DEPARTMENT OF NATURAL RESOURCES

Minnesota Lake Plant Survey Manual

Version 4

For use by MNDNR Fisheries Section, EWR Lake Ecology Unit, EWR Minnesota Biological Survey Unit

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Purpose

For use by MNDNR Fisheries Section, EWR Lake Ecology Unit, EWR Minnesota Biological Survey Unit to assess lake habitat across the state.

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Notes

This is the fourth revision of the original Manual (originally published on May 4, 2015). This version contains new information on woody habitat assessment (Chapter 9), aquatic botanical inventories and rare plant surveys (Chapter 10) and collection and preservation of aquatic plant specimens (Chapter 11).

For the purposes of this manual, the terms "aquatic plants" and "aquatic macrophytes" are considered the same and include vascular flowering plants, ferns and fern allies [example *Isoetes* spp. (quillworts), *Equisetum* spp. (horsetails)], liverworts (*Riccia* spp. and *Ricciocarpus* spp.), bryophytes, and macroalgae in the Characeae family. Emergent wetland plants that occur in the shoreline zone between the lake and upland are not generally included in MNDNR aquatic plant surveys except when they occur within aquatic sampling locations.

A note on measurement units. In Minnesota, most of the statewide lake hydrologic data have been recorded in English units. Specifically, lake depth contour data, lake area and shoreline length measurements available from MNDNR are recorded in feet. It is generally unnecessary to convert these data to metric units. Conversely, establishment of survey site locations in GIS and in-field navigation with GPS are primarily done using UTM (universal transverse Mercator) coordinates (meters) and likewise there is little reason to convert these data. Latitude – longitude are a standard for herbarium voucher specimens. Therefore, the data collection and reporting will be a mix of metric and English units.

Table of Contents

Chapter 1 Introduction

A tiered approach to statewide lake plant assessments

This manual provides a tiered approach to lake plant assessments where managers select protocols based on statewide and local priorities and objectives. These standardized protocols help ensure that appropriate data are collected in an objective, unbiased, and repeatable manner. Survey methods in this manual are science-based and are designed to identify and characterize in-lake and lakeshore habitat.

This manual was developed by MNDNR staff in Ecological and Water Resources (EWR) Lake Ecology Unit (LEU) and Minnesota Biological Survey Unit (MBS), in consultation with the MNDNR Fisheries Section. The manual was designed primarily for use by these groups, but protocols may also be used by other MNDNR Programs, other agencies and consultants. Various MNDNR programs, such as the Mississippi River Long Term Resource Monitoring Program, Wildlife Shallow Lakes Program, and Aquatic Invasive Species Program have specific protocols tailored to their individual survey objectives; some of their protocols are similar to those described in this manual, but staff should refer to Program-specific manuals (MNDNR 2011, Yin et al. 2000) when appropriate. This manual is divided into chapters based on different plant communities and survey objectives (Table 1-1).

Objectives for management and monitoring

The manual includes protocols focused on both inventory and monitoring. An inventory survey assesses the location or condition of a particular plant species or plant communities at a specific time. Data from these surveys can be used to compare plant communities in different lakes. These surveys may provide baseline or reference data for subsequent monitoring. They may also identify locations of rare species. If an inventory is well-designed, it may be repeated over time to assess plant community status and trends in the same location. Monitoring surveys are repeated over time to learn how plant species or communities within a lake vary over time. Monitoring may also be used to inform management and conservation. For example, a survey may be designed to learn how a management decision may influence a specific plant community. Inventory and monitoring data can be used to:

1. Learn more lake habitat and the habitat of specific plant species
2. Compare and contrast the plant communities of the surveyed lake with other Minnesota lakes
    a. Develop statewide and regional species distribution maps
    b. Identify lakes of high biological significance
    c. Identify lakes where plant community indicates potential impairment
3. Identify trends that may be used to predict future changes
    - Example: Is large-leaf pondweed distribution changing in Minnesota?
    - Example: How do ice and snow cover influence submerged plant growth?

4. Evaluate the effects of past management
5. Guide locations and scope of future surveys
6. Guide conservation activity of rare species and plant communities

The ability to detect habitat change depends on the magnitude of change that is of interest and the precision of estimates of change (Manley et al. 2006). Because the monitoring scale for each plant community will vary, the minimum change and precision standards will also vary. The manual outlines minimum sampling standards required to detect various levels of change and identifies situations where the sampling effort necessary to meet minimum standards may not be feasible. Additionally, there are some situations where a higher-than-minimum standard may be desired to detect subtle changes. Background information on plant sampling theory and design is provided in Appendix A.

Habitat specific protocols

Plant communities associated with lakes include:

- Terrestrial and wetland plants along shorelands (Chapter 3),
- Emergent and floating-leaf plants that are commonly found in near-shore shallow areas (Chapter 4)
- Submerged plants that may occur in both shallow and deep water (Chapters 5 and 6).
- Rare plant species whose habitats may include all the above (Chapter 9)

Different protocols are needed to assess each of these communities because they differ in:

- Logistical access to habitat (e.g., boat access vs. survey on foot)
- Botanical expertise required (e.g., general life form vs. species-level identification)
- Metrics (e.g., area covered by waterlilies vs. maximum depth of submerged plant growth)
- Methods and equipment required to measure metrics in different habitats (e.g., emergent and floating-leaf coverage vs. submerged plant occurrence)
- Temporal window of survey (e.g., trees can be assessed year-round while most species of submerged aquatic plants can only be assessed during open water growth period)

Prioritizing lakes for plant surveys

Prioritizing lakes for plant surveys is necessary to 1) ensure that data are representative of statewide plant communities and conditions, 2) ensure that data required for priority projects are collected, 3) maximize the limited staff time available for plant surveys, and 4) avoid duplication of effort among various survey programs.

In general, MNDNR prioritizes lakes with public access for surveys. Lake depth type (deep or shallow), lake surface area, development level, availability of existing recent data, and specific program goal are also used to prioritize lakes for field surveys. Because MNDNR Wildlife Shallow Lakes Program already assesses and manages shallow lakes, MNDNR Fisheries focuses their survey efforts on deep lakes. MNDNR EWR Programs survey both deep and shallow lakes in consultation with Fisheries and Wildlife to avoid duplication of efforts. Since 1993, Fisheries has prioritized lake plant surveys on a statewide basis with most game-fish lakes scheduled for a Transect Vegetation Survey (Ch. 5) on an approximate 10-year rotation. From 1995 to 2016, MBS conducted over 2,000 lake plant surveys with a focus on lakes in central and northern Minnesota; current surveys continue to expand this geographic focus statewide.

These statewide data collections remain critical and are now also considered within the framework of the Minnesota Pollution Control Agency (MPCA) watershed assessment schedule, where water quality and biological conditions of lakes in each of the state's 80 major watersheds are assessed on a 10-year rotation. Individual Program priorities and special projects, such as MNDNR Sentinel Lakes, continue to influence survey priorities.

Table 1-1 Community specific methods to meet specific objectives

Chapter	Method	Community or Zone	Objective	Botanical Expertise	GIS Knowledge
3	Score The Shore (STS)	Shore	Rapid assessment of habitat	low	low
4	Floating and Emergent Plant Mapping (FLEM)	Shallow water plant stands	GIS-based delineation and dominant taxa classification	moderate	moderate
5	Vegetation Transect (VT)	Littoral zone	Compile lakewide taxa list and generalized geographic distribution of taxa	moderate	low
6	Point-Intercept (PI)	Littoral zone	Quantitative estimates of taxa distribution and frequency	moderate	low
7	Nearshore Vegetation Plots	Shallow water plant communities	Quantitative estimates of taxa distribution and frequency	high	low
8	Hydroacoustic Transect	Submerged plants	Quantitative estimate of plant height	low	moderate
9	Wood Habitat Survey	Littoral zone	Rapid assessment of wood pieces	low	moderate
10	Aquatic Botanical Inventory and Rare Plant Searches	Targeted lake habitats	Compile high quality botanical inventory list and locate rare species	high	low

Priority lakes and data for use in MPCA's Watershed Assessment

For MPCA's Watershed Assessment, MNDNR EWR has developed an Aquatic Plant Index of Biological Integrity (IBI) to assess lake plant health based on nutrient loadings (Radomski and Perleberg 2012). This tool requires a lakewide plant taxa list and utilizes data collected from multiple MNDNR survey programs, including Fisheries Lake Survey Program, LEU and MBS. Surveys that produce lakewide plant taxa lists (Ch.5, Ch.6, Ch. 7, or Ch. 9) are needed to assess each lake. Survey priority is given to larger lakes with high development and lakes where existing plant data indicates potential impairment (Figure 1-1). Surveys include lakes across the gradient of disturbance, from reference conditions to highly impacted sites. Lakes where recent quantitative plant surveys have been conducted will be given lower priority.

MNDNR EWR developed additional tools to assess lake plant health in response to shore disturbance. Score the Shore (Ch. 3) assesses shore habitat and Floating-leaf and Emergent Mapping (Ch. 4) assesses the distribution of emergent and floating-leaf plant stands. To effectively provide data for the watershed assessment projects, survey priority is given to larger lakes with high development (Figure 1.2).

Figure 1-1. For MPCA Watershed Assessment: Lake survey priorities to collect plant taxa list (Transect, Point-Intercept or Near-shore Plots)

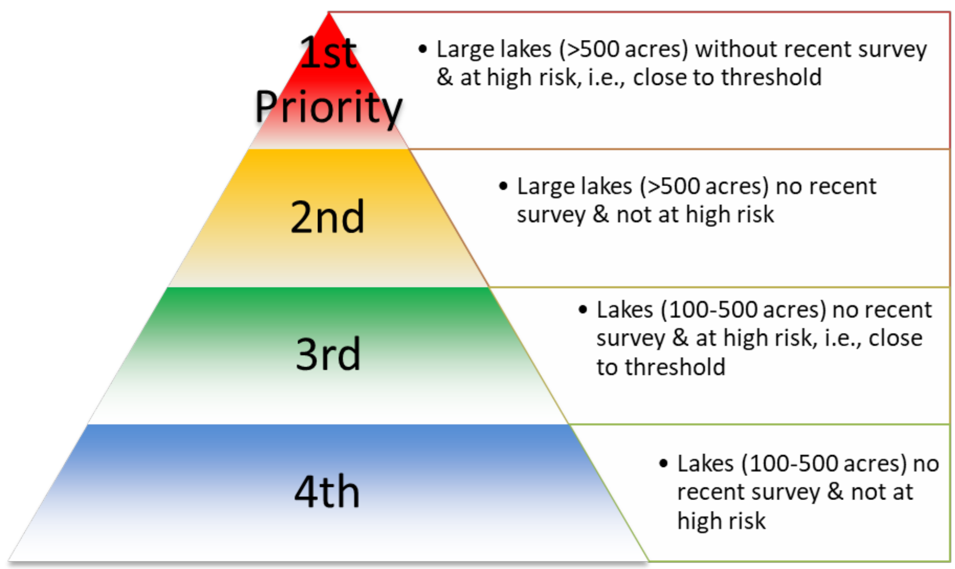
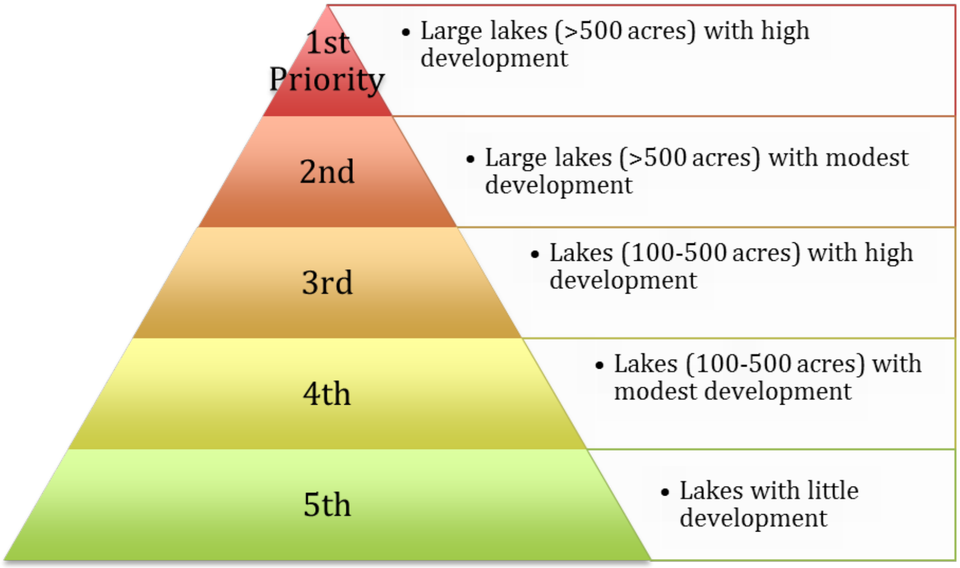


Figure 1-2. For MPCA Watershed Assessment: Prioritizing for Score The Shore surveys and Floating-leaf and Emergent Mapping surveys



Priority lakes and data for special survey projects

In addition to the annual set of prioritized lakes for MPCA Watershed Assessment, lakes may be surveyed on a more frequent basis because they are the focus of a statewide or Area-level project. Examples may include:

- Sentinel Lakes
- Lakes where changing conditions may result in vegetation changes
- Lakes where rare species have been documented, reported or where habitat conditions suggest they may occur
- Lakes where new county or state records have been reported or where habitat conditions suggest they may occur
- Lakes where surveys would facilitate better understanding of specific plants or plant communities
- Lakes with Lake Vegetation Management Plans (LVMP's)
- Lakes that are included in research projects

The survey method or methods used on these lakes will depend on the specific survey objectives.

Sampling timeline and survey frequency

Most vegetation sampling is conducted during peak growth and before plants senesce – typically from July through early September. Survey timing is dependent on survey objectives, specific growth conditions and life histories of target plants and individual lake characteristics. Lakewide submerged plant surveys are conducted after significant plant growth is noted in early summer. Depending on the life history of the species, rare aquatic plant species surveys can be conducted from June through September. Surveys to delineate and describe emergent and floating-leaf plant stands and other unique plant areas are conducted from July through September. Shoreline habitat assessments can be done from early spring through fall. Because most of these surveys are conducted by boat, kayak or canoe, surveyors should select times when weather permits safe watercraft operation. Periods of higher winds and potential storms should be avoided. If feasible, surveyors should also avoid surveying on weekends and holidays when recreational boat activity is high.

It may not be feasible to assess all plants with one survey. If curly-leaf pondweed (*Potamogeton crispus*) is an important part of a lake plant community, surveys may be conducted in May or June, before this species senesces. Recent searches for macroalgae in the family Characeae suggest that spring or early summer surveys may be necessary to detect some species in lakes where water clarity declines by mid-summer. Annual species, such as wild rice (*Zizania palustris*) and bushy pondweeds (*Najas* spp.), however, may be missed in surveys conducted before July. In lakes with extensive wild rice stands, surveys to assess submerged plants may be conducted earlier (June) to minimize damage to wild rice.

The decision to repeat a survey and the frequency at which those repeat surveys are conducted are dependent on the specific objectives. For objectives relating to management, repeat surveys may not be a priority for undeveloped lakes where little change in development is anticipated and/or remote lakes that are logistically difficult to access. For lakes where monitoring change is a management priority, annual surveys may be warranted, particularly if lake conditions are expected to fluctuate on an annual basis. If annual monitoring is not feasible, or if significant changes are not detected with annual surveys, repeating surveys every 3 to 5 years may be sufficient. For management objectives related to MPCA's watershed approach, priority lakes should be surveyed every 10 years. For objectives relating to rare species, repeat visits, possibly in a single season, may be required for proper identification, collection and documentation.

Pre-planning

Checklists of required and recommended field equipment are provided in Appendix B. Specific survey method and plant identification training is available from LEU and MBS staff and can include formal workshops, printed and visual study aids, and in-field assistance. Remember to obtain any access permission and required collecting permits prior to survey.

Chapter 2 A Primer on Plant Sampling

Minnesota Lakes and Plant Communities

Glacial activity formed most Minnesota lakes and led to differences in the distribution, size and characteristics of lakes throughout the state. Differences in land-use across Minnesota have further influenced lake characteristics at the regional level. Minnesota lakes range in size from small ponds to waterbodies that exceed 100,000 acres in surface area. Northeast Minnesota lakes are generally deeper, oligotrophic systems with forested, minimally developed shorelands while southern Minnesota lakes are often shallow, nutrient-rich systems within shorelands dominated by agriculture or other development. Moyle (1945) describes the major flora of Minnesota lakes as they relate to chemical properties of lakes.

MNDNR Fisheries manages more than 3,700 lakes, most of which are deep and dimictic, ranging from 25 to 305,000 acres with a mean surface area of 368 acres. MNDNR Wildlife manages an additional set of about 3,800 shallow lakes (maximum depth of 15 feet or less), ranging from 25 to 38,000 acres with a mean area of 235 acres. Other MNDNR programs such as Aquatic Plant Management (APM), Shoreland Restoration, Aquatic Management Area (AMA) and Invasive Species Program (ISP) are involved in site level and lakewide plant management activities in both deep and shallow lakes.

Because of the wide range in plant abundance and diversity across Minnesota lakes, and the variety of program level survey objectives, it can be challenging to select survey methods that are appropriate for all lakes and all projects. Visual observation may be useful in clear lakes of northern Minnesota but not feasible in more turbid lakes in the south. Rake tosses are useful for sampling submerged vegetation but can be destructive in emergent stands of wild rice. A grid placement of points may be an efficient way to sample a broad littoral zone in a mesotrophic lake but not in a sparsely vegetated oligotrophic lake with a narrow littoral zone. To compensate for some of these difficulties, the manual provides a suite of survey methods targeted at specific plant community types. The general protocols are designed for the most frequently encountered plant communities. Special circumstances where protocols may need to be altered are discussed.

Measuring lake plant community attributes

Plant surveys can measure a variety of community attributes including plant distribution (the location and arrangement of plants throughout the lake), abundance (the amount of vegetation) and composition (the types of plants present). There are numerous methods to assess each attribute, but the approaches are not equal in the time, expertise and equipment required to conduct each survey or their ability to generate reliable estimates. The manual includes methods that can be used at a statewide scale, by non-botanists and that can be conducted relatively rapidly.

Quantitative data that are collected in a statistically valid manner are required to assess changes in plant communities over time or in response to management activities (Madsen and Bloomfield 1993, Spencer and Whitehand 1993). In designing quantitative vegetation surveys, it is important to consider survey objectives and available resources which will help determine the best method. Other considerations include the appropriate number of sample sites, area of each sample site, and arrangement of sample sites throughout the study area.

There are several standard ways to quantify plant abundance including biomass, cover, plant height, density, and frequency. Each metric varies in complexity and usefulness in assessing aquatic systems. The specific methods required to estimate each metric differ in expense, time, equipment, precision, adaptability to aquatic systems, and surveyor expertise. For example, many quantitative plant sampling methods require SCUBA surveys to adequately sample aquatic plants. While advances have been made in remote sensing techniques, such as hydroacoustics, these methods require specialized equipment and training, post-processing of data, standardization, and lack the ability to identify plants to the species level. For lakewide aquatic plant surveys where species identification is a priority, boat-based sampling with rakes remains the simplest, fastest and most economical method of sampling.

Abundance

Abundance is a generic term to describe the amount of vegetation present within a given area. Standard quantitative measures of plant abundance include biomass, cover, density and frequency and each provides different information about the plant community. Sample quadrats are typically used to measure plant abundance, but the appropriate size, shape and number of quadrats varies with each metric. Survey effort and expertise required to collect each metric also vary.

Frequency of occurrence

Frequency of occurrence, or frequency, refers to the uniformity of a species in its distribution over an area. It is the number of sample sites where a plant is detected (Figure 2-1). Frequency of occurrence is defined as the percent of sample sites in which the target taxon is detected and reflects the probability of encountering that taxon at any location within a specified area (Greig-Smith 1983). Because no counting or estimating is involved, frequency of occurrence is a simple, objective and rapid measure that can be consistently collected by different surveyors; other advantages include the ability to monitor a variety of plant growth forms, opportunity to monitor at flexible times throughout the growing season, and uncomplicated data analysis (Nichols 1984, Elzinga et al. 2001). Frequency data are recommended as an appropriate abundance estimate when studying long-term changes in communities (Nichols 1999).

Frequency data are a function of both plant dispersion and plant abundance. With georeferenced data, large changes in plant dispersion patterns can be detected by viewing frequency data in GIS. However, changes in abundance (cover, density, or biomass) can be more difficult to detect. It is also possible for plant abundance and/or plant dispersion to change without a detectable change in frequency (Figure 2-2).

Plot size, or the physical area sampled at each vegetation survey site, is important in frequency sampling because the size of the plot influences the probability of any taxa occurring within the plot. The optimal plot size for collecting frequency data decreases both with increasing spatial structure and with increasing number of plots per survey (Heywood and DeBacker 2007). The best sampling precision is reached for a particular taxon when it is present in 30% to 70% of the plots sampled; this distribution will provide the most sensitivity to changes in frequency (Elzinga et al. 2001). Frequency values of 100% generally indicate plot size exceeds the maximum size of gaps between individuals (Daubenmire 1968). If frequency data appear to not detect perceived changes in plant abundance, decreasing the plot size may result in better resolution (Figure 2-3).

Because frequency data are dependent on plot size, data must be reported with reference to plot size and plot size must be consistent between surveys if data are to be compared. Surveyors must be careful not to include plants observed outside the plot boundaries as “present” in the plot because by doing so, they are in effect increasing the plot size. This can be challenging for surveys where plot area is visually estimated and a quadrat sampler is not used to determine plot boundaries.

Figure 2-1. Example: plant density and frequency decrease from Year 1 to Year 2.

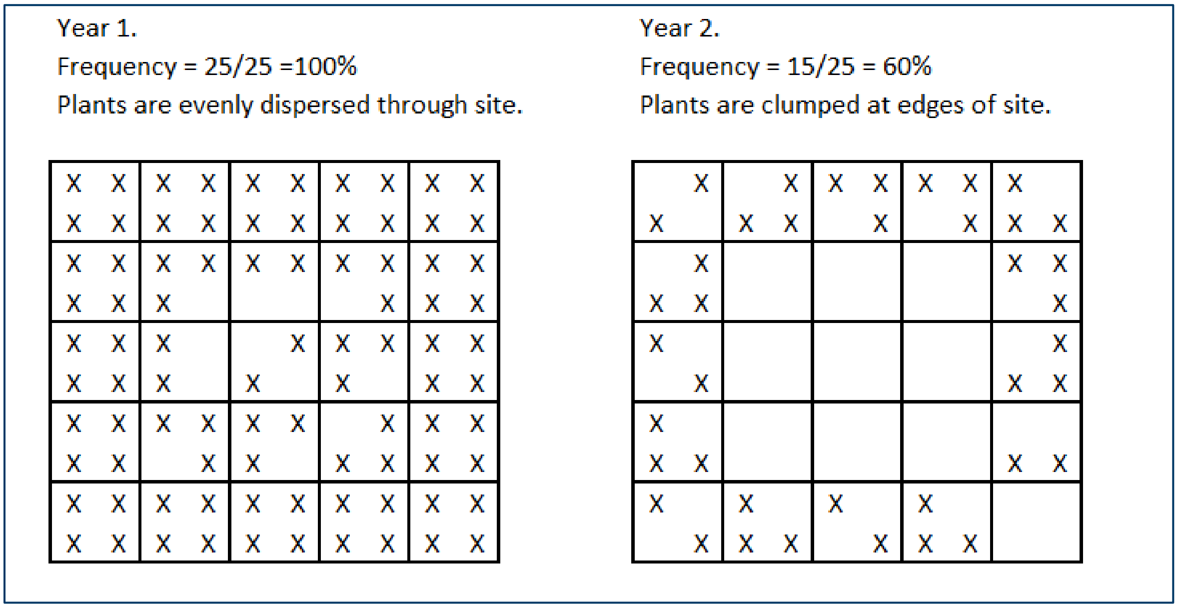


Figure 2-2. Example: plant density decreases from Year 1 to Year 2 but frequency does not change

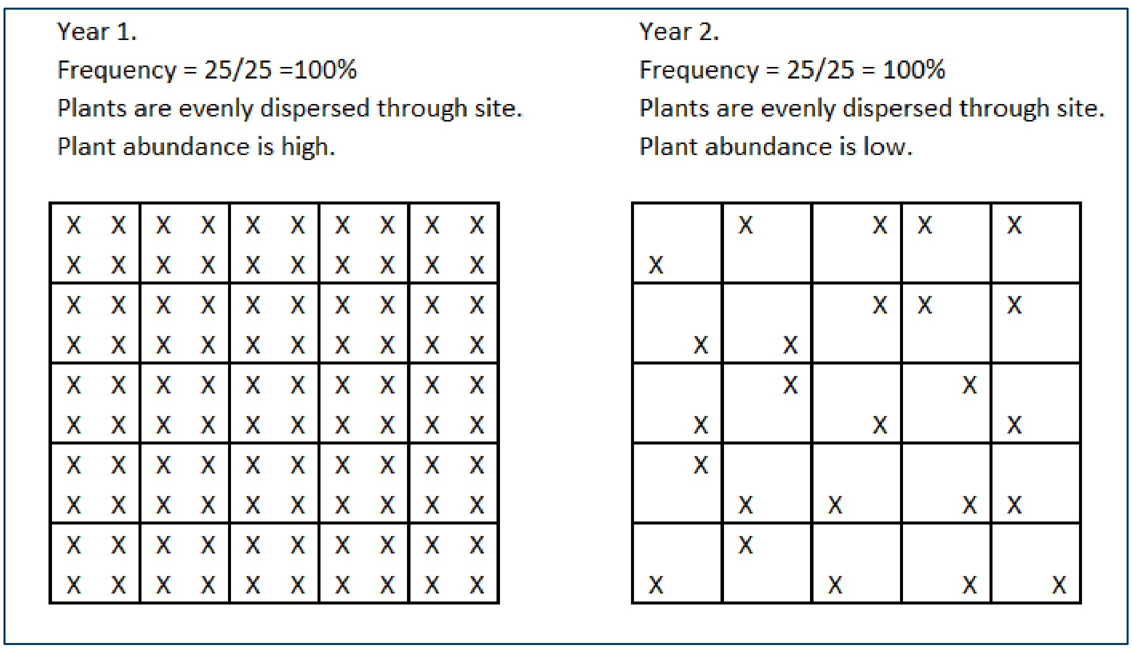
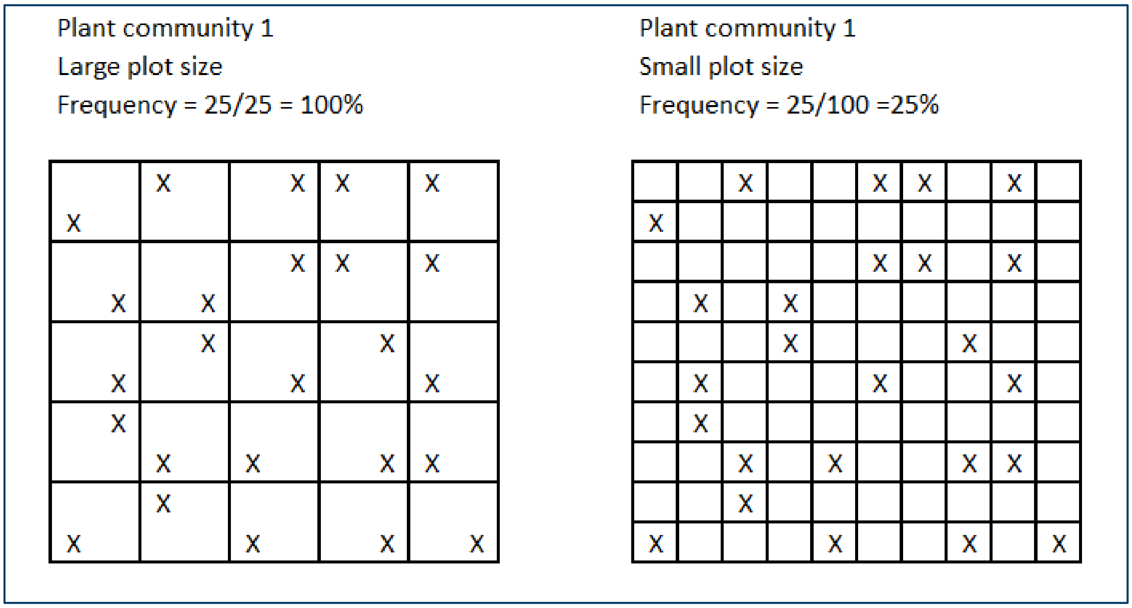


Figure 2-3. Example: survey area size is decreased for more accurate estimation of frequency



Coverage and cover

Coverage is the area covered by a plant community or stand. For example, emergent or floating-leaf stands may be inventoried by delineating the stand boundary. Cover is an estimation of how much a plant dominates an area. It may be estimated as the amount of the canopy or the ground occupied by the plant or as the proportion of the plant that extends into the soil (basal cover), or the vertical projection of the plant's exposed leaf area (foliar cover). Cover is estimated visually within quadrats, making it particularly difficult to estimate in deep water and/or turbid conditions. Because cover estimates are subjective, there is often variation between surveyors, and it is difficult to determine the accuracy of the estimate (Cheal 2008). Cover classes (e.g., 1-10%, 11-20%, etc.) reduce precision, but may increase surveyor repeatability. Obtaining accurate, repeatable estimates of plant cover can be difficult but errors can be minimized by using classes (Daubenmire 1959, Braun-Blanquet 1965). Hatton et al. (1986) found that in an artificial setting (paper illustrations), extremes of cover were estimated with less error than intermediate cover, and they therefore recommended that cover estimation classes be relatively narrow at the extremes and wider for intermediate ranges. They acknowledged that, in field settings, the actual ability of observers to estimate cover will vary.

Other estimates of abundance

Biomass – is the weight of living plant tissue and is the best single measure of a species' structural importance in a community. However, direct measurement can be difficult and damaging because it requires destructive harvesting of plants, both above and below-ground, particularly for species with extensive root systems. Madsen and Wersal (2012) discuss the tradeoffs between collecting many small biomass samples or fewer large biomass samples, with larger samples requiring more processing time.

Biomass sampling is labor intensive and includes cleaning and drying of plant material to obtain dry weight biomass; it is most often used for small survey area assessments to assess specific management activities rather than lakewide surveys (Madsen 1993). For time and cost reasons, biomass estimates are not recommended as a standard protocol.

Density – is the number of individuals, or number of stems, within an area. This measure may have little meaning if individuals of a species vary greatly in size. Sample quadrats are used to estimate density, but different size quadrats may be needed to adequately sample all plants in a community. For aquatic plants, it can be very difficult to define an individual or stem and density counts typically require SCUBA divers. For time and cost reasons, density estimates are not recommended as a standard protocol.

Mean Plant Height – is a measure of the mean of maximum plant heights of a submerged plant community using hydroacoustic survey techniques. This measure may be converted to a relative value, often called biovolume, by dividing by water depth. If the submerged macrophyte community has a consistent canopy without a scattering of taller plants, the average of the maximum plant height will be similar to the mean plant height. However, submerged plant communities with variable plant heights are common. Radomski and Holbrook (2015) studied two commonly used hydroacoustic systems and found differences in the estimates of mean plant height and frequency of plant occurrence. Their study indicated that standardization of data collection equipment and the signal processing approach is necessary prior to using this technology as an assessment tool. Standardization of the hydroacoustic system includes transducer frequency, beam angle, and signal processing. Second, the survey design would also need to address sampling timing and frequency. Third, surveyors need to consider whether the objective includes the creation of maps of mean plant height by depth strata or whether collecting data from a representative sample of the littoral area is sufficient. The former requires considerably more field survey time and resources.

Descriptive abundance rating

Descriptive abundance ratings are subjective, often visual estimates that have been used as a surrogate for quantitative abundance estimates (Madsen and Wersal 2012). Some aquatic plant survey protocols (Indiana Department of Natural Resources 2007, Harman et al. 2008, Hauxwell et al. 2010, Yin and Kreiling 2011) use some form of an abundance rating to overcome the labor intensity associated with biomass techniques and the requirement for direct visual surveys associated with cover and density estimates. Such abundance ratings attempt to combine plant height, plant density and plant cover to describe the amount of the water column occupied by vegetation. Samples are collected with a garden rake that is divided into discrete increments and when plants are harvested an abundance ranking is given for each species. Theoretically, tall plants with high cover and high density receive the highest rating because the rake sample would collect a large amount of plant material and short plants with low cover and low density would receive the lowest rating; plants with intermediate abundance features would receive intermediate ratings.

