randomly selected point of origin for the construction of a grid. The grid consisted of 41 geo-referenced waypoints having an interval of 50 m that was generated in the Universal Trans Mercator (UTM) coordinate system North American Datum 1983 (NAD 83) using Trimble TerrsSync™ software (Fig. 4). The use of 50 m grid intervals provided adequate coverage for surveying Silver Lake because of its small size, almost uniform shallow depth, and relative homogeneous macrophyte community structure. This grid and a digitized base map of Silver Lake were transferred onto a Trimble GeoXT™ global positioning system (GPS) unit outfitted with a Trimble Beacon-on-a-Belt (BoB™) real-time differential corrected receiver, which was used to navigate from point to point and record data.

At each waypoint, an area of 3 m^2 was surveyed for the occurrence of aquatic macrophytes. In areas having a depth $\leq$0.5 m, submersed, free-floating, and emergent macrophytes were collected by hand. At depths >0.5 m, an extendable thatching rake was used to collect macrophytes from the side of a kayak. The frequency of occurrence was calculated for each taxon and represents the percentage of survey areas from which a given taxon was present. Each percentage corresponds to a specific frequency category based on a scale modified from Alix & Scribailo (1998). Frequency categories for taxa are defined as follows: rare = occurrence at $\leq$10% of the total number of survey areas; infrequent = occurrence at >10%, but <20% of the total number of survey areas; occasional = occurrence between 20–50% of the total number of survey areas; common = occurrence at >50%, but <75% of the total number of survey areas; abundant = occurrence at $\geq$75% of the total number of survey areas. Each taxon was assigned to its corresponding frequency category. Frequency values were also converted to relative frequencies by dividing the frequency of an individual taxon by the sum frequency for all taxa. The frequency of occurrence, frequency category, and relative frequency of each taxon are provided in the Appendix.

The floristic quality of the lake was evaluated using Swink & Wilhelm's (1994) floristic quality index (*I*), which uses coefficients of conservatism (*C* values) of native vascular plant taxa in its calculation. A *C* value assigned to a native vascular plant taxon is rep-

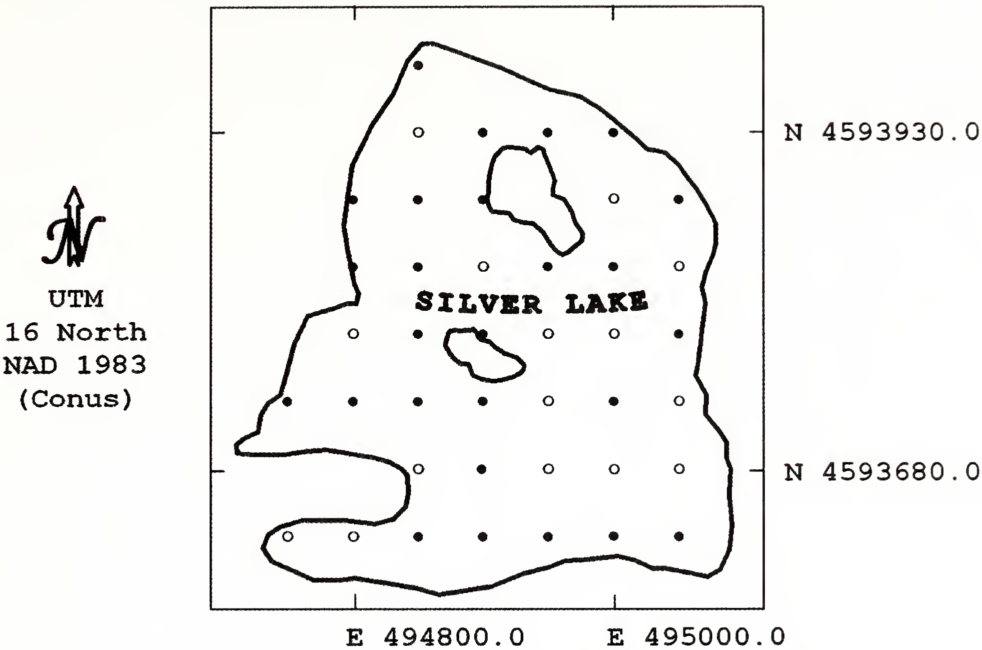


Figure 4.—Base map of Silver Lake with sampling grid. All circles (● and ○) represent point intercept survey areas. Open circles (white with black margins—○) represent sites sampled for physical and chemical parameters.

resented by an integral value ranging from 0 to 10. Each integral value theoretically represents an estimated level of fidelity to an area that has remained relatively unaltered from pre-settlement conditions (Swink & Wilhelm 1994). Taxa having a high *C* value often appear to be very sensitive to habitat degradation and show fidelity to undisturbed natural areas, whereas taxa having a low *C* value show little or no fidelity to specific natural communities and can be quite resistant to environmental disturbance. Typically, *C* values are subjectively assigned to plant taxa of a given region or political boundary based on the judgments made by a committee of professional botanists familiar with particular attributes of their behavior, such as sensitivity to disturbance and patterns of occurrence, independently of their rarity (see Swink & Wilhelm 1994; Andreas & Lichvar 1995; Herman et al. 1996; Taft et al. 1997; Nichols 1999; Rothrock 2004; Rothrock & Homoya 2005).

Because Porter County was one of seven Indiana counties included in the development of *C* values for the native flora of the Chicago region (Swink & Wilhelm 1994) and *C* values have recently been independently created for the State of Indiana (Rothrock 2004), there are two sets of *C* values available for the FQA of Silver Lake. Thus, *C* values from both sources were recorded for the native aquatic vascular taxa collected during the surveys of Silver Lake. These taxa have been assigned to conservatism groups based on their corresponding *C* values and their respective source (Table 1). Each conservatism group is defined by a specific range of *C* values (see Table 1). Non-native and native taxa currently without *C* values have been assigned to group A (Table 1) and were excluded from the calculations of the FQA metrics described below.

Swink & Wilhelm's (1994) FQA of an area requires a mean coefficient of conservatism (C_{mean}) value, which is calculated as follows:

$$C_{mean} = \sum C/N$$

where $\sum C$ is the sum of all *C* values of the native aquatic vascular macrophytes recorded from the lake and *N* is the total number of taxa having *C* values. The C_{mean} is used to calculate *I*:

$$I = C_{mean} * \sqrt{N}$$

where $\sqrt{N}$ is the square root of the total num-

Table 1.—Conservatism groups (modified from Alix & Scribailo 1998) for taxa collected from Silver Lake based on two sets of *C* values: IN = Indiana (Rothrock 2004); CR = Chicago region (Swink & Wilhelm 1994). Groups are: A (native and non-native taxa without assigned *C* values and taxa with a *C* value of 0 or 1); B (taxa with a *C* value of 2 or 3); C (taxa with a *C* value of 4, 5, or 6); D (taxa with a *C* value of 7 or 8); E (taxa with a *C* value of 9 or 10). Each group indicates a different level of habitat fidelity: N = not yet determined; EL = extremely low; L = low; M = moderate; H = high; EH = extremely high.

