MINNESOTA LAKE PLANT SURVEY MANUAL

FOR USE BY MNDNR FISHERIES SECTION AND EWR LAKES PROGRAM

May 4, 2015

PREPARED BY

Donna Perleberg, Paul Radomski, Stephanie Simon, Kristin Carlson and Josh Knopik
Minnesota Department of Natural Resources
Ecological and Water Resources Division
Lakes Program
1601 Minnesota Dr., Brainerd, MN 56401

FUNDING SUPPORT

Development of this manual was supported by the Game and Fish, Heritage Enhancement and Clean Water Funds.

HOW TO CITE THIS DOCUMENT

Perleberg, D., P. Radomski, S. Simon, K. Carlson, and J. Knopik. 2015. Minnesota Lake Plant Survey Manual, for use by MNDNR Fisheries Section and EWR Lakes Program. Minnesota Department of Natural Resources. Ecological and Water Resources Division. Brainerd, MN. 82 pp. and appendices

ACKNOWLEDGEMENTS

We thank Steve Persons, Al Stevens and other members of MNDNR Fisheries Lake Survey Program Committee, Donna Dustin, Peter Jacobson, Andrew Carlson, and Chip Welling for their review and comments on earlier versions of this manual.

We also thank student workers Alex Binsfeld and Courtney Niemela for their careful review of the final document.

CONTENTS

List of Tables

List of Figures

List of Appendices

A. Equipment checklists
B. Field data forms
C. Score The Shore training PowerPoint
D. GIS instructions and tip sheets
E. Key to emergent and floating-leaf aquatic plant classes
F. Vouchering aquatic plant specimens
G. List of Minnesota aquatic plant species including common names, database codes and cross-walk to MNTAXA

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. Therefore, the data collected will be a mix of metric and English units.

CHAPTER 1. INTRODUCTION

Minnesota lakes and plant communities

Glacial activity formed the majority of 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.

Plant community assessments

This manual provides protocols for lake and lakeshore plant data collection so that appropriate data can be collected in an objective, unbiased, and commonly 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 the Division of Ecological and Water Resources (EWR) Lakes Program, in consultation with the MNDNR Fisheries Lake Survey Program Committee. The manual was designed primarily for use by EWR’s Lakes Program and the Fisheries Section. These protocols may also be used by other MNDNR Programs as well as other agencies and consultants. Various MNDNR programs, such as the Mississippi River Long Term Resource Monitoring Program, Wildlife Shallow Lakes Program, Minnesota Biological Survey, and Invasive Species Program have specific protocols that are 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. The Minnesota Lake Plant Survey Manual is divided into chapters based on different plant communities and survey objectives. This manual includes separate protocols for the following plant community types:

1. Lakeshore habitat (rapid assessment) – Chapter 2
2. Shallow water plant stands (mapping and classification) – Chapter 3
3. Lakewide plants (compilation of taxa list) – Chapters 4,6
4. Lakewide vegetation community (quantification of community using the grid point-intercept method) – Chapter 5

Defining management and monitoring objectives

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

1. Learn more about the habitat of the specific lake surveyed.
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 does ice and snow cover influence submerged plant growth?
4. Evaluate the effects of past management.

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.

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 of target plants and individual lake characteristics. Lakewide submerged plant surveys are conducted after significant plant growth is noted in early summer. 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 all of these surveys are conducted by boat, surveyors should select times when weather permits safe boating. 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. 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 management objectives. Undeveloped lakes where little change in development is anticipated and/or remote lakes that are logistically difficult to access may not be scheduled for repeat surveys. 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.

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 in a relatively rapid time period.

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 times a plant is present in a given number of quadrats of a particular size or at a given number of sample points (Figure 1.1). 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 and therefore it may be difficult to determine how the plant community has actually changed based on observed changes in the data without supporting data from other parameters. With georeferenced data, large changes in plant dispersion patterns can be detected by viewing frequency data in GIS but 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 1.2).

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 1.3).

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.

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.

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.

In reality, 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 1.2, 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 specific protocols

Plant communities associated with lakes include:

- terrestrial and wetland plants along shorelands (Chapter 2),
- emergent and floating-leaf plants that are most commonly found in near-shore shallow areas (Chapter 3), and
- submerged plants that may occur in both shallow and deep water (Chapter 4).

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., tree height vs. submerged plant height)
- 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)

Habitat zone definitions

For the purpose of this manual, Habitat Zones are defined as shown in Figure 1.4 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. Some local governments use a distance of 1320 feet. The methods in this manual use land located within 1320 feet of the ordinary high water level in order 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.

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 1.5):

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

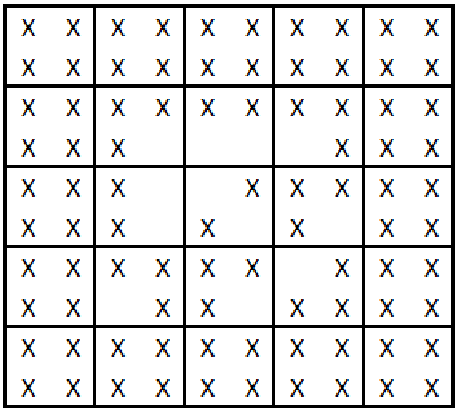
Floating-leaf plants are rooted on the lake bottom, and during peak growth their leaves and flowers float on or just above the water surface. Floating-leaf aquatic plants are defined in M.R. 6280.02 as "aquatic plants that are rooted in the bottom and have their lower portions submersed in water and 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 the majority of vegetative growth is beneath the water surface (Figure 1.6). 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 1.1 Example where frequency data can be used to detect change in plant dispersion and abundance between years or between lakes

Year 1.
Frequency = 25/25 =100%
Plants are evenly dispersed through site.



Year 2.
Frequency = 15/25 = 60%
Plants are clumped at edges of site.