Deppe and Lathrop (1992), who pioneered the rake abundance rating method, noted that such visual estimates involve subjectivity, require additional field time and may be most appropriate for assessing short-term changes in general plant abundance as opposed to assessing individual plant species abundance. In a comparison of rake abundance ratings and diver-collected biomass samples, Johnson and Newman (2011) found that abundance ratings were significantly higher and less precise than biomass estimates and that the comparability of the two methods is dependent upon the dominant taxa present. Yin and Kreiling (2011) concluded the efficiency of the rake to collect biomass varied among species and correlations of visual density ratings with biomass may be appropriate only if confirmed by diver-collected biomass samples for each individual species. Harman et al. 2008 reached similar conclusions and found that the rake abundance ratings and dry weight biomass estimates were comparable in only 17% of the instances with results varied among species growth forms.

The amount of vegetation collected on a rake toss is not only dependent on plant height, density and cover, but by individual species growth form and the "catchability" of each plant type and different site conditions. Tall, branching plants are more readily collected by a rake toss than are non-branching plants, those commonly growing at low densities relative to other species, and those growing lower in the canopy relative to other species (Harman et al. 2008). For example, bulrush (*Schoenoplectus* spp.) plants have minimal leaf area and if a moderately dense bulrush stand is sampled by rake, it is likely that only a few leafless stems will be collected on a rake and the rake abundance rating will be low. Conversely, coontail (*Ceratophyllum demersum*) plants have leaves that are densely arranged along the stem; if sampled by rake, coontail is likely to fill a large portion of the rake regardless of whether one or multiple plants were present in the sample. Rake sampling is more effective in shallow water where surveyors can better manipulate the area of lake bottom sampled. As water depth increases, there is more uncertainty about how much, if any, of the actual sample site is sampled.

Because plant height, cover and density are not always related, it is not possible to relate an abundance rating back to the quantitative plant features. A high abundance rating may indicate that plants were tall and/or cover was high, and/or density was high. Abundance ratings at sites with sparse occurrences of high cover plants (ex. a single waterlily) may not be distinguished from sites with high density, low cover plants [ex. dense bulrush (*Schoenoplectus* spp.) stand].

Despite the subjectivity and uncertainty associated with descriptive abundance ratings, they can serve as supplemental information when collected as part of a quantitative survey. Reducing the number of ratings to a three level "high", "medium" and "low" scale can help minimize ambiguity. In the example shown in Figure 2-2, an abundance rating could help distinguish the Year 1 community, where frequency is high and an abundance rating may be high (many plants per site), from the Year 2 community, where frequency is high but an abundance rating may be low (fewer plants per site). Abundance ratings may also be used to identify potential lake areas where recreational lake use may conflict with aquatic plant growth (sites of high plant abundance ratings).

Habitat zone definitions

For this manual, Habitat Zones are defined as shown in Figure 2-4 and the following definitions are used:

Lakes are enclosed basins filled or partly filled with water; they may have an inlet and/or outlet stream or may be completely enclosed.

Lakewide refers to the area defined by the lake boundary. It is used to identify sampling that occurs at a broad level where the entire lake is the experimental unit.

Lakeshore is the area comprised of the Shoreland, Shoreline, and Aquatic Zones.

Shoreland is defined in Minnesota Rule 6120, which for lakes is that land located within 1000 feet of the ordinary high water level (OHWL). Some local governments use a distance of 1320 feet. The methods in this manual use land located within 1320 feet of the OHWL to encompass both definitions. For this manual, we divide the Shoreland into two zones; these zones are not defined in Rule and do not have distinct boundaries or distances but are distinguished here because they are often managed differently by riparian owners (see Chapter 2 for detailed definitions):

Shoreland Zone is the landward portion of the Shoreland.

Shoreline Zone is the lakeward portion of the Shoreland. It is the transition zone between the Shoreland and Aquatic zones.

Aquatic refers to the lake and is used to distinguish this area from surrounding wetlands and terrestrial uplands.

Littoral area is defined in Minnesota Rule 6216 as "any part of a body of water 15 feet deep or less." Biologically, it is the portion of the lake where light is available for aquatic macrophyte growth. The legal definition is useful because it provides a general standard that can be used as a statewide reference. However, the actual depth of plant growth may exceed 15 feet on many lakes and it may vary seasonally, annually and between lakes. For the purposes of this manual, we use the biological definition of littoral zone and use it to distinguish shallow, potentially vegetated aquatic areas from deep zones that do not support vegetation.

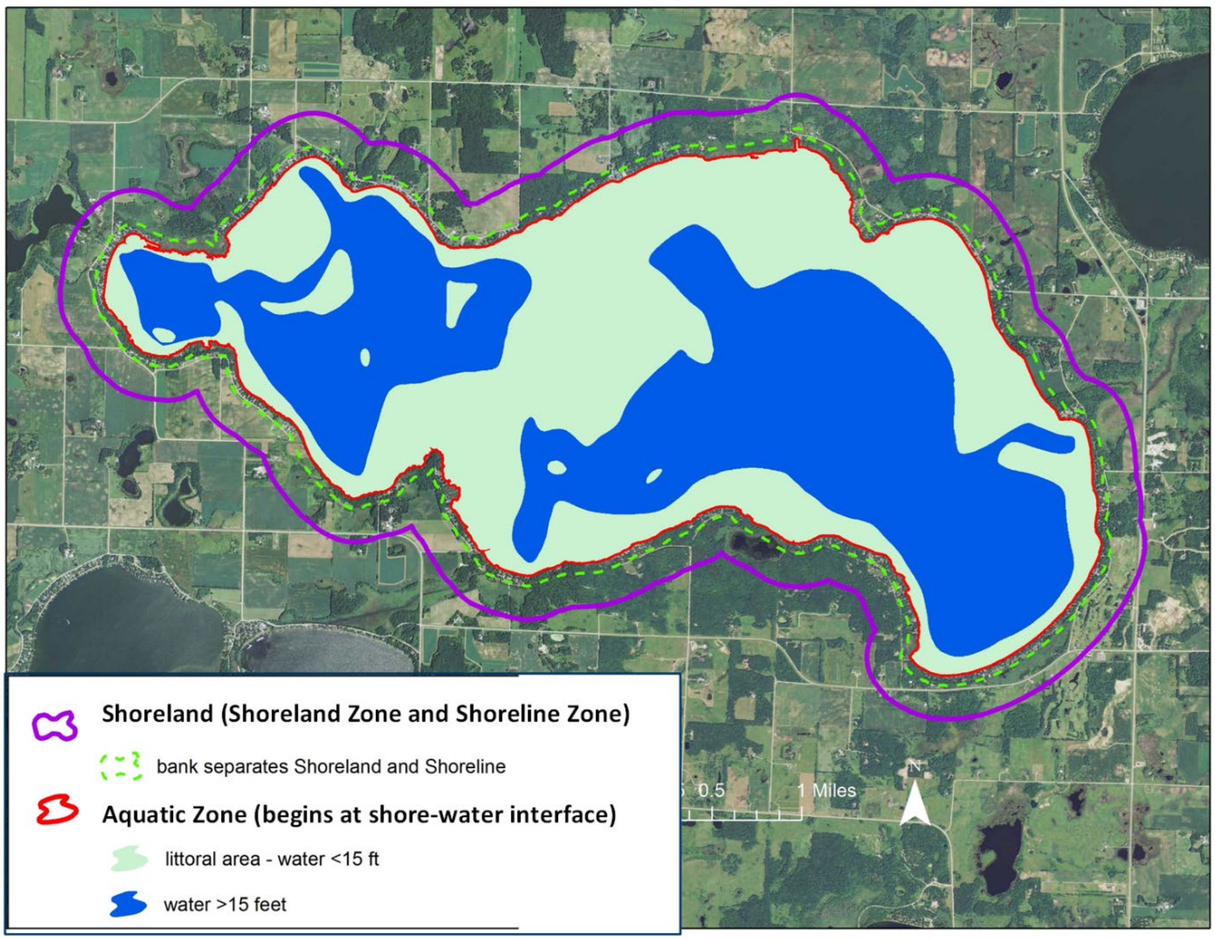
Near-shore is the shallow water area of the littoral area within a short distance of the shoreline where lake development impacts are likely to occur. Such impacts include dock installation, plant removal and woody habitat removal. This impact area varies within and between lakes because water depth can vary between sites but is generally less than 5 to 7 feet.

<u>For Score The Shore surveys</u>: Surveyors assess only a riparian portion (about 100 feet) of the shoreland. At developed sites, surveyors include only the area viewable from the lake and extending to the lakeward side of the structure. This area is then subdivided into the Shoreland and Shoreline Zones.

Surveyors also only assess a portion of the Aquatic Zone, generally the first 50 feet extending lakeward from the shore-water interface.

For Transect and Point-Intercept Surveys**:** Sample locations are established within the Aquatic Zone only and may extend beyond the standard littoral zone (15 feet).

Figure 2-4. Lake Habitat Zones



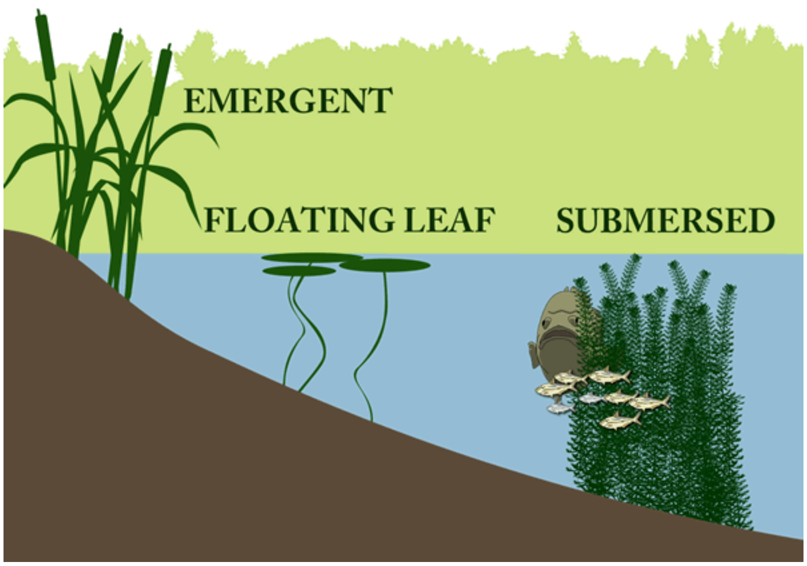
Types of aquatic plants

Aquatic macrophyte is defined in Minnesota Statute 84D.01 as "a macroscopic non-woody plant, either a submerged, floating leaved, floating, or emergent plant that naturally grows in water." Aquatic macrophytes include vascular flowering plants, mosses, ferns, and macroalgae in the *Characeae* family. These plants require hydric conditions for at least a portion of their life cycle.

Aquatic plant is defined in Minnesota Statute 84D.01 as “a plant, including algae and submerged, floating leaved, floating, or emergent plants, that naturally grows in water, saturated soils, or seasonally saturated soils.”

For the purposes of this manual, the terms “aquatic plants” and “aquatic macrophytes” are considered the same. Emergent wetland plants that occur in the shoreline zone between the lake and upland are not generally included in MNDNR aquatic plant surveys except when they occur within aquatic sampling locations. Plants can be grouped based on where they grow in relation to the lake bottom and water surface, and Minnesota Statute 84D.01 defines four major lifeforms (Figure 2-5):

Figure 2-5. Aquatic Plant Life Forms



Emergent plants are rooted in the lake bottom, and during peak growth most of their leaves and/or stems extend out of the shallow water.

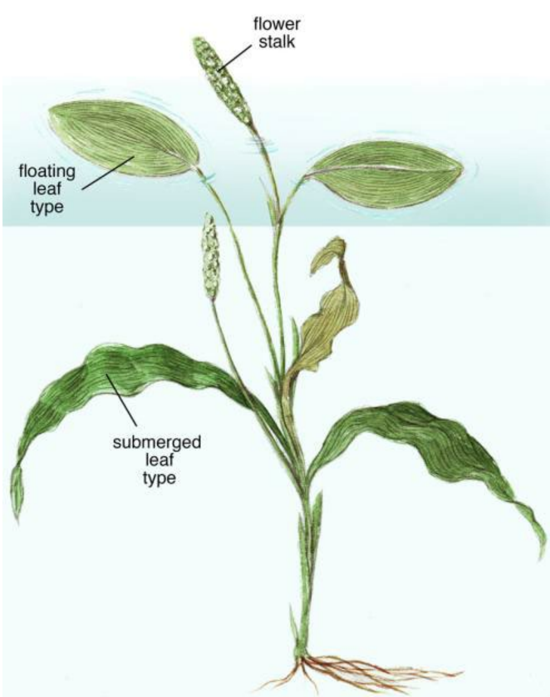
Floating-leaf plants are rooted on the lake bottom, and during peak growth their leaves and flowers float on or just above the water surface. Floating-leaf aquatic plants are defined in M.R. 6280.02 as “aquatic plants that are rooted in the bottom and have their lower portions submersed in water and leaves that float on the surface of the water including species in the genera *Nymphaea*, *Nuphar*, *Brasenia*, and *Nelumbo*. Species in the genera *Potamogeton*, *Callitriche*, and *Ranunculus*, which are submersed aquatic plants that may produce some floating leaves, are not included in this definition.”

Submerged plants grow primarily under the water surface and may or may not be rooted in the lake bottom. Flowers of submerged plants may occur above or below the water surface. Many submerged plants are “heterophyllous” and have both submerged and floating leaves, but most vegetative growth is beneath the water surface (Figure 2-6). These heterophyllous plants are considered submerged. Plants such as coontail (*Ceratophyllum demersum*), bladderworts (*Utricularia* spp.), and macroalgae

(*Characeae*) that do not strongly attach to the lake bottom but have vegetative growth that occurs primarily below the surface are considered submerged.

Free-floating plants are not anchored to the lake bottom and have vegetative portions that primarily float on or just below the water surface. This group primarily includes duckweeds (*Lemnaceae*).

Figure 2-6. Heterophyllous aquatic plant



Submerged plants that can form floating leaves are grouped into the “Submerged” class for MNDNR aquatic plant surveys.

Image courtesy of MNDNR MnAqua Program

Chapter 3 Score The Shore: Rapid Assessment of Lakeshore Habitat

Objectives

Score The Shore is a protocol developed to rapidly assess the quantity and integrity of lakeshore habitat. The survey is designed to assess differences in habitat between lakes and to detect changes over time. Many of Minnesota's shorelands are under private ownership and this survey method may be used to assess both public and private lands. The MNDNR assesses conditions of private lands through various programs, some of which are done in cooperation with the landowner and others that are larger scale assessments that use remote sensing. Score The Shore surveys require visual observation of lands accessible by boat. The intent of this survey is to assess habitat, not to inspect for violations. Data are not tied to individual properties and will not be displayed at the individual lot level. A separate but similar survey titled "Score Your Shore" has been developed for riparian landowners to self-assess their developed lot (Perleberg et al. 2012). In Score Your Shore, the individual lake lot is the study site, and the survey area can vary based on lot size. In Score The Shore, the entire lakeshore serves as the study site. Specific objectives of the Score The Shore Survey are:

1. For each individual lake, determine the lakewide lakeshore habitat score with modest precision.
2. Detect substantial lakewide lakeshore habitat score changes (>20%) over time and monitor trends in lakeshore habitat.
3. Compare lakewide lakeshore habitat scores within and between watersheds and ecoregions to assess patterns and trends.

Introduction

The lakeshore is a transition zone that attracts a wide variety of birds and animals that move back and forth between the upland and water. It is a filtering zone that can trap sediments and nutrients as water flows from the upland into the lake. A natural Minnesota lakeshore may include a mix of live and dead trees, shrubs, wildflowers, grasses and rocks. Some depositional-zone shores have natural sand covering most or a portion of the site, with only scattered vegetation. Erosional-zone shorelines often have high banks and rocky substrates. Wind-protected bays and small lakes may have shorelines with organic sediments and rich plant communities. Upland trees hang over the water's edge and create shade and cooler water for fish and animals in the lake. But as people remove vegetation, this zone becomes destabilized and resulting erosion allows silt and sediment into the lake. In response to this, landowners may inappropriately opt to install riprap or retaining walls to prevent further erosion. Humans can also alter the habitat in the lake itself. Installation of docks and other structures can reduce or alter the aquatic plant growth (Garrison et al. 2005). Emergent and floating-leaf plant beds are often reduced at developed sites (Radomski and Goeman 2001, Jennings et al. 2003). As Minnesota lakeshore zones are changed from “wild” naturally vegetated areas to “domesticated” sites of turf grass and hard surfaces, critical areas for wildlife and important filtering effects are lost.

Another important component of the lakeshore ecosystem is woody habitat that is created when whole trees, tree limbs, branches, twigs and leaves fall into the lake from the adjacent upland. Fish and other aquatic life use this woody habitat in a variety of ways: as shade from sunlight, refuge from predators, spawning and nesting sites, and for foraging. When lakeshore trees are cut for development, they are often removed from the site, reducing the potential for woody habitat to be added to the aquatic zone. Homeowners often remove existing woody habitat (Francis and Schindler 2006) and may not realize that these materials provide critical habitat.

Many Minnesota lakeshores have been altered by human activities, but describing, quantifying and comparing these alterations statewide can be challenging. As narrow transition zones, lakeshores are often not included in landscape assessments unless they are part of a larger contiguous land tract. Aerial photography can assess major vegetation changes such as deforestation, but subtle changes in forest understory are more difficult to detect. Because many lakeshores are divided into small, private ownership tracts, field assessments are logistically complicated.

Survey design

This is a rapid assessment method in which surveyors assess the amount of vegetation and other features within zones of the lakeshore. This survey is designed to be conducted from a boat not only because of property ownership issues but to provide for a rapid assessment. Even at lakes with publicly owned shoreline or with the permission of a private property owner, surveyors should view the survey area from the boat to retain consistency between survey sites. This survey is designed for lakes with shoreline lengths of 50 miles or less. It can be conducted on large lakes, such as Mille Lacs, Leech, and Rainy, but it may be useful to target specific bays or shorelines on these large lakes rather than attempting to survey the entire shoreline.

The entire lake is the unit of analysis, and the sampling zone includes portions of the upland and aquatic zones and the transition zone between them. Survey sites are established in a systematic, regular interval along the lake perimeter and are independent of property ownership. At each survey site, three habitat zones are independently assessed, or scored, based on specific features related to habitat. Higher scores indicate a greater amount of natural habitat. Lower scores indicate a low percent of the site remains natural and a higher amount has been physically disturbed or altered by humans. The feature scores within each zone are summed for an overall Site Habitat Score. This scoring process provides a simple method of ranking sites based on the percent of each site that is in a natural condition versus the percent of the site that has been altered.

A lakewide score is calculated using the mean Site Habitat Score. Scores range from 0 to 100 and lakes with a high percentage of unaltered habitat score higher than lakes that have been highly altered. Because lakes are often not developed in a regular pattern (for example, the north shore may be entirely developed while the south shore is undeveloped), a lakewide score may be high but some individual sites may score low.

Establishing survey sites

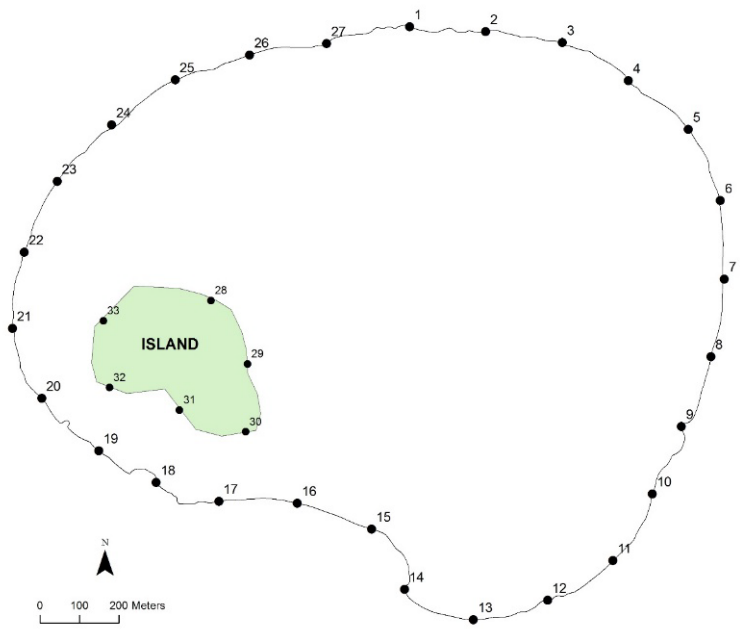
Each individual survey site is a 30.5-meter (100 feet) shoreline segment. The recommended minimum number of survey sites per lake is 20, which results in at least 610 meters of shoreline assessed on each lake; on all lakes at least 8% of the entire shoreline is assessed. The spacing of survey sites, and therefore the total number of survey sites and percentage of shoreline assessed, are determined by the length of the shoreline (Table 3-1). On lakes with 3.3 to 15 miles of shoreline (which accounts for most Fisheries-managed lakes in Minnesota), survey sites are spaced 200 meters apart. This results in an assessment of 17% of the total shoreline (i.e., 33 meters of every 200-meter segment, or 17%, is assessed). Survey sites are spaced closer together on lakes with less than 3.3 shoreline miles and further apart on lakes with more than 50 shoreline miles. On very small lakes with less than 1.22 shoreline miles, surveyors place 20 survey sites at equal distances around the shoreline and that distance may range from 60 to 95 meters.

Table 3-1. Determining the Score the Shore survey site spacing based on shoreline miles

Shoreline length (miles)	Spacing of sites (meters)	Number of points per lake	Survey segment length (meters)	Percent of Lakeshore Surveyed
0.75-1.21	60 to 95	20	30.5	35 to 55
1.22-2.24	100	20-36	30.5	33
2.25-3.29	150	24-35	30.5	22
3.30-14.99	200	27-121	30.5	17
15.00-50.00	400	60-201	30.5	8

GIS software is used to create center points of these shoreline segments at equal intervals around the lake perimeter (Figure 3-1). A GIS tool has been created to automate the point creation (refer to GIS Manual). If a Shore The Shore survey has been previously conducted on a lake, then surveyors should reuse the original survey site locations.

Figure 3-1. Score The Shore survey site placement along shore (Example lake with 4.5 shoreline miles (including island perimeter). Survey points are spaced 200 meters apart.)



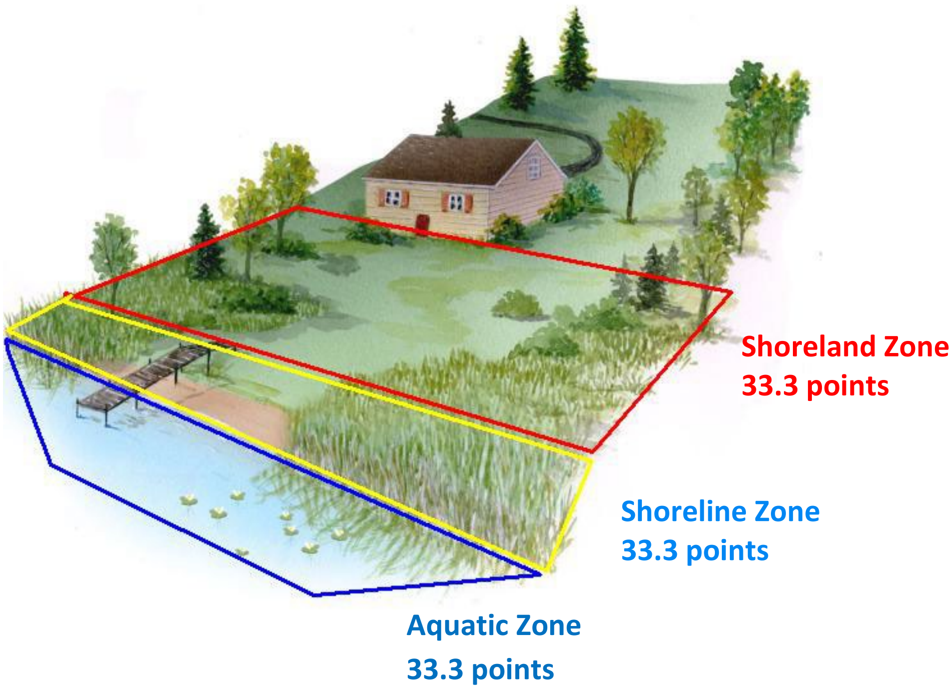
Assessment of habitat by zones

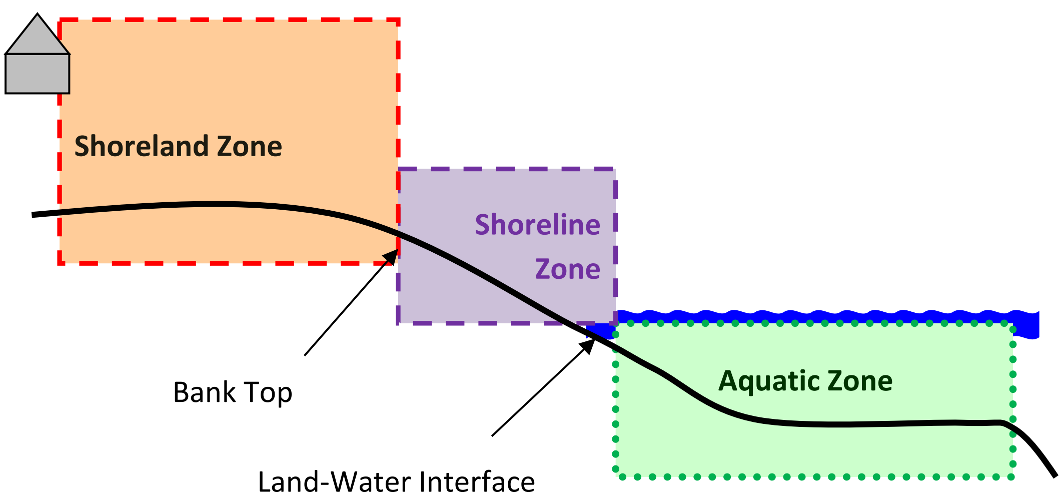
Surveyors use standard criteria to divide the lakeshore into three zones: Shoreland, Shoreline and Aquatic (Figure 3-2). Because physical measurements are not used to determine the boundaries, it is important for surveyors to practice delineating these zones using photographs of example sites. Given that these protocols are designed for rapid assessment, the boundaries of each zone are approximate.

The landward portion of the site is divided into the Shoreland and the Shoreline Zones. If a bank is present, it can be used as a visual separation between the Shoreland and Shoreline Zones with the Shoreland beginning at the top of the bank and continuing landward and the Shoreline beginning at the bank and extending to the water's edge. If there is no slope or a very gradual slope, surveyors use their best judgment to divide the land zone into the 2/3 Shoreland and 1/3 Shoreline Zones. Compared to the Shoreline Zone, the Shoreland Zone often extends a greater distance landward, but each zone's dimensions will vary based on slope.

Because assessments are conducted visually by boat, surveyors are limited to assessing only two dimensions of each site: the length of the site (the 100 feet segment), and the height of vegetation. The third dimension, the landward extent of habitat, is not assessed. In effect, when surveyors photograph the site, the image provides the two-dimensional view that will be assessed. Another way to consider this is to assess the percent of the site that is "screened" by vegetation. The "landward depth" of that screen, which is the third dimension, is not assessed.

Figure 3-2. Score The Shore habitat zones





Visual estimation of plant cover

Surveyors make visual estimates of the survey area boundaries and vegetation cover. Broad categories of plant life forms (trees, shrubs, ground cover) are evaluated and plant taxa identification is not required. Surveys are conducted between May and mid-October when upland vegetation is present. Depending on specific objectives, surveys may be targeted for specific dates within that time.

Because surveyors are estimating cover for a wide range of plant life forms (trees, shrubs and ground cover), broad cover classes are used for the entire range of cover. To improve accuracy and repeatability associated with plant cover estimates, cover classes are broad (25% increments), and neighboring cover classes have small differences in point scores. For example, while estimating tree cover in the Shoreland Zone, if surveyor A selects the cover class 25-49% and surveyor B selects 50-74%, their final scores will only differ by three points. The goal of this survey is focused on detecting large differences in habitat. For example, if Shoreland tree cover at Site X is 75-100% but only 1-24% at Site Y, the final scores for those sites will differ by at least 10 points.

While developing this method, surveyors expressed high confidence in their ability to accurately assess cover when the site was near the extremes of the cover range (sites that had very little vegetation and sites that had very little disturbance). At sites of intermediate plant coverage, surveyors were less confident of their coverage assessments and took longer to arrive at a final estimate.

Pre-survey preparation

Training

LEU provides annual Score the Shore Survey training that includes a classroom portion and on the water survey experience. A “pre-survey” standardization should be conducted to help ensure that all surveyors are recording similar information when they observe a site. A refresher training presentation is provided in Appendix D. This includes a set of shoreland photographs for surveyors to view and independently “score”. The survey organizers should review the results and select sites for group discussion. It is particularly important to discuss sites where surveyors did not agree on scores. This “trial run” of the actual survey provides an opportunity for surveyors to better understand how to score each feature within the three Zones.

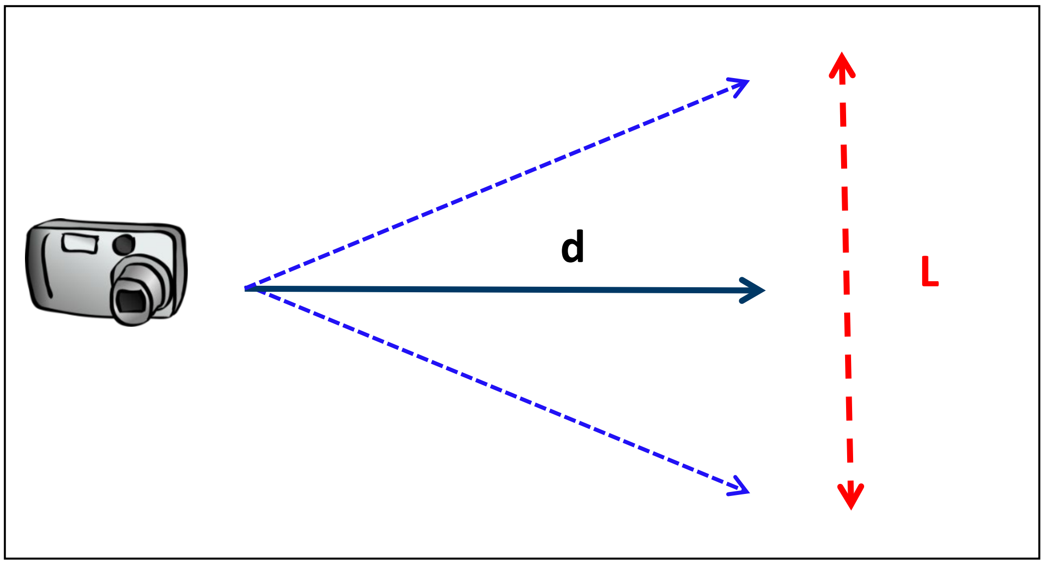
Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix A. Data are entered electronically or on paper forms (Appendix B). Survey point waypoints are created in GIS and uploaded to GPS units (GIS Manual).

For photo-points, surveyors should pre-determine the field of view for the specific camera they use and ensure that the entire 100 feet of shoreline is included (Figure 3-3). For example, the Garmin Montana Surveyors should predetermine the distance from which they need to photograph the survey site to include about 100 feet (30.5 meters) of lakeshore in the photograph. For Garmin Montana cameras and iPad cameras, that distance is approximately 100 feet or 30.5 meters

GPS camera and an iPad camera will photograph about 100 feet of shoreline when the photographer is stationed about 100 feet (30.5 meters) from shore.

Figure 3-3. Determining field of view for camera (d = distance from camera to midpoint of photographed image, L = length of photographed image)



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Conducting the survey

The preferred data collection method for this survey is electronic data collection using Collector for ArcGIS on an iPad contained in a waterproof case. If an iPad is not available, data can be recorded on paper (Appendix B) and later entered into the Geodatabase.

Navigating to the site

Surveyors use a GPS receiver to navigate the boat approximately 30.5 meters (100 feet) lakeward of the shoreline survey point that was generated in GIS. Each site extends 15 meters (50 feet) in either direction along shore from the GPS point for a total of 30.5 meters (100 feet) along shore (Figure 3-4). On developed lakes, survey sites are independent of lot ownership and often include portions of more than one lake lot. Photographing the site from a preset distance and the Collector for ArcGIS app can be used to help estimate the shoreline segment to be surveyed.

Figure 3-4. Score The Shore survey site

- Survey site extends 100 feet along shore: 50 feet on both sides of GPS point (yellow star).
- Survey site extends landward about 100 feet, or the setback distance for shoreland structures.
- Survey site extends lakeward about 50 feet and includes the area from shore to about the 5 feet depth where near-shore vegetation may occur.