Group			*C* value		Fidelity	
IN	CR	Taxon	IN	CR	IN	CR
A	A	*Chara braunii*	N	N	N	N
A	A	*Chara globularis*	N	N	N	N
A	A	*Chara foliolosa*	N	N	N	N
A	A	*Myriophyllum spicatum*	N	N	N	N
A	A	*Nitella flexilis*	N	N	N	N
A	A	*Riccia fluitans*	N	N	N	N
A	A	*Ricciocarpus natans*	N	N	N	N
A	C	*Ceratophyllum demersum*	1	5	EL	M
A	A	*Typha latifolia*	1	1	EL	EL
B	C	*Elodea canadensis*	3	5	L	M
B	D	*Juncus effusus*	3	7	L	H
B	C	*Lemna minor*	3	5	L	M
B	C	*Lycopus americanus*	3	5	L	M
B	D	*Persicaria hydropiperoides*	3	7	L	H
B	C	*Sagittaria latifolia*	3	4	L	M
B	C	*Stuckenia pectinata*	3	5	L	M
C	E	*Brasenia schreberi*	4	10	M	EH
C	C	*Carex comosa*	6	5	M	M
C	C	*Cephalanthus occidentalis*	5	5	M	M
C	D	*Heteranthera dubia*	4	8	M	H
C	D	*Lemna trisulca*	6	7	M	H
C	C	*Najas flexilis*	5	6	M	M
C	D	*Nuphar advena*	6	7	M	H
C	D	*Nymphaea odorata* subsp. *tuberosa*	6	7	M	H
C	E	*Peltandra virginica*	6	10	M	EH
C	C	*Persicaria amphibia*	4	4	M	M
C	E	*Pontederia cordata*	5	10	M	EH
C	D	*Potamogeton foliosus* subsp. *foliosus*	4	7	M	H
C	D	*Potamogeton pusillus* subsp. *tenuissimus*	4	7	M	H
C	E	*Saururus cernuus*	4	9	M	EH
C	D	*Spirodela polyrrhiza*	5	7	M	H
C	E	*Utricularia gibba*	4	10	M	EH
C	E	*Utricularia macrorhiza*	5	9	M	EH
C	D	*Wolffia brasiliensis*	6	7	M	H
C	D	*Wolffia columbiana*	5	7	M	H
C	E	*Zannichellia palustris*	6	10	M	EH
D	E	*Eleocharis palustris*	8	10	H	EH
D	E	*Sparganium emersum*	8	10	H	EH
D	D	*Vallisneria americana*	7	7	H	H
E	E	*Ceratophyllum echinatum*	10	10	EH	EH
E	E	*Myriophyllum verticillatum*	10	10	EH	EH
E	E	*Potamogeton amplifolius*	10	10	EH	EH

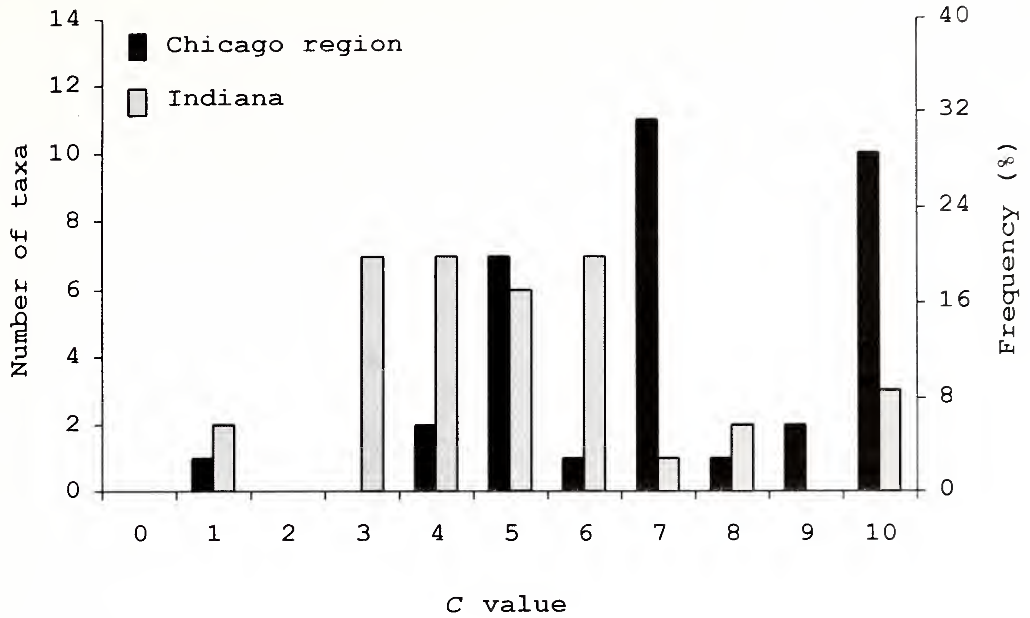


Figure 5.—Frequency distributions of aquatic vascular plant taxa recorded from Silver Lake grouped by *C* value. Frequencies represent the percentage of taxa with the same *C* value.

ber of taxa having *C* values and serves as an area-based standardization for species richness. These metrics were calculated twice for Silver Lake, first by using the Indiana set of *C* values and second by using the set from the Chicago region. Although sites surveyed at Silver Lake were equal in inventory area, the lake proper was defined as the inventory unit. Therefore, *I* and C_{mean} values were not calculated for individual survey areas, though the utility of these metrics when applied to individual samples has been demonstrated (Swink & Wilhelm 1994; Herman et al. 1996; Taft et al. 1997). Unlike other metrics, FQA does not rely on a suite of indicator species or the labor intensive, and often time-consuming, measurements of abundance (Swink & Wilhelm 1994).

The frequency distributions and median *C* values from each set of *C* values (i.e., Indiana and the Chicago region) recorded for the taxa documented during the study were compared by Mann-Whitney *U* tests utilizing normal approximation (Zarr 1974). The nonparametric two-sample tests were conducted because these data do not meet the assumptions of normality required for the application of analogous parametric statistical tests. *P* values less than 0.05 are considered significant.