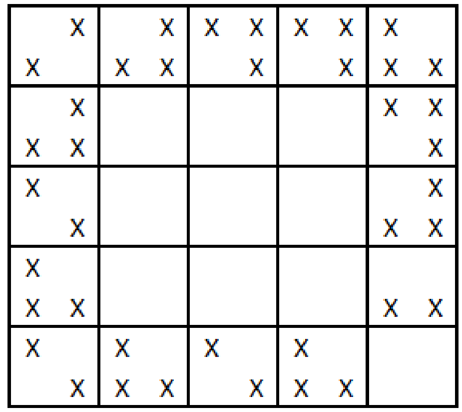
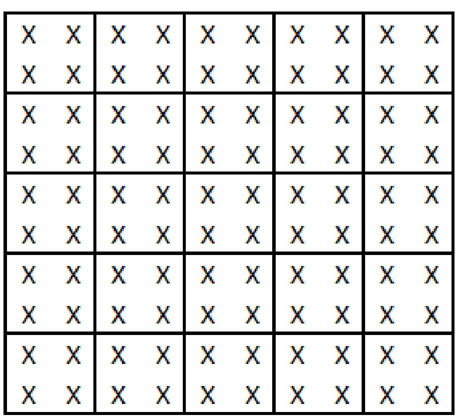


Figure 1.2 Example where plant density increases from Year 1 to Year 2 but frequency does not change

Year 1.
Frequency = 25/25 =100%
Plants are evenly dispersed through site.
Plant abundance is high.



Year 2.
Frequency = 25/25 = 100%
Plants are evenly dispersed through site.
Plant abundance is low.

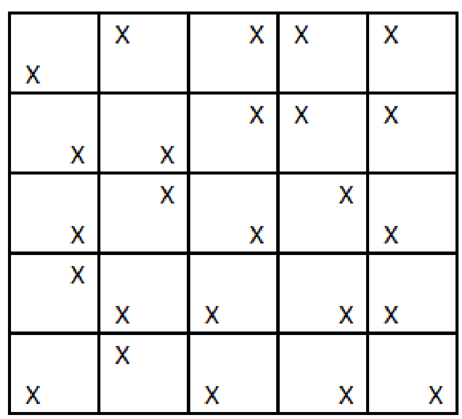
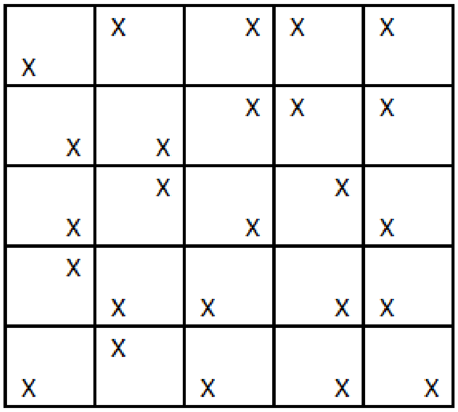


Figure 1.3 Example where survey area size is decreased for more accurate estimation of frequency

Plant community 1
Large plot size
Frequency = 25/25 = 100%



Plant community 1
Small plot size
Frequency = 25/100 =25%

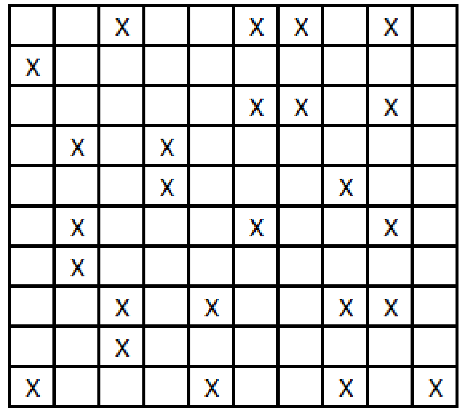


Figure 1.4 Lake habitat zones

For Score The Shore surveys: 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).