Inaccessible sites

It may not be physically possible to motor within 100 feet of every site due to low water level, vegetation, navigational hazards, and/or recreational users. Surveyors may be able to view the site from an angle or from a distance greater than 100 feet and should record the GPS location of their viewpoint with a georeferenced photo. Note that the boundaries on the photo may include areas outside the actual survey site because it was taken at a distance greater than 100 feet. If the site cannot fully be viewed from the boat (example – located at end of long, narrow channel, at top of a steep bank), record as much information as feasible with an explanation that it was not entirely viewable by boat. Aerial photos may be used to help assess site conditions, but surveyors should note this in the comments field (example, “Shoreland Zone was not viewable from boat and was assessed from aerial photograph”).

Photographic reference

True photo-points are landscape photographs retaken each time from the same spot and filling the same frame so that landscape differences between years may be compared (Elzinga et al. 2001, Hall 2001). Score The Shore survey site photos document the site location and condition, but because they are taken from the boat and not a stationary, fixed location, they are not true photo-points. These photographs can be useful for quality control of data and to help monitor change in the type and amount of habitat within each lakeshore zone over time. The photographer’s location likely changes slightly between years and the area included in each year’s photo also changes; therefore, caution must be used when assessing the degree of change from photos alone.

The reference photo of the 100 feet shoreline survey site is taken from the boat, positioned approximately perpendicular from the center point of the survey site. For example, if using a Garmin Montana GPS camera, center the boat about 100 feet (30.5 meters) from shore to photograph the entire 100 feet segment of shore. When feasible, surveyors should try to survey sites and take photos with the sun at their back (early morning, later afternoon) and minimize sampling during poor visibility conditions (fog, heavy rain) or when sun can create dark shadows or harsh glare. Georeferenced photos are preferred but if this is not an option, surveyors should record the geographical coordinates at the site where the photograph was taken.

Assessing land use class

At each site surveyors determine the major land use class based on visual observation from the boat (example photos are provided in Appendix D). Aerial photography available on the Collector for ArcGIS app may be used to assist surveyors in their land use classification. Land use is assessed independently from land ownership. For example, survey sites within a State Park may be classified as developed (campsite, roadway, public park, boat access) or undeveloped and should not be classified as “Public Park” merely based on their presence within the State Park. Similarly, an undeveloped site may occur adjacent to a large agricultural field, but if the agricultural field does not extend into the survey site, the site should be classified as “undeveloped”.

Surveyors first assess if any portion (Shoreland, Shoreline and/or Aquatic) of the site is developed and if so, the entire site is classified as developed.

Developed sites may or may not have building structures but do have some indication of human disturbance, such as removal of or cut vegetation, presence of a dock and/or structures on shore, and/or unnatural ground cover. Developed sites include eight classes:

- Single-Family Residential (one home within survey site)
- Several Single-Family Residential Lots (more than one home within survey site)
- Multi-Dwelling Development (e.g., apartment, condominium)
- Resort or Commercial Campground (typically multi-camper site)

- Other Commercial (e.g., restaurant, marina, hotel, school, etc.)
- Agricultural (pasture or cropland)
- Roadway
- Public Park (e.g., ball field, hiking trails, picnic area; without campground)
- Campsite (tent site or single camper)
- Boat Access (with or without parking lot and/or dock)

Only one development class is recorded for each developed site. If more than one type of development occurs at a site, select the class that occupies most of the site. For example, if a road runs through a site and there is a house on the landward side of the road, record the site as "roadway" because the majority of the (two-dimensional) site is occupied by the road. If the house occurs between the road and the lake, record the site as "single-family residential".

If no portion of the site shows signs of human disturbance, it is classified as undeveloped.

Undeveloped sites no portion of site shows signs of human disturbance and include two classes:

- Undeveloped Nonwetland (may or may not include trees)
- Undeveloped Wetland (may or may not include trees)

If an undeveloped site contains both nonwetland and wetland areas, select the class that occupies most of the site. Only sites where the Shoreland Zone is wetland should be listed as "Wetland." An undeveloped site that has a wetland Shoreline Zone but a nonwetland Shoreland Zone should be classed as "Undeveloped Nonwetland."

Shoreland Zone assessment

The Shoreland Zone is the portion of land which is most likely to be developed and approximates the required minimum setback distance for shoreland structures (Figure 3-4). The survey does not assess structures that may occur in the Shoreland or Shoreline Zones, such as boat houses, decks, staircases, and retaining walls. Depending on specific survey objectives, these types of data may be added to individual surveys. If a lake home and/or other buildings are present, surveyors can use the landward edge of the structures to determine the landward edge of the zone. The extent of the upland that can be viewed from a boat will vary with slope. Vegetation and structures may also limit the surveyors' view onto the land. Surveyors score three features in the Shoreland Zone:

1. **Trees or Wetland**: the percentage of the 100 feet length of shore that contains trees or wetland vegetation. This estimate does not include trees found in the Shoreline Zone.
2. **Shrubs or Wetland**: the percentage of the 100 feet length of shore that contains a mid-canopy layer of shrubs and/or tree saplings or wetland vegetation. This estimate is independent of the tree cover. There may be no trees present in the zone but a shrub layer may be present.
3. **Natural Ground Cover or Wetland**: the percentage of the 100 feet length of shore that is undisturbed and covered by natural ground cover, which may include:

a. un-mowed vegetation, like grasses and wildflowers (note: surveyors are not asked to distinguish between native and non-native plants because this could require close inspection of individual plants and would require extensive botanical knowledge).
b. tree leaves and needles, and mosses
c. sand/rocks/bedrock that have not been placed by humans

- Unnatural and/or disturbed ground cover includes:
  a. mowed vegetation
  b. cultivated sites including horticultural and agricultural gardens
  c. areas covered by mulch
  d. areas covered by pavement, retaining wall or other placed impervious surfaces

Shoreline Zone assessment

The Shoreline Zone is the portion of land between the Shoreland and Aquatic Zones (Figure 3-4). It begins at the water's edge and extends landward to the bank. This zone may be narrow or broad, depending on the slope. Scoring the Shoreline Zone is similar to the Shoreland Zone assessment, but the tree layer and the shrub/sapling layer are combined and wetland vegetation may be present instead of terrestrial plants. Surveyors score three features in the Shoreline Zone:

4. **Trees/Shrub or Wetland**: the percentage of the 100 feet length of shore that contains trees and/or shrubs and/or wetlands.
5. **Natural Ground Cover or Wetland**: the percentage of the 100 feet length of shore that is undisturbed and covered by natural ground cover (as defined above for the Shoreland Zone) and/or wetlands.
6. **Overhead woody habitat**: presence of overhead woody habitat anywhere along the 100 feet of shore. This includes live or dead trees and/or shrub branches that extend over the water surface.

Aquatic Zone assessment

The Aquatic Zone begins at the land-water interface and extends lakeward 50 feet (Figure 3-4). It includes shallow water where rooted aquatic plants may grow; this is also the zone of a lake most likely to be utilized and impacted by riparian residents. The presence or absence of aquatic vegetation at a particular lake site can be influenced by a variety of natural and human factors and determining the relationship between development and current in-lake conditions can be challenging. Submerged vegetation can be difficult to observe visually if there is wave action and/or turbid water. The lakeward distance to which vegetation grows is dependent in part on depth, which varies considerably between sites and lakes. For these reasons surveyors assess only two dimensions of the aquatic zone: the length of the site (the 100 feet segment), and the layers of above-water vegetation (floating, emergent, overhanging vegetation). The third dimension – the lakeward distance to which vegetation extends, and the fourth dimension – the depth to which aquatic vegetation extends, are not assessed. Surveyors score three features in the Aquatic Zone:

7. **Openings in plant stands**: surveyors record whether any plant stands have any unnatural openings such as boat channels or other cleared areas around docks and swim beaches. Note that plant stands may have natural openings, and it can be difficult to determine the difference between natural and unnatural openings. Unnatural openings are most easily detected if they have sharp, rectangular edges (such as boat channels).
8. **Downed woody habitat**: surveyors record if downed woody habitat is observed anywhere in the Aquatic Zone. Downed woody habitat includes trees, limbs, branches, roots and wood fragments at least four inches in diameter (Ahrenstorff et al. 2009) that are entirely in the water as well as woody habitat that is partly on the shoreline.
9. **Number and types of docks**: surveyors record the number of in-water structures by type:
    a. Simple dock – a straight or L-shaped dock; no platforms or slips
    b. Complex dock – a dock that includes platforms and/or slips
    c. Lift – a device for elevating boat above water surface; typically attached to a dock
    d. Raft or other recreational objects – a platform that is anchored offshore and not connected to a dock; may be constructed of wood or other building materials or inflatable; and includes other recreational objects such as slides or trampolines
    e. Marina – a dock with numerous slips that is associated with a commercial facility or multi-dwelling residence
10. **Emergent and Floating-Leaf Vegetation**

Surveyors record the percent of the 100 feet of shore that contains emergent and floating-leaf plants. Surveyors don't need to measure or map these plant stands, but simply estimate the shoreline extent where these plants occur. The lakeward extent of these plant stands is not assessed because it will vary with water depth, substrate, fetch and other factors. This feature is not included in the site score.

Data management and analysis

Scoring system

For each of the nine features, a numeric point value is assigned based on the natural condition of that feature (Table 3-2). The number of points assigned to an individual feature may range from 0 to 20, with a maximum of 150 points per site. The total points are then converted to a score on a scale from 0 to 100. The maximum possible weighted score in each of the three Zones is 33.33 for a maximum possible site score of 100.

$$Final\ Weighted\ Site\ Score = \left(\frac{TotalPoints}{150}\right) * 100$$

Table 3-2. Scorable features for Score the Shore survey

Zone / Feature	Category	Points	Score
1. Shoreland -Percent of frontage with trees	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
2. Shoreland - Percent of frontage with shrubs	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
3. Shoreland - Percent of frontage with natural ground cover	75-100	10	6.67
	50-74	7.5	5.00
	25-49	5	3.33
	1-24	2.5	1.67
	0	0	0
4. Shoreline - Percent of frontage with Trees, Shrubs and/or Wetland	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
5. Shoreline - Percent of frontage with Natural Ground Cover or Wetland	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
6. Shoreline - Overhead Woody Habitat	yes	10	6.67
	no	0	0
	no	10	6.67

Table 3-3. Scorable features for Score the Shore survey (continued)

Zone / Feature	Category	Points	Score
7. Shoreline - Overhead Woody Habitat	yes	10	6.67
	no	0	0
8. Aquatic - Human made openings in plant beds	yes	20	13.33
	no	10	6.67
9. Aquatic - Downed woody habitat	yes	0	0
	no	0	0
9. Aquatic - In-water structures			
	No docks, rafts, lifts, or marinas	20	13.33
	1 simple dock	15	10.00
	At least one simple or complex dock AND <3 lifts	10	6.67
	At least one simple or complex dock AND >2 lifts	5	3.33
	1 or more marina	0	0

Based on data collected through 2015, mean lakewide scores are interpreted as Excellent, Good, Fair or Poor and a similar rating interpretation is provided for each zone component (Table 3-3).

Table 3-4. Interpretation of Score The Shore survey data

Mean Lakewide Score	Mean Shoreland Score	Mean Shoreline Score	Mean Aquatic Score	Rating
85-100	28.0-33.3	28.0-33.3	28.0-33.3	High
66-84	22.0-27.0	22.0-27.0	22.0-27.0	Moderate
50-65	17.0-21.5	17.0-21.5	17.0-21.5	Low
<50	<17.0	<17	<17	Very Low

Quality control

In general, data observed and recorded on-site should be considered accurate. Although much of the habitat can be observed in photographs, surveyors at the site can better view and interpret the amount of habitat present. Features such as in-lake woody habitat cannot usually be detected on photographs.

Photo-points can be used as quality control checks, and they may be particularly useful for verifying surveys conducted by new student interns. For example, a new surveyor may misunderstand directions on where to delineate the boundaries between zones and record Shoreline Zone trees as present in the Shoreland Zone. It is most helpful to try to detect these types of errors early in the season before the new surveyor conducts additional surveys. Photo-points may be most useful for verifying large amounts of change at survey sites between repeated survey years.

Data storage and analysis

Field data collected with Collector for ArcGIS app on an Ipad are synced to a geodatabase that is backed up on a network drive. Data collected on paper are manually added to this database (see directions in GIS Manual). Georeferenced photos are stored separately on a network drive.

Summary Score the Shore data are available on MNDNR GIS QuickLayers.

Example metrics that can be obtained from these data include:

1. Lakewide mean Habitat Score, ranging from 0 to 100
2. Lakewide mean score for each of the 3 habitat zones (Shoreland, Shoreline, Aquatic) ranging from 0 to 33.3
3. Mean Habitat Score for developed sites
4. Mean Habitat Score for undeveloped sites
5. Individual Site Habitat Scores

Chapter 4 Mapping Stands of Floating-leaf and Emergent Plants

Objectives

1. Delineate, classify and digitize boundaries of shallow water plant stands in lakes
2. Collect additional information on the geographic locations, size (boundaries) and floristic composition of plant stands to further refine classification and management
3. Detect a 10% change in the lakewide quantity of emergent and floating-leaf plant communities

Introduction

Classifying and mapping vegetation is critical for natural resource planning, management and protection. A map can provide a physical delineation of plant growth occurrence in a lake. By classifying vegetation, selected properties of the plants can be used to describe and differentiate areas of plant growth. The tasks of mapping and classifying plant communities are intimately related – the purpose of the map determines the classification used and the choice of a classification strongly affects the map (Kuchler 1951). For example, if the map purpose is to locate areas of emergent plant growth, the classification must distinguish taxa by life form, but species level identification may not be required.

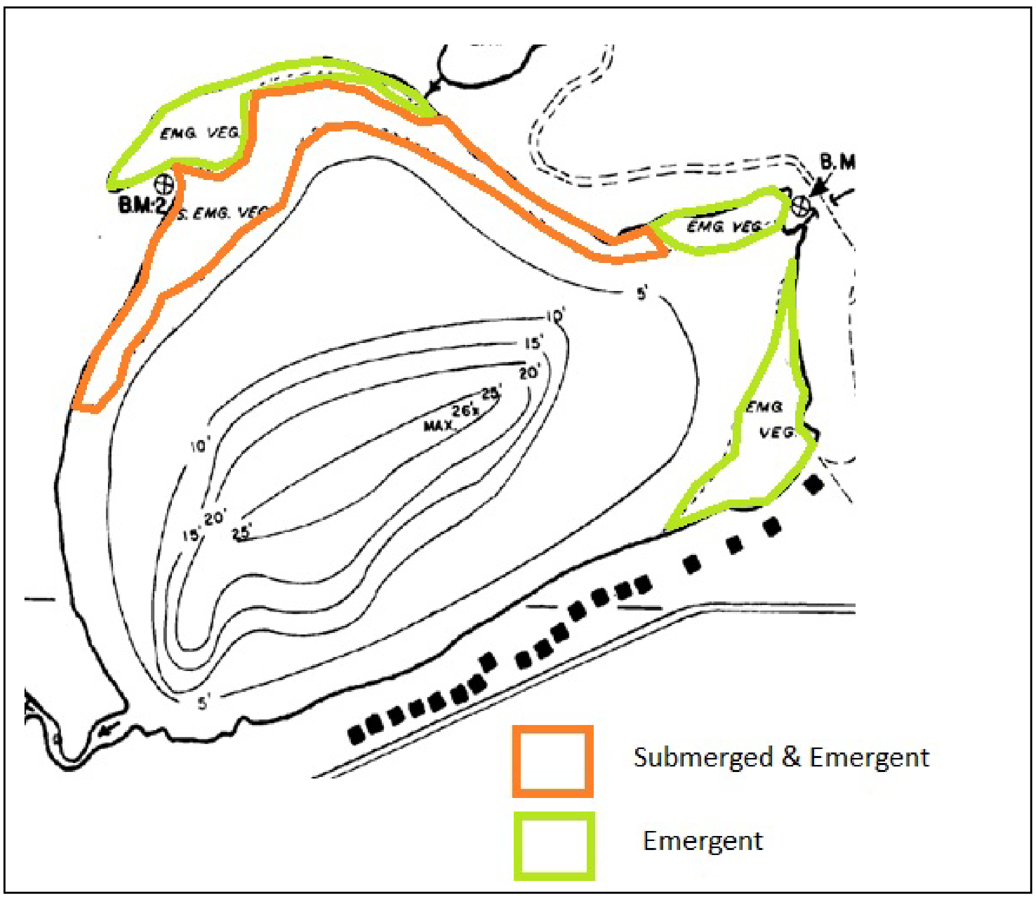
MNDNR Native Plant Community (NPC) classification system focuses on terrestrial and palustrine systems (Aaseng et al. 2011). This ecologically based classification system was developed from detailed (species level identification) vegetation relevé plot data collected across the state. Ecologists and other resource managers use field guides (MNDNR 2003) developed from this classification to categorize plant communities at several scales.

Because detailed relevé plot data are lacking for lakes, lacustrine plant communities were not classified in MNDNR's NPC Classification System. This created a gap for resource managers. Sites of high quality terrestrial and/or wetland native plant communities have been identified and mapped throughout the state, but a substantial quantity of aquatic habitat remains un-mapped. This is particularly problematic for landscape-scale planning where terrestrial and aquatic habitat should be considered together.

There are multiple needs for data on aquatic plant stands. Maps and descriptions of aquatic plant stands are required to support a variety of resource assessment, management and conservation goals. MNDNR Fisheries needs information on current locations and extent of bulrush (*Schoenoplectus* spp.) stands and unique aquatic plants that should be protected from most plant control activities. MNDNR Wildlife, MPCA and Tribal Nations want to document the occurrence and dynamics of wild rice stands (*Zizania* spp.), which includes information on stand size and composition (monotypic vs. mixed with perennials). MNDNR Aquatic Invasive Species Program, lake groups and local units of government are interested in mapping non-native species, documenting potential spread and monitoring impacts of control activities. MNDNR Natural Heritage Program records boundaries of rare plant stands.

Historically, Minnesota lake surveyors mapped lake plant stands by hand drawing the estimated perimeter of plant stands on lake depth contour maps and recording taxa observed, often to the species level (MNDNR 1993). While these types of data are different than the relevé plot-based data used for MNDNR's NPC classification, they can be used to classify each stand into one of three broad life form categories (emergent, floating-leaf or submerged) (Figure 4-1).

Figure 4-1 Historical hand-drawn map of emergent and submerged vegetation stands



In 2005, MNDNR Fisheries and Ecological Services biologists revised lake plant mapping protocols and incorporated GPS data collection and GIS mapping (MNDNR 2005). These new protocols included a combination of aerial photography interpretation and field surveys. Field survey methods included delineation of plant stand boundaries with GPS, identification of canopy dominant taxa, estimates of overall plant cover, and estimate of species cover. This effort built on earlier work, incorporated lessons learned from the past decade of GPS mapping conducted by MNDNR biologists and included new options available through recent advancements in GPS technology and GIS software.

In a protocol repeatability study, Radomski et al. (2011) demonstrated that coverage mapping of emergent plant stands can be completed in a timely manner and with reasonable precision. For example, in lakes with monospecific bulrush stands, it may be reasonable to detect a whole lake change of 10% or greater using the techniques described in this manual.

In this manual, we consider the increasing advances in GPS technology and GIS software that now allow more efficient georeferenced vegetation delineation. We re-evaluated the process for classifying lake plant communities and developed a method that meets the primary needs of resource managers within the constraints of the available data types. Provided here is a hierarchical approach for mapping aquatic vegetation designed to meet the specific needs of individual aquatic vegetation surveys that can also be integrated into broader Departmental planning processes.

Definitions

Vegetation: a generic term used to describe the collective plant cover of an area.

Stand: an area of vegetation that is identified based on distinctiveness and uniformity.

Class: a group of individuals or other units similar in selected properties and distinguished from all other classes of the same population by differences in these properties (Buol et al. 1973). Plant classes may be defined based on shared physiognomic and/or floristic characteristics that distinguish them from other kinds of plant communities or vegetation. In lakes, vegetation classes may be based on shared growth forms and be reflective of patterns of water depth, substrate, water clarity, water chemistry and disturbances.

Classification: the process of grouping similar entities together into named classes based on shared characteristics. Vegetation classifications are typically hierarchical with varying levels of detail available to map. Classification systems can be organized using a dichotomous key.

Ecological classification: a classification in which numerous differentiating criteria are selected to highlight relationships of the most important properties of the population being classified without reference to any single specified and applied objective; vegetation types are based on assemblages of plant species that co-occur in an area and are linked by their interactions with each other and their environment (Whittaker 1978).

Dominance-type classification: A classification based on the dominant taxon or taxa. Classifying by dominance-type requires a basic understanding of plant communities (Jennings et al. 2004). In this context it is “a recurring plant community defined by the dominance of one or more species which are usually the most important ones in the uppermost or dominant layer of the community” (Gabriel and

Talbot 1984 as cited in Jennings et al. 2004). This manual uses a dominance-type classification with the following levels:

- **Life Form**: the highest and broadest level in which plant stands are classified. Life Form is useful at the statewide and/or regional mapping scale. There are three life forms: Emergent, Floating-leaf, and Submerged.
- **Class**: the intermediate level where plant stands are primarily classified by dominant taxa.
- **Primary-Secondary Taxa Group**: the lowest and finest-scale classification level where plant identification to the species level or species complex level may be feasible and useful.
- **Associated Taxa**: taxa that are observed in the plant stand but that do not dominate.

Aquatic plant stand classification system

This aquatic plant classification system is a dominance-type classification (Whittaker 1978) based on collective field experience of MNDNR biologists, existing descriptive data and a review of lake plant studies. This classification was developed mainly for use in documenting the location, size and floristic composition of lake plant communities. Broad units of classification (e.g., wild rice) can be used to guide management of the largest and most frequently occurring community types. Lower units of classification may be used for local or regional management planning, to identify community types in need of conservation, and to gain knowledge about less frequently occurring taxa associations. Compilation of associated taxa within mapped polygons may be used to document geographical range and extent of individual taxa (e.g., which mapped polygons contain *Equisetum*, (horsetail)) and possibly to further refine this classification.

This classification system is a three-level hierarchical design (Table 4-1) permitting a gradation of refinement appropriate for most lake plant GIS cover mapping projects. Plant stands are assigned to groups within a system of categories distinguished primarily by life form, dominant taxa, and the ability of surveyors to recognize groups in the field and/or by remote sensing.

Table 4-1. Three levels of Minnesota's Aquatic Plant Stand Classification

Classification Level	Dominant Factors	Example
Life Form	Physical height of plant with respect to water level	Emergent
Class	Canopy dominants with options restricted to rushes, wild rice, cattail, or waterlilies and all other taxa are grouped as “other”	Rushes
Primary-Secondary Taxa Group	Finer distinctions in canopy dominants	Three-square bulrush (*Schoenoplectus pungens*)

Life Form is the highest and broadest level where plant stands are classified and is useful at the statewide and/or regional mapping scale. There are three life forms: Emergent, Floating-leaf, and Submerged. This level has been used by surveyors since the 1940s to delineate major stands of vegetation in lakes. It is also the level at which most field staff can conduct aerial photointerpretation of stands from readily available photos and without having extensive photo-interpretation experience (e.g., while it is possible to distinguish burreed (*Sparganium*) from cattails (*Typha*) on some aerial photos, without ground-truthing most field staff may only be able to identify "emergent" vegetation).

Class is the intermediate level where plant stands are primarily divided by dominant taxa. We have identified 11 Lake Plant Classes which represent the main types of aquatic plant stands in Minnesota. The Class level may be useful for mapping at the lakewide and/or watershed scale. These are groupings that can be readily recognized by field biologists who are not trained as botanists. These classes are large enough (acreage-wise) that it makes sense to display them at a regional, multi-lake scale.

The 11 Lake Plant Classes (Table 4-2) attempt to place plant stands into groups that have ecological meaning. Structurally heterogeneous stands are distinguished from monotypes because different canopy layers and types provide different microhabitats (example: presence of floating-leaf plants creates shade; leafy emergents provide above water surface area for invertebrates). Temporal variation in stands is also distinguished. For example, stems of bulrush and cattails typically persist throughout the winter while waterlilies, wild rice, and other emergents disintegrate. Finally, physical habitat variation in stands is distinguished. For example, wild rice, waterlilies and many broad-leaf emergents are often associated with soft-sediments and protected bays while bulrush are associated with hard substrates and once established, can withstand more fetch.

Primary-Secondary Taxa Group is the lowest and finest-scale level where plant identification to the species level or species complex level Fig be feasible and useful. Plant stands identified at this level may represent regionally important types of plant stands [e.g., watershield (*Brasenia schreberi*)] or minor components of the statewide aquatic plant communities (i.e., generally small stands that if mapped would not show up on a multi-lake level map). These groups have important ecological significance, and more data may be required for better understanding their distribution and function (e.g., three square bulrush (*Schoenoplectus pungens*) distribution may be strongly influenced by ice scour; yellow waterlily (*Nuphar variegata*) may grow in deeper water than white waterlily (*Nymphaea odorata*); the presence of certain broadleaf emergents in bulrush stands may signal that the substrate type is shifting to more organic). The primary taxon is the most dominant taxa in the stand. If a second taxon is also frequent (occurring in at least 30% of the stand), but not the dominant taxon, it may be listed as the secondary taxon. A secondary taxon is not required and only one secondary taxon can be listed.

Associated Taxa are recorded in each stand. These taxa are not the primary or secondary dominant taxa and typically occur in less than 30% of the stand. By recording these taxa, we retain the ability to identify stands that contain specific taxa (e.g., identify all plant stands where horsetail (*Equisetum*) was observed).

Table 4-2. Minnesota Aquatic Plant Stand Classification based on Life Form and Dominant Taxa

Class	Dominant Taxa	Secondary Taxa
1. Cattail	***Typha* spp.** *Typha* sp. (cattail genus) *Typha angustifolia* (narrow-leaf cattail) *Typha x glauca* (hybrid cattail) *Typha latifolia* (broad-leaf cattail)	None or other cattails
2. Cattail and Other	***Typha* spp.** *Typha* sp. (cattail genus) *Typha angustifolia* (narrow-leaf cattail) *Typha x glauca* (hybrid cattail) *Typha latifolia* (broad-leaf cattail)	Leafy (non-Cattail) emergent plants and /or floating-leaf plants
3. Rushes	***Schoenoplectus* spp.** (bulrush genus) *S. acutus* (hardstem bulrush) *S. tabernaemontani (*softstem bulrush) *S. pungens (*three-square) *Bolboschoenus fluviatile* (river bulrush) ***Eleocharis* spp.** (spikerush genus) *Eleocharis palustris* (marsh spikerush)	None or other Rushes
4. **Rushes & Other**	***Eleocharis* spp.** (spikerush genus) *Eleocharis palustris* (marsh spikerush)	None or various – This Class includes homogenous and heterogeneous stands
5. **Wild Rice**	***Zizania palustris*** (manoomin, wild rice)	
6. **Wild Rice & Other**	***Zizania palustris*** (manoomin, wild rice)	None or various – This Class includes homogenous and heterogeneous stands
7. Other Emergents	**Other Emergent Examples include:** *Equisetum fluviatile* (horsetail) *Phragmites australis (*common reed grass) *Sparganium* spp. (emergent bur reed) *Sagittaria* spp. (arrowhead)	None or various – This Class includes homogenous and heterogeneous stands
8. Waterlilies	***Waterlilies (Nymphaeaceae)*** *Nuphar variegata (*yellow waterlily) *Nymphaea odorata* (white waterlily)	
9. Waterlilies and Others	***Waterlilies (Nymphaeaceae)*** *Nuphar variegata (*yellow waterlily) *Nymphaea odorata* (white waterlily)	None or various – This Class includes homogenous and heterogeneous stands
10. Other Floating-leaved	**Other Floating-leaf taxa** *Brasenia schreberi* (watershield) *Persicaria amphibia* (smartweed) *Potamogeton natans* (floating-leaf pondweed) *Sparganium* spp. (floating-leaf bur reed)	None or various – This Class includes homogenous and heterogeneous stands
11. Submerged	**Submerged** Examples may include: Rare or unique submerged species that are visible from water surface (ex. *Potamogeton vaseyi, Hippuris vulgaris*)	None or various – This Class includes homogenous and heterogeneous stands

Since plant abundance measures are not a component of this survey, this protocol minimizes cognitive burdens to the surveyor while conducting the survey. Having to determine relative abundance is difficult, especially across the full extent of a stand, and such subjective abundance estimates are often not repeatable. If the surveyor determines that an area includes a distinct aquatic plant stand of sufficient size, then the stand is delineated and mapped.

This is not an ecological classification developed to incorporate abiotic attributes such as water depth, water chemistry (e.g., alkalinity), substrate nutrients, flooding regimes, and biological attributes (e.g., associations of plant taxa). An ecological classification has been done for non-aquatic plant communities in Minnesota where relevé plot vegetation and soils data form the basis for classifying plant communities (Aaseng et al. 2011).

Survey Design

Protocols include a combination of aerial photo interpretation and delineation with field-truthing, and field delineation and classification. Only large stands of emergent and floating-leaf vegetation are mapped, as mapping of small stands is resource intensive and imprecise using available GIS tools. Minimum mapping area is about the size of a pontoon boat (>10 m^2). Plant stands are characterized by life form, plant class, the dominant genera or species, and associated species or taxa.

While the Submerged life form is included in this classification system, surveyors should focus on Emergent and Floating-leaf life forms. The ability to visually observe the boundaries of submerged stands vary with water clarity, depth, wind, plant height and plant cover. Types of submerged plant stands that may be most suitable to delineation include matted submerged plant areas, submerged plants that form floating-leaves, and unique shallow water plant stands growing in clear water. IMPORTANT: If surveyors elect to map submerged stands, the polygons cannot overlap with emergent or floating-leaf stand polygons.

Pre-survey preparation

Training

LEU staff provide training on aquatic plant stand classification and field mapping techniques. Training helps ensure that all surveyors are recording similar information when they observe plant stands. The most difficult types of stands to classify are those that have multiple species and it is useful for surveyors to observe these stands together and discuss appropriate classifications prior to mapping.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix A. The preferred method of data collection is with the Collector for ArcGIS App. For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (GIS Manual).

Conducting the survey

Aerial photo delineation

If recent aerial photos are available, they may be used to map some types of emergent, floating-leaf, and matted stands of submerged plants. Detection and identification of plants is influenced by water depth, plant cover, plant condition and image date, quality and type. Remote sensing, with photography or other imagery, can be useful for sites where land ownership and/or navigation issues prevent staff from conducting field assessments. For extensively large sites, remote sensing may be more cost and time effective than field surveys. It also provides the option to assess historical vegetation if imagery is available (Xie et al. 2008).

Some issues associated with aerial photo delineation include difficulties identifying dominant taxa within stands or failure to even detect vegetation stands. The first issue can be improved by experience and training of staff. The second issue may occur if plant stands are small and/or were not visible on the photos (example: narrow stands of plants that occur near the shore may be blocked from view by overhanging shoreline trees). There may also be situations where only a portion of the actual stand appears on the photo; examples of this include stands where plant cover is not uniform throughout the stand and the sparsely vegetated portions of the stand do not appear on the photo.

If aerial photos are used, document the photo source, scale, and date. Use photos that have been rectified and realize that the locations on the photo are only as accurate as the photo rectification. Use several photo sources, if possible, because different types of vegetation may appear different on separate photos. Spring, “leaf-off”, black and white photos can be helpful in distinguishing cattail stands from ephemeral vegetation. Aerial photo delineated maps often require field-checking to determine or verify species compositions of stands. Changes in vegetation observed between different photo dates can also be confirmed.

Field delineation

Plant stands that cover more than 10 m^2 (about the area covered by a pontoon boat) can be delineated in the field. Surveyors may use field mapping to delineate all the emergent and floating-leaf plant stands or they may elect to focus on emergent and floating-leaf vegetation stands that may be difficult to see on aerial photos. Special project objectives may dictate mapping only selected stands, such as rare or non-native species locations.

If surveyors are not familiar with the lake, a review of aerial photos and any existing plant survey data, along with a reconnaissance survey, can help estimate the extent of vegetation to be mapped. Field surveys are generally conducted during mid to late summer during the peak of plant growth and before non-persistent plants die back. There may be specific seasonal requirements for mapping some taxa; for example, the submerged plant, curly-leaf pondweed, must be delineated in the spring or early summer because it dies back around early July. Surveys are done under low to moderate wind conditions (< 20 km/hr). Shallow sites may be mapped on foot by wading along the plant stand perimeter while deeper sites are conducted by boat. A boat less than 5.8 m length, with console steering and/or a trolling motor, is easiest to maneuver around plant stand perimeters.