Systematics.—Taxonomy and nomenclature of vascular aquatic macrophytes follow familial treatments of the Flora of North America Editorial Committee (1997, 2000, 2002a, 2002b, 2005) with the following exceptions: Haloragaceae (Aiken 1981), Lamiaceae and Rubiaceae (Gleason & Cronquist 1991), and Lentibulariaceae (Taylor 1989). Taxonomic treatment of the Characeae follows Daily (1953) with nomenclatural revisions where necessary, and that of the Ricciaceae follows Mayfield et al. (1983). Abbreviations for nomenclatural authorities follow the rules recommended by Brummitt & Powell (1992) and are from the International Plant Names Database (2004).

Voucher specimens of all taxa reported herein have been deposited in the Aquatic Plant Herbarium of Purdue University North Central (indicated here as PUNC). Duplicate specimens of some taxa (see Appendix) have been prepared and sent to the Friesner Herbarium at Butler University (BUT).

Physical and chemical parameters.—Field and lab analyses of subsurface water samples from 15 locations within Silver Lake (Fig. 5) were conducted on 15 July 2004. Water temperature, pH, specific conductance, and salinity were measured *in situ*. Water temperature and pH were measured using an IQ Model 150 multi-parameter meter with a stainless steel ion-selective field effect transistor (ISFET) probe. Specific conductance and salinity were measured using a YSI Model 85 handheld meter. Water samples for the analysis of total alkalinity were collected from 10 of the 15 locations using a polycarbonate vertical point water sampler. Total alkalinity was determined *ex situ* using the Gran titration method (Wetzel & Likens 1991). Water samples were stored in 125 ml Nalgene® bottles and kept on ice at ≈ 4 °C in a cooler for no longer than 2 h prior to analysis. Water depth was determined at each of the 15 locations using a 3.0 m braided polyester line weighted on one end and calibrated in 0.1 m increments.

RESULTS

The inventory of aquatic macrophytes of Silver Lake documented 42 taxa, including three (7.1%) state-listed species (*Ceratophyllum echinatum*, *Myriophyllum verticillatum*, and *Zannichellia palustris*), one (2.4%) exotic (*Myriophyllum spicatum*), four (9.5%) charophytes (*Chara braunii*, *Chara foliolosa*, *Chara globularis*, and *Nitella flexilis*), and two (4.8%) liverworts (*Riccia fluitans* and *Ricciocarpus natans*). These taxa represent 32 genera from 23 families. Vascular plant families having the greatest richness were the Lemnaceae and Potamogetonaceae with five and four taxa, respectively. Families represented by a single species are the Alismataceae, Araceae, Cabombaceae, Juncaceae, Lamiaceae, Najadaceae, Rubiaceae, Saururaceae, Sparganiaceae, Typhaceae, and Zannichelliaceae.

Three taxa, *Potamogeton foliosus* subsp. *foliosus*, *Myriophyllum verticillatum*, and *Nuphar advena*, occurred at ≥50% of the survey areas; the latter taxon occurring at >75% of the areas. *Brasenia schreberi*, *Vallisneria americana*, *Chara braunii*, *Ricciocarpus natans*, *Ceratophyllum echinatum*, and *Zannichellia palustris* were the rarest species, occurring at <5% of the survey sites, with the latter four species having been recorded from only a single site. Other species, particularly emergents, have been categorized as rare or infrequent in our annotated list (see Appendix). This rarity of emergent species has most likely resulted from a low sampling frequency of sites on or near the shoreline (i.e., only 10% of the total number of survey areas occurred 3 m or less from shore).

Application of the FQA methodology at Silver Lake resulted in a C_{mean} of 5.0 ($N = 35$) and an I of 29.6, using C values for Indiana (Rothrock 2004); however, a higher C_{mean} (7.2) and I (42.6) were calculated by using C values for the Chicago region (Swink & Wilhelm 1994). When Indiana C values were used in the calculation of I, less than 18% of the taxa had a C value ≥7, whereas over 82% of them had a C value ≤6 (Fig. 5). In contrast, over 68% of the taxa had a C value ≥7; and less than 32% of them had a C value ≤6 when the calculations were made using C values for the Chicago region (Fig. 5). Indiana C values of 0, 2, and 9 and the Chicago region C values of 0, 2, and 3 were not represented or included in calculations of their respective indexes. Results of the Mann-Whitney test revealed a significant difference between the frequency distributions of C values from the Chicago region and Indiana (Fig. 5; $U = 939$; $Z = 3.88$; two-tailed $P < 0.001$). In addition, Indiana C values represented by the Silver Lake taxa were at least one C value lower than those from the Chicago region ($U = 809.5$; $Z = 2.35$; one-tailed $P < 0.01$).

The analysis of Indiana conservatism groups indicated that 86% of the taxa exhibit extremely low-to-moderate fidelity (groups A, B, and C) and that only 14% of the taxa were represented by the higher fidelity Groups D and E (Fig. 6). In contrast, the Chicago region conservatism groups A and C were represented by 43%, whereas 57% of the taxa were represented by groups D and E (Fig. 6). Group B of the Chicago region was not represented by a single taxon. One apparent similarity between the two sets of conservatism groups is that approximately 56% of taxa exhibiting extremely low to moderate fidelity were classified as group C plants.

Chemical and physical water data are summarized in Table 2. Silver Lake appears to be circumneutral, having a mean pH of 6.93 and a mean total alkalinity of 55.2 mg $CaCO_3$/L (Table 2). These values indicate that Silver Lake has poor buffering characteristics and is likely kept circumneutral in part by the decomposition of floating remnant peat deposits. Measurements of specific conductivity are moderate and range from 233.5–354.1 μS/cm