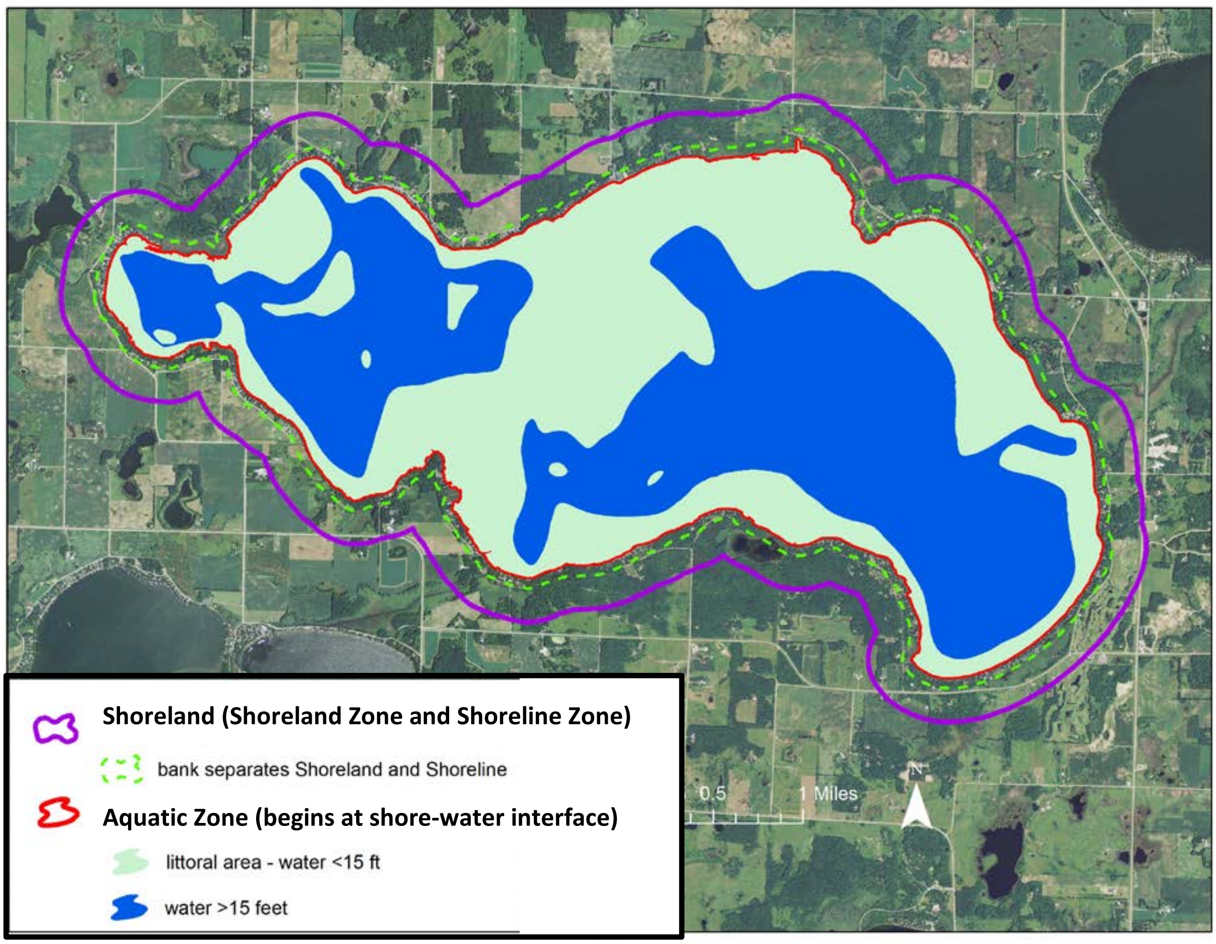


Figure 1.5 Aquatic plant life forms

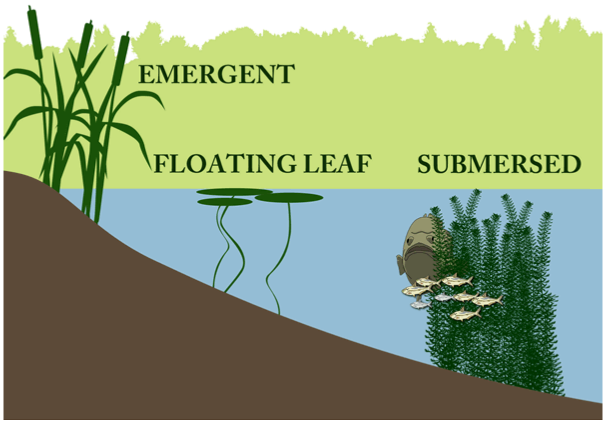


Figure 1.6 Heterophyllous aquatic plant

Submerged plants that have the ability to form floating leaves are grouped into the "Submerged" class for MNDNR aquatic plant surveys.

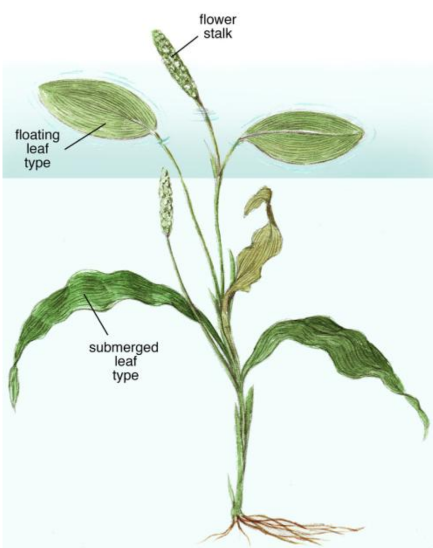


Image courtesy of MNDNR MnAqua Program

CHAPTER 2. 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%) 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 rip-rap 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 such as those conducted by the Minnesota Biological Survey 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 natural 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. An equipment checklist is provided in Appendix A and data entry form can be found in Appendix B.

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. 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.

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.

Establishing survey sites

Each individual survey site is a 33.3 meter (100 feet) shoreline segment. GIS software is used to create center points of these shoreline segments at equal intervals around the lake perimeter (Figure 2.1). The recommended minimum number of survey sites per lake is 20, which results in at least 660 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 2-1). 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. If a Shore The Shore survey has been previously conducted on a lake, then surveyors should use the original survey site locations.

Assessment of habitat by zones

Surveyors use standard criteria to divide the lakeshore into three zones: Shoreland, Shoreline and Aquatic (Figure 2.2). 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. Surveyors should not attempt to physically measure the site boundaries.

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 only that 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.

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 should be 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 period.

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

Pre-survey standardization *(or "Classroom training")*

A "pre-survey" standardization should be conducted to help ensure that all surveyors are recording similar information when they observe a site. A training presentation is provided in Appendix C. 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 can be recorded on paper forms (Appendix B) or electronically. For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS to determine if boundary edits are required (Appendix D). Survey point waypoints are created in GIS and uploaded to GPS units (Appendix D.)

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 2.3). For example, the Garmin Montana

GPS camera and an iPad camera will photograph about 100 feet of shoreline when the photographer is stationed about 100 feet (33.3 meters) from shore.

Conducting the survey

This survey can be conducted using paper or electronic data entry. A paper field data entry form is provided in Appendix B. EWR staff currently record data electronically using a database on iPads contained in waterproof cases. Database programs are available for use with Microsoft Windows computers.

Navigating to the site

Surveyors use a GPS receiver to navigate the boat approximately 100 feet (33.3 meters) lakeward of the shoreline survey point that was generated in GIS. Each site extends 17m (50 feet) in either direction along shore from the GPS point for a total of 100 feet (33.3 meters) along shore (Figure 2.4). On developed lakes, survey sites are independent of lot ownership and may, and often do, include portions of more than one lake lot.

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 (33.3 meters) 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 (33.3 meters). If the site cannot fully be viewed from the boat (example – located at the end of a long, narrow channel, at the 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

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). They can be used to document the location of each survey site and can be used to help relocate the site in future surveys. These photographs can help monitor change in the type and amount of habitat within each lakeshore zone.

While the boat is positioned at the center point of the survey site, surveyors photograph the site. (For example, if using a Garmin Montana GPS camera, center the boat about 100 feet (33.3 meters) from shore to photograph the entire 100 feet segment of shore. This photo-point documents the location and boundaries of the survey area and can be used to assess change in future survey years (Hall 2001).