Habitat is mapped and digitized using GPS and GIS. Because surveys often include a combination of boat work and wading, a hand-held GPS unit is appropriate. These devices can be temporarily mounted on the boat console and easily removed for use while wading. GPS units are set to automatically collect location data at a minimum one-second interval. Position accuracy of the Garmin unit is typically less than 10 meters (Garmin 2006). In emergent mapping tests, estimated position error for the Garmin units averaged about three meters during surveys (Radomski et al. 2011).

Mapping with ESRI App and Garmin Glo unit

ArcGIS Field Maps is a mobile GIS application developed for collecting spatial data in the field. This app coupled with an iPad and Garmin GLO GPS unit, may be used to map and classify plant stands in the field. Information on the plant class and associated taxa are selected and recorded within a geodatabase at the time of field delineation. This approach increases consistency, reduces data entry errors and reduces time required to process field-collected data. The collected data are then automatically integrated with a centralized geodatabase.

Mapping with hand-held GPS unit

Hand-held units that have been used successfully to date include Trimble GeoExplorer and Garmin units (Map 76 series, Montana). Trimble units allow surveyors to record the plant class that is associated with each mapped polygon. Most MNDNR staff have Garmin units which do not provide this option. If mapping with a hand-held GPS unit and more than one plant class is mapped, surveyors must collect a series of waypoints, track and notes to identify the plant class associated within each polygon. Post-processing must occur back in the office to create polygons from the tracks and then to assign a plant class to each polygon.

Field classification

At the time of delineation, each aquatic plant stand is classified into one of 11 classes (Table 4-3) by identifying 1) the dominant life form (emergent, floating, or submerged), 2) the dominant plant taxon, and 3) the presence or absence of a secondary dominant taxon. For emergent and floating-leaf plant stands, any additional emergent or floating-leaf plant taxa observed are recorded. A dichotomous key to the 11 Lake Plant Classes is provided in Appendix D.

<u>No overlapping stands are delineated</u> [e.g., if bulrush stands grade into waterlily stands, surveyors must decide on a boundary to separate the stands (Figure 4-2, Figure 4-3)]. If it is not physically feasible to navigate between the two stands without destroying vegetation, an aerial photo may be used to help

place the boundary line. In extensive plant stands, surveyors may not be able to physically view the entire stand to confirm plant community uniformity. Aerial photos may be useful to help determine if portions of the stand should be subdivided into separate plant classes.

Figure 4-2 Example delineations of Floating-leaf and Emergent plant stands

A) Waterlily plants occupy area below the minimum mapping area (10m^2) (about the area of a pontoon boat)
B) Wild rice stands are bisected by docks and can be mapped as three polygons in the field or as one polygon that is subdivided later (see inset E)
C) Waterlily stand occurs adjacent to D
D) Cattail stand but they are delineated separately. This can either be done in the field by motoring between the plants or in the office using aerial photos.
E) Wild rice stands subdivided by docks

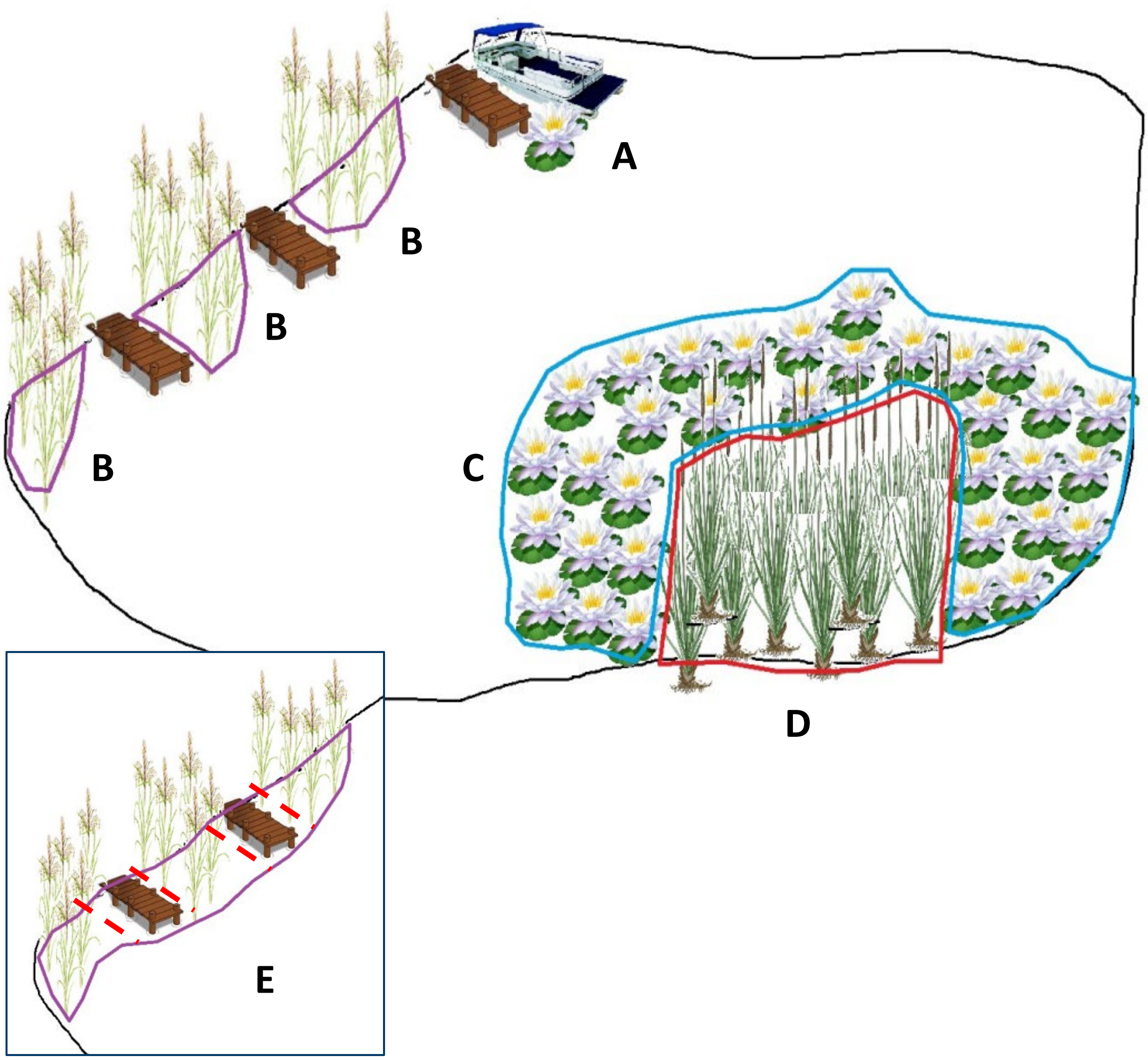
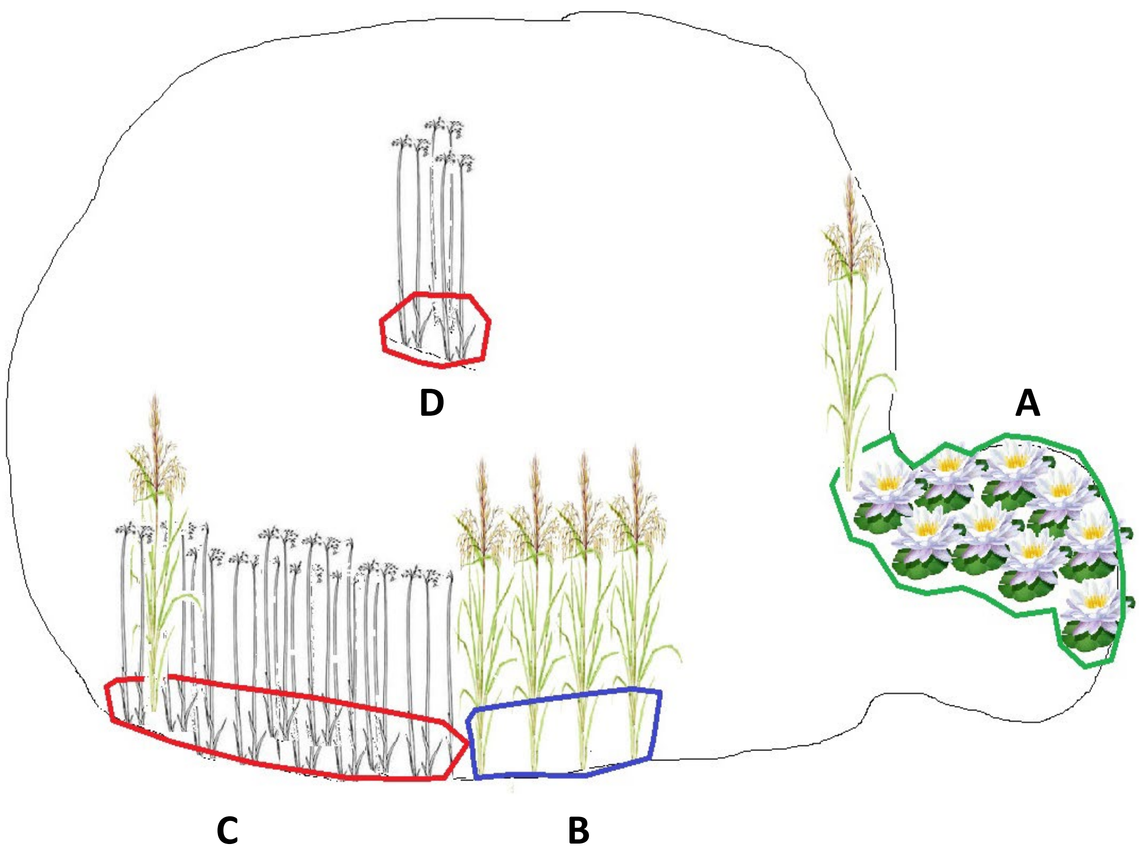


Figure 4-3 Example delineations of aquatic plant stands

A) Class = Waterlily (Individual plant of wild rice is included in polygon but because of low abundance it does not change the Class)
B) Class = Wild Rice
C) Class = Bulrush (Individual plant of wild rice is included in polygon but because of low abundance it does not change the Class)
D) Offshore stand; Class = Bulrush



Data management and analyses

Post-processing of field GIS data

The amount and type of post-processing data management depends on the field method used to delineate plant stands.

GIS data collected with ArcGIS Field Maps
This is the preferred method for delineating and classifying plant stands because it enforces a standardized classification system and improves efficiency by reducing GIS processing back at the office.

GIS data collected with hand-held GPS
Data collected using hand-held GPS can be imported to the statewide geodatabase but require more extensive post-processing. This method is not recommended, particularly if there is more than one plant class on a lake and/or if plant stands are not monotypic. GPS data are imported into a GIS for processing. GPS track lines are edited to create stand polygons. This is accomplished by snapping near-shore plant stand track lines to the land/lake boundary layer and by connecting track lines of offshore stands. This means that surveyors need to make a small data processing decision for nearly every stand. In addition, lake plant class, primary-secondary taxa, and associated taxa from field notes must be assigned to each created stand polygon.

Data storage and analysis

Field data collected with Collector for ArcGIS app on an Ipad are synced to a geodatabase that is backed up on a network drive. Data collected on paper are manually added to this database (see directions in GIS Manual). Georeferenced photos are stored separately on a network drive.

After polygons for each mapped vegetation stand are created and classified, whole-lake estimates of plant stand coverage are determined by plant class. The percent of shoreline with adjacent plant stands can also be estimated.

Floating and emergent lake plant stand data are available on MNDNR GIS QuickLayers.

Chapter 5 Lakewide Plant Taxa Inventory - Transect Survey

Objectives

The protocol within this chapter is designed to structure the collection of a lake plant taxa list to obtain standardized taxa richness data.

Introduction

Taxa richness, or the estimated number of taxa in a community, is the oldest, most fundamental, and perhaps least ambiguous concept of diversity. This metric can be a useful tool to describe and compare aquatic plant communities and may also reflect and detect changes in water quality conditions. The term “richness” is often used instead of “taxa number” to emphasize that the actual number of species or taxa in a community may be difficult or impossible to determine. Any estimate of number of species or taxa is dependent on sample size; the larger the sample size the greater the expected number of species, (i.e., as more individuals are sampled, more species will be recorded).

MNDNR Fisheries began using the transect vegetation survey in 1993. It was designed before GPS was readily available for field survey work and provided a method to systematically survey lake vegetation in a relatively rapid manner. It was adopted from a method (Jesson and Lound 1962) where transects are established perpendicular to shore at equal distances around the lakeshore. In the Jesson and Lound method, surveyors sample at predetermined depth intervals or at distance intervals along the transect; the boat is anchored at each site and four subsamples are collected with a rake sampler. To minimize sampling time, the 1993 Transect Survey eliminated the sample stations along the transect, making the survey area the entire area of the transect. It is a highly effective way to collect a species list because a relatively large portion of the lake is included in the survey area. However, because the individual sample stations were eliminated and the individual survey area is very large, this method is less effective at estimating plant abundance in a repeatable, quantitative manner.

Survey design

Transect number and spacing

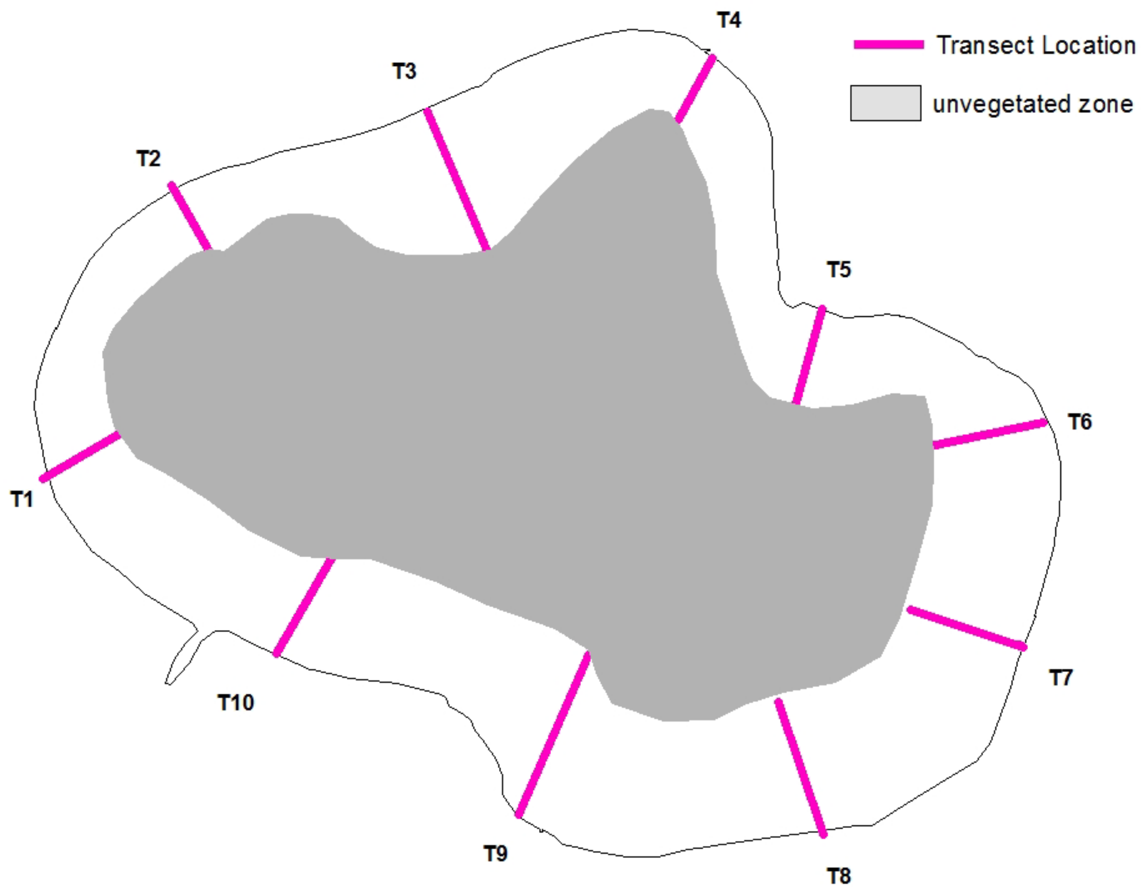
The number of transects is determined by lake size (Table 5-1) and transects are spaced at equal distances around the lakeshore (Figure 5-1). If a transect survey has been previously conducted on a

Table 5-1. Determining number of vegetation transects by lake area

Lake Size (acres)	Number of vegetation transects
<150	10
150-500	20
501-1000	30
1001-5000	40
>5000	50

Source: MNDNR 1993 Fisheries Lake Survey Manual

Figure 5-1 Placement of transects at equal intervals around lakeshore



lake, then surveyors should use the original transect locations. Transects run perpendicular from shore to the maximum depth of vegetation growth. If vegetation extends all the way across the lake, transects will end at the halfway point, or at the maximum depth in which plants are growing if the distance across the lake is substantial.

Transect length and area

The length of each transect is not standard and will vary within and between lakes because it is determined by the maximum depth at which vegetation is detected. Each transect is about 25 feet in width and includes about 10 feet on either side of the boat as well as the area under the boat. Because the survey includes a combination of visual observations and rake sampling, the actual area of each transect that is sampled will vary with water clarity and depth.

Pre-survey preparation

Training

LEU provides annual training on aquatic plant identification.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix B. Data are entered electronically (e.g., Fisheries Lake Survey database interface) or recorded on paper forms (Appendix C).

On lakes where transect surveys have previously been conducted, GPS coordinates may be available for the shoreward and lakeward ends of each transect. For other lakes, transect locations will need to be created in GIS and surveyors will upload coordinates to a GPS unit.

Conducting the survey

Surveyors begin at the shoreward end of the transect and navigate to the lakeward end. A depth finder may be useful to help determine the maximum depth at which vegetation occurs. Surveyors use a combination of visual observations and rake sampling to detect vegetation within the transect area. To help standardize sampling, it is recommended that a rake toss sample be taken at every 5 feet depth interval along the transect. All vegetation observed and collected along the transect is identified to the lowest taxonomic level possible (often to the species level) and recorded as “present” on that transect. Surveyors also record the dominant substrate (Table 5-2) that was observed at the shallow end of the transect (< 4 feet water depth). In addition to the transect sampling, all other plant species observed should be recorded as present in the lake.

Table 5-2 Shoal substrate descriptions and codes

Substrate Group	Code	Type	Description
Ledge Rock	LR	hard	Large mass of solid rock
Boulder	BO	hard	Diameter over 10 inches
Rubble	RU	hard	Diameter 3 to 10 inches
Gravel	GR	hard	Diameter 1/8 to 3 inches
Sand	SA	hard	Diameter less than 1/8 inch
Sand/Silt	SS	hard	Sand bottom overlaid with thin layer of silt
Silt	SI	soft	Fine material with little grittiness
Clay	CL	soft	Compact, sticky material
Marl	MR	soft	Calcareous material
Muck	MU	soft	Decomposed organic material
Detritis	DE	soft	Organic material (leaves, twigs, etc.)

Adapted from: MNDNR 1993 Fisheries Lake Survey Manual

Data management and analysis

Surveyors enter data into Program-specific databases (for Fisheries this is the Lake Survey Module). Data are used to estimate lakewide plant taxa richness (the total number of taxa observed) and can be used to calculate floristic quality.

Chapter 6 Quantitative Lakewide Point-Intercept Survey

Objectives

The lakewide point intercept survey is designed to assess the distribution of plants on a lakewide or bay-wide scale. Because it is conducted by boat, this survey is most appropriate on lakes where most of the littoral zone can be accessed by boat. Frequency of occurrence is the metric used to estimate abundance. This survey is designed to, with moderate effort, assess changes in frequently occurring taxa and an extensive effort with a large number of sample sites is required to statistically assess infrequently occurring taxa. Primary goals include:

1. Describe the geographical distribution of plants throughout the littoral zone and within specific depth zone intervals.
2. Estimate the percent of the littoral zone that contains vegetation and be 95% confident that frequency estimates are within +/-20% of the estimated true value.
3. Estimate the abundance of frequently occurring taxa (those occurring in 30% or more of the vegetated zone) and be 95% confident that frequency estimates are within +/-20% of the estimated true value.

NOTE: It is not appropriate to use results of point intercept surveys to delineate sites for aquatic plant management. The mere presence of a plant at one site does not infer anything about the distribution or abundance of that plant in the area between survey sites.

Introduction

The traditional point-intercept survey is a plotless vegetation survey method used when delineation of a survey area is not possible or not desired. It is a method originally designed for grassland surveys. Surveyors establish a network of sampling points and use a frame of descending pins to record the plant species or ground cover classes that contact each pin (Goodall 1952, Kershaw 1966, Greig-Smith 1983). Plant frequency is estimated by determining the proportion of survey points that “hit” or intercept vegetation. Because the pinpoint is theoretically dimensionless, the frequency of contacts can be considered equivalent to percent cover. Surveyors view the plant community from above and the method is best suited for vegetation types less than one meter in height (Caratti 2006) with single canopies, such as grasslands. Park (1972) discusses modifications for assessing multiple canopy layers.

Terrestrial point-intercept surveys are often non-destructive because surveyors visually record observations without removing vegetation. For aquatic vegetation, particularly in water depths greater than one meter, harvesting samples from a boat with a rake is more rapid and less costly than visual observation by SCUBA. Physical sampling may be minimally destructive because aquatic plants typically regenerate by fragmentation, rake harvesting does not often remove the entire plant, and repeat surveys are usually near, but not at, the original site. Nevertheless, physical disturbance to the plants is a factor to be considered when establishing long-term monitoring programs.

Madsen (1999) adapted the point-intercept method for lakes and established sample points across a grid pattern in the littoral zone; surveyors most often work from a boat using long-handled rakes or grapple hooks to sample vegetation. Using Madsen's modifications, the method is not "plotless" but rather incorporates a series of small plots approximately about one meter squared in size (the approximate lake bottom area covered by the rake grab). Because of this, it is most appropriate to estimate frequency of occurrence rather than true cover. If frequency is used as a proxy for coverage, such estimates are dependent on the resolution of the survey (Williams et al. 2008, Figure 6-1) and accuracy varies by species (Figure 6-2).

Figure 6-1 Usefulness of frequency data as proxy for cover is scale dependent

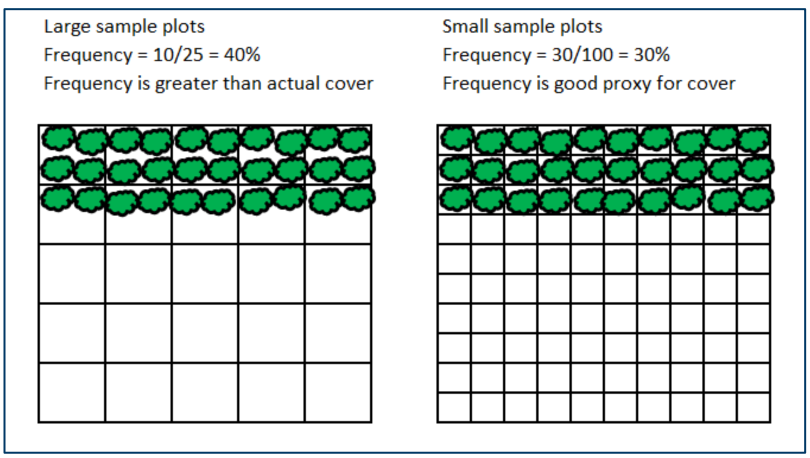
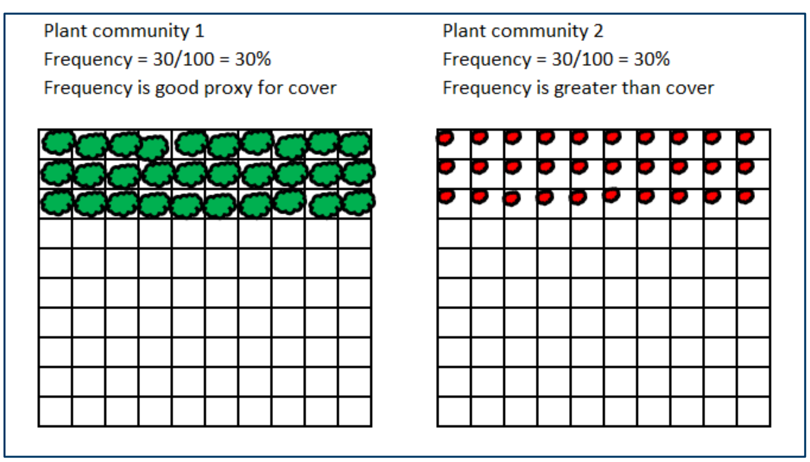


Figure 6-2 Usefulness of frequency data as proxy for cover is species and life-form dependent



In comparisons of several boat-based aquatic vegetation survey methods, the grid point-intercept method was found to provide the most rapid, repeatable, GIS-based method to assess lakewide plant species abundance and associated depth data (Perleberg 2001a, Perleberg 2001b). Other boat-based methods (Jesson and Lound 1962, Yin et al. 2000) provide more site-specific detail, but require the boat to be anchored at each sample site, thus reducing the total number of sites that can be sampled per hour. Point-intercept method advantages include consistency in data collection between different surveyors, ability to monitor a variety of plant growth forms, opportunity to monitor at flexible times throughout the growing season, and uncomplicated data analysis (Nichols 1984, Elzinga et al. 2001). Williams et al. (2008) recommended the point-intercept survey for whole-lake assessments where statistical comparisons are needed. The technique has been extensively used by MNDNR for quantitative lake vegetation surveys conducted by EWR Division, Wildlife Shallow Lakes Program, and Fisheries Sentinel Lakes Long Term Monitoring Program. This method has also been adopted by the Wisconsin DNR as their standard lake vegetation survey method (Hauxwell et al. 2010).

Important reminders

After reviewing point intercept data collected by numerous surveyors, we have identified common survey design and/or data collection errors that should be avoided. These are discussed in detail in this chapter and highlighted here:

- A minimum of 225 sample sites per lake is recommended with:
    - A minimum of 75 points in the 0 to 5 feet depth zone
    - A minimum of 75 points in the 6 to 10 feet zone
    - A minimum of 50 points in each deeper strata
- Sampling should extend to water depths of 20 feet on most lakes.
- The maximum depth consistently sampled should be recorded.
- Stratifying sample sites by water depth helps ensure adequate sampling within each depth zones of interest.
- To avoid bias in sampling, surveyors should not move or add survey sites in the field and should not increase the individual sample site area (limit sampling to one rake toss and a visual observation of approximately $1m^2$).
- It is critical to distinguish between a site that was not sampled and a site that was sampled but where no vegetation was detected.
- If a depth zone is targeted for sampling, all sites are sampled regardless of whether vegetation is detected.

Survey design

Defining the survey area

The survey area should include the area of the lake where information on aquatic vegetation is needed. This may include areas that may not be vegetated during the current survey year but were vegetated in past years or where it is anticipated that they will be vegetated in future years. This is particularly important if the survey objective is to compare data between survey years. In most lakes the survey area will include all water depths from the shore-water interface to a depth of at least 15 to 20 feet, or the maximum lake depth, whichever is less. On many Minnesota lakes, water clarity is sufficient for plant growth to 20 or more feet and sampling should include these depths on clearer lakes. In general, survey points should be established in deeper water and can be omitted in the field if surveyors determine that plant growth does not occur in deeper zones. It is much more difficult to add survey sites in-situ without biasing the placement of survey sites. Surveyors should err on sampling too deep rather than limiting sampling to only shallow waters.

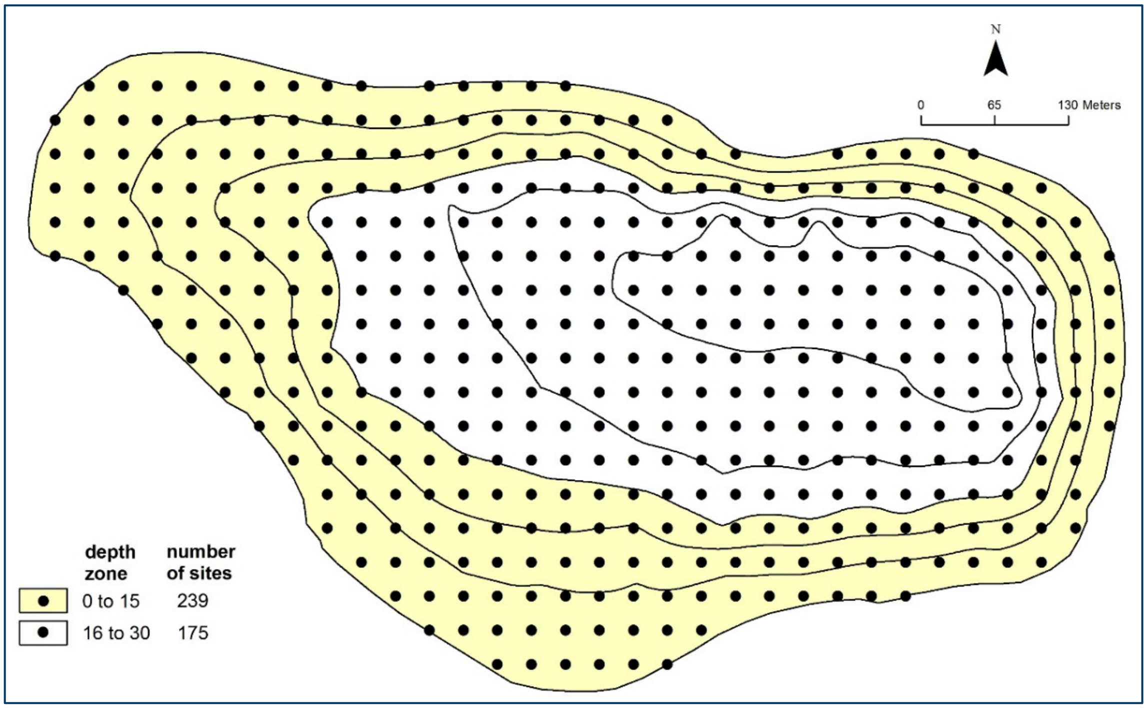
Mid-summer water clarity data may be useful for estimating the approximate maximum depth of vegetation; rooted plants often grow to depths of 1.5 times the mid-summer Secchi depth. Previous knowledge of the lake and a review of historical surveys can also provide insight on how deep to sample. A recent hydrologic map is helpful when designing a lakewide vegetation survey. A pre-survey field visit can also be used to help assess the maximum depth zone at which plant growth occurs.

With current GIS programs and GPS technology, surveyors can navigate to pre-determined sample sites with high precision. However, accurately locating the actual sample site is difficult due to inherent error in GPS readings, difficulty maintaining a fixed location with a boat, and error locating the actual sample site on the lake bottom from the boat surface. This inaccuracy is advantageous because it reduces problems associated with destructive vegetation sampling (it is unlikely surveyors will resample the exact location in subsequent surveys). This inaccuracy is minimal enough to not affect statistical analyses based on repeated sampling.

Sample site arrangement – systematic grid or stratified grid

Madsen (1999) recommends using GIS and GPS to establish sample sites systematically along a grid across the survey area. This is particularly useful when surveyors are interested in estimating the distribution of vegetation; a purely random distribution of sample sites may result in large un-sampled areas of the lake. While a grid ensures even placement of sites across the basin, it often results in an uneven distribution of points across the depth gradients. Near-shore, shallow sites (that may contain the highest plant diversity), are often under-sampled while deeper water sites tend to be over-sampled (Figure 6-3). In these situations, stratifying sample site placement within an area of interest (Yin et al. 2000) helps to ensure adequate sampling (Figure 6-4).

Figure 6-4 Simple grid placement of sample points



If sample sites are stratified, more sites should be placed in shallow water where vegetation is likely to be more diverse and abundant; fewer points should be sampled in deep water where vegetation is typically sparse, and a lower number of sample sites may adequately assess vegetation.

Even with stratification, near-shore vegetation, particularly emergent and floating-leaf stands, may be under-sampled with this method, often because surveyors cannot physically navigate through these stands without damaging the plants. To compensate for this shortcoming, sampling protocols are outlined in Chapter 4 to delineate, map and describe emergent and floating-leaf habitat and other unique aquatic plant communities and in Chapter 7 to describe near-shore plant communities. Surveyors are strongly encouraged to consider the use of those survey types when a point-intercept survey is conducted.