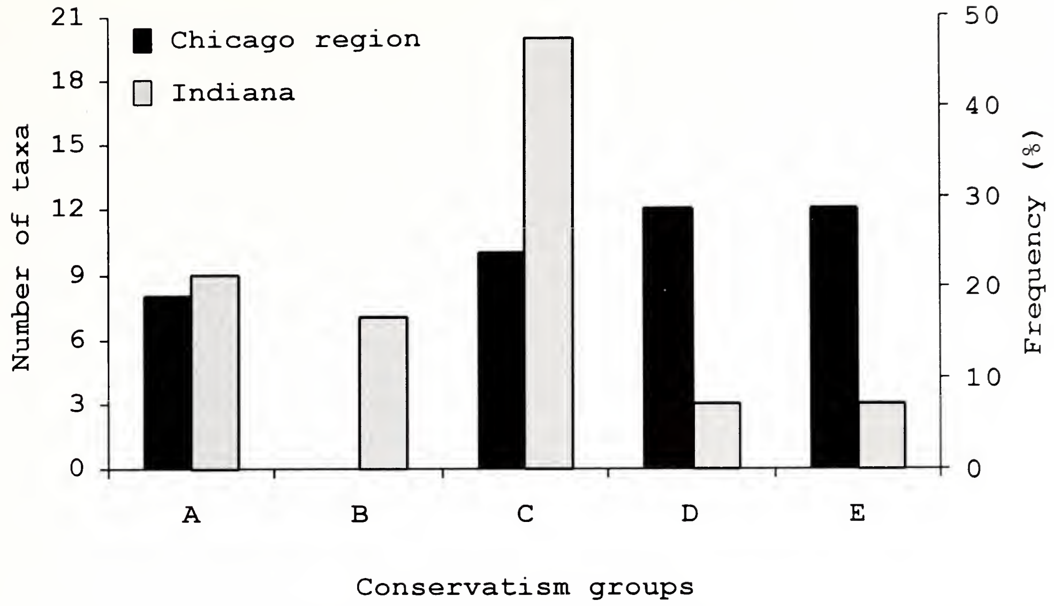


Figure 6.—Frequency distributions of aquatic macrophytes recorded from Silver Lake grouped by conservatism group. Frequencies represent the percentage of taxa within a group.

(Table 2). As expected of freshwater systems, salinity is low, having a mean value of 0.1 ppt and a statistical range of 0.1 ppt across survey areas (Table 2).

DISCUSSION

Successional history of Silver Lake.—If anecdotal accounts of the pre-burn flora of Silver Lake are correct, this area once represented an extremely unusual community of vegetation since an oak-history composition typically characterizes an upland forest community. It is possible that extensive ditching around the lake could have lowered the water table sufficiently to make the habitat very dry. This would also explain why the substrate caught fire so readily and burned down to the lake basin. However, a more plausible and typical successional history is that the lake was once a swamp, containing such species as swamp white oak (*Quercus bicolor*) and pin-oak (*Quercus palustris*), where sphagnum moss slowly invaded this area and eventually formed a peat substrate. The former two species are often found in bog habitats in the midwestern US, primarily as swamp remnants (Potzger 1934; Jones 1941). In general, the classic bog succession of the North, culminating in northern white cedar (*Thuja occidentalis*) or black spruce (*Picea mariana*) as dominants, is often not seen in northern Indiana and southern Michigan bogs where red maple (*Acer rubrum*), black ash (*Fraxinus nigra*) as well as tulip poplar (*Liriodendron tulipifera*) and oak are often common constituents (Transeau 1903; Cain 1928; Collins et al. 1979).

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Table 2.—Summary of physical and chemical parameters measured from sites within Silver Lake.

Parameter	*N*	Mean	Minimum	Maximum
Water depth (m)	15	0.6	0.2	0.9
Temperature (°C)	15	22.3	19.4	24.6
pH	15	6.93	6.43	7.26
Salinity (ppt)	15	0.1	0.1	0.2
Total alkalinity (mg $CaCO_3$/L)	10	55.2	44.1	66.4
Specific conductivity (μS/cm)	15	307.9	233.5	354.1

trees from the forest on Silver Lake are still present as submerged logs, we will continue our analysis of successional changes by obtaining wood samples for tree identification. It is also hoped that we may be able to locate undisturbed remnant peat deposits for coring and subsequent pollen stratigraphy analysis to document the longer term changes that led to the formation of a bog community.

Floristic quality of Silver Lake.—According to Swink & Wilhelm (1994), an assessment resulting in a C_{mean} value ≥ 3.5 and ≤ 4.5 or an I value ≥ 35 and ≤ 45 is indicative of an area having sufficient floristic quality to be at least of marginal natural area quality. Furthermore, areas having a C_{mean} or an I value exceeding the aforementioned values are floristically important from a statewide perspective, suggesting the presence of relatively high quality habitat(s) having natural area potential (Swink & Wilhelm 1994). The two sets of FQA metrics calculated for the Silver Lake flora provide somewhat contradictory results. Based on Swink & Wilhelm's (1994) suggestions, the C_{mean} value (5.0) calculated from Indiana *C* values (Rothrock 2004) indicates that Silver Lake is high in natural quality; however, the I value (29.7) indicates that Silver Lake possesses insufficient conservatism and richness. When the calculations were made using *C* values for the Chicago region (Swink & Wilhelm 1994), we observed a 42% increase in both the C_{mean} value (7.1) and I value (42.3), indicating that Silver Lake has high floristic quality and characteristics of a remnant natural area.

In this study, it appeared acceptable to use either source of *C* values because Porter County is in Indiana and it is also one of seven Indiana counties included in the Chicago region by Swink & Wilhelm (1994). However, the statistical comparison of the Indiana and Chicago region distributions of *C* values represented by the Silver Lake taxa revealed that they are significantly different. A similar result was obtained by Rothrock & Homoya (2005) when they compared the *C* values for the State of Indiana (Rothrock 2004) with those of the Chicago region (Swink & Wilhelm 1994) by examining the divergence of *C* values on a species by species basis and the mean divergence within specific conservatism cohorts. Rothrock & Homoya (2005) found that only 30% of taxa common to both Indiana and the Chicago region were assigned to the same cohorts. In addition, Rothrock & Homoya (2005) have shown that over 33% of Indiana taxa diverged from the *C* values of the Chicago region by 1–3 cohorts and that on average the Indiana *C* values were 1.2 cohorts lower than those of the Chicago region.

One question that arises from this study is which source of *C* values most accurately defines the floristic and natural area quality of Silver Lake? Based on our surveys and assessments of over 100 lakes and ponds in Indiana, a majority of which have been conducted in the Indiana counties of the Chicago region and have resulted in the documentation of many new localities for state-listed aquatic macrophytes (Scribailo & Alix 2002a), it appears that many *C* values assigned to aquatic vascular plants of the Chicago region (Swink & Wilhelm 1994) are inflated and that the Indiana *C* values (Rothrock 2004) are more appropriate. Nonetheless, we would certainly also question some of the Indiana *C* values assigned to aquatic vascular plants from Rothrock (2004) and will address this issue in a future paper.

Our overall assessment of Silver Lake indicates that it is low in natural area quality. This conclusion is based on additional factors admittedly not included in standard FQA methodology (Swink & Wilhelm 1994), such as the frequency of taxa, the history of the site, and the negative impacts of repeated drawdown events on the stability of habitat for a submerged flora. Having stated this, it is important to note that Silver Lake contains some floristically significant taxa, such as *Myriophyllum verticillatum* and *Ceratophyllum echinatum*.