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 C). Aerial photography may be used to assist surveyors in their land use classification but should not be the primary tool. 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 the majority 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 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 show little or no 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 the majority 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 mostly likely to be developed and approximates the required minimum setback distance for shoreland structures (Figure 2.4). 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 2.4). 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 tree 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 100 feet (Figure 2.4). 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 (Figure 8) 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 off-shore 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

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 2-2). 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.

$$\text{Final Weighted Site Score} = \left[\frac{\text{Total Points}}{150}\right] \times 100$$

Quality control

In general, data observed and recorded on-site should be considered accurate. Although much habitat data 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 change at survey sites between repeated survey years.

EWR staff store electronic field data in a database that is backed up on a network drive. Georeferenced photos are stored separately on a network drive.

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 33.33
3. Mean Habitat Score for developed sites
4. Mean Habitat Score for undeveloped sites
5. Individual Site Habitat Scores

Table 2-1 Determining Score The Shore survey site spacing based on shoreline miles (for waterbodies >24 acres).

	EXAMPLE LAKES				Spacing of sites (meters)	Number of points per lake	Length of each survey segment (meters)	% of lakeshore surveyed
Shoreline length (miles)	Region 1 Northwest	Region 2 Northeast	Region 3 Central	Region 4 South				
0.75 - 1.21	Upper Lindgren	McKinney	Hiawatha	Ochotto	Varies 60 to 95	20	33	35-55
1.22 - 2.24	Upper Milton Dead Horse	Tetagouche Little Wabana	Wabasso Battle Creek	Roemhildts Carrie	100	20-36	33	33
2.25 - 3.29	2nd Crow Wing Pillager	Upper Dean L. Hanging Horn	Calhoun Bavaria	East Toqua Manuella	150	24-35	33	22
3.30 - 14.99	Bemidji Little Mantrap	Northern Light Upper Cullen	Shamineau Big Marine	Big Kandiyohi Shakopee	200	27-121	33	17
15.00 – 50.00	Woman Ten Mile	White Iron Pokegama	Osakis Sauk	Shetek Big Stone	400	60- 201	33	8

Table 2-2 Scoreable habitat features for Score The Shore survey

Zone		Feature			Category	Points	Score
Shoreland	1	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	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	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
Shoreline	4	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	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	Overhead Woody Habitat			yes	10	6.67
					no	0	0
Aquatic	7	Human made openings in plant beds			no	20	13.33
					yes	0	0
	8	Downed woody habitat			yes	10	6.67
					no	0	0
	9	# Docks	# Rafts	# Lifts	# Marinas	Points	Score
		0	0 to many	0	0	20	13.33
		1 simple, 0 complex	0 to many	0	0	15	10.00
		At least 1 simple or 1 complex	0 to many	0-2	0	10	6.67
			0 to many	>2	0	5	3.33
		0 to many	0 to many	0 to many	1 or more	0	0

Figure 2.1 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

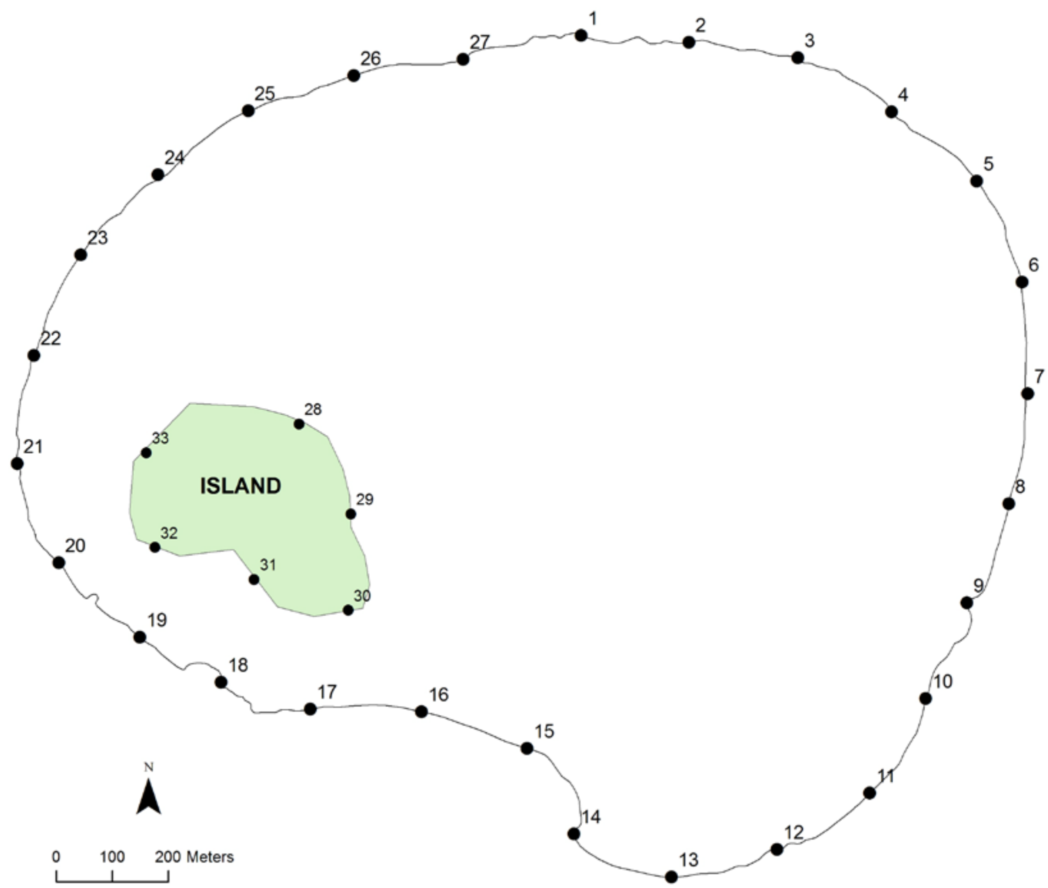
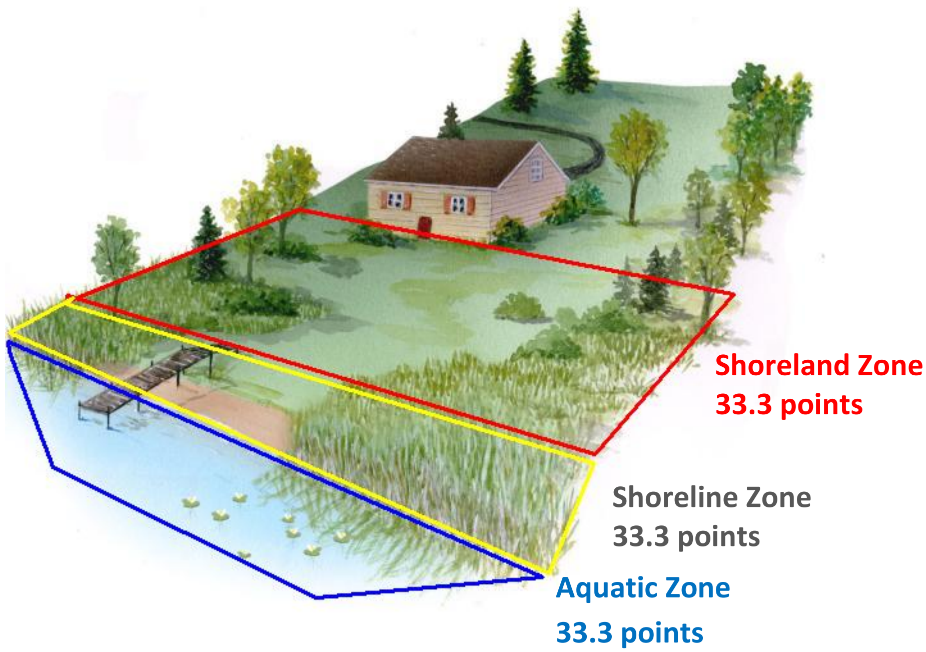