Required sample number for frequency data

The number of sample sites required to reliably estimate species frequencies (Newman et al. 1998) can be calculated using the formula: $N = (t/D)^2 * (1-p)/p$, where:

> N= required sample size
> t = appropriate value from t distribution table (1.96 for 95% confidence interval)
> p = estimate of frequency of occurrence
> D = error as a fraction of p (i.e., 0.1 to estimate p within 10%)

The error associated with frequency data is proportional with the highest error at intermediate frequencies (Newman et al. 1998). A high number of samples are needed to detect plants that occur at low frequencies and to detect small changes in frequencies (Mikulyuk et al. 2010). Sample size should be determined based upon the range of frequency difference desired to detect and the acceptable probability of not detecting that difference (Whysong and Brady 1987). Unless plant frequency is high (50% or higher), detecting changes in vegetation frequency of plus or minus 10% with a high degree of success can only be obtained with sample sizes approaching 500 (Table 6-1). For aquatic plant surveys, Nichols (1984) recommended that the most frequently occurring species should be used for calculating the adequacy of the sample and added that it may be appropriate to accept a greater error (for example 15% error instead of 10%) to reduce sampling effort.

Table 6-1 Required sample number for frequency data using 95% confidence limits, 10% or 20% error

Frequency of vegetation	Required sample number for 10% error	Required sample number for 20% error
10%	3457	864
20%	1537	384
30%	896	224
40%	576	144
50%	384	96
60%	256	64
70%	165	41
80%	96	24
90%	85	21

The size of the littoral zone influences the actual number of points and the grid resolution (spacing between points). Newman (1998) concluded that sample sizes do not need to be adjusted for lake size and smaller lakes should receive as much effort as larger lakes. But on larger lakes, increasing sampling may provide additional information on species spatial distribution. Existing information about the plant community should also be considered when determining sample site number and spacing. For example, while the physical littoral zone may extend to 15 feet and deeper, on many lakes vegetation may be restricted to shallower depths. In these situations, sample points should be concentrated within the actual vegetated zone.

Sample number and grid spacing

A minimum of 225 sample sites should be surveyed in each lake to estimate the percent littoral zone that contains vegetation and be 95% confident that frequency estimates are within +/-20% of the estimated true value. If a higher level of confidence and/or lower error is desired, more sites should be sampled. Fewer points may be sufficient if the main objective is to simply assess the plant community and statistical comparisons between survey years are not needed.

Surveyors should consider stratifying sample sites by water depth to ensure adequate sampling within important depth zones. Contour lines at five feet increments are available for most Minnesota lakes and can be used to stratify sample sites. A minimum of 75 points should be sampled in both the 0 to 5 feet depth zone and in the 6 to 10 feet zone; these shallow zones are most likely to contain vegetation as well as high species richness. In each deeper strata surveyed, a minimum of 50 points is recommended (Table 6-2).

Table 6-2 Recommended minimum sample number by depth strata for point-intercept surveys

Depth strata (feet)	Minimum number of points	Acres in depth strata	Spacing of points (meters)
0 to 5	75	<75	<65
		75-150	65
		75-150	≥65
6 to 10	75	<50	<65
		75-150	65
		75-150	≥65
11 to 15	50	<50	<65
		75-150	65
		75-150	≥65
16 to 20	50	<50	<65
		75-150	65
		75-150	≥65
21 to 30	tbd	<50	<65
		75-150	65
		75-150	≥65

The default spacing for points in each stratum will be 65 meters (one point per acre) unless:

1. Minimum sample number for that stratum is not met (then decrease spacing)
2. Sample number for that stratum requires excessive survey effort (then increase spacing)

On most lakes, sample points will be placed 65 meters apart, which will result in approximately one sample point per littoral acre. LEU has used 65 meter spacing as a standard spacing but sample spacing has ranged from 200 meters on very large lakes (Leech), to 150 meters on moderately large lakes (Ten Mile, Woman) to 40 meters on small lakes or lakes with narrow littoral zones. The minimum distance between sample points is determined by the accuracy of the GPS and, with current technology, a minimum distance of 30 meters is recommended to avoid overlap of sampling location. A two-person crew can generally survey between 100 and 200 sample sites per day, but the actual number depends on surveyor experience, plant density and ability to navigate through sites, plant diversity and drive time to lake.

Individual survey area size

For boat-based sampling using rakes, the individual survey area is restricted to the area covered by a single rake toss, or about a $1m^2$ area. A single rake toss is used at each site to help ensure consistency between sample sites. Surveyors should not enlarge the survey area on an ad hoc basis – for example by including species that are visible "just outside" of the survey area and/or by tossing multiple rake tosses at each site. This should not be done because it creates unequal survey areas if not done consistently and the multiple rake tosses are in effect "subsamples" that are statistically related to each other. An additional problem is created at sites with steep depth contours, where multiple rake tosses at the same site are likely to sample unequal depths. For statewide and lakewide consistency, only one rake toss should be used at each site.

Pre-survey preparation

Training

LEU provides training and technical assistance on Point Intercept Survey method on request.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix B. Data are recorded electronically or on paper forms (Appendix C).

For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (GIS Manual). Survey point waypoints are created (GIS Manual) and uploaded to handheld GPS units. When generating survey points, first establish draft sample sites in GIS and use trial and error to determine final sample site number and placement. It is sometimes easier to create a grid of points at equal spacing throughout the survey area and then modify that grid if deemed necessary. For example, within certain depth strata, surveyors could eliminate every other point to reduce sample site number.

Conducting the survey

Sampling is conducted primarily from a boat and GPS units are used to navigate to each sample point. The sample points are not intended to be permanent sampling locations and are not marked with permanent markers. Rather, the goal is to navigate to the approximate location of each sample point. Given the inherent inaccuracy of field-model GPS units, and the shifting movement of the boat due to wave action, surveyors are not always able to stop precisely on the sample point location. Surveyors are directed to navigate to within five meters of sample point coordinates shown on the GPS unit. The boat operator maintains the position of the boat without anchoring.

To avoid bias in sampling, surveyors preselect one side of the boat where sampling will occur. The survey area is approximately one square meter (1 m by 1 m). In shallow water, it may be feasible to use a premeasured plastic hoop to delineate the survey area, but for most sites, the survey area is only approximate. Actual survey area dimensions will vary slightly between surveyors and with wave conditions. Surveyors should be conservative in estimating the survey area and not include vegetation that is well outside the $1m^2$ sample site.

Determining maximum sampling depth

Surveyors record the maximum depth that was consistently sampled (all sites at this depth and shallower are surveyed or the reason for omission is recorded). Progressive sampling may be used to determine the maximum sampling depth: for example, surveyors may begin by sampling to a maximum depth of 30 feet but if they fail to find vegetation in depths greater than 15 feet, they may reduce their maximum sampling depth to 20 feet if all sites within the 0-20 feet depth zone are sampled. If surveyors need to reduce sampling in the field to complete a survey in a timely manner, sample sites should be omitted in a systematic manner (for example, every other sample site should be omitted).

Some protocols use the presence or absence of vegetation at a sampling point as an indicator of whether they should sample the next nearest point on the grid. This is not recommended because it can produce a dataset where some depth zones are not fully sampled, and it is difficult to determine the percent of the depth zone that was sampled (Figure 6-5). Instead, sampling should be based on minimum sample number by depth zone, regardless of whether vegetation is detected (Figure 6-6).

Figure 6-3 Sampling pitfall - sampling based on detection of vegetation at adjacent sites

This strategy may result in inadequate sampling of important zones

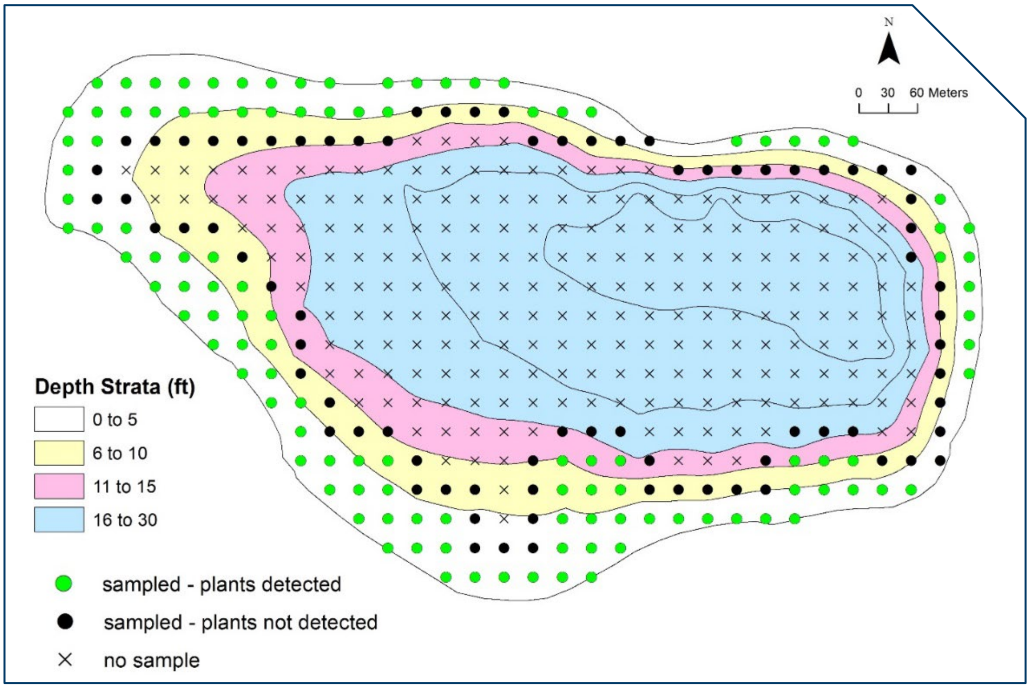
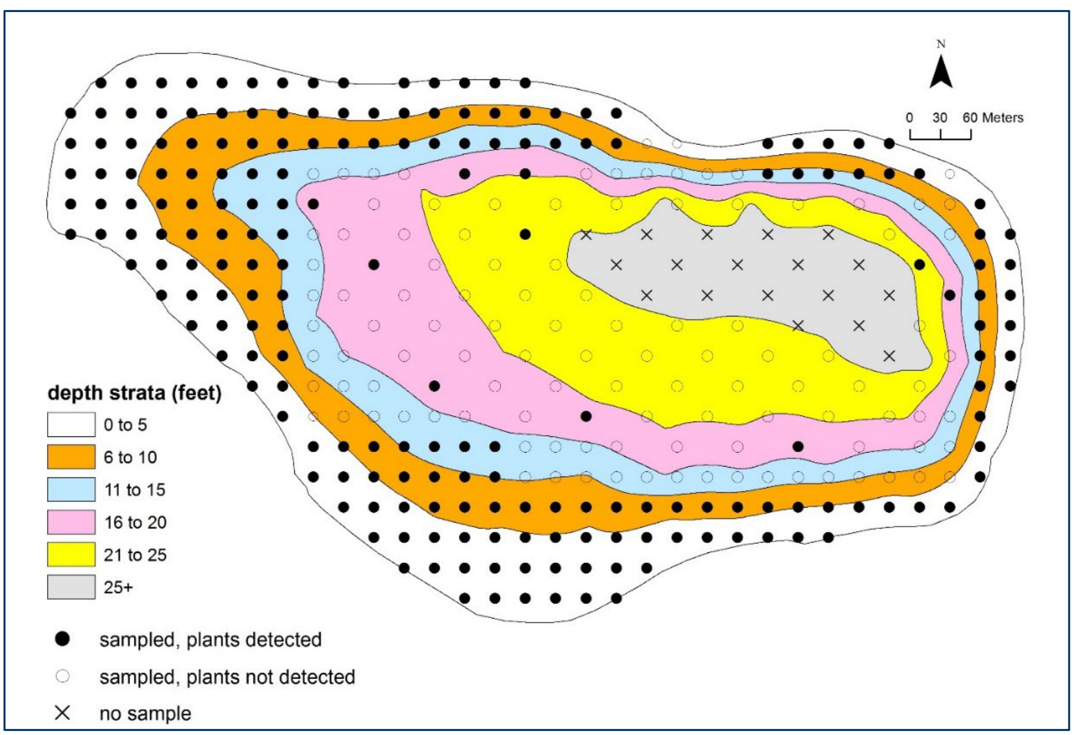


Figure 6-4 Stratified sampling with minimum sample number by depth zone



Survey site accessibility

Surveyors should attempt to sample all sample sites within the targeted depth zone. On shallow lakes, survey sites will be sampled across the entire lake (Figure 6-7). On deep lakes with even contour lines, there will be a defined deep-water zone beyond which no sampling occurs (Figure 6-8). On deep lakes with offshore shallow bars and/or irregular contours, it will be difficult to predict which sites are to be sampled until the water depth is measured at each site (Figure 6-9). If any sites within the pre-designated survey area are not surveyed, surveyors record the reason for omitting sites so that omitted sites can be distinguished from surveyed sites where vegetation was not detected. The reason for not sampling a site is recorded:

1. Too deep - occurs in water depths greater than the predetermined sampling depth. As surveyors progress along a row of points (from shallow to deep water) they may encounter sites that exceed the maximum sampling depth. Surveyors should record the depth for these sites, particularly if the depth is near the maximum sampling depth (see example). These sites are retained in the database.
2. Emergents - site location is within a dense and/or shallow stand of emergent or floating-leaf vegetation and motoring into the site would likely destroy vegetation (surveyors may record general observations about the site, including dominant species within visible area, but do not include data in calculations)
3. Shore - site location is on shore (sample station is permanently removed from database)
4. Other - access to site is prevented by structure or activity including dock, swim area, other boats, and herbicide application.

Figure 6-5 Point-Intercept Survey on Shallow Lake

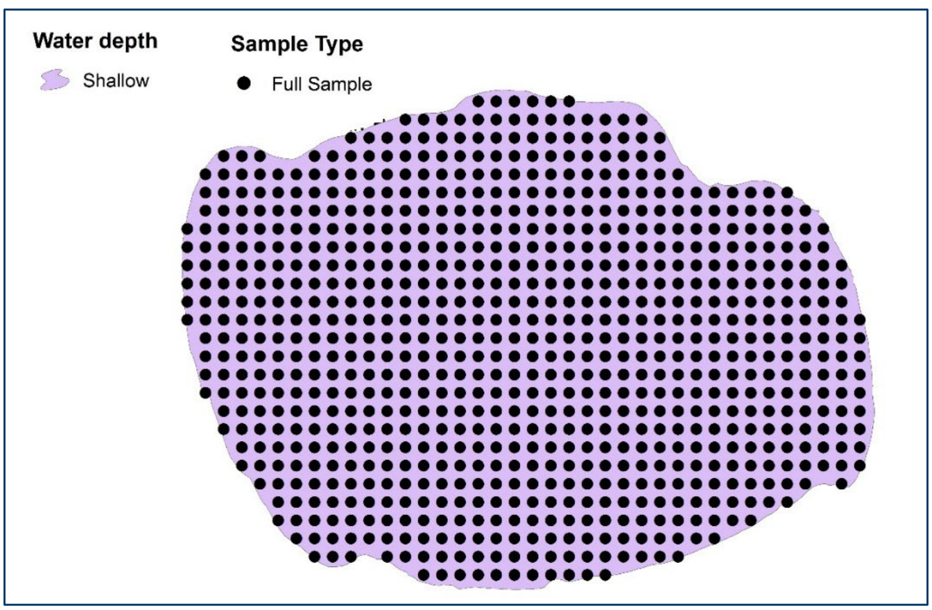


Figure 6-6 Point-Intercept on Deep Lake with Regular Contours

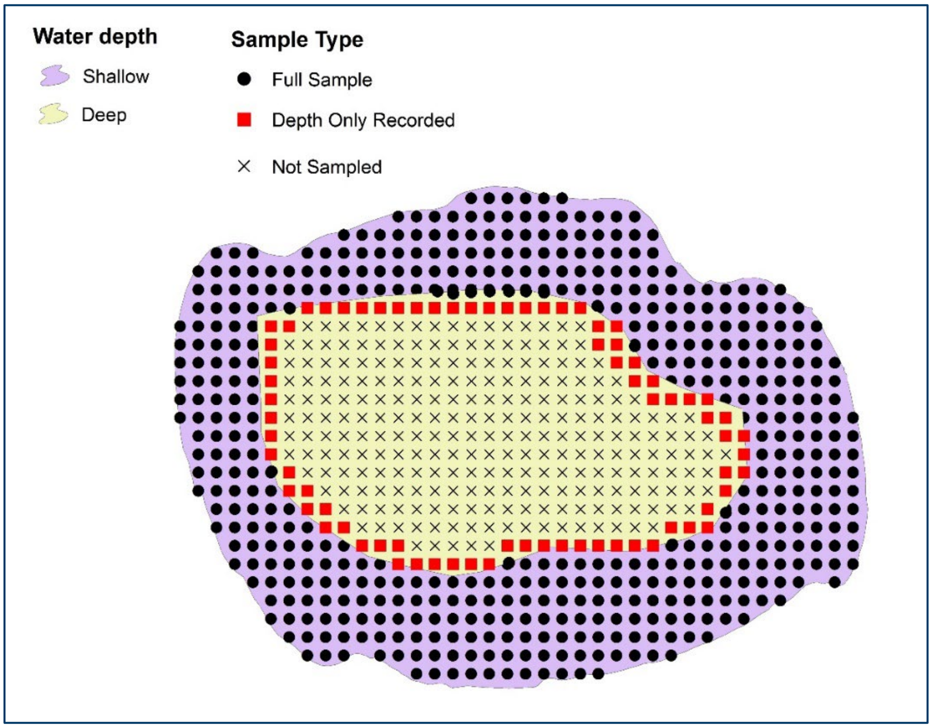
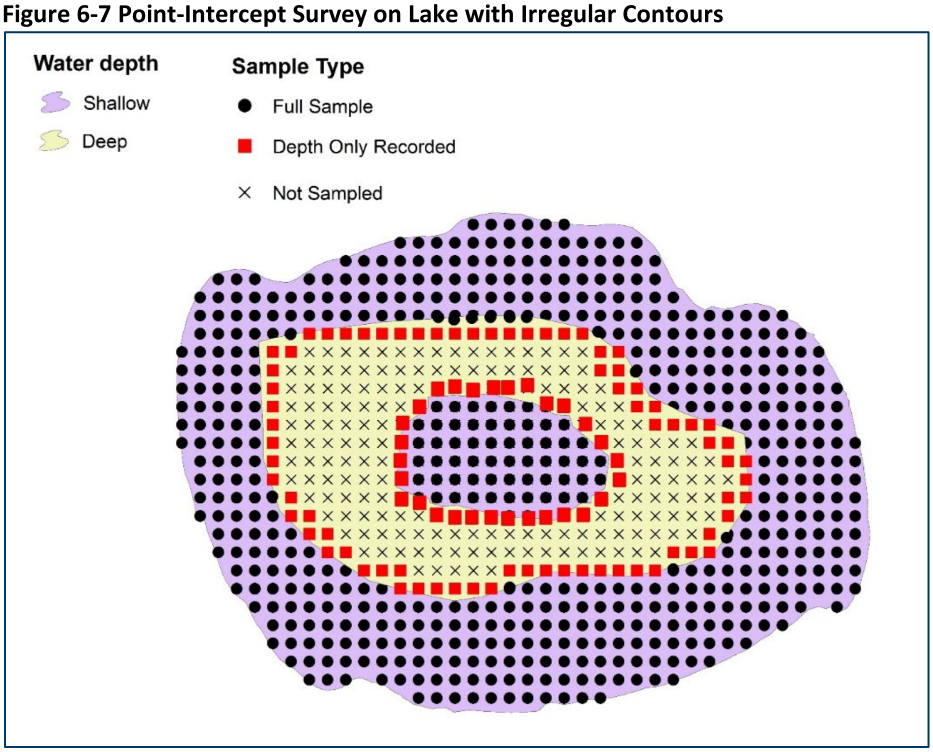


Figure 6-7 Point-Intercept Survey on Lake with Irregular Contours



Water depth

At each sampled site, water depth is measured as close to the actual vegetation and substrate sample site as feasible. In water depths less than eight feet (2.5 meters), surveyors use a measuring stick, or the rake handle marked in one-foot increments; an electronic depth finder is used in deeper water. Water depth is recorded to the nearest foot, or to the quarter foot in depths less than one foot. On lakes with steep contours, the water depth at the boat stern may be several feet different than the depth at the boat bow. In this situation, orienting the boat parallel to shore may help mitigate errors in depth estimates.

Substrate sampling

Substrate is sampled only in shallow sites of seven feet (two meters) and less and should be sampled at the same site where vegetation is sampled. Surveyors tap a pole into the lake bottom to evaluate lake substrate. Soft substrate can usually be brought to the surface on the pole or sampling rake for evaluation. Standard lake substrate classes (Table 5-2) are recorded. If several substrate types occur at a site, surveyors record the most common type.

Vegetation sampling

Sample Site

At each site, plants within an approximate $1m^2$ area are sampled visually and with a rake sampler (see Appendix B). This is not a plot sample where the boundaries of the sample area are delineated. The main goal in tossing the rake is to collect a representative sample of vegetation at the sample site. A $1m^2$ area is suggested to help maintain consistency between surveyors and between sites. It should not be inferred as the appropriate sample area to estimate site level taxa richness or plant cover. A surveyor's ability to approximate a $1m^2$ area is complicated by boat movement and was water depth increases. Surveyors must balance their attempt to sample a $1m^2$ area with their need to ensure the rake hits the lake bottom and contacts a sufficient area of vegetation to collect a sample. The rake should be tossed only once and dragged not more than 3 to 5 meters (about a 16 feet boat length). If the rake is tossed multiple times and/or dragged for longer distances, it will likely cross multiple depths and include vegetation that is outside the intended $1m^2$ area. The rake should not be thrown a second time simply because no vegetation was detected on the first rake toss. If surveyors question whether the rake is contacting the lake bottom, they should temporarily halt the survey and conduct sampling tests to determine if the rake is sufficiently weighted and if wind conditions are appropriate to permit sampling.

Subjective estimate of abundance

Frequency of occurrence, or detection at each sample site, is the metric assessed in this method. If surveyors are interested in assessing plant cover, density, biomass or other features, they should use additional and/or alternative methods. With that clarification, surveyors may find it useful to record a subjective estimate of “abundance” at each site. Abundance estimates described for point intercept surveys are subjective but may be helpful for managers to describe lake areas of potential recreational use issues.

If true cover estimates are required, a plot-based survey is required. Abundance estimates are influenced by water depth, visibility, plant taxa, time of year, and individual surveyor bias. Some surveyors elect to use “rake coverage” or the approximate area of the rake covered by vegetation as an estimate of abundance. These estimates are highly variable and if used should be defined and calibrated by taxa (Yin and Kreiling 2011). Estimates are also relative to the individual lake. What may be “abundant” on one lake may be relatively “common” on another. To minimize confusion and to increase agreement within a specific survey, surveyors should meet on the lake before the survey and agree on the specific categories for that survey.

We provide some general descriptions of abundance categories (Figure 6-10). For each site, total plant abundance is described as one of the four categories:

1. Not detected within survey area
2. Sparse: only one or few fragments collected on rake or visible in water within a $1m^2$ survey area
3. Common/frequent/occasional: neither sparse nor matted
4. Abundant/matted: plants at or near surface, generally making boat navigation difficult

Because these abundance estimates will be lake specific, we recommend surveyors pre-determine more specific descriptions for their survey and review the categories as a team before surveying. We recommend taking example photographs of each category for reference during and after the survey.

Plant identification

At each site, all plants observed are recorded. Taxa are identified to the species level when feasible. Vascular plant taxonomy follows Crow and Hellquist (2000) and nomenclature follows MNTaxa (2015). Collection of voucher specimens are recommended for all taxa observed during survey. Procedures for collecting, labeling and preserving voucher specimens are provided in Chapter 9.

Surveyors may record specimens as “unknown” if insufficient plant material exists for identification. If sufficient plant material is collected but the surveyor is not familiar with the plant, they may temporarily record the specimen as “unknown” and preserve the specimen for later identification.

Figure 6-10. Example photos of subjective estimates of abundance

Example of plant conditions surveyors may elect to describe as “Sparse” (on some lakes, surveyors may place these into the “Common” category if they frequently encounter sites with even less vegetation).

Sparse

Sparse

Common

Common

Abundant

Abundant

Off-grid sample sites

Off-grid sample sites are an option when surveyors want to collect georeferenced data that would not otherwise be collected at specific grid survey points. Off-grid sample sites are subjectively established, and a GPS location is recorded. A common use of off-grid sites is to report any additional plant taxa observed outside of the pre-established sample sites. These data are used to compile a lakewide species list but are not used in frequency calculations. Surveyors may also record information about general plant condition, particularly if the survey objective is to monitor plant management activities. Off-grid sample sites are not a substitute for inadequate sample number; if surveyors determine that the original grid of sample sites is inadequate then additional sample sites should be objectively added using GIS software.

Data management and analysis

Data collected with this method can also be used to:

- Develop GIS-based, lakewide distribution maps for the common species
- Estimate the maximum depth of rooted vegetation
- Describe the shoal water (0 to 7 feet) substrate types
- Assess changes in overall vegetation and frequently occurring taxa

Plant taxa richness

Data obtained from lakewide point intercept surveys can be used to estimate lakewide plant taxa richness, or the number of plant taxa present in the lake (Radomski and Perleberg 2012). Taxa richness at each individual sample site can also be tallied, but caution should be used when comparing these individual site estimates between sites and between years. The rake toss sample site size (approximately $1m^2$) is typically too small to adequately assess site-specific species richness (see Chapter 7). It may be more appropriate to assess and compare collective richness values within broader depth zones and lakewide.

Frequency of occurrence

Frequency of occurrence is calculated for all vegetation and for specific taxa as the number of sites in which a target plant occurred divided by the total number of sampled sites. Frequency is calculated for the entire sampled area and by water depth intervals. Results should indicate if significant portions of the basin were not surveyed, and the resulting frequency data are applicable only to the surveyed zones.

It is important to record the maximum depth strata where all sample sites were surveyed and the total number of sample sites from shore to this depth. Frequency of occurrence values should be reported along with the sampled depth zone, the total number of sample sites and the sample site size. The error associated with this estimate can be provided with a specific confidence interval:

$D = t \sqrt{(1-p)\,(p)/N}$

Where:

- D = error as a fraction of p (e.g., 0.1 to estimate p within 10%)
- t = appropriate value from t distribution table (1.96 for 95% confidence interval)
- p = estimate of frequency of occurrence
- N= sample size

Example: Within the shore to 20 feet depth zone, plants occurred in 30% of the $1m^2$ sample sites (N=250). There is 95% confidence that this value is within 6% of the estimated value (24% to 36%).

$\text{Error} = 1.96 \sqrt{(0.70*0.30)/250} = 0.06 = 6\%$

Before-and-after analyses or comparisons between surveys for all vegetation, or for given species, can be made using a two-by-two or Chi-square analysis using the actual numbers of intervals with and without the species (Madsen 1999). Use the actual number of observations rather than frequencies (or percentages) for the statistical test.

Chapter 7 Quantitative Nearshore Plots

Objectives

The protocol of this chapter standardizes the collection of a lake plant taxa list within the near-shore, shallow water zone where the highest diversity of species is expected. Because the near-shore zone typically contains the highest diversity of taxa, and most taxa occur in this zone, data from this method can be used to estimate lakewide taxa richness.

Introduction

Estimates of plant community richness, or number of taxa, are influenced by the areas selected for searching. Searches are most successful if surveyors target lake areas where a high number of plant taxa are likely to occur but determining where those areas occur is not straightforward and leads to non-standardized efforts (different surveyors may select different search areas and produce different search results). Investigators can standardize their searches by systematically placing sample sites within the near shore.

Search effort (time spent searching and/or total area searched) also influences estimates of plant community richness. LEU staff conducted pilot near-shore sampling on high diversity lakes and used those data to select 25 m^2 as the appropriate survey area size for richness sampling. Increasing survey area size did not result in a significant increase in species richness estimates.

While this method has some similarities to the Transect Method, it provides a more efficient way to collect a species list because the survey area size is standardized on the near shore. Additionally, surveyors are more likely to view inconspicuous taxa by wading than from a boat. Because this survey is restricted to the near-shore zone, several deep-water taxa may be missed. Examples of taxa that are more likely to occur in deep water include coontail (*Ceratophyllum demersum*), floating-leaf pondweed (*Potamogeton natans*), Robbin’s pondweed (*Potamogeton robbinsii*), white-stem pondweed (*Potamogeton praelongus*), stonewort (*Nitella* sp.), and aquatic bryophytes. As with other surveys described in this Manual, as surveyors navigate between survey sites, they should record any additional species they detect outside of the survey areas as “present in the lake but not detected within survey sites”. These are categorized as “off grid” sample sites.

Data from this survey can also be used to supplement the taxa list obtained in the point-intercept survey, particularly if that survey design had a limited number of sample points in shallow water. However, since frequency data are expressed in relation to sample size area, the frequency data from the 25m^2 survey sites cannot be combined with or directly compared to frequency data obtained from the 1m^2 point intercept survey sites because survey area differs between those surveys.

Survey Design

Defining the survey site area and establishing survey sites

The surveyable zone is the narrow band extending from the shore-water interface lakeward 5 meters. Within this zone, survey sites, measuring 5 meters along the shore by 5 meters lakeward (Figure 7-1) are established in a systematic, regular interval along the lake perimeter. Survey site locations are established using the same protocol used to establish Score The Shore survey sites (Figure 3-1). If a Score The Shore survey has or will be conducted on the lake, those survey site locations (the center point of the established 100 feet shoreline segment) may be used for the near-shore sites.

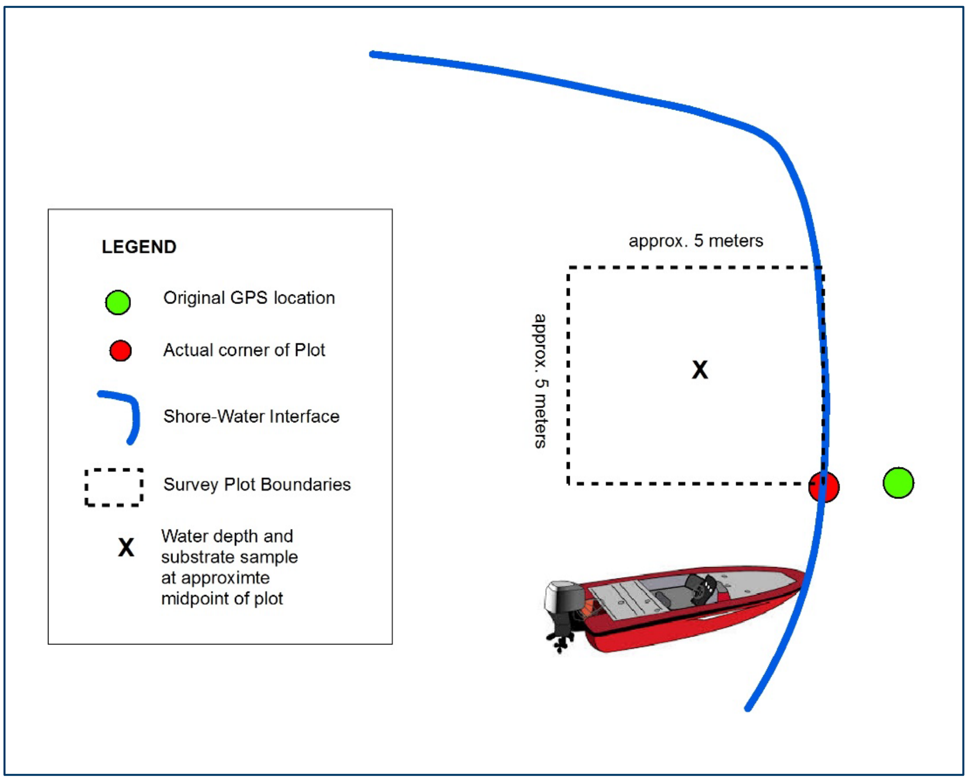


Figure 7-1 Near-shore sample site

The recommended minimum number of survey sites per lake is 20. The spacing of survey sites and the total number of survey sites are determined by the length of the shoreline (Table 7-1). On lakes with 3.3 to 15 miles of shoreline, survey sites are spaced 200 meters apart. Survey sites are spaced closer together on lakes with less than 3.3 shoreline miles and further apart on lakes with more than 15 shoreline miles. On very small lakes with less than 1.22 shoreline miles, surveyors place 20 sample sites at equal distances around the shoreline and that distance may range from 60 to 95 meters. This survey is designed for lakes with shoreline lengths of 50 miles or less. It can be conducted on large lakes, such as Mille Lacs, Leech, and Rainy, but surveyors should consider the feasibility of assessing such large shoreline areas; it may be useful to target specific bays or shorelines on these large lakes rather than attempting to survey the entire shoreline.

Table 7-1 Determining spacing for near-shore sites

Shoreline length (miles)	Spacing of sample sites (meters)	Number of sample sites per lake
0.75-1.21	Varies 60 to 95	20
1.22-2.24	100	20-36
2.25-3.29	150	24-35
3.30-14.99	200	27-121
15.00-50.00	400	60-201

Pre-survey preparation

Training

LEU provides annual training and technical assistance on Nearshore Plot Survey method on request.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix B. Data can be recorded on paper forms (Appendix C) or electronically.