Myriophyllum verticillatum (whorled watermilfoil), which is state-listed as rare by the Indiana Department of Natural Resources (Division of Nature Preserves 2004), forms extensive beds in deeper portions of Silver Lake. These beds encompass the largest flowering population of *M. verticillatum* we have seen in the state. The only other significant flowering population of *M. verticillatum* we have observed in Indiana is located in the sloughs east of the gravel pit ponds at the Jasper-Pulaski Fish and Wildlife Area. It is of interest that *Myriophyllum spicatum* (Eurasian watermilfoil), which is the one of the most troublesome invasive submersed species in Indiana lakes, and much of North America (Grace & Wetzel 1978; Nichols & Shaw 1986; Smith & Barko 1990;), is only found in a few small pockets of the lake and does not appear to be expanding its population size.

Myriophyllum verticillatum is typically found in circumneutral waters of relatively low alkalinity (Moyle 1945; Crow & Hellquist 1983; Nichols & Yandell 1995). Most lakes in Indiana are alkaline with a pH above 8; therefore, habitat of the type found at Silver Lake is rare in the state. Silver Lake is the only lake we have surveyed with a mean pH <7. This fact should also have some bearing on conservation decisions regardless of what the results of FQA indicate.

Ceratophyllum echinatum (prickly coontail) is a recent addition to the aquatic flora of Indiana (Scribailo & Alix 2002b) where it is state-listed as rare (Division of Nature Preserves 2004). The occurrence of this species at Silver Lake marks its fifth documented record for Porter County and its sixteenth for the state, which includes Lake, La Porte, St. Joseph, Steuben, and Warren counties (Scribailo & Alix 2002b). *Ceratophyllum echinatum* was found growing with *Ceratophyllum demersum*, one of the most common aquatic vascular plant species in Indiana (unpubl. data), at one inventory site located in the southwestern corner of the lake. Observations of *C. echinatum* and *C. demersum* in Indiana indicate that the latter species is a common associate of the former (Scribailo & Alix 2002b). In Indiana, *C. echinatum* has been primarily found in shallow, mesotrophic to eutrophic lakes, having muck-type bottoms and waters that are circumneutral to moderately alkaline in pH (Scribailo & Alix 2002b). In Silver Lake, *C. echinatum* is restricted to a portion of the lake where the influx of sediments from surface runoff creates high turbidity.

The presence of some floristically significant taxa, a C_{mean} value >4.5, and the low relative frequency of *Myriophyllum spicatum* indicate considerable potential for maintenance and enhancement of floristic quality in Silver Lake, assuming that the appropriate management practices are adopted and enforced. A primary management concern impacting the floristic quality and ecological health of Silver Lake is that of hydrology. Over the past three years, we have observed drawdowns of up to 0.7 m in Silver Lake's water levels with the most significant and drastic drawdown occurring in the growing season of 2005. This drawdown transformed approximately 50% of the submersed habitat into mud flats. Muskrat, which normally maintain open channels through the spatterdock, creating habitat for the state-listed species recorded here, could not forage under these conditions. This drawdown also allowed spatterdock to colonize these areas that formerly were habitat for submerged plants.

Silver Lake is too shallow to withstand prolonged periods of drawdown, which may eventually eradicate floristically significant aquatic plant taxa as well as most other submerged species. Options to increase the extent of deep-water habitat in Siver Lake and to ameliorate the impacts of drawdown, such as establishing a state-mandated lake level and dredging, should be considered to reduce further degradation of the lake.

Problems associated with the use of FQA metrics for lakes.—Although we have used the FQA methodology (Swink & Wilhelm 1994) for our analysis of Silver Lake, we perceive several fundamental problems with the use and adequacy of this method as a diagnostic tool in evaluating lake ecosystems. The first of these shortcomings is that assessments of floristic quality of lakes have almost invariably failed to include characean algae (charophytes). The ecological attributes of charophytes make them important contributors to the stability of floristic quality and overall ecosystem health of lakes. These macrophytic algae often form extensive meadows in the littoral zone of lakes and ponds and are an integral component in both the structure and function of aquatic ecosystems (see Hutchinson 1975; Jeppesen et al. 1998; Coops 2002). The significance of charophytes in the conservation, management, and restoration of water bodies has recently been a source of considerable discussion (Van den Berg et al. 1998; Coops 2002). As we have suggested in the past (Alix & Scribailo 1998), *C* values must be assigned to charophytes at the species level, and in some cases the subspecific ranks, if the goal is to improve the effectiveness of the FQA metrics in evaluating lake ecosystems. It should be noted that there are at least 25 charophyte species in the Great Lakes region alone (unpubl. data) of an estimated 400 species world-wide (Moore 1986), thus not to use charophytes in the assessment of floristic quality of lakes is akin to leaving out the Cyperaceae in the floristic quality assessment of wetlands.

A step in the right direction was taken by Nichols (1999), who assigned a single *C* value to the genera *Chara* and *Nitella* during his development and calibration of FQA metrics for macrophyte communities in Wisconsin lakes. However, the grouping of all charophyte species by genus and assigning a single *C* value to each group results in a loss of information and may not provide an accurate evaluation of the floristic quality of a given site.

We recognize that the morphological characters of charophyte species often vary markedly, which can make the identification of these species difficult even if one is fairly acquainted with the taxonomy of this group. Much of the current difficulty with charophyte identification was engendered by Wood's (1965) treatment of the Characeae in which numerous taxa were lumped under individual species and assigned subspecific ranks. Many of these taxa are now considered "good species" (e.g., see Proctor 1975). Unfortunately, no complete revisionary manual for the charophytes, of North America in particular, has been published since Wood (1965). Despite this problem, it is still important that efforts be made to include them in the FQA since many charophyte species show varying levels of fidelity to different aquatic habitats (Mann et. al. 1999). We are currently evaluating appropriate *C* values for the charophytes of Indiana. These values will be included in a paper that will present our assessment of *C* values for submersed and floating aquatic plants of Indiana.

A second problem with the use of the FQA for lakes, as Nichols (1999) suggested, is that lakes differ in a number of significant ways from terrestrial and wetland areas. Thus, the FQA metrics need to be calibrated to reflect these differences. For example, Nichols' (1999) examination of data on plant communities in Wisconsin lakes revealed that 95% of 554 natural lakes and man-made flowages had a C_{mean} value ≥ 3.5 and that only 8% had an *I* value ≥ 35. Furthermore, the average *C* value of 128 aquatic taxa from his study was 7.4, and 90% of these taxa had a *C* value ≥ 5. Since *I* values indicate that these lakes possess marginal floristic quality despite having a substantial number of highly conservative taxa, it is evident that the standard threshold values of the FQA metrics proposed by Swink & Wilhelm (1994) do not adequately serve as a gauge of the floristic quality of the Wisconsin lake plant communities. Nichols (1999) indicated that the low *I* values are often a product of low species richness, and that in contrast to terrestrial and wetland habitats, lakes are defined areas having a limited selection of species. Therefore, floristic surveys of terrestrial and wetland habitats may often result in the documentation of a far greater number of taxa and a higher *I* value than those of lakes since a higher *N* will increase *I* independently of any other factor.