Figure 2.2 Score The Shore habitat zones



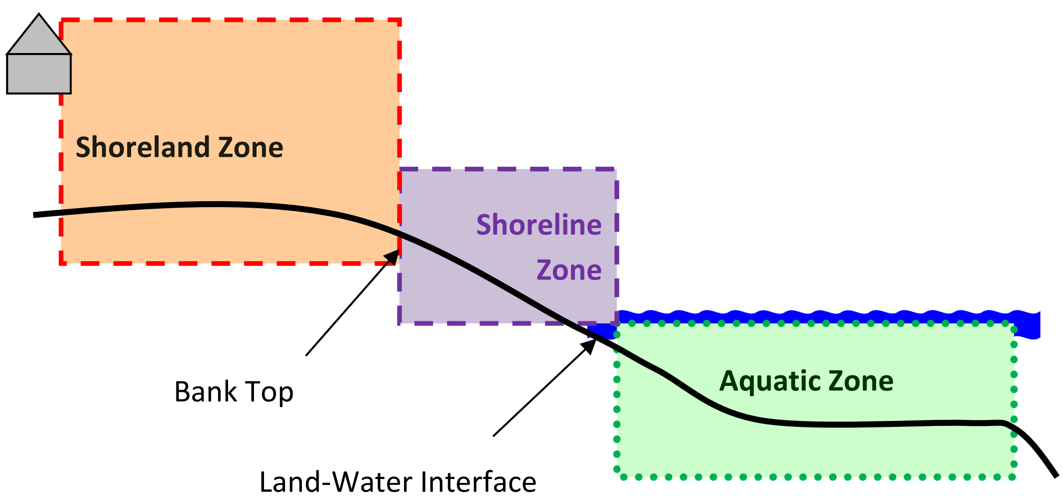


Figure 2.3 Determining field of view for camera

d= distance from camera to midpoint of photographed image

L = length of photographed image

Surveyors should predetermine the distance from which they need to photograph the survey site in order to include about 100 feet (33.3 meters) of shore in the photograph.

For Garmin Montana cameras and iPad cameras, d is approximately 100 feet or 33.3 meters.

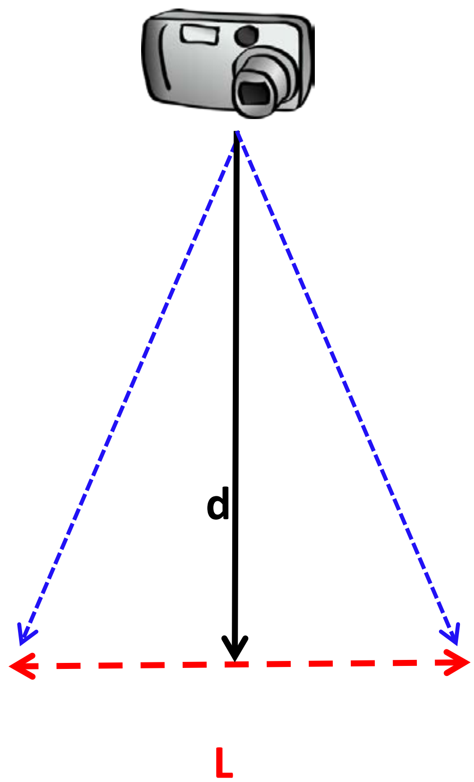


Figure 2.4 Score The Shore individual survey site

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.

CHAPTER 3. SHALLOW WATER PLANT STANDS – DELINEATION, CLASSIFICATION AND INVENTORY

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 be used to provide a physical delineation of where plant growth occurs 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.

Minnesota has an existing Native Plant Community (NPC) classification system that 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 (MDNR 2003) that were developed from this classification to categorize plant communities they encounter during vegetation inventory at a variety of scales.