For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (GIS Manual). Survey point waypoints are created (GIS Manual) and uploaded to handheld GPS units.

Conducting the survey

This survey is conducted by wading in shallow water, or by boat if water depth and/or substrate prevent wading. The survey points are not intended to be permanent sampling locations and are not marked with permanent markers. Rather, the goal is to navigate to the approximate location of each sample point. Given the inherent inaccuracy of field-model GPS units and the uncertainty associated with the GIS coverage of the shore-water interface boundary surveyors are not always able to navigate precisely to the survey point location.

Surveyors navigate to the survey site with GPS but land the boat at a distance from the survey site to avoid disturbing the site. The waypoint marks the right, shoreward corner of the site as the surveyor faces the shore (Figure 7-1). At each site, surveyors approximate a 5 meter by 5-meter area, with one side of the survey site along the shore-water interface. As a general guide, most MNDNR survey boats are about 16 feet (5 meters) in length. This is a rapid assessment method, and it is not necessary to measure the survey area dimensions in detail. Actual survey area dimensions will vary slightly between surveyors and site conditions. Surveyors should be conservative in estimating the survey area and not include vegetation that is well outside the $25m^2$ survey area.

Water depth

At each survey site, water depth is measured at the mid-point of the survey site (Figure 7-1). Surveyors use a measured stick, or the rake handle marked in one-foot increments. Water depth is recorded to the nearest foot, or to the quarter foot in depths less than one foot.

Substrate sampling

Surveyors describe the substrate, in approximately the middle of the plot, by tapping a pole into the lake bottom to evaluate lake substrate. Soft substrate can usually be brought to the surface on the pole or sampling rake for evaluation. Standard lake substrate classes (Table 5-2) are recorded. If several substrate types occur at a site, surveyors record the most common type.

Vegetation sampling

At each site, plants within the $25m^2$ area are sampled visually. A view tube or snorkel may be used to survey the area. A rake may be used to supplement sampling, particularly if water clarity and/or depth limit visibility. The rake may be tossed multiple times to ensure the area is sufficiently sampled but surveyors should not toss the rake outside of the survey area. Surveyors should note any additional taxa that are observed outside of survey sites, but those taxa will not be included in frequency of occurrence estimates.

For each site, total plant abundance is described as one of the following categories (for more information see Chapter 6):

1. Not detected within survey area
2. Sparse: only one or few fragments visible and/or collected on each rake toss
3. Common/frequent/occasional: neither sparse nor matted
4. Abundant/matted: plants at or near surface, generally making boat navigation difficult

At each site, all plants observed are recorded. Taxa are identified to the species level when feasible. We recommend voucher specimens be collected for all taxa observed (Chapter 11).

Data management and analysis

Data are managed by individual programs.

Data collected with this method can also be used to:

- Estimate near-shore plant taxa richness, or the number of plant taxa present in the near-shore (in many lakes this may be a good proxy for lakewide taxa richness)
- Develop GIS-based, near-shore distribution maps for the common species
- Describe the shallow water (0 to 4 feet) substrate types
- Assess changes in near-shore vegetation and frequently occurring taxa
- Evaluate potential relationships between near-shore plant communities and shoreland management practices assessed with Score The Shore survey

Chapter 8 Hydroacoustics

Objectives

The hydroacoustic survey is designed to assess the distribution of submerged vegetation on a lakewide or bay-wide scale. This survey is designed to, with moderate effort, assess changes in frequency of occurrence and plant height statistics by depth strata. The main metric assessed is “biovolume” which can be generally defined as the percent of the water column occupied by vegetation (Valley and Drake 2007).

Primary goals include:

1. Describe the geographical distribution of submerged vegetation throughout the littoral zone and within specific depth zone intervals.
2. Estimate the biovolume of vegetated covered areas of the lake bottom.
3. Compare the submerged vegetation biovolume across years.

This survey does not collect taxonomic information on plant communities and managers may elect to use it in combination with a Transect, Point Intercept, Nearshore Plots and/or Botanical Inventory Surveys.

Introduction

Submerged vegetation communities are dynamic, reflecting the varied life histories and environmental preferences of their species, e.g., nutrient availability, wind exposure, bottom substrate, water level fluctuations, and water depth (Wetzel 2001). While, quantification of submerged plant abundance is important, abundance estimates are expensive to obtain and are highly variable across littoral areas (Downing and Anderson 1985).

Investigators have used hydroacoustics, or transmitted sound pulses in water to sample aquatic plants for over 30 years (Maceina and Shireman 1980). One of the main advantages of this remote sensing technique is that sound travels quickly in fresh water (~1480 m/s), so the entire water column can be sampled almost instantaneously using mobile survey techniques. The distance between the transducer and an acoustically reflective target (e.g., aquatic plant) can be calculated based on the time delay between an emitted signal and a return signal using the velocity of sound in water (Simmonds and MacLennan 2005). The resulting information can be used to estimate aquatic plant abundance and height. Sabol et al. (2002) noted that the acoustic reflectivity of submerged macrophytes was likely based on the presence of gases within the leaves and stems of plants so that more buoyant plant species were more acoustically reflective. Thomas et al. (1990) published one of the first studies that determined hydroacoustic techniques yielded substantially greater precision of biovolume estimates and lower data collection costs than SCUBA-based estimates.

There are multiple hydroacoustic systems available to assess aquatic plant communities. One of these, the BioBase system, provides a cost-effective method to identify areas of dense or matted submerged macrophytes for the purposes of aquatic plant management. This system can quickly create maps of dense vegetation when surveyors adequately cover an area of interest, although BioBase may produce different estimates plant heights compared with other systems (Radomski and Holbrook 2015). Hydroacoustics survey techniques are unique with regards to submerged plant assessment in that this approach allows large-scale assessment of submerged plants. However, standardizing data collection equipment and the signal processing approach is necessary prior to using this technology as an assessment tool (Radomski and Holbrook 2015).

Survey design

Defining the survey area

The survey area should include the area of the lake where information on aquatic vegetation is needed. This may include areas that may not be vegetated during the current survey year but were vegetated in past years or where it is anticipated that they will be vegetated in future years. This is particularly important if the survey objective is to compare data between survey years. In most lakes the survey area will include all water depths from the shore-water interface to a depth of at least 15 to 20 feet, or the maximum lake depth, whichever is less. On many Minnesota lakes, water clarity is sufficient for plant growth to 20 or more feet and sampling should include these depths on clearer lakes. As with point-intercept surveys, hydroacoustic surveys should error on sampling too deep rather than limiting sampling to only shallow or mid-depth waters.

Mid-summer water clarity data may be useful for estimating the approximate maximum depth of vegetation; rooted plants often grow to depths of 1.5 times the mid-summer Secchi depth. Previous knowledge of the lake and a review of historical surveys can also provide insight on how deep to sample. A recent hydrologic map is helpful when designing a lakewide vegetation survey. A pre-survey field visit can also be used to help assess the maximum depth zone at which plant growth occurs.

Transect arrangement or Track Design

Two options can be considered in designing hydroacoustic sampling. First, hydroacoustic sampling can be conducted using numerous transects that are selected to provide a range of depth, substrate, and aquatic plant abundance. If a point intercept survey is also being conducted, one could set transects on the same grid as the point intercept with the orientation of the transects selected that best covers the littoral area of the lake. The number of transects depends on lake size, resources, and precision of the abundance estimates needed. For the creation of biovolume maps, consult the hydroacoustic systems' documentation. Transects should be standardized for a lake, and the same transects should be used if a lake is resampled. Alternatively, if biovolume maps are not the objective, hydroacoustic sampling can be completed using a zigzag pattern to systematically sample the entire littoral area. A zigzag pattern can be designed to ensure representative sampling of the entire littoral area by applying a systematical random pattern using GIS. First, evenly spaced shoreline points are created around the lake. Second, points are created at approximately equidistant locations between shoreline points and at water depths exceeding the depth of plant colonization. The points are then connected to form the zigzag pattern.

Pre-survey preparation

Training

LEU provides training and technical assistance on hydroacoustic survey method on request.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix C. Transects are created and uploaded to handheld GPS units. Hydroacoustic data are collected with the Lowrance High Definition System consumer echosounder integrated with wide area augmentation system-corrected GPS and Installed as recommended by the manufacturer. Typically, a single-beam 200-kHz transducer (20° x 20° half-power beam angle) is oriented vertically and mounted on the boat stern.

Conducting the survey

Consult and review your hydroacoustic system's documentation prior to conducting the survey, data uploading, and data processing. Use recommended settings for the echosounder unit. For example, BioBase logs data at a rate of 15 to 20 data signals per second, and GPS locations are typically recorded every second from the Lowrance HDS. Since BioBase analyzes data by aggregating by time, it is critical to maintain constant boat speed; otherwise, biases in abundance will be introduced.

Standardize boat speed and then traverse transects or tracks using a consistent speed (e.g., 2 m/second). If the lake is resampled, then use the same speed as the earlier survey. Thus, it is crucial for the boat speed to be standardized when conducting a BioBase hydroacoustic survey.

Data management and analysis

Consult our organization's protocols for data management. Ideally, raw data are stored for possible reprocessing and processed data are incorporated into MNDNR GIS QuickLayers.

For BioBase, data are analyzed with their proprietary software. BioBase is a cloud-based software platform that automates acoustic and GPS signal processing and GIS data layers of estimated depth, percent of area covered by vegetation, plant height, and biovolume (percentage of the water column occupied by vegetation). Exported data include record number, latitude, longitude, bottom depth, depth to plant, and plant height. Bottom depths can be corrected for transducer depth at the time of data upload. BioBase evaluates each ping to determine if features could be extracted, and those failing this test are removed. For each valid ping, the algorithm calculates plant height as the difference between bottom depth and the top of the plant signal. Since GPS positions are typically recorded every second, bottom and vegetation features from pings that elapsed between positions are averaged. The algorithm aggregates the signals by 1-second intervals rather than a set distance, so a record typically summarized 5-30 pings along a traveled track. BioBase then processes the depth and vegetation estimates with the use of a kriging algorithm that predicts depth and vegetation values in unsampled locations based on the geostatistical relationship of the inputs. Kriging smooths feature values when variability is high but there is a positive relationship between error of kriged estimates and the distance from sampled locations.

Chapter 9 Wood Habitat Survey

Objectives

This protocol is designed to rapidly assess wood habitat within a lake by conducting a whole lake inventory or a systematic random sampling survey. The Wisconsin DNR developed this protocol (WI DNR 2020), which was adapted from a wood habitat sampling method used by the North Temperate Lake Long-Term Ecological Research program (WI DNR 2008). The largest difference between the protocol listed here compared to the WI DNR protocol is an inclusion of the systematic random sampling option for larger lakes.

This survey protocol can be used to:

1. Determine wood habitat occurrence for a lake with modest precision.
2. Detect large in-lake changes in wood habitat density over decades.
3. Assess differences in wood habitat between lakes.
4. Determine, by pooling survey data, the factors influencing the quantity of wood habitat along Minnesota lake shorelines.

Introduction

Wood habitat in lakes has many ecological benefits. Logs and fallen trees provide fish refuge, fish spawning substrate, and wildlife resting and basking sites (Sass et al. 2006, Roth et al. 2007). Lakeshore residential development reduces wood habitat in lakes (Christensen et al. 1996, Marburg et al. 2006). Management of wood habitat in lakes includes conducting inventories of this habitat, reducing wood habitat loss, encouraging natural shorelines, and adding wood back to lake nearshore areas when the estimate of loss has likely reduced fish and wildlife productivity (Sass et al. 2012, Sass et al. 2023).

Survey design

The protocol involves boating slowly along shore and recording GPS locations of wood habitat, and the wood and site attributes. The water should be clear during the survey (Secchi disk depth of 2 feet or more). For eutrophic lakes, surveys should be conducted in spring or fall. If the Secchi depth is less than 2 feet, this protocol should not be used as visual estimates of woody habitat are likely unreliable.

The survey distinguishes between two types of wood habitat:

1. beaver houses/food caches
2. large wood

Large wood is defined as any tree log or branch at least 4 inches in diameter at any point along its length and at least 5 feet in length (10 cm x 1.5 m). Record wood of sufficient size when it occurs between the ordinary high water level (OHWL) and the 4-foot depth contour.

"Large wood" includes wood of sufficient size found:

- submerged or on the water surface in shallow (0 to 4 feet) water.
- lying on the ground during low water periods, but still below the OHWL.
- tree roots that occur below the OHWL.
- live branches and non-anchored logs that occur below the OHWL.
- live or dead tree branches hanging over the water that occur below the OHWL.

Do not record:

- lumber (e.g., railroad ties, fish cribs, wood retaining walls).
- wood buried in the sediment.
- wood above the OHWL.

Pre-survey preparation

Lake size determines the survey type. For small lakes (shoreline miles less than ~10 miles) with a low or modest amount of wood, the entire shoreline of the lake should be surveyed. For large lakes or lakes with large amounts of wood, surveys should utilize systematic random sampling stations. Sampling stations will be spaced at standard shoreline lengths (e.g., 100, 200 or 400 m), depending on lake size and likely density of wood. GIS software is used to create these shoreline segments around the lake perimeter. A GIS tool has been developed to establish shoreline segment stations (refer to the latest GIS tipsheet or manual to complete this task). If a wood habitat survey has been previously conducted for the lake, then surveyors should strongly consider reusing the original shoreline segment stations.

Since large wood greater than 4 inches diameter and 5 feet long that is in the water and/or below the OHWL will be recorded, it is important that the surveyors are familiar with wood of this size. There are several ways to 'calibrate' your eye. The surveyor could have a pole marked in 1-foot increments and a 4-inch log end in the boat for reference, or the surveyor can measure a few logs in the field until confident about their quick visual assessment of size.

Conducting the survey

After confirmation of sufficient water clarity and an assessment of OHWL, begin survey.

1. Record survey details, including the type of survey:
    a. whole lake
    b. systematic random sampling survey

        i. record the station number

2. For each beaver house or food cache:
    a. Record GPS location
    b. Record condition of the submerged wood:
        i. Recently submerged (Yes/No)
    c. Record a *branchiness* ranking:
        i. Heavily branched
        ii. Consists of poles with fish hiding spaces
        iii. Few fish hiding places
3. For each piece of large wood (at least 4-inch diameter and at least 5 feet in length) that is between the OHWL and the 4-foot depth contour:
    a. Record GPS location
    b. Record if the log has at least 5 feet of its length underwater
    c. Record a *branchiness* ranking:
        i. Log with no branches
        ii. Log with few branches
        iii. Full crown
    d. Record if the wood crosses or touches the OHWL (Yes/No)
    e. Record source:
        i. Unknown
        ii. Stump or standing tree in water
        iii. Beaver log drop
        iv. Human (e.g., saw marks, log addition project)
    f. Record land use class (use Score the Score classifications)

Data management and analysis

Field data collected with an ArcGIS app will be synced to a geodatabase. The data steward will contact the surveyor on potential data quality issues.

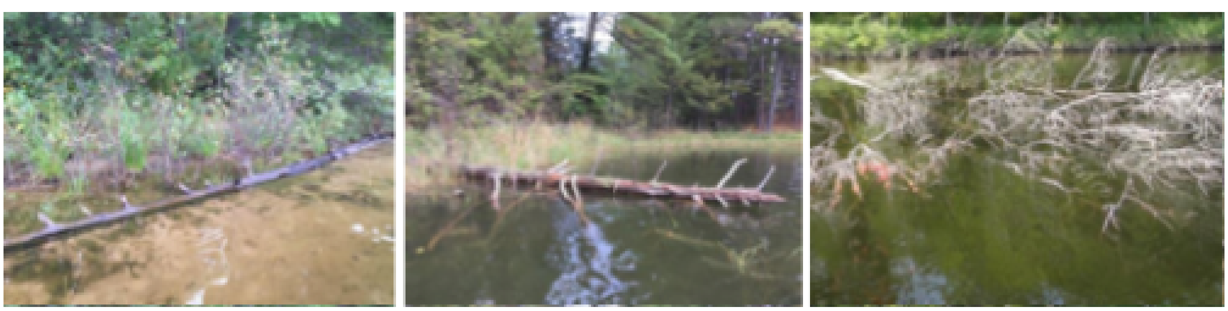


Figure 9-1. From left to right, wood without branches, with branches, and with full crown. Source: Wisconsin DNR.

Chapter 10 Aquatic Botanical Inventory and Rare Aquatic Plant Species Surveys

Objectives

This chapter describes qualitative lake survey methods and considerations to employ when pursuing the following objectives:

1. Compile a species list through botanical inventory of aquatic vascular and non-vascular plant species

2. Document new locations of rare and uncommon aquatic plant species

Introduction

Many aquatic plant species, and rare species in particular, have unique habitat preferences or requirements and/or life history traits that limit their distribution in the state and within a waterbody. Even if appropriate habitat is available within a waterbody, some plant species may still occur infrequently. Systematic surveys with objectively selected sites, such as transect (Ch. 5), point-intercept (Ch. 6) and nearshore plots (Ch. 7) surveys sites may fail to locate rare and less common plant species because they tend to under-sample less frequently occurring species and may not include small areas of unique habitat.

Therefore, aquatic botanical inventories should be conducted in appropriate lake habitats, with sufficient effort by surveyors with high botanical knowledge and expertise to ensure compilation of comprehensive species lists. Because professional judgement and experience are required to successfully locate and identify less common and obscure species, it can be difficult to standardize this type of inventory. In addition, standardized and objective procedures may result in excessive survey time without increased inventory results.

Botanists with specific knowledge of aquatic plants can often identify suites of species that may occur in certain habitat types and can thereby subjectively select survey sites to maximize their search efforts. While these survey approaches are subjective, they often result in a more complete inventory of the lake plant taxa. If quantitative estimates of species distribution and/or abundance are needed, additional surveys, such as point intercept (Ch. 6) and/or nearshore plots (Ch. 7) can be added and can be designed to target key species or address specific plant community questions.

Pre-survey Preparation

Surveyors should review existing distribution and habitat information for plants known to occur in the survey region and lake type. Consult sources such as MNTAXA, Natural Heritage Information System (NHIS), Rare Species Guide, and the University of Minnesota's Bell Museum. For many Minnesota lakes, a species list compiled by a MNDNR botanist is available on MNDNR LakeFinder.

A checklist of required and recommended field equipment is provided in Appendix A. Obtain any access permission and/or required collecting permits prior to the survey.

Search strategy

Review land ownership, access points, lake bathymetry and aerial photography to aid in search strategies. Depending on the waterbody size and search effort available to invest, a combination of strategic searching and meandering of the littoral zone around the lake can be employed. Shoreline wading or snorkeling and watercraft such as a kayak, canoe, or boat can be utilized. Inconspicuous taxa are more likely to be detected by shoreline wading, snorkeling or non-motorized watercraft than by tossing rakes from boats. Consider how to access both shallow and deep-water zones: watercraft can be used to more quickly access multiple sites in both of these zones. Visual surveying through moderate wave action or compromised clarity can be facilitated with use of a view tube (Figure A3). A double-sided rake (Figure A1) or grapple hook can be used to search for submerged plants in depths that cannot be visually surveyed.

Because this is a non-standardized survey with subjectively chosen sites, the area searched and the number of sites visited will not be used to make statistical inferences about plant taxa distribution or abundance. That said, search effort is critical because higher search effort (search time and search area) can increase the likelihood of locating species and compiling a more comprehensive list of plant species present in a waterbody. To help maximize search effort, it can be useful to predetermine a search area and/or search time. For example, a surveyor may plan to search a given shoreline stretch for 15 minutes then move to a new site if the target species and/or no new taxa are located during that time.

Survey timing

When determining survey timing, it's important to consider the life history of the target species. For example, the rare, submerged plant species, *Najas marina,* is an annual that can be found in fruit through September (MNDNR 2008). The best time to search for this species is later in the summer and thus, a survey to capture this species in late spring or early summer would not be appropriate. Multiple visits to sites may be required to locate target species at maturity.

Conducting the Survey

An appropriate and convenient starting point for both a botanical inventory and rare plant surveys may be at the point of entry to the waterbody (i.e. public water access). In general, the shallow, nearshore zone can be particularly important habitat for rare aquatic species (Myhre 1998) and is also the zone most likely to contain the highest number of plant taxa.

Botanical inventory

Navigate through the chosen survey area and record all observed taxa to the species level when feasible. Collect specimens when identification or a record of the occurrence is needed (i.e. rare species; county record) (see Chapter 9). Take note of any washed up or drifting plants that may have been uprooted by wave action or human disturbance if they have not yet been recorded.

For general botanical inventories and searches for rare species that lack defined habitat characteristics, it's important to include search areas of various habitats in the lake. These areas can include different depths, substrate types and degree of wave and wind exposure. For example, some emergent species can grow on windswept sandy shoals while floating-leaf and free-floating plants are more often found in quiet, protected bays. The deep edge of the vegetated zone should also be explored for certain submerged species, such as macroalgae and aquatic mosses, which may occur in this zone but often go undetected. Search areas should include known unique features that have potential to yield additional species such as protected bays, channels, sandy or rocky points, and islands. Also consider visiting shallow areas of intact, undeveloped shoreline, and areas where shoreline vegetation changes. Continue searching until sites of different habitat and potential for additional species have been exhausted and additional search effort does not continue to grow the species list. Sketching a species/area curve in the field can help surveyors judge the value of spending additional search time at a site.

Rare species survey

Depending on specific objectives, surveyors may elect to simply search for the target plant and not immediately record other taxa. This focused effort can allow the surveyor to cover a larger area in a shorter time. Focus the initial search area on the known habitat preferences of the target species and adjust mode of search accordingly. Consult resources such as the MNDNR Rare Species Guide and herbaria specimens to gain insight on reported associations with water depth, water chemistry, substrate type, and other plant species and plant community types.

If the target plant is located, record additional information such as location, environmental site characteristics and associated plant species. Collect a voucher specimen if appropriate to do so (Chapter 11). If possible, spend additional time on the lake to describe the distribution.

Data Management and Analysis

Rare species observations should be submitted to the Natural Heritage Information System (NHIS) following their specific requirements. An Excel worksheet template and a GIS shapefile template are available for data entry on the NHIS website. Contact the NHIS data manager, Karen Cieminski, Karen.cieminski@state.mn.us with questions.

To aid in consistent submission of data, the following are general guidelines for MNDNR staff submitting rare aquatic plant data:

1) Observation Type

- Rare plant species observations may be documented by a verified herbarium voucher specimen (preferred), a photograph, or a visual observation. Examples of situations where collection of a voucher specimen may not be feasible or appropriate include the following:
    - Plant is observed in an inaccessible site. A specific example is a population of purple-flowered bladderwort (*Utricularia purpurea*) that was in bloom in a small pond (visible from a road) on inaccessible private property. A photograph was taken to verify the plant's identity and estimate population size.
    - Collection of plant may threaten population. In most cases, rare aquatic plants are found at sites with multiple individuals and collection of a single plant will not harm the population. However, when in doubt, do not uproot a rare plant to make a voucher. Record the location of the plant and if feasible, take photographs including any flowers or fruits that may be present.

2) Point and Polygon Observations

- Surveyors submit rare plant observations using points or polygons in GIS. Factors that may influence how you report the observation include the search area size and the size of the area where you observed the plant.
    - Point observation: A point is most appropriate for a single observation site where the surveyor did not search beyond the point. Rare aquatic plants observed at individual stations on a Point Intercept survey are usually best documented with a point shapefile.
    - Polygon observation: A polygon may be used to document a rare plant observation at a site where the surveyor searched a known area of suitable habitat, and the polygon shape and size represents the approximate area where the plant was found. It is helpful to provide a text comment that describes the plant population and how the polygon was mapped (i.e. polygon created from three waypoints). Rare aquatic plants observed during a meandered search are often best documented with a polygon, particularly if multiple plants were observed or the population covered an extensive area, and the extent of the population is known.

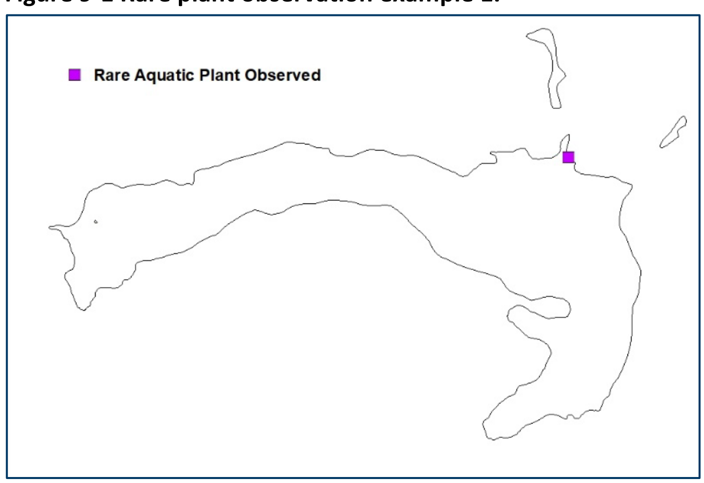
3) Confidence of the Extent of Rare Aquatic Plant Population

- Surveyors reporting sites of rare aquatic plants will also be asked to provide information on the confidence of the mapped observation of the rare plant.
    - Confident Full Extent of Observation is Not Known: This category is appropriate if no information was collected on the plant population or if only a portion of suitable habitat was searched. This category might also be used when a surveyor visits a single site on a lake (such as a public water access) and locates a rare plant; they have no information on the potential occurrence of the plant elsewhere in the lake.
    - Uncertain if Full Extent of Observation is Known: This category indicates uncertainty around the extent of the population in relation to the specific observation. Some information is known about the rare aquatic plant population, but more information is needed to assess the full extent of the population. For aquatic plant surveys, this category may be most appropriate when rare plants are located during a systematic survey. For example, if a rare plant is observed at some sample stations during a lakewide point intercept survey, the surveyor has some confidence that a large portion of the potential habitat has been searched and they can provide an estimate of the distribution of the rare plant within that lake. However, “uncertain” indicates that there are still large littoral areas that were not searched.
    - Confident Full Extent of Observation is Known: This category is used when the surveyor is confident they have searched through all suitable habitat within the area and that search conditions were conducive to locate the plant (good weather, good water clarity, appropriate time of year). If, for example, a rare plant is found on a high percentage of sites in a lakewide point intercept survey, the surveyor may be confident in stating that the plant population extends along a specific shoreline and within a specific depth range. Surveyors may be more confident in reporting population extents for emergent and floating rare aquatic plants than for submerged plants where detection is more difficult.

Example 1. Student interns collected and unknown plant and recorded GPS location at collection site. Plant later determined to be a rare species.

Observation Type: Voucher Specimen
GIS File Type: Point
Population Extent: Confident Not Known
Comments: Search effort was limited to actual point of collection

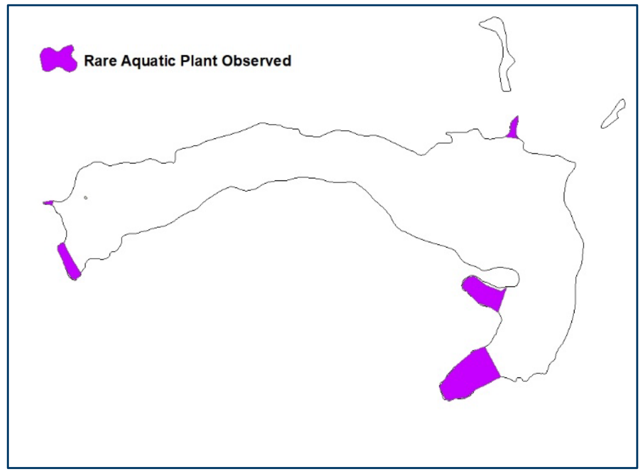
Figure 9-1 Rare plant observation example 1.



Example 2. Surveyor with plant identification experience locates rare plant during a targeted meandered search for that species in suitable habitat. Surveyor is confident, based on their knowledge and search effort, that there are no unmapped areas of the rare plant.

Observation Type: Voucher Specimen
GIS File Type: Polygon
Population Extent: Confident Known
Comments: Entire littoral area searched and rare plant only found in protected bays adjacent to undeveloped shores.

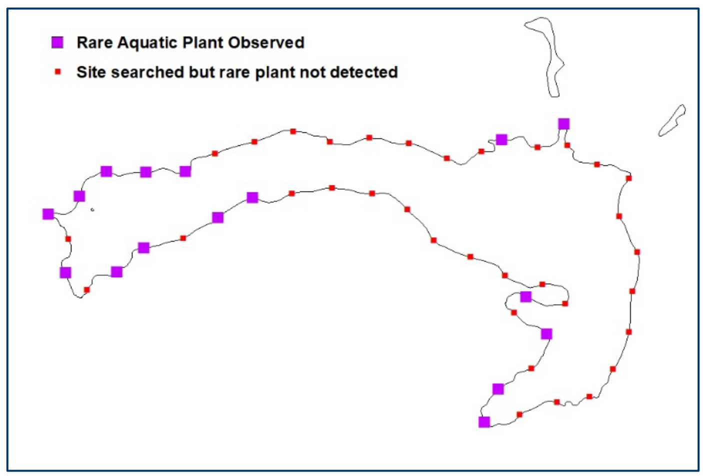
Figure 9-2 Rare plant observation example 2.



Example 3. Surveyor with plant identification experience surveys nearshore plots around entire lake and locates rare species on numerous sites.

Observation Type: Voucher Specimen
GIS File Type: Point
Population Extent: Confident Not Known
Comments: Entire shoreline was included in survey and rare plant was located on 16 of 50 sites but 200 meter stretches between sites were not searched and deep water zone was not searched.

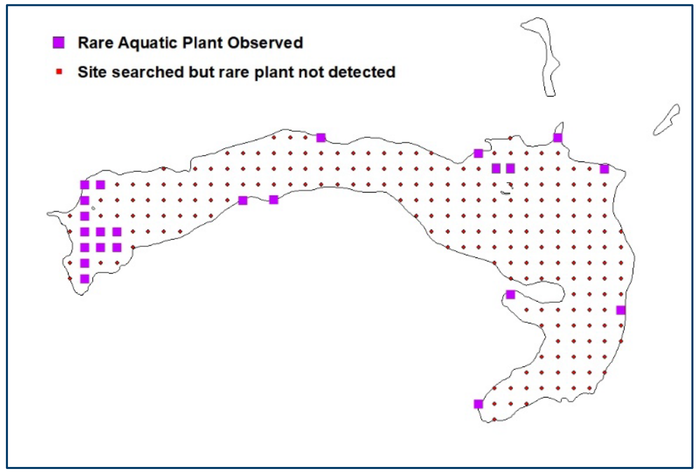
Figure 9-3 Rare plant observation example 3.



Example 4. Surveyors with plant identification experience collect submerged rare plant on multiple sites during a lakewide point intercept survey. Area between survey stations may be suitable habitat but is not searched. It is likely that there are unmapped areas of the rare plant.

Observation Type: Voucher Specimen
GIS File Type: Point
Population Extent: Confident Not Known
Comments: Entire lake was included in survey and rare plant was located on 23 of 243 sites but 80 meter stretches between survey sites were not searched.

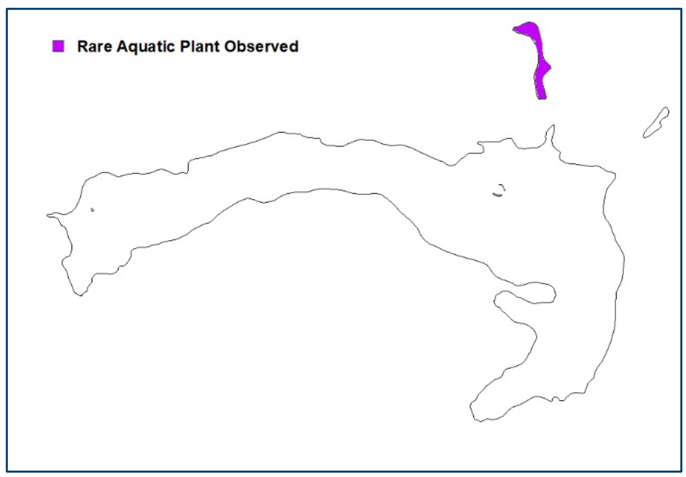
Figure 9-4 Rare plant observation example 4.



Example 5. Surveyors with plant identification experience view rare plant in flower from a distance and cannot physically access site to collect voucher specimen. Surveyors observe that plant extends across entire basin.

Observation Type: Photo
GIS File Type: Polygon
Population Extent: Confident Known
Comments: Observed from road that flowering plants present across entire basin.

Figure 9-5 Rare plant observation example 5.