To attempt to produce metrics useful in distinguishing floristic quality and natural area value among Wisconsin lakes and flowages, Nichols (1999) calibrated their values on both a statewide and an ecoregional-lake type scale. This type of calibration allowed for the comparison of the FQA metrics of lakes on two scales and avoided the reliance on inappropriate threshold values. Nichols (1999) has shown that when the metrics are calibrated, the median C_{mean} values of Wisconsin's four ecoregional-lake type groups only dropped by approximately half a unit (0.5) between each group from the highest value (6.7) to the lowest one (5.0). This is counter-intuitive given considerable diversity in the ecoregions of Wisconsin (Omernik et. al. 2000) and reinforces the argument for calibrating the FQA metrics specifically for lakes.

Nichols (1999) also found that lakes in Wisconsin having both the highest and lowest *I* values are man-made and suggested that the floristic quality of a lake is more likely related to its water quality than to its mode of origin. This suggests that attempting to assign *C* values to aquatic macrophytes based upon their fidelity to pre-settlement conditions may be problematic and indicates that man-made lakes may have a C_{mean} value equal to or greater than that of natural lakes.

An additional problem with the FQA of lakes is that non-native aquatic plant taxa are excluded from the calculation of the metrics used in this methodology. Typically, non-native taxa, whether they are terrestrial or aquatic, are not formally assigned *C* values and thus are not included in Swink & Wilhelm's (1994) FQA. It is widely recognized that non-native taxa have a negative impact on the floristic and natural area quality of their respective habitats because they are often weedy and aggressive, displacing native species. Given this is the case; we believe that some effort should be made to provide additional information that might indicate the extent of this negative impact on habitat quality.

A proposed solution to this problem is to calculate the FQA metrics twice, first by including only native taxa and second by including native and non-native taxa, with the latter having been assigned a default value of $C = 0$ (Taft et al. 1997; Wilhelm & Masters 1999; Rothrock 2004; Rothrock & Homoya 2005) and then compare the results. This alternative approach, as recently suggested by Rothrock & Homoya (2005), "allows one to assess both the natural value of a site and the somewhat separate question of how much impact adventive species are having on the site." Examples, which use a default value of $C = 0$ for non-native taxa, can be found in Rothrock & Homoya (2005, Appendix), who provide FQA metrics, representing a diversity of sampling efforts and inventory units, for a variety of community types in Indiana.

Although the utility of this approach appears evident, we contend that this method will prove to be largely uninformative in assessing the impact of non-native taxa on lake ecosystems. The primary reason for this is that lakes tend to contain far fewer non-native taxa than their typical terrestrial counterparts, and yet the impacts of these taxa on the quality and natural value of lake habitats are often far more extensive and severe. For example, we have not encountered a water body with greater than four non-native submersed plant species during our inventories of Indiana lakes and ponds. The four species most commonly encountered are *Myriophyllum spicatum*, *Egeria densa*, *Najas minor*, and *Potamogeton crispus* (unpubl. data). A similar situation exists in Wisconsin where Nichols (1999) reported less than six non-native aquatic plant taxa for the entire Wisconsin lake flora. In contrast, the mean number of non-native taxa from 29 examples of terrestrial and wetland habitats provided by Rothrock & Homoya (2005, Appendix) is 24 and the range is from 0–148. Sixty-five percent of these habitats have five or more non-native species, and at least 30 non-native species are generally present at a given site before a reduction in I of 5.0 or more units is observed.

Although not explicitly stated by Alix & Scribailo (1998), the low number of non-native submersed aquatic taxa in the flora of Indiana and their insignificant impact on I was the basis of their support and promotion of the assignment of negative C values to non-native plant taxa, a practice used in an earlier index to evaluate natural areas (Swink & Wilhelm 1979). It is obvious that the use of negative C values for non-native aquatic taxa will reduce the values of ΣC, C_{mean}, and I further than the use of a default value of $C = 0$ for these taxa. What is not as obvious is whether the reduction in the I value is indicative of the level of negative change occurring in the floristic or natural area quality of the habitat. Using Swink & Wilhelm's (1994) defined threshold I values of 20, 35, and 50, which represent areas that are not floristically significant, regionally significant, and rare and highly significant, respectively, it is apparent that a reduction in I of 15 or more units would suggest substantial degradation. We have already shown that such a decrease would be extremely unusual for lakes and would possibly constitute the entire range of variation of I across all lakes.

It is apparent that neither treatment of non-native taxa (i.e., the assignment of a default value of $C = 0$ or the assignment of negative C values) in the FQA is likely to reveal the extent of the current negative impact of these taxa on a given habitat nor is it likely to indicate any change in their invasive spread. Ultimately, this means that without a change in the composition or number of taxa the floristic quality metrics will not change whether the population of a non-native species consists of a few individuals or thousands. Conventional wisdom holds that the spread of a non-native taxon will impact the FQA metrics indirectly by reducing the C_{mean} of a given area because of the loss or replacement of conservative taxa (Swink & Wilhelm 1994). The problem with this idea is that a lake could undergo substantial degradation in quality with the spread of a non-native taxon before it had significant effect on the values of the floristic quality metrics. Non-native aquatic species, such as *Egeria densa*, *Eichhornia crassipes*, *Myriophyllum spicatum*, and *Salvinia molesta* often occur in large monospecific stands, dominating lake plant communities and out-competing native plant taxa for light and space. Nonetheless, highly conservative taxa are generally still present in the aquatic flora, though they may have suffered a large reduction in numbers of individuals. Therefore, it is apparent that if non-native taxa are to be included in the FQA, with the goal of determining the impact of these taxa on habitat quality, that some quantitative or semi-quantitative description of their frequency should be incorporated into the FQA methodology.

Since their inception, FQA metrics have been derived without considering species abundance (i.e., density or cover) or frequency. It has been argued that these parameters are influenced by seasonal and yearly fluctuations and thus are considered to be irrelevant when assessing the qualitative value of a site (Swink & Wilhelm 1994). Although this is arguably true for native taxa, this is not the case for non-natives where documenting their increase in frequency or abundance is critical in a management context.