Because detailed relevé plot data are lacking for lakes, lacustrine plant communities were not classified in DNR'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, Minnesota Pollution Control and Tribal Nations want to document the occurrence and dynamics of wild rice stands (*Zizania* spp.), which includes information on size and composition (monotypic vs. mixed with perennials). MNDNR Invasive Species Program, lake groups and local units of government are interested in mapping stands of invasive 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 3.1).

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, estimations of plant cover, and estimations 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 also consider the increasing advances in GPS technology and GIS software that now allow more efficient geo-referenced 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 on the basis of shared physiognomic and/or floristic characteristics that distinguish them from other kinds of plant communities or vegetation. In lakes, vegetation classes may be based strongly on shared growth forms and 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 taxa. 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). Classifying by dominance-type requires a basic understanding of plant communities (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 "expert-based" 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*) and possibly to further refine this classification.

This is not an ecological classification developed to incorporate abiotic attributes such as water depth, water chemistry such as alkalinity, substrate nutrients, flooding regimes, and biological attributes such as associations of plant taxa. An ecological classification has been done for non-aquatic plant communities in Minnesota in the NPC Classification where relevé plot vegetation and soils data form the basis for classifying plant communities (Aaseng et al. 2011). A comparison, or cross-walk, between the existing MNDNR Native Plant Community Classification and the Aquatic Plant Stand Classification is provided in (Table 3-1).

This classification system is a three-level hierarchical design (Table 3-2) 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.

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 1940's to delineate major stands of vegetation in lakes. It is also the level at which most field staff can conduct aerial photo-interpretation of stands from readily available photos and without having extensive photo-interpretation experience (e.g., while it is possible to distinguish bur reed (*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 ten 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 ten Lake Plant Classes (Table 3-3) 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 emergent provide above water surface area for invertebrates). Temporal variation in stands is also distinguished. For example, stems of bulrush (*Schoenoplectus* spp.) 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 may 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 may 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).

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.

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 varies 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 standardization *(or "classroom training")*

Training should be conducted to help ensure that all surveyors are recording similar information when they observe plant stands. EWR staff will provide training on plant stand classification and techniques of field delineation.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix A. Data can be recorded on paper forms or electronically. For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (Appendix D). Survey point waypoints are created (Appendix D) and uploaded to GPS units.

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 invasive 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 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 Collector and Garmin Glo unit

Collector for ArcGIS is a mobile GIS application developed for collecting spatial data in the field. Collector, 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 DNR 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 ten classes (Table 4) 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 ten Lake Plant Classes is provided in Appendix E.

No overlapping stands are delineated [e.g., if bulrush stands grade into waterlily stands, surveyors must decide on a boundary to separate the stands (Figure 3.2, Figure 3.3)]. 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.

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 Collector for ArcGIS

Collector for ArcGIS 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. 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.

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 off-shore 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.

Table 3-1 Cross-walk between MNDNR Native Plant Community Classification and new Aquatic Plant Stand Classification

MN Native Plant Community Classification System				**New Aquatic Plant Stand Classification**		
System Group	System	Plant Community Class	Plant Community Type and description	**Taxa Group** (use primary dominant to distinguish between dominant genus or species; use secondary dominant to describe combinations)	**Class**	**Life Form**
Wetland Grassland, Shrubland and Marsh	Marsh	Northern Mixed Cattail Marsh	**Cattail-Sedge Marsh (Northern)** – dominated by cattails but with a significant component of graminoids including sedges, woolgrass and bluejoint (*Calamagrostis canadensis*)		**Cattail**	**Emergent**
			Cattail Marsh (Northern) – dominated by nearly pure stands of cattails. If sedges and grasses are present, they are minor components.	Specify taxa to distinguish between narrow-leaf and broad-leaf cattails		
		Northern Bulrush-Spikerush Marsh	**Bulrush Marsh (Northern)** – dominated by bulrushes.	Specify taxa to distinguish between rush taxa and to name rush combinations.	**Rushes**	
			Spikerush – Bur Reed Marsh – dominated by spikerushes or bur reeds.	Example: Spikerush – Bur Reed Prairie Bulrush - Arrowhead	**Rushes & Other Leafy**	
		Prairie Bulrush – Arrowhead				
No Cross-walk option				Specify taxa to distinguish between northern and southern wild rice	**Wild Rice**	
				Example: Wild Rice - Bulrush	**Wild Rice & Other**	
				Example: White waterlliy	**Waterlilies**	**Floating-Leaf**
				Example: Waterlily - Pickerelweed	**Waterlilies & Other**	
				Example: Floating-leaf bur reed	**Other Floating**	
				Example: Large-leaf pondweed	**Submerged**	Submerged

Table 3-2 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*)

Table 3-3 Classes of Aquatic Plant Stands

Life form	Item	Class	Primary Dominant Taxa Most common taxa are shown below	Taxa codes	Secondary Dominant Taxa
EMERGENT	1.	**Rushes**	***Schoenoplectus* spp.** Bulrush (*Schoenoplectus* sp.) Hardstem bulrush (*S. acutus*) Softstem bulrush (*S. tabernaemontanii*) Three-square (*S. pungens*) River bulrush(*Bolboschoenus fluviatile*) ***Eleocharis* spp.** Marsh spikerush (*Eleocharis palustris*) Spikerush (*Eleocharis* sp.) Needlerush (*Eleocharis* sp.)	 SCS SA SV SCP SCF EP ELSP ELNE	None or other Rushes
	2.	**Rushes & Other** Leafy Emergent or Floating-leaf plants	***Schoenoplectus* spp.** Bulrush (*Schoenoplectus* sp.) Hardstem bulrush (*S. acutus*) Softstem bulrush (*S. tabernaemontanii*) Three-square (*S. pungens*) River bulrush(*Bolboschoenus fluviatile*) ***Eleocharis* spp.** Marsh spikerush (*Eleocharis palustris*) Spikerush (*Eleocharis* sp.) Needlerush (*Eleocharis* sp.)	 SCS SA SV SCP SCF EP ELSP ELNE	Yes- Leafy (non-Rush) emergent plants and/or floating-leaf plants
	3.	**Wild Rice**	***Zizania palustris*** Wild rice	ZIP	None
	4.	**Wild Rice & Other** Emergent or Floating-leaf plants	***Zizania palustris*** Wild rice	ZIP	Yes - Other emergent plants and/or floating-leaf plants