Chapter 11 Collection, Preservation, and Photographic Documentation of Aquatic Plant Specimens

Objectives

Collecting aquatic plant specimens for laboratory analysis, herbaria submission, and/or identification verification can be challenging because aquatic plants can quickly dry, change in appearance, and die when removed from lake water. This chapter standardizes the collection, preservation, and photographic documentation of aquatic plant specimens to help ensure the following:

b. Plants are collected when appropriate
c. Plants are correctly identified
d. Live or preserved plant material can be accepted in collaborative research projects
e. Museum quality specimens are properly preserved

Introduction

The most common reason to collect aquatic plants during surveys is to verify taxonomic identification. Aquatic plant identification can be challenging, and surveyors may not always be confidently able to identify a plant to the species level. Additionally, plant classification is constantly changing. Voucher specimens can be examined to verify the identity of plants located during surveys and can be used to cross-reference these changes to previous studies. Plants may also be collected to document new locations of rare plants, new county or state records, and for a variety of research projects. The types of plant collection associated with MNDNR lake surveys include:

- Live plant collection for immediate identification
- Low quality preserved specimen for identification
- Museum quality preserved voucher collection
- Live plant collection for use in a research project, such as genetic analysis.

A voucher herbarium specimen is a pressed plant specimen deposited in a recognized herbarium which is typically associated with a university or research organization. Herbarium specimens serve many purposes which can include some of the following: to aid botanists in plant identification; to serve as subjects in morphological, systematic and genetic studies (Carter 2009, Espinosa and Pinedo 2018); to study phenology and ecological responses to climate change (Calinger et al. 2013; Everill et al. 2014); and even to study herbivory trends (Beaulieu et al. 2019) and catalog organisms that may be present on collected specimens. As more herbaria digitize collections and make them available online, researchers can more quickly access and analyze data from massive numbers of specimens covering broad geographic and temporal ranges (Park 2012, Primack and Gallinat 2017).

Surveyors may often collect low quality specimens during surveys because plants may not be fully mature (with flowers or fruit) and only a portion of the plant may be collected on a sample rake. Even if they will not be permanently retained in an herbarium, the collection methods are the same as high quality specimens.

Surveyors should also be prepared to properly collect and transport aquatic plant specimens. This includes taking precautions to prevent the spread of non-native organisms to new locations. If correctly processed, live specimens of most taxa can remain viable for at least a week. If longer term preservation of the specimen is required, the specific steps depend on the plant type and the intended use of the plant sample.

LEU and MBS provide annual workshops on aquatic plant identification. Techniques to collect and preserve specimens are included. Staff in these programs can provide additional technical assistance on plant identification on request.

Collecting Aquatic Plants

Permits

Obtain all necessary access permissions and permits prior to collecting. This may include:

- General permit to transport aquatic plants and lake water
- General permit for herbarium specimens of prohibited species [Permit for herbarium AIS specimens]
- Permit to collect rare species
- Permit(s) to collect in State Parks and/or other jurisdictions

When to collect

Plant collections for herbarium vouchers should be collected during plant maturity when feasible. Ideally, plant reproductive structures (flowers or fruits in vascular plants; gametangia in non-vascular plants from the Characeae Family) should be included. For heterophyllous plants (Fig 2-6), all leaf types present (submerged, floating, emergent) should be included. Roots and rhizomes can be important in identification, particularly for most emergent plants such as bulrushes (*Schoenoplectus*), sedges (*Carex*) and spikerushes (*Eleocharis*). Multiple trips may be needed to locate and collect plants in their entirety.

That said, for some unique species, if the only available specimen is immature or lacking reproductive structures, it may still be worth collecting to document the species occurrence.

How to collect

When collecting plants for identification purposes, the goal is to collect enough plant material for more detailed observation in the office and/or by an experienced botanist. It is important to collect the appropriate plant parts and transport them in a manner that retains their integrity (a dried mass of plants is not easily identified).

The general guidelines for aquatic plant collection include the following:

- Collect plant by hand when feasible. Collecting single individual plants is recommended (as opposed to rake tines of tangled stems or branchlets).
- Collect sufficient plant material to meet identification, voucher, or research needs. If collecting as part of a collaborative project where multiple collections are needed, all material collected from a site is considered as the same collection. Collections from a different geographic location on the lake, or on a different date, are considered unique collections.
- Gently rinse plants in lake water to remove excess substrate, phytoplankton, and calcium deposits. A plastic tray and a plastic squirt bottle can be used to help rinse at the lake.
- Place each plant taxon collected in a unique collection bag to help ensure that plant fragments remain with the parent plant.
- Label each bag and collect associated notes (see detailed collecting notes below).
- Dispose of all water and unused plant material according to MNDNR protocols to prevent spread of non-native species.

Collecting protocols also depend on the type of plant and should be adjusted as follows:

Vascular plants

- Ziploc bags work well for transporting and temporarily storing plants.
- If plants will be stored for several days, remove most of the lake water from the bag, blow into bag to add carbon dioxide (this reduces bacterial growth), and refrigerate.
- If plants will remain in extreme heat for an extended period, place stored plants in a cooler with ice packs.

Macroalgae (Characeae Family)

These plants can be more fragile than vascular plants and extra care must be taken to minimize damage to key diagnostic features. The goal is to transport live plants to an office or laboratory where they can be examined under a microscope, used in genetic analyses research, and pressed and preserved as herbarium mounts.

- Whirl-pak bags should be used to transport and temporarily store specimens.
- Use lake water to fill whirl-pak to bottom of white line (about 2/3rds full).
- Place only a few individual plants in each whirl-pak bag.
- Grasp each wire end of the bag and twirl quickly until the bag is tightly sealed. Twist the wire ends together to secure the twirled bag. This should result in a large air pocket at the top of the bag that provides a protective cushion for the plants while transporting.
- Protect from sun while in the field; place bags in a shaded area such as inside a cooler (no ice).
- ***DO NOT REFRIGERATE! DO NOT ADD ICE!***

If collecting Characeae as part of the MNDNR collaborative research project with The New York Botanical Garden (contact Donna Perleberg for more information):

- Collect plants in triplicate – one sample per bag.
- Label each whirl-pak bag.
- Place the 3 whirl-pak bags into one labeled gallon Ziploc bag.
- Live specimens can be shipped via FedEx or other carrier, but overnight delivery is recommended.

Mosses (bryophytes)

- Use a 2 lb brown paper bag (never plastic) to store collected samples in the field (Janssens 2007).
- Collect only enough to fill the bottom of the bag with a single layer of stems.
- Keep freshly collected samples in a large mesh laundry or burlap bag so they have adequate circulation until they can be dried properly.

Collecting equipment

- Field notebook or iPad to record collection information
- GPS
- Permanent marker
- Labels on Waterproof paper (if not marking outside of bag)
- View tube (Figure A3) or snorkel and mask
- Hand lens
- Garden rake (Figure A1) or grappling hook
- Small shovel to collect roots of emergent plants

- Plastic tray to float and rinse plants
- Plastic squirt bottle to rinse plants
- Ziploc bags (assortment of quart and gallon size)
- Whirl-pak bags (18 oz., 4.5"x 9", write-on)
- 2 lb brown paper bags (for aquatic mosses)
- Cooler (with ice for vascular plants; no ice for macroalgae)

Collection information

An example herbarium label is provided (Figure 10-1). The minimum required information for each collection includes:

- Scientific name
- Site location – a georeferenced location; latitude/longitude is preferred by most herbaria. UTM coordinates can be converted using online calculators such as geoplaner
- Lake name, county and MNDNR Lake Identification number
- Collector name
- Collection date

Additional information such as associated plant taxa, water depth, substrate type and plant abundance can also be included on the label to help inform statewide information on the habitat of the species.

If you collect more than a few specimens per year, it is also useful to assign a unique collection number to each plant collection and include it on the label. Some collectors assign a number in chronological order as they collect such as the following:

> Coll. #CLM95 (represents the 95th collection made by Courtney L. Millaway)

An alternative is to assign a collection number based on the survey date and total number of collections made that date such as the following:

> Coll. #DJP2018.0822-28 (represents the 28th collection made on August 22, 2018 by Donna J. Perleberg)

Labels should be printed on acid-free archival paper, cut out, and included with each specimen inside the newsprint once the specimen is properly dried. (For bryophytes, attach label to outside of paper bag). If submitting the specimen to an herbarium, refer to the institution's specific guidelines for specimen collection and submission.

Preserving aquatic plants

Pressing vascular plants and macroalgae for herbarium mounts

Most aquatic plants can be preserved for long term storage by pressing in a plant press (a primary exception is aquatic mosses which should not be pressed). A wood frame plant press can be purchased or constructed (two pieces of wood, 11”x 16” x1/4”). Plant specimens and a label (or collection number) are placed in newsprint to separate individual collections. Each specimen is then layered between two pieces of blotter paper and then with a piece of corrugated cardboard on top and bottom. The blotter paper absorbs water, and the cardboard provides vents for aeration. Repeat layering with each additional specimen. Stacks of pressed specimens (with blotters and cardboard) are placed between the wooden herbarium press and the press can be tightened with straps (Figure 10-2).

Time and care should be taken to make create quality specimens. For most specimens, it is best to press material immediately upon collection. For some species of Characeae, pressing the plants in the boat or at the lake is the best way to keep branchlets intact.

Plant arrangement on herbarium sheet

Arrange plants in a way that leaves an open space in the lower right-hand corner of the herbarium sheet for a specimen label. Arrange plants carefully to maximize preservation of diagnostic features. Spread out leaves, flowers and fruits to avoid overlap and so they can be observed from different angles. Plants with stems taller than the herbarium sheet can be folded in a “V” or “W” shape. Plant parts, including seeds, that detach from the specimen can be placed in a small fragment envelope, labeled and included with the specimen.

Most emergent and some submerged plants can be arranged, pressed and dried directly between newspaper sheets. For many submerged plants, however, leaves and other structures need to be “floated” onto paper to facilitate separation of plant features to a more natural, non-collapsed form:

- Place plant on archival paper in a tray of water and arrange features
- Jointly lift paper and plant from water, allowing water to drain from bottom of paper

Alternatively, a plastic squirt bottle can be used to add water onto the paper to separate leaves and other plant parts. Parchment paper or wax paper can be placed on top of plants to prevent the plant specimen from adhering to the newspaper. This is particularly important for macroalgae (Characeae Family), *Brasenia* (watershield), *Utricularia* (bladderwort), *Myriophyllum* (water milfoil) and other fine-leaved submerged plants.

Pressing and drying plants

Do not overtighten or place heavy weights on the press as this will break plant cells, particularly in Characeae. The plant press should be checked daily to replace wet blotters with dry blotters. Dried specimens should be stored in an airtight plastic box or herbarium cabinet to prevent insect damage. Do not use a microwave to dry plants and do not use a heated drier for Characeae specimens; both can result in cell damage that prevents DNA analysis and may hinder morphological analysis.

Pressing equipment

- Plastic tray
- Squirt bottle for water
- Archival (100% cotton) paper (8”x11”) for Characeae
- Archival (100% cotton) paper (11.5’’x16.5’’) for vascular plants
- Parchment or wax paper (place directly over Characeae specimens and vascular specimens that may stick to newsprint)
- Newsprint
- Blotters (12”x18”)
- Cardboard ventilators (12”x18”)
- Plant press (or 2 pieces of plywood approx. 12”x18”x14”)
- Pencil (for writing collection number on newsprint or herbarium sheet)

Preservation of aquatic mosses

Aquatic mosses should not be pressed. The preferred method of preservation is to dry the plants within the paper collection bag (Janssens 2007).

- Remove excess substrate if present to prevent abrasion to plant
- Label paper bag with collection number and date
- Dry plants in the paper collection bag in front of a fan or in a plant dryer at $60^{O}C$

Photographic documentation of plants

When not to collect plant vouchers

In some unique situations it may not be possible or wise to collect and preserve live plant material to document a species. In these situations, good quality photographs may be helpful to verify the species’ identity and document its occurrence.

If a plant population appears to be small with only a few individuals present, surveyors should consider whether collecting a voucher specimen may harm the population. This is a particular concern for rare species. Fortunately, most submerged aquatic plant species that are listed as rare are often found to be locally abundant.

In Minnesota, collecting plants in State Parks, National Forests and many other municipal parks is prohibited. Special permits can be obtained for scientific surveys and rare plant collection, but these must be obtained in advance.

Finally, surveyors may encounter situations where they can visually see a plant but cannot safely or legally access the site to make a collection. In all these situations, photographs may be the most appropriate means to verify the plant's identity and document its occurrence.

Taking photographs to aid in plant identification and documentation

Photographs are most useful for plants that can be identified using macroscopic features such as flower color and leaf arrangement. Tips for taking good quality photographs to aid in plant identification include the following:

- If possible, take photographs of the plant as you encountered it at the site. (Is it growing as an emergent? Matted to the surface?). Try to include photographs of the entire plant as well as close-up photographs of key features.
- If tangled with other plants, gently separate and photograph the individual plant on its own
- Include an item in the photograph for scale (i.e. ruler, coin)
- For submerged aquatic plants, photograph the plant in a tray of water or against a solid color background
- If present, photograph plant parts that may be diagnostic (flowers, fruit, leaf arrangement, leaf veins)
- If using a digital camera, turn on "location" to obtain a dated, georeferenced photograph

Data management

Herbarium specimens collected by LEU are entered in a FileMaker database; MBS enters collection data in a Microsoft Access database. These databases are used to create herbarium labels and to export required data to herbaria. Minnesota aquatic plant specimens collected by MNDNR are primarily deposited at the University of Minnesota Bell Museum and New York Botanical Garden. These herbaria have online websites where digital images of specimens can be viewed and data on species collections can be downloaded.

Figure 10-1 Example herbarium label

Aquatic Plants of Minnesota, U.S.A.
CERATOPHYLLACEAE
Ceratophyllum demersum L.

Lake: Elephant ID:69081000 St. Louis County, MN
Latitude 48.18410 Longitude -92.733206
southeast bay. Substrate: muck; Depth: 6 ft

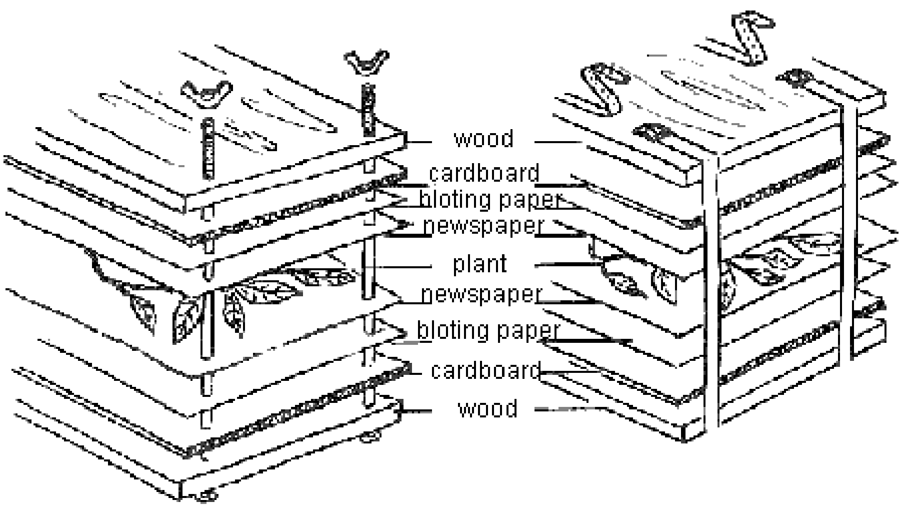
Associates: *Nymphaea odorata, Nuphar variegata, Potamogeton epihydrus, P. zosteriformis, Myriophyllum sibiricum*

Donna J. Perleberg
Coll. #DJP2018.0822-28

August 22, 2018 DNR Permit #23218
Minnesota Department of Natural Resources

Figure 10-2 Herbarium press components

(Source: American Museum of Natural History)



[How to press and preserve plants]

References

Aaseng, N.E., J.C. Almendinger, R.P. Dana, D.S. Hanson, M.D. Lee, E.R. Rowe, K.A. Rusterholz and D.S. Wovcha. 2011. Minnesota's native plant community classification: A statewide classification of terrestrial and wetland vegetation based on numerical analysis of plot data. Biological Report No. 108. Minnesota County Biological Survey, Ecological Land Classification Program, and Natural Heritage and Nongame Research Program. Minnesota Department of Natural Resources. St. Paul.

Ahrenstorff, T.D., G.G. Sass and M.R. Helmus. 2009. The influence of littoral zone coarse woody habitat on home range size, spatial distribution, and feeding ecology of largemouth bass (*Micropterus salmoides*). Hydrobiologia. 623:223-233.

Beaulieu C, Lavoie C, Proulx R. 2018 Bookkeeping of insect herbivory trends in herbarium specimens of purple loosestrife (*Lythrum salicaria*). Phil. Trans. R. Soc. B 374: 20170398.

Braun-Blanquet, J. 1965. Plant sociology; the study of plant communities. (Transl. rev. and ed. by C.D. Fuller and H.S. Conard). Hafner, London.

Calinger K.M., S. Queenborough, P.S. Curtis. 2013. Herbarium specimens reveal the footprint of climate change on flowering trends across north-central North America. Ecology Letters. 16:1037–1044.

Caratti, J.F. 2006. Point Intercept (PO). IN: Lutes, D.C., R.E. Keane, J.F. Caratti, C.H. Key, N.C. Benson, S. Sutherland, and L.J. Gangi. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Research Station. P. PO-1-17.

Carter, R. 2009. Preparation and Use of Voucher Specimens for Documenting Research in Weed Science. Weed Technology. 21-1101-1108.

Cheal D. 2008. Repeatability of cover estimates? Ecological Management & Restoration 9(1): 67-68.

Christensen, D.L., B.R. Herwig, D.E. Schindler, and S.R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecological Applications 6:1143–1149.

Crow, G.E. and C.B. Hellquist. 2000. Aquatic and wetland plants of Northeastern North America. 2 volumes. The University of Wisconsin Press, Madison.

Daubenmire. R.F. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:43-64.

Daubenmire, R.F. 1968. Plant communities; a textbook of plant synecology. Harper and Row. NY. 300 pp.

Deppe, E.R. and R.C. Lathrop. 1992. A comparison of two rake sampling techniques for sampling aquatic macrophytes. In: Research Management Findings, Bureau of Research – Wisconsin Department of Natural Resources, No. 32, March 1992.

Downing J. A., M. R. Anderson. 1985. Estimating the standing biomass of aquatic macrophytes. Canadian Journal of Fisheries and Aquatic Sciences 42:1860-1869.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby and J.P. Gibbs. 2001. Monitoring Plant and Animal Populations. Blackwell Science. Malden, Massachusetts. 360 pp.

Espinosa, F. and M. Pinedo. 2018. On the use of herbarium specimens for morphological and anatomical research. Botany Letters. 165:361-367.

Everill P.H., R.B. Primack, E.R. Ellwood, E.K. Melaas. 2014. Determining past leaf-out times of New England's deciduous forests from herbarium specimens. American Journal of Botany 101:1293–1300.

Francis, T.B. and D.E. Schindler. 2006. Degradation of littoral habitats by residential development: woody debris in lakes of the Pacific Northwest and Midwest, United States. Ambio 35: 274-280

Garrison, P.J., D.W. Marshall, L. Stermick-Thompson, P.L. Cicero and P.D. Dearlove. 2005. Effects of pier shading on littoral zone habitat and communities in Lakes Ripley and Rock, Jefferson County, Wisconsin. Wisconsin Department of Natural Resources. PUB-SS-1006 2005.

Goodall, D.W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. Australian Journal of Scientific Research. Series B5:1-41.

Greig-Smith, P. 1983. Quantitative Plant Ecology. University of California Press, Berkeley, California, USA.

Hall, F.C. 2001. Photo point monitoring handbook: Part A - field procedures. Gen. Tech. Rep. PNW-GTR-526.Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 pp. 2 parts.

Harman, W. N., M. F. Albright and C.M. Snyder. 2008. Aquatic macrophyte management plan facilitation, Lake Moraine, Madison County, N.Y., 2007 Tech. Sept. #25. SUNY Oneonta Bio. Fld. Sta., Oneonta, NY.

Hatton, T.J., N.E. West and P.S. Johnson. 1986. Relationships of the error associated with ocular estimation and actual total cover. Journal of Range Management. 39(1):91-92.

Hauxwell, J. S. Knight, K. Wagner, A. Mikulyuk, M. Nault, M. Porzky, and S. Chase. 2010. Recommended baseline monitoring of aquatic plants in Wisconsin: sampling design, field and laboratory procedures, data entry and analysis, and applications. Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010. Madison, Wisconsin, USA.

Heywood, J.S. and M.D. DeBacker. 2007. Optimal sampling designs for monitoring plant frequency. Rangeland Ecology and Management. 60(4): 426-434.

Indiana Department of Natural Resources. 2007. Tier II aquatic vegetation survey protocol. Indiana Department of Natural Resources, Division of Fish and Wildlife. Indianapolis, IN.

Janssens, J.A. 2007. Description of Bryophyte Assemblages of Mesohabitats. (available as PDF from the author, janss008@umn.edu).

Jennings, M.J., E.E. Emmons, G.R. Hatzenbeler, C. Edwards, and M.A. Bozek. 2003. Is littoral habitat affected by residential development and land use in watersheds of Wisconsin lakes? Lake and Reservoir Management. 19(3) 272-279.

Jennings, M, D., Faber-Langendoen, R. Peet., et al. 2004. Guidelines for describing associations and alliances of the U.S. national vegetation classification. Version 3.0. Vegetation Classification Panel, Ecological Society of America. Washington, DC.

Jesson, R., and R. Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Game Investigational Report No. 6. Minnesota Department of Conservation, Division of Game and Fish, Section of Research and Planning, Fish and Wildlife Surveys Unit, St. Paul. 10 pp.

Johnson, J.A. and R.M. Newman. 2011. A comparison of two methods for sampling biomass of aquatic plants. Journal of Aquatic Plant Management 49:1-8.

Kershaw, K. 1966. Quantitative and dynamic ecology. Edward Arnold Ltd. London. 183 pp.

Knopik, J. and Simon, S. 2016. GIS Manual for MN DNR Lake Plant Surveys.

Kuchler, A.W. 1951. The relation between classifying and mapping vegetation. Ecology 32:275-283.

Maceina, M.J., Shireman, J.V., Langeland, K.A., and D.E. Canfield Jr. 1984. Prediction of submersed plant biomass by use of a recording fathometer. J. Aquat. Plant Manage. 22:35-38.

Madsen, J.D. 1993. Biomass techniques for monitoring and assessing control of aquatic vegetation. Lake and Reservoir Management. 7: 141-154.

Madsen J.D. and J.A. Bloomfield. 1993. Aquatic vegetation quantification symposium: an overview. Lake and Reservoir Management 7:137-140.

Madsen, J.D. 1999. Point intercept and line intercept methods for aquatic plant management. *APCRP Technical Notes Collection* (TN APCRP-M1-02). U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Madsen, J.D. and R.M. Wersal. 2012. A review of aquatic plant monitoring and assessment methods. Geosystems Research Institute, Mississippi State Univ. A report for Aquatic Ecosystem Restoration Foundation.

Maceina, M. J. and J. V. Shireman. 1980. The use of a recording fathometer for determination of distribution and biomass of hydrilla. Journal of Aquatic Plant Management 18:34-39.

Manley, P.N., B. Van Horne, J.K. Roth, W.J. Zielinski, M.M. McKenzie, T.J. Weller, F.W. Weckerly and C. Vojta. 2006. Multiple species inventory and monitoring technical guide. Gen. Tech. Rep. WO-73., U.S. Department of Agriculture, Forest Service, Washington D.C. 204 pp.

Marburg, A.E., M.G. Turner, and T.K. Kratz. 2006. Natural and anthropogenic variation in coarse wood among and within lakes. Journal of Ecology 94:558–568.

Mikulyuk, A., J. Hauxwell, P. Rasmussen, S. Knight, K.I. Wagner, M.E. Nault and D. Ridgely. 2010. Testing a methodology for assessing plant communities in temperate inland lakes. Lake and Reservoir Management 26:54-62.

Minnesota Department of Natural Resources. 1993. Lake Survey Manual. Section of Fisheries, St. Paul.

Minnesota Department of Natural Resources. 2003. Field Guide to the native plant communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, St. Paul.

Minnesota Department of Natural Resources. 2005. Aquatic vegetation mapping guidelines (working version). Minnesota Department of Natural Resources. Section of Fisheries. St. Paul.

Minnesota Department of Natural Resources, Division of Ecological Resources. 2008. Rare Species Guide: An online encyclopedia of Minnesota's rare native plants and animals. Minnesota Department of Natural Resources, St. Paul, Minnesota. www.dnr.state.mn.us/rsg. Accessed 20 December 2018.

Minnesota Department of Natural Resources 2011. Shallow Lakes Program Intern Handbook. Minnesota Dept. Of Natural Resources. Shallow Lakes Program. Brainerd, MN.

Minnesota Department of Natural Resources. 2019. Division of Ecological Resources, Minnesota Biological Survey. Procedures: Rare Plant Surveys. Minnesota Department of Natural Resources, St. Paul, Minnesota. Rare plant survey procedures. Accessed 04 January 2019.

MNTaxa. 2013. Minnesota State checklist of vascular plants. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, St. Paul. Minnesota state checklist of vascular plants Accessed 04 January 2019.

Moyle, J.B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. American Midland Naturalist 34:402-420.

Myhre, K.M. 1998. Method Used in Creating Species Lists for Lakes. Minnesota Department of Natural Resources. Minnesota County Biological Survey Unit.

Newman, R.M. and K. Holmberg, J. Foley, D. Middleton. 1998. Assessing macrophytes in Minnesota's game lakes. Final Report to the Minnesota Dept. of Natural Resources, Wetland Wildlife Populations and Research Group, Bemidji. 69 pp.

Nichols, S.A. 1984. Quantitative methods for assessing macrophyte vegetation. In: Ecological assessment of macrophyton: collection, use, and meaning of data. ASTM STP 843. W.M. Dennis and B.G. Isom, eds. American Society for Testing and Materials. pp. 7–15.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Lake and Reservoir Management 15(2):133–141.

Park, G.N. 1972. Point height intercept analysis a refinement of point analysis for structural quantification of low arboreal vegetation. New Zealand Journal of Botany. 11(1): 103-114.

Park, I.W. 2012. Digital herbarium archives as a spatially extensive, taxonomically discriminate phenological record; a comparison to MODIS satellite imagery. International Journal of Biometeorology. 56: 1179−1182.

Perleberg, D.J. 2001a. Evaluation of DNR Fisheries Lake Vegetation Survey Method. Unpublished report. Minnesota Department of Natural Resources, Ecological Services Division, Brainerd. 32 pp.

Perleberg, D.J. 2001b. Estimating species abundance and distribution: a comparison of three quantitative survey methods for lakewide assessment of submerged macrophyte communities. Unpublished report. Minnesota Department of Natural Resources, Ecological Services Division, Brainerd. 13 pp.

Perleberg, D., P. Radomski, and S. Simon. 2012. Score Your Shore: citizen shoreline description survey. Version 2. Minnesota Department of Natural Resources. Division of Ecological and Water Resources. Lakes and Rivers Program. Brainerd, MN 56401.

Primack, R. and A.S. Gallinat. 2017. Insights into grass phenology from herbarium specimens. New Phytologist. 213: 1567-1568.

Radomski, P. and T. Goeman. 2001. Consequences of human lakeshore development on emergent and floating-leaf vegetation abundance. North American Journal of Fisheries Management 21:46-61.

Radomski, P., K. Woizeschke, K. Carlson and D. Perleberg, D. 2011. Reproducibility of emergent plant mapping on lakes. North American Journal of Fisheries Management 31 (1) 144-150.

Radomski, P. and D. Perleberg. 2012. Application of a versatile aquatic macrophyte integrity index for Minnesota lakes. Ecological Indicators 20:252-268.

Radomski, P. and B.V. Holbrook. 2015. A comparison of two hydroacoustic methods for estimating submerged macrophyte distribution and abundance: a cautionary note. Journal of Aquatic Plant Management 53:151-159.

Roth, B.M., I.C. Kaplan, G.G. Sass, P.T. Johnson, A.E. Marburg, A.C. Yannarell, T.D. Havlicek, T.V. Willis, M.G. Tuner, and S.R. Carpenter. 2007. Linking terrestrial and aquatic ecosystems: the role of woody habitat in lake food webs. Ecological Modelling 203:439-452.

Sabol, B. M., R. E. Melton Jr., R. Chamberlain, R., P. Doering, and K. Haunert. 2002. Evaluation of a digital echo sounder system for detection of submersed aquatic vegetation. Estuaries 25:133–141.

Sass, G.G., J.F. Kitchell, S.R. Carpenter, T.R., Hrabik, A.E. Marburg, and M.G. Turner. 2006. Fish community and food web responses to a whole-lake removal of coarse woody habitat. Fisheries 31:321–330.

Sass, G.G., S.R. Carpenter, J.W. Gaeta, J. F. Kitchell, and T.D. Ahrenstorff. 2012. Whole-lake addition of coarse woody habitat: response of fish populations. Aquatic Sciences - Research across Boundaries 74:255–266.

Sass, G.G., S.L. Shaw, C.C. Grenstermacher, A.P. Porreca, and J.J. Parkos III. 2023. Structural habitat in lakes and reservoirs: physical and biological considerations for implementation. North American Journal of Fisheries Management 43:290–303.

Simmonds, J., and D. MacLennan. 2005. Fisheries Acoustics: Theory and Practice, 2nd edition. Blackwell Science, Oxford.

Spencer D.F. and L.C. Whitehand. 1993. Experimental design and analysis in field studies of aquatic vegetation. Lake and Reservoir Management. 7:165-174.

Thomas, G. L., S. L. Thiesfeld, S. A. Bonar, R. N. Crittenden, and G. B. Pauley. 1990. Estimation of submergent plant bed biovolume using acoustic range information. Canadian Journal of Fisheries and Aquatic Sciences 47: 805-812.

Valley, R. D., and M. T. Drake, 2007. What does resiliency of a clear-water state in lakes mean for the spatial heterogeneity of macrophytes? Aquatic Botany 87: 307–319.

Wetzel, R.G., 2001. Limnology, Lake and River Ecosystems. 3rd ed. Academic Press, New York.

Whittaker, R.H. (ed). 1978. Classification of Plant Communities. Junk Publishers, The Hague, Boston. 408 pp.

Whysong, G.L. and W.W. Brady. 1987. Frequency Sampling and Type II Errors. Journal of Range Management. 40(5): 472-474.

Williams, L.D., G.O. Dick, R.M. Smart, and C.S. Owens. 2008. Point-intercept and surface observation GPS (SOG): A comparison of survey methods-Lake Gaston, NC/NV. ERDC/TN APCRP-EA-019. U.S Army Engineer Research and Development Center, Vicksburg, MS.

Wisconsin Department of Natural Resources. 2008. Wisconsin's critical habitat designation manual: a comprehensive conservation strategy for identification of sensitive areas and public rights features in Wisconsin lakes. Madison, WI.

Wisconsin Department of Natural Resources. 2020. Lake shoreland and shallow habitat monitoring field protocol. EGAD # 3400-2020-19. Madison, WI.

Xie, Y., Z. Sha, and M. Yu. 2008. Remote sensing imagery in vegetation mapping: a review. Journal of Plant Ecology 1: (1) 9-23.

Yin, Y., J.S. Winkelman and H.A. Langrehr. 2000. Long Term Resources Monitoring Program procedures: Aquatic vegetation monitoring. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, April 2000. LTRMP 95-P002-7. 8 pp + Appendices A-C.

Yin, Y. and R. Kreiling 2011. The evaluation of a rake method to quantify submersed vegetation in the Upper Mississippi River. Hydrobiologia. 675:187-15.

Glossary

Organization Abbreviations

Abbreviation	Definition
EWR	Ecological and Water Resources Division (within MNDNR)
LEU	Lake Ecology Unit (Unit within MNDNR – EWR)
MBS	Minnesota Biological Survey (Unit within MNDNR – EWR)
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency

Appendix A: Equipment Checklists and Photos

Table A1. Checklist of equipment

Chapter		**3**	**4**	**5**	**6**	**7**	**8**	**9, 10**
Survey Method		**Score the Shore**	**Mapping Floating and Emergent Plant Stands**	**Transect**	**Point Intercept**	**Quantitative Nearshore**	**Hydroacoustics**	**Plant Collecting**
Clipboard, pencils, permanent markers		X	X	X	X	X	X	X
Paper data forms: Lake contour map Aerial photograph of lake Survey station map		X	X	X	X	X	X	X
iPad	With Filemaker App				X	X		
	With Collector for GIS App	X	X					
Georeferenced camera		X						
GPS (and spare batteries)		X		X	X	X		X
Standard Depth finder		X	X	X	X	X		
Lowrance HDS depth finder with sonar							X	
SD card with microchip							X	
Sampling rake (double-headed attached to 30+ feet of rope)				X	X	X		X
8 feet pole marked in 1-foot increments				X	X	X		
View tube or snorkel				X	X	X		X
Plant field guides			X	X	X	X		X
Hand lens				X	X	X		X
Tray and wash bottle								X
Plant collecting bags								X

Figure A1. Double-headed, weighted garden rake for plant sampling

Figure A2. Using RAM mounts to secure electronic equipment to boat console

Figure A3. Commercially purchased View tube used to observe submerged vegetation

A "view tube" can be used to improve visual observation of submerged aquatic plants. The tube allows the surveyor to wade through shallow water and view plants as if they were snorkeling.