It is important to recognize that the choice of parameters used in describing the extent of the non-native component of plant community structure determines the overall quality of impact assessment. Frequency, based on presence-absence techniques, is less dramatically influenced by seasonal fluctuations in lake plant community structure than measurements of abundance, such as density or cover (Swindale & Curtis 1957; Nichols 1984; Nichols 1997; Madsen 1999). Although frequency varies with quadrat size or sample area (Greig-Smith 1964; Mueller-Dombois & Ellenberg 1974; Titus 1993) and is somewhat dependent on the density and distribution of taxa (Greig-Smith 1964; Mueller-Dombois & Ellenberg 1974), it is also the easiest quantitative measure to determine (Greig-Smith 1964; Mueller-Dombois & Ellenberg 1974; Nichols 1984; Madsen 1999). The most preferable measure of frequency for the assessment of the impact of non-native taxa on floristic quality is relative frequency because it takes into account the frequency of non-native taxa relative to all taxa at a given site.

Utilizing relative frequency, we propose a more informative method for assessing the impact of non-native taxa (rather than assigning them a default C value of 0 or -10). The first step in this process is to develop a separate floristic quality index value with non-native impact (I_{nni}) by calculating a specific impact term for non-native taxa (T):

$$T = \sum R_{nn} * I$$

where ΣR_{nn} is the sum frequency of non-native aquatic taxa divided by the sum frequency of all aquatic taxa for the inventory unit (i.e., sum relative frequency of non-native taxa) and I is the floristic quality index calculated without the inclusion of non-native taxa (Swink & Wilhelm 1994). The value of T can then be used to calculate I_{nni}:

$$I_{nni} = I - T$$

where I is the floristic quality index (as described above). One advantage of proposing this method is that it does not involve altering the C_{mean} (by the addition of non-native taxa) or compromise the integrity of the original equation for I. The utility of this method becomes apparent when we consider changes in the value of I using default C values for *Myriophyllum spicatum* at Silver Lake versus changes in I as a response to a hypothetical increase in the relative frequency of this taxon as shown below.

When the default values of $C = 0$ and $C = -10$ are assigned to *Myriophyllum spicatum* and used in the standard FQA calculations of C_{mean} and I, the original metric values of 5.0 and 29.6 are reduced to 4.9 and 29.2 and 4.6 and 27.5, respectively, regardless of the relative frequency of this species at Silver Lake. However, the calculations of I_{nni} using the hypothetical increase in the relative frequency of *M. spicatum* from 0.016 to 0.08, and to 0.4, result in a reduction of I from 29.1 to 27.2 to 17.8. Therefore, proportionately increasing the relative frequency of *M. spicatum* decreases the value of I_{nni} by a percentage equivalent to the change in T. This provides an indirect measure of the spread of this species, which is interpreted to be indicative of a negative impact on the aquatic macrophyte community. Changes in the original I value can also be examined to concomitantly indicate if species richness or C_{mean} has been significantly altered as this species continues to increase in relative frequency.

It is important to note that an increase in the relative frequency of non-native taxa has a greater influence on I_{nni} values of floristically significant and high quality habitats than on those that are of marginal quality. For example, a habitat with an I value of 60 and a sum relative frequency of non-native taxa of 0.30 will result in an I_{nni} value of 42, whereas a habitat having an I value of 30 and the same relative frequency of non-native taxa will result in an I_{nni} value of 21. Given that the encroachment and impact of non-native taxa is more likely to reduce the relative frequency of highly conservative taxa than that of generalists, it would seem appropriate that the corresponding influence on the value of I_{nni} should reflect this.

Although we suggest that the sum relative frequency of non-native taxa is appropriate for the calculation of T, it is appealing to substitute this parameter with a measure of percent cover, especially since many lake assessments often involve the rapid collection of coverage data on only non-native taxa. A good example of this is the simple GPS mapping of patches or large beds of non-native taxa in lakes, where percent cover of these taxa is typically calculated as a portion of the total surface area of the water body or littoral zone. As a cautionary note, estimates of percent cover will most likely result in much greater values of T than relative frequency since the former is not directly proportional to the number of native species present at a sample location. Thus, there is a decided loss of information and assessment value with the use of percent cover in the calculation of T and I_{nni}.

Throughout this discussion, we have outlined the utility of an impact term for non-native taxa and have provided a hypothetical example of its usage. Future studies that track the long-term spread of non-native taxa in lakes should provide more information on the effectiveness of this method in describing changes in floristic and natural area quality.

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APPENDIX

AQUATIC MACROPHYTES DOCUMENTED FROM SILVER LAKE, INDIANA

The annotated list of aquatic macrophytes collected from Silver Lake is arranged alphabetically within three phyla. A taxon preceded by an asterisk (*) is considered non-native, whereas a taxon preceded by a double asterisk (**) is relatively new to Indiana. Identification code, common name, habit type, frequency of occurrence (%), frequency category, and relative frequency (%) are included for each taxon, respectively. All specimens were collected and identified by the authors, and deposited in the Aquatic Plant Herbarium of Purdue University North central (PUNC). When collected and prepared, duplicates were sent to and deposited in the Friesner Herbarium at Butler University (BUT) in Indianapolis, Indiana. State-listed taxa have their corresponding state status noted in brackets (e.g., [Endangered], [Threatened], [Rare], or [Extirpated]) as assigned by the Indiana Department of Natural Resources (Division of Nature Preserves 2004).

PHYLUM CHLOROPHYTA (Green Algae)

Characeae C. Agardh (Muskgrass Family)

Chara braunii S.G. Gmel.: CHABRA; Braun's muskgrass; submersed; 2.4; rare; 0.3; BUT, PUNC.

Chara foliolosa Muhl. *ex* Willd.: CHAFOL; Leafy muskgrass; submersed; 14.3; infrequent; 1.9; BUT, PUNC.

Chara globularis Thuill.: CHAGLO; Fragile muskgrass; submersed; 21.4; occasional; 2.9; BUT, PUNC.

Nitella flexilis (L.) C. Agardh: NITFLE; Flexible stonewort; submersed; 14.3; infrequent; 1.9; BUT, PUNC.

PHYLUM HEPATOPHYTA (Liverworts)

Ricciaceae Dumort. (Liverwort Family)

Riccia fluitans L.: RIAFLU; Slender riccia; submersed and free-floating; 14.3; infrequent; 1.9; BUT, PUNC.

Ricciocarpus natans (L.) Corda: RIONAT; Purple-fringed riccia; free-floating; 2.4; rare; 0.3; BUT, PUNC.