Table 3-3 Classes of Aquatic Plant Stands (continued)

EMERGENT (continued)	5.	**Cattail**	***Typha* spp.** Cattail (*Typha* sp.) Broad-leaf cattail (*T. latifolia*) Narrow-leaf cattail (*T. angustifolia*) H ybrid cattail (*T* x *glauca*)	 TS TL TA TG	None or various – This Class includes monotypic and diverse stands
	6.	**Other Emergent**	**Other Emergent Examples include:** Common reed grass (*Phragmites australis)* Emergent Bur reed *(Sparganium* spp.) Arrowhead (*Sagittaria spp.)* Horsetail (*Equisetum palustris*) Sedges (*Carex* spp.) Pickerelweed *(Pontederia cordata*) Three-way sedge *(Dulichium arundinaceae*)	various	None or various – This Class includes monotypic and diverse stands
FLOATING-LEAF	7.	**Waterlilies**	***Waterlilies (Nymphaeaceae)*** Yellow waterlilies *(Nuphar variegata)* White waterlilies *(Nymphaea odorata*)	 NV NO	None or various – This Class includes monotypic and diverse stands
	8.	**Waterlilies and Other** Floating and/or Emergents	***Waterlilies (Nymphaeaceae)*** Yellow waterlilies *(Nuphar variegata)* White waterlilies *(Nymphaea odorata*)	 NV NO	None or various – This Class includes monotypic and diverse stands
	9.	**Other Floating-Leaf**	**Other Floating-leaf** <u>Examples include:</u> Watershield *(Brasenia schreberi*) Floating pondweed *(Potamogeton natans*) Floating-leaf bur reed *(Sparganium* spp.)	various BRS PN SFLO	None or various – This Class includes monotypic and diverse stands
SUBMERGED	10.	**Submerged**	**Submerged**. <u>Examples may include:</u> Rare or unique submerged species that are visible from water surface (ex*. Potamogeton vaseyi, Hippuris vulgaris*)	various	None or various – This Class includes monotypic and diverse stands

Figure 3.1 Historical hand-drawn map of emergent and submerged vegetation stands

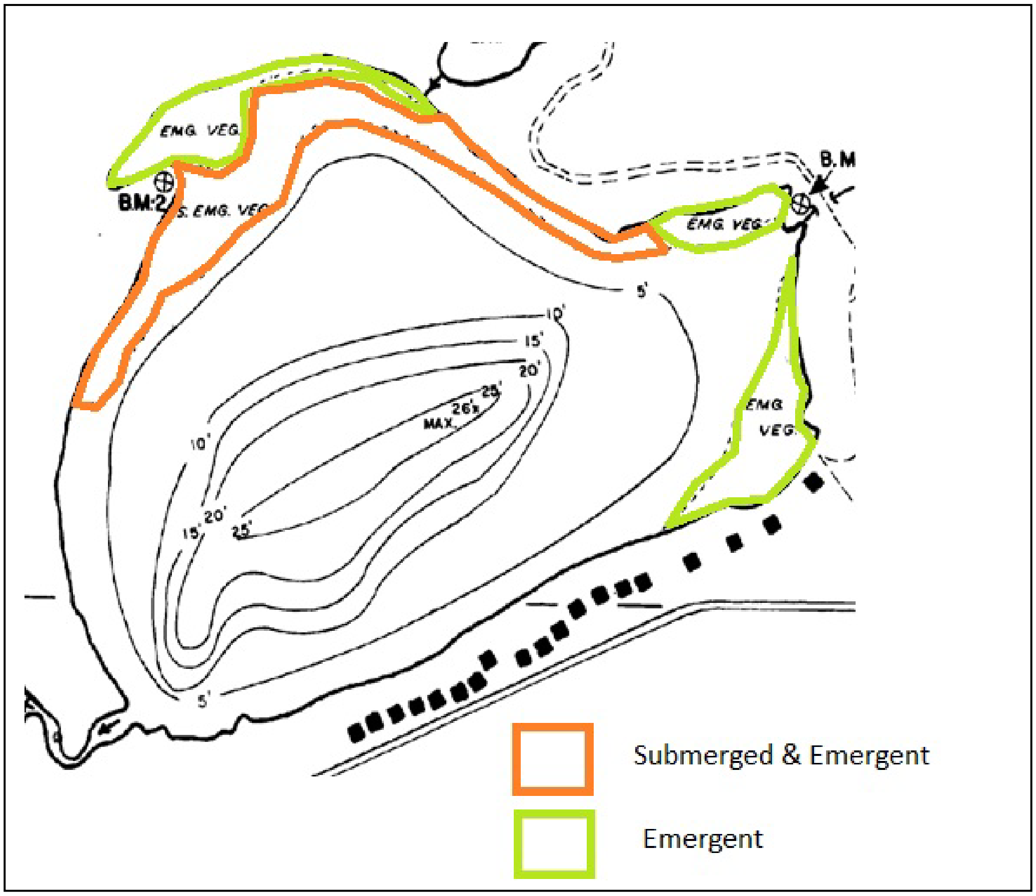
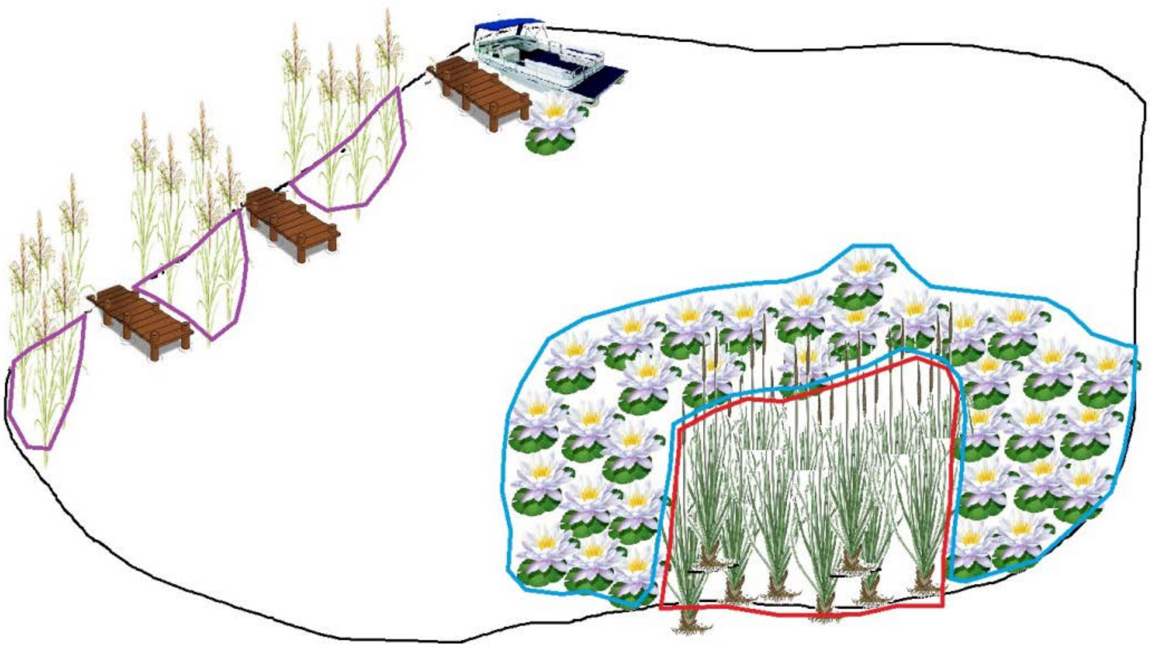