Commercially produced tubes are available from several outdoor product companies and range in prices from about $70 to $125.

A view tube can also be constructed from pvc pipe or a plastic bucket or trash bin by sealing one end with clear plexiglass. Handles and a foam or neoprene face cushion can be added.

For specific directions and materials to construct a view tube:

1. from pvc pipe: University of Wisconsin Extension Lakes, Steven Point, Wisconsin
   Aquascope directions

2. from a plastic bucket: State of Connecticut, Department of Energy and Environmental Protection
   How to make a clear bottom bucket

3. from a plastic trash bin: Reed, R.N., C.A. Young and R.T. Zappalorti. 2012. Snake Hibernacula and Communal Denning. Chapter 7. In: Reptile Biodiversity, Standard Methods for Inventory and Monitoring. Edited by Roy W. McDiarmid, Mercedes S. Foster, Craig Guyer, J. Whitfield Gibbons, and Neil Chernoff. University of California Press. 424 Pp.

Appendix B: Field Data Forms

1. Score the Shore Survey Form
2. Point-Intercept Survey Form
3. Near-Shore Plant Survey Form
4. Sample Plant Label

MNDNR SCORE THE SHORE SURVEY

Survey Date: ________________ pg ___ of ____

LAKE __________________________ Surveyors: ____

LAKE ID __ __ - __ __ __ __ - __ __

Section	Category	Class	Site Number														
LAND USE	Single-Family Residential																
	Several Single-Family Residential Lots																
	Multiple Dwelling Development																
	Resort or Commercial Campground																
	Other Commercial																
	Agricultural																
	Roadway																
	Public Park																
	Campsite																
	Boat Access																
	Undeveloped Nonwetland																
	Undeveloped Wetland																
SHORELAND	Trees	75-100															
		50-74															
		25-49															
		1-24															
		0															
	Shrubs	75-100															
		50-74															
		25-49															
		1-24															
		0															
	Natural Groundcover	75-100															
		50-74															
		25-49															
		1-24															
		0															
SHORELINE	Trees / Shrubs or Wetland	75-100															
		50-74															
		25-49															
		1-24															
		0															
	Natural Groundcover	75-100															
		50-74															
		25-49															
		1-24															
		0															
	overhead woody habitat (Y/N)																
	Emergent and Floating-Leaf Cover	75-100															
		50-74															
		25-49															
		1-24															
		0															
AQUATIC	Man-made openings in plant beds (Y/N)																
	downed woody habitat (Y/N)																
	number of simple docks																
	number of complex docks																
	number of marinas																
	number of lifts																
	number of rafts or other																

MNDNR Point-Intercept Survey Survey Date: __________ pg ___ of ____

LAKE __________________________ Surveyors: _________________________________

LAKE ID __ __ - __ __ __ __ - __ __

	Site number									
DEPTH (ft)										
substrate (BO, RB, GR, SA, SI, MR, MU)										
NO SURVEY - (**SH** = on shore, **D**= too deep)										
Abundance (0 = none, S = sparse, C = common, A = matted)										
PLANT SPECIES NAME										

X = species present in 1m2 sample area/ 0 = found in lake but not in survey point

MNDNR Near-Shore Plant Survey Survey Date: ________ pg ___ of ____

LAKE ________________________ Surveyors: ________________________________

LAKE ID __ __ - __ __ __ __ - __ __

	Site number									
DEPTH (ft)										
substrate (BO, RB, GR, SA, SI, MR, MU)										
NO SURVEY - (**SH** = on shore, **D**= too deep)										
Abundance (0 = none, S = sparse, C = common, A = matted)										
PLANT SPECIES NAME										

X = species present in 25m2 sample area/ 0 = found in lake but not in survey point

Example Aquatic Plant Collection Form

MNDNR Aquatic Plant Collection Form

Plant Id: ____

County: ___________________ DOW: __ __ - __ __ __ __ - __ __

Lake: ____________________________________

GPS (Zone 15 Nad 83) N: __ __ __ __ __ __ __E: __ __ __ __ __ __

Depth zone ____ to ____ feet Substrate _________________

Collector(s) ____

Area Office ____________________

Phone _______________________

Date: __ __ / __ __ / ____

Field
Notes____

Example Aquatic Plant Collection Form

MNDNR Aquatic Plant Collection Form

Appendix C: Score the Shore training guides

Contents

Score The Shore: Land Use Classes

Only one development class is recorded for each developed site. If more than one type of development occurs at a site, select the class that occupies most of the site.

SINGLE-FAMILY RESIDENTIAL

one permanent living structure entirely or partly within survey site

One house entirely within survey site

One house entirely within survey site

Boat house with living quarters

Boat house with living quarters

One home with multiple structures

Trailer house

SINGLE-FAMILY RESIDENTIAL

one permanent living structure entirely or partly within survey site

This site is classified as Single-Family because development (garage) extends into site even though house is outside of site boundaries.

House is hidden but evidence of development includes staircase and garden. May need to review aerial photograph to confirm presence of house.

SEVERAL SINGLE-FAMILY RESIDENTIAL

more than one permanent living structure entirely or partly within survey site

RESORT OR COMMERCIAL CAMPGROUND

May/may not include permanent structures (only developed sites within resort boundaries are classified as resort)

OTHER COMMERCIAL

(e.g., Restaurant, Marina, Hotel, School, etc.)

AGRICULTURAL

Includes pastureland and cropland. If house is present in site, classify as Single-Family Residential


ROADWAY

If house roadway is between lake and house, classify site as roadway. For example, if a road runs through a site and there is a house on the landward side of the road, record the site as “roadway” because most of the site is occupied by the road. If the house occurs between the road and the lake, record the site as “single-family residential”.


PUBLIC PARK

(e.g. ball field, hiking trails, picnic area, may or may not include permanent structures)




CAMPSITE

(may or may not include tent site or single camper)

Sites with mowed paths but no house are classified as campsite

BOAT ACCESS

With or without parking lot and/or dock

UNDEVELOPED – NON-WETLAND

Shoreline vegetation may be terrestrial or wetland but Shoreland vegetation is terrestrial

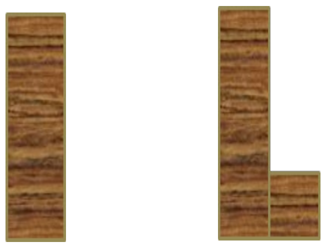
UNDEVELOPED – WETLAND

includes forested and unforested wetland

Score The Shore: Dock Types

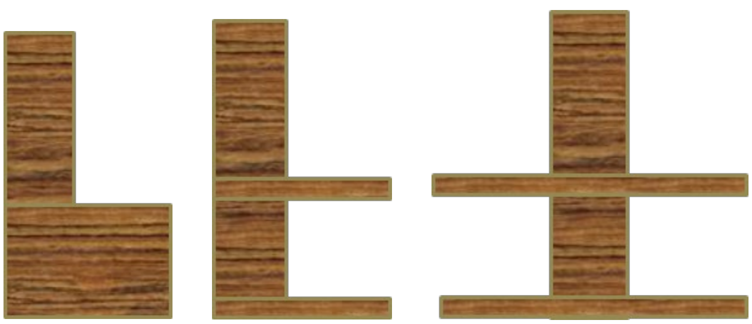
Simple dock

a straight or L-shaped dock; no platforms or slips



Complex dock

a dock that includes platforms and/or slips



Lift

a device for elevating boat above water surface; typically attached to a dock

Raft or other recreational objects

a platform that is anchored offshore and not connected to a dock; may be constructed of wood or other building materials or inflatable; and includes other recreational objects such as slides or trampolines

Marina

a dock with numerous slips that is associated with a commercial facility or multi-dwelling residence

Appendix D: Key to emergent and floating-leaf aquatic plant classes

I. **Emergent plants present in >50% of stand (polygon).** Floating-leaf plants may be absent or present in patches or throughout most of stand and may even cover a substantial portion of stand. Submerged plants may be present or absent. Areas of open water may be interspersed throughout the stand. Identify the most encountered emergent taxa; this will be considered the dominant taxa and will typically comprise more than 50% of the emergent plants. If a dominant emergent taxon cannot be identified, consider mapping the stand as two separate polygons.

-

2. Rush-like plants are the most frequently encountered emergent in stand and are distributed throughout the stand. Dominant taxa typically include bulrush (Schoenoplectus spp.) and/or spikerush (*Eleocharis* spp.). Broad-leaf emergent and/or floating-leaved plants may be present but do not dominate. Submerged plants may be present at any abundance level or may be absent. Sites are often comprised of hard substrates such as sand, gravel, and boulders but may include silt substrates; these are generally not highly organic sites.

-

1. Broad-leaf emergent and floating-leaf plants are absent, or occur in less than 30% of bed………………………………………………………………………………………… Rushes Class

- *dominant taxa may include:*

a. Bulrush (*Schoenoplectus* spp.)
b. Three-square bulrush (*Schoenoplectus pungens*)
c. River bulrush (*Schoenoplectus fluviatile)*
d. Spikerush (*Eleocharis* spp.)

-

2. Broad-leaf (non-Rush) emergent plants and/or floating-leaf plants are present in 30% or more of stand……………………………………………….……… Rushes & Others Class

-

2. Broad-leafed emergent plants (non-Rush) are the most frequently encountered plants in the stand and are distributed throughout the stand. Bulrush and/or spikerush may be present but do not dominate. Floating-leaved and/or submerged plants may be present at any abundance level or may be absent. Sites are often, but not always, comprised of soft substrates and may be high in organic content. *Identify dominant taxa:*

1. Cattails (*Typha* spp.)…………………………………………………………….……Cattail Class

- *Dominant taxa may include:*

a. Cattail (*Typha* spp.): Narrow-leaf cattail and broad-leaf cattail may both be present but it is difficult to identify plants to species and/or only a small portion of the stand can be assessed for species-level identification. Cattail stands identified through aerial photo interpretation should also be placed into general type.
b. Narrow-leaf (*Typha angustifolia*) and/or hybrid (*T. x glauca*) dominate the stand and no areas of broad-leaf cattail are observed.
c. Broad-leaf cattail (*Typha latifolia*).

2. Broad-leaf (non-Cattail) emergent plants and/or floating-leaf plants are present in 30% or more of stand………………………………………….……… Cattails & Others Class

-

2. Wild rice (*Zizania* spp.)………………………………………………………………………………………... go to **2a**
   a. Other emergent and floating-leaf plants are absent, or occur in less than 30% of bed……………………………………………………………………Wild Rice Class
   b. Other emergent and/or floating-leaf plants are present in 30% or more of bed; floating-leaf plants may be present throughout stand……………………………………………………………Wild Rice & Others Class

•

2. Other emergent ………………………………………………………………Other Emergent Class
   - *This class may be subdivided by dominant taxa, examples include:*
     a. arrowhead (*Sagittaria* spp.)
     b. common reed grass (*Phragmites australis*)
     c. pickerelweed (*Pontederia cordata*)
     d. horsetail (*Equisetum fluviatile*)
     e. sedge (*Carex* spp.)
   -

II. **Emergent plants present in <50% of stand (polygon).** Floating-leaf plants are present throughout most of stand often covering >50% of stand. Submerged plants may be present or absent. Areas of open water may be interspersed throughout the stand. Identify the most commonly encountered floating-leaf taxa; this will be considered the dominant taxa and will typically comprise more than 50% of the floating-leaf plants. If a dominant floating-leaf taxa cannot be identified, consider mapping the stand as two separate polygons. <u>Identify the dominant taxa:</u>

•

A. Waterlilies (white waterlily or yellow waterlily)
   1. Other emergent and floating-leaf plants are absent, or occur in less than 30% of stand. Waterlily stands identified through aerial photo interpretation should be placed into this general class………………………………………………………………………………………Waterlily Class
      Dominant taxa may include:
      a. White waterlily (*Nymphaea* odorata)
      b. Yellow waterlily (*Nuphar variegata*)
      c. Both white and yellow waterlily

   •

   2. Other emergent and/or floating-leaf plants are present in 30% or more of bed………………………………………………………………………Waterlily and Others Class

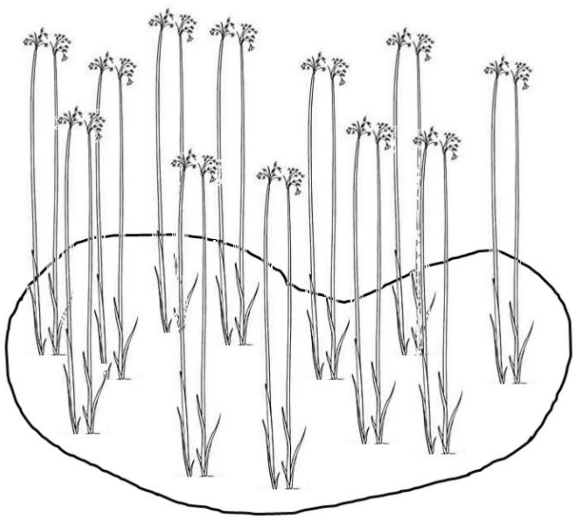
   •

B. Other floating-leaf plant……………………………………………………Other Floating-leaf Class

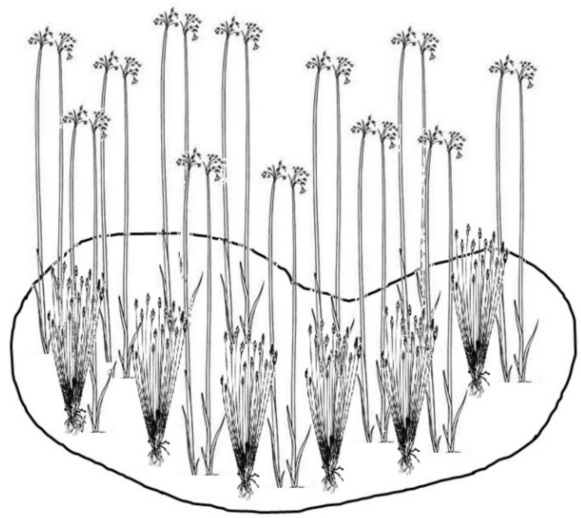
   This subclass may be subdivided by dominant taxa including:
   a. Watershield *(Brasenia schreberi*)
   b. Floating-leaf pondweed (*Potamogeton natans)*
   c. Floating-leaf bur *reed (Sparganium* spp.)
   d. Floating-leaf smartweed *(Persicaria amphibia)*

CLASS: RUSHES

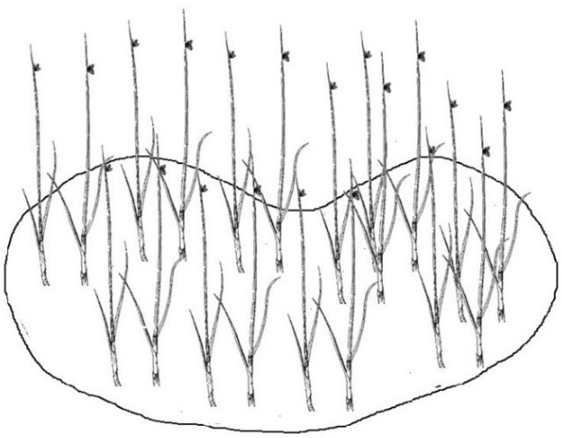
Bulrush



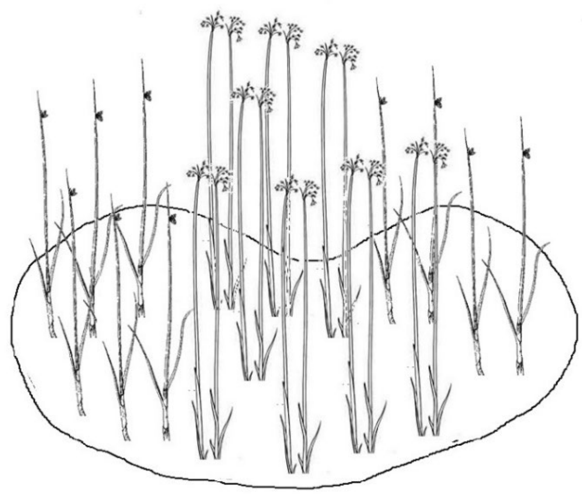
Bulrush-Spikerush



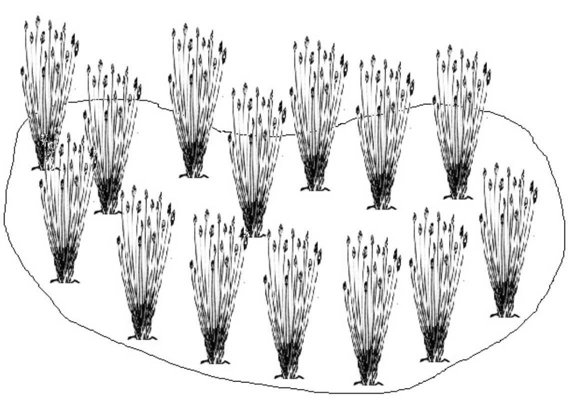
Three-square bulrush



Bulrush-Three-square bulrush



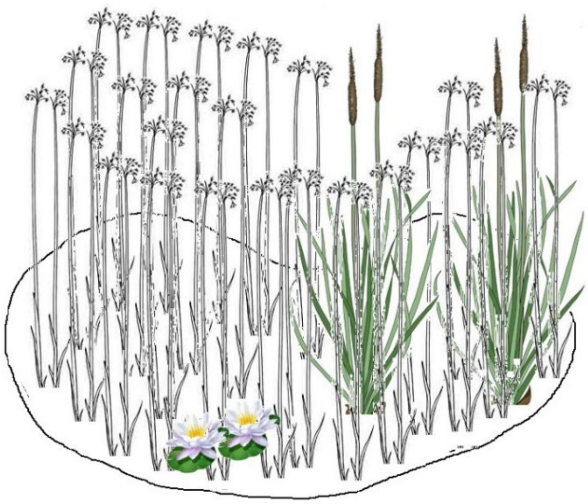
Spikerush



CLASS: RUSHES and Other (leafy plants)

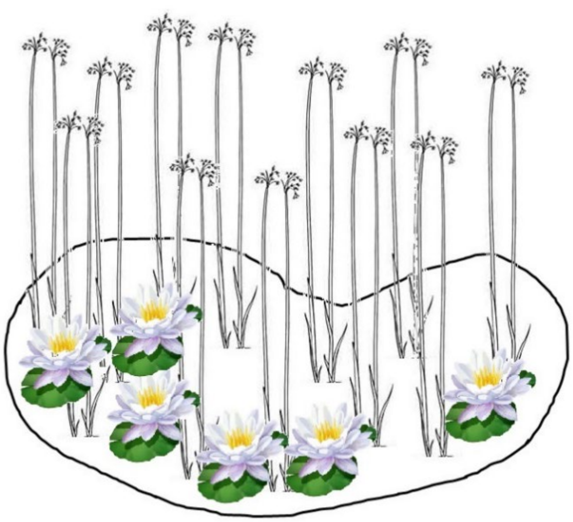
Examples:

Bulrush – Cattail

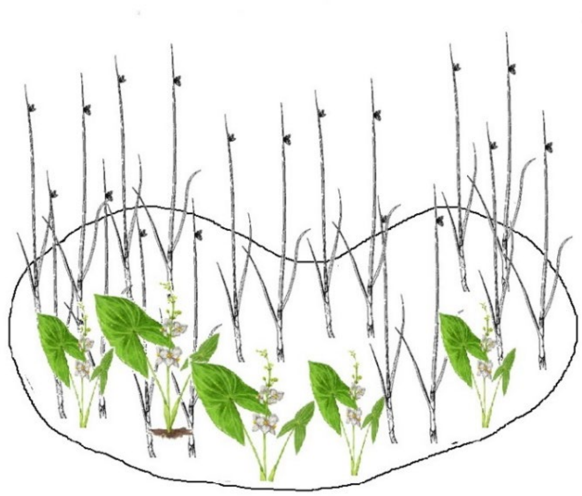


Bulrush – Wild rice

Bulrush – Waterlily



Three-square bulrush - Arrowhead

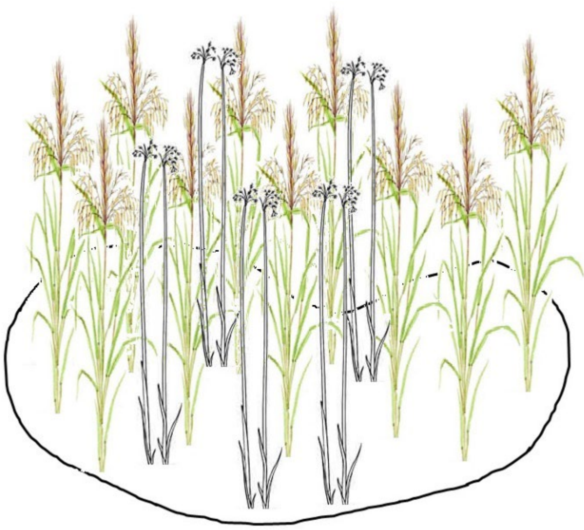


CLASS: Wild Rice

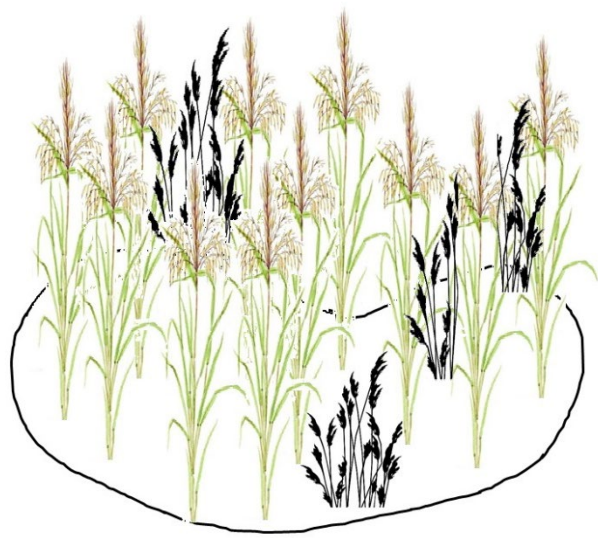
Wild rice

CLASS: Wild Rice & Other (Emergent/Floating)

Wild rice – Rush



Wild rice – Common reed grass

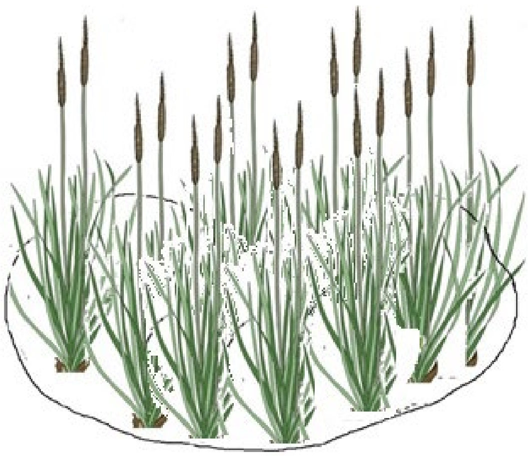


Wild rice – Waterlily

Wild rice – Waterlily

CLASS: Cattail

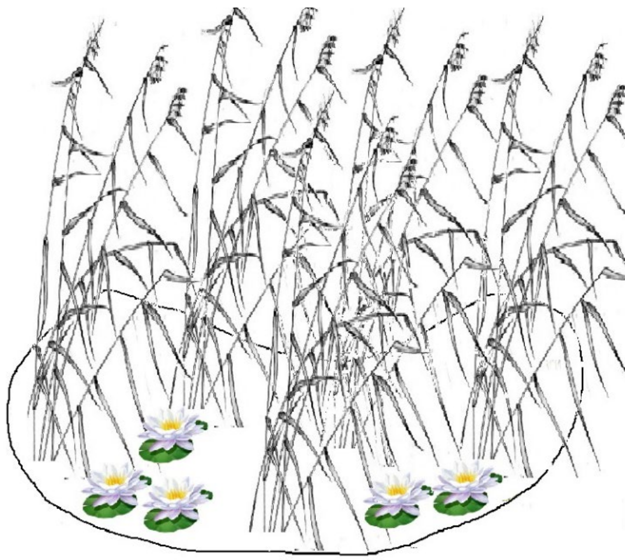
Cattails *Cattail-Arrowhead*



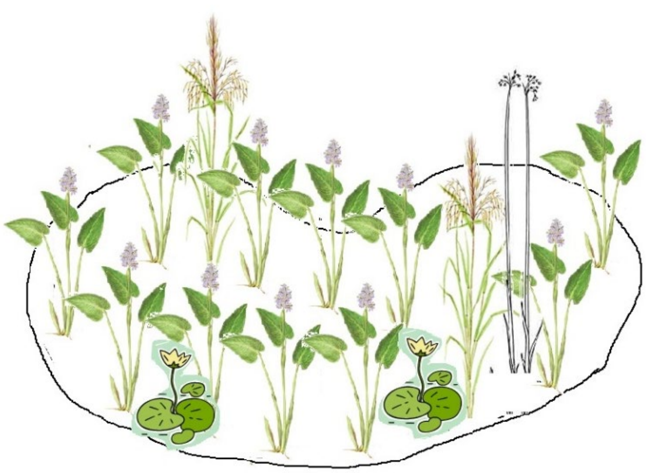
CLASS: Cattail and Others

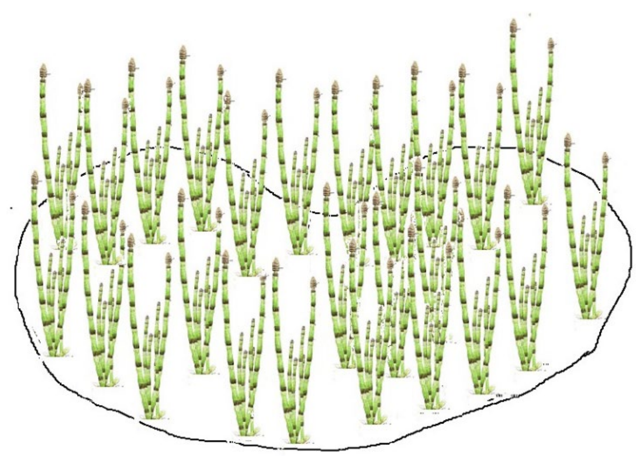
CLASS: Other Emergents

Common reed grass – white waterlily *Bur reed*



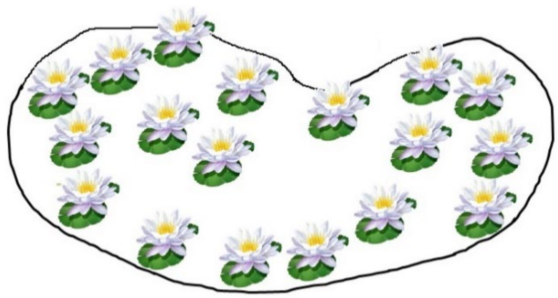
Pickerelweed *Horsetail*



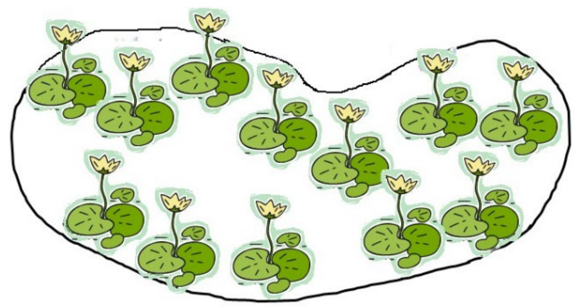


CLASS: Waterlilies

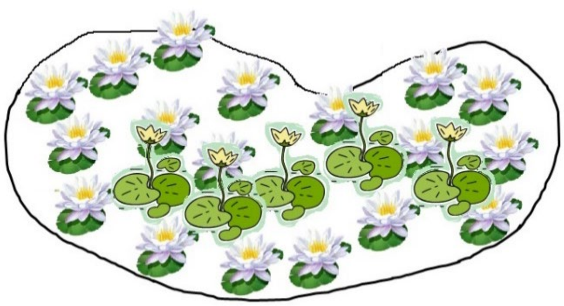
White waterlily



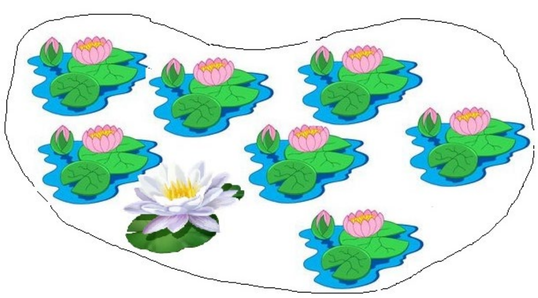
Yellow waterlily



White waterlily – Yellow waterlily

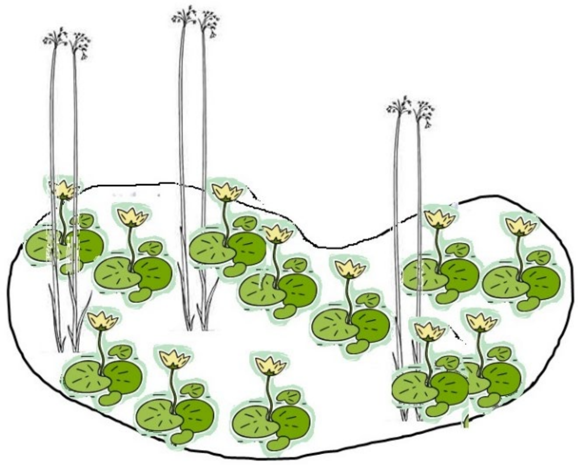


Hybrid Pink Waterlily



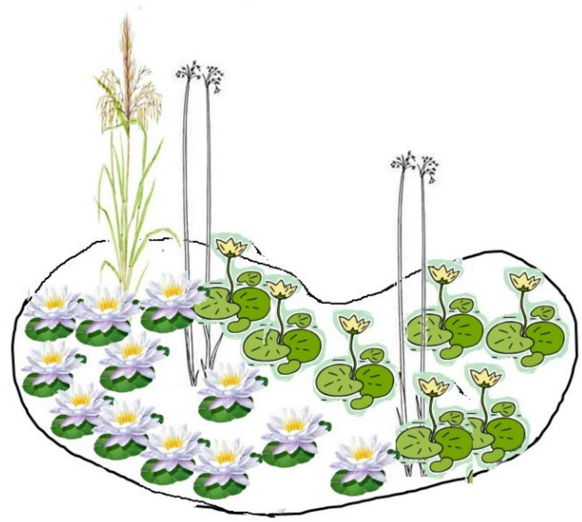
CLASS: Waterlilies with Emergents or other Floating-leaf plants

Waterlily– Bulrush



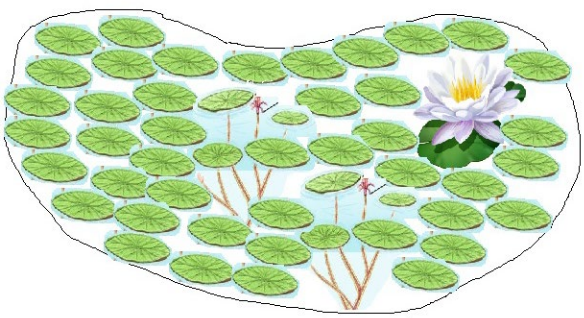
Waterlily – Wild Rice

Waterlily - Bulrush

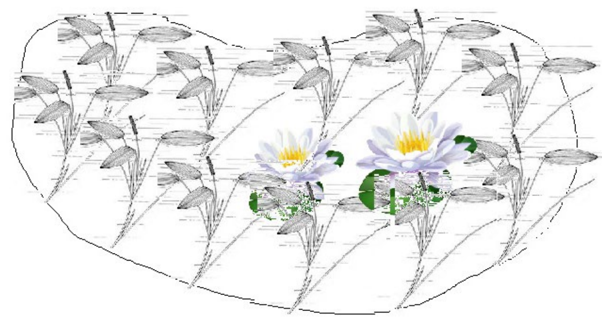


CLASS: Other Floating-leaf plants

Watershield



Floating-leaf pondweed



Floating-leaf Bur reed