PHYLUM MAGNOLIOPSIDA (Flowering Plants)

Alismataceae Vent. (Water-plantain Family)

Sagittaria latifolia Willd.: SAGLAT; Common arrowhead; emergent; 4.8; rare; 0.6; BUT, PUNC.

Araceae Juss. (Arum Family)

Peltandra virginica (L.) Schott: PELVIR; Arrow arum; emergent; 21.4; occasional; 2.9; BUT, PUNC.

Cabombaceae A. Rich. (Water-shield Family)

Brasenia schreberi J.F. Gmel.: BRASCH; Water-shield; floating-leaved; 4.8; rare; 0.6; BUT, PUNC.

Ceratophyllaceae Gray (Hornwort Family)

Ceratophyllum demersum L.: CERDEM; Common coontail; submersed and free-floating; 19.0; infrequent; 2.5; BUT, PUNC.

***Ceratophyllum echinatum* A. Gray: CERECH; Prickly coontail; submersed and free-floating; 2.4; rare; 0.3; BUT, PUNC. [Rare]

Cyperaceae Juss. (Sedge Family)

Carex comosa Boott: CARCOM; Bristly sedge; emergent; 4.8; rare; 0.6; BUT, PUNC.

Eleocharis palustris L.: ELOPAL; Marsh spike-rush; emergent; 7.1; rare; 1.0; BUT, PUNC.

Haloragaceae R. Br. (Water-milfoil Family)

**Myriophyllum spicatum* L.: MYRSPI; Eurasian water-milfoil; submersed; 11.9; infrequent; 1.6; BUT, PUNC.

Myriophyllum verticillatum L.: MYRVER; Whorled water-milfoil; submersed; 52.4; common; 7.0; BUT, PUNC. [Rare]

Hydrocharitaceae Juss. (Frog-bit Family)

Elodea canadensis Michx.: ELOCAN; Canadian water-weed; submersed; 28.6; occasional; 3.8; BUT, PUNC.

Vallisneria americana Michx.: VALAME; Eel-grass; submersed; 4.8; rare; 0.6; PUNC.

Juncaceae Juss. (Rush Family)

Juncus effusus L.: JUNEFF; Soft rush; emergent; 4.8; rare; 0.6; BUT, PUNC.

Lamiaceae Lindl. (Mint Family)

Lycopus americanus Muhl.: LYCAME; American water-horehound; emergent; 4.8; rare; 0.6; PUNC.

Lemnaceae Gray (Duckweed Family)

Lemna minor L.: LEMMIO; Small duckweed; free-floating; 35.7; occasional; 4.8; BUT, PUNC.

Lemna trisulca L.: LEMTRI; Ivy-leaved duckweed; free-floating, 31.0; occasional; 4.1; BUT, PUNC.

Spirodela polyrrhiza (L.) Schleid.: SPIPOL; Giant duckweed; free-floating; 35.7; occasional; 4.8; BUT, PUNC.

Wolffia brasiliensis Wedd.: WOABRA; Brazilian water-meal; free-floating, 11.9; infrequent; 1.6; PUNC.

Wolffia columbiana H. Karst.: WOACOL; Columbian water-meal; free-floating, 11.9; infrequent; 1.6; PUNC.

Lentibulariaceae Rich. (Bladderwort Family)

Utricularia gibba L.: UTRGIB; Humped bladderwort; submersed and free-floating; 35.7; occasional; 4.8; BUT, PUNC.

Utricularia macrorhiza J. Le Conte: UTRMAC; Common bladderwort; submersed and free-floating; 14.3; infrequent; 1.9; BUT, PUNC.

Najadaceae Juss. (Water-nymph Family)

Najas flexilis (Willd.) Rostk. & Schmidt: NAJFLE; Slender water-nymph; submersed; 23.8; occasional; 3.2; BUT, PUNC.

Nymphaeaceae Salisb. (Water-lily Family)

Nuphar advena (Ait.) W.T. Ait.: NUPADV; Spatterdock; floating-leaved; 81.0; abundant and widespread throughout the lake; 10.8; BUT, PUNC.

Nymphaea odorata Ait. subsp. *tuberosa* (Paine) Wiersema & Hellq.: NYMODT; White water-lily; floating-leaved; 19.0; infrequent; 2.5; BUT, PUNC.

Polygonaceae Juss. (Buckwheat Family)

Persicaria amphibia (L.) Gray: PERAMP; Water smartweed; emergent; 11.9; infrequent; 1.6; PUNC.

Persicaria hydropiperoides (Michx.) Small: PERHYO; False water-pepper; emergent; 21.4; occasional; 2.9; BUT, PUNC.

Pontederiaceae Kunth (Pickerel-weed Family)

Heteranthera dubia (Jacq.) Small: HETDUB; Water star-grass; submersed; 7.1; rare; 1.0; PUNC.

Pontederia cordata L.: PONCOR; Pickerel-weed; emergent; 4.8; rare; 0.6; PUNC.

Potamogetonaceae Dumort. (Pondweed Family)

Potamogeton amplifolius Tuckerm.: POTAMP; Broad-leaved pondweed; submersed; 7.1; rare; 1.0; BUT, PUNC.

Potamogeton foliosus Raf. subsp. *foliosus*: POTFOF; Leafy pondweed; submersed; 50.0; common; 6.7; BUT, PUNC.

Potamogeton pusillus L. subsp. *tenuissimus* (Mert. & Koch) R.R. Haynes & Hellq.: POTPUT; Small pondweed; submersed; 21.4; occasional; 2.9; BUT, PUNC.

Stuckenia pectinata (L.) Börner: STUPEC; Sago pondweed; submersed; 23.8; occasional; 3.2; BUT, PUNC.

Rubiaceae Juss. (Madder Family)

Cephalanthus occidentalis L.: CEPOCC; Buttonbush; emergent; 11.9; infrequent; 1.6; BUT, PUNC.

Saururaceae E. Mey. (Lizard's-tail Family)

Saururus cernuus L.: SAUCER; Lizard's-tail; emergent; 4.8; rare; 0.6; PUNC.

Sparganiaceae Rudolphi (Bur-reed Family)

Sparganium emersum Rehmann: SPAEME; Narrow-leaved bur-reed; emergent; 11.9; infrequent; 1.6; BUT, PUNC.

Typhaceae Juss. (Cat-tail Family)

Typha latifolia L.: TYPLAT; Broad-leaved cat-tail; emergent; 28.6; occasional; 3.8; PUNC.

Zannichelliaceae Dumort.
(Horned-pondweed Family)

Zannichellia palustris L.: ZANPAL; Horned-pondweed; submersed; 2.4; rare; 0.3; BUT, PUNC. [Rare]

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