Figure 3.2 Example delineations of aquatic plant stands

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) 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.



D

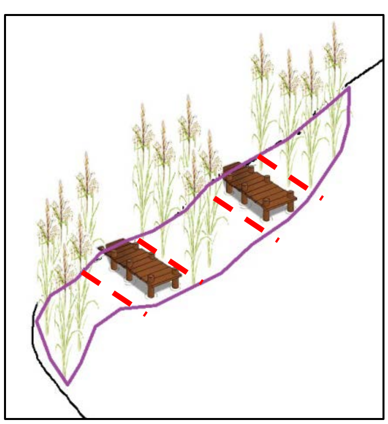
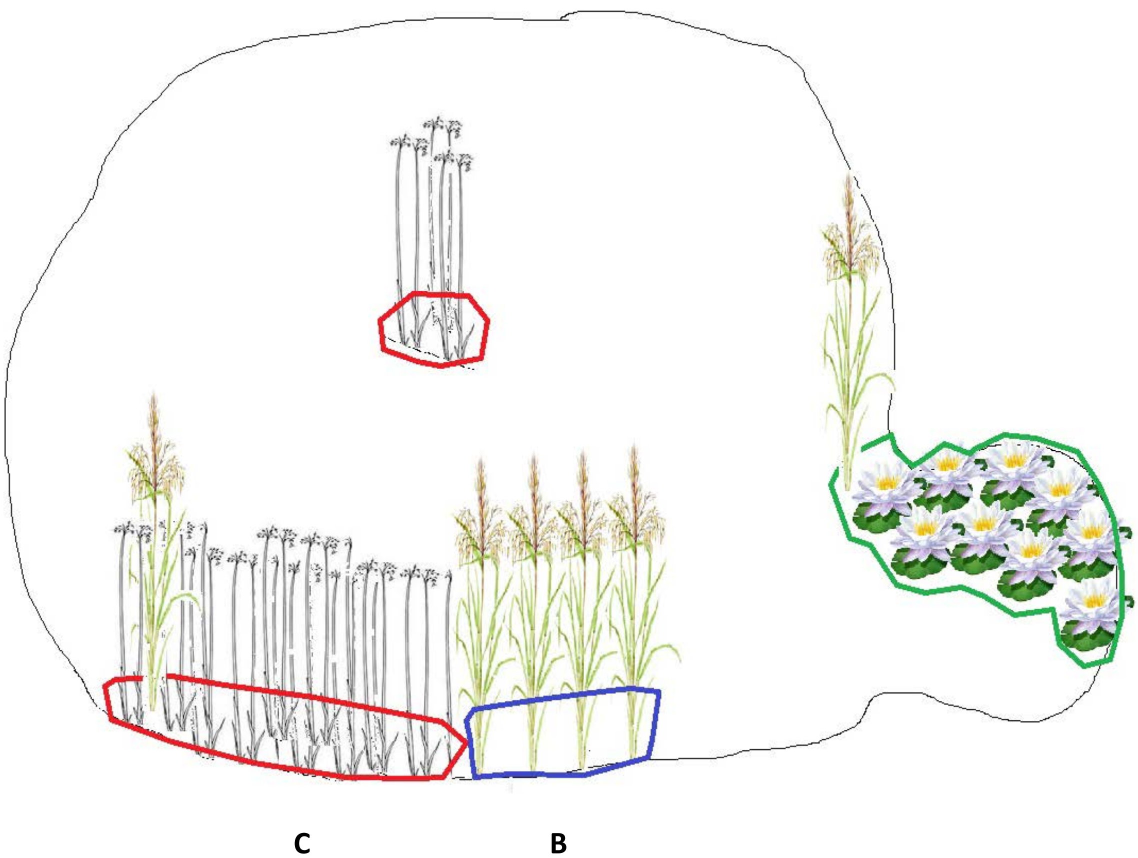


Figure 3.3 Example delineations of aquatic plant stands

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



CHAPTER 4. PLANT SPECIES 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. In an effort to minimize sampling time, the 1993 Transect Survey eliminated the sample stations along the transect and the entire length of the transect is the survey area. 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. 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 4-1) and transects are spaced at equal distances around the lakeshore (Figure 4.1). If a transect survey has been previously conducted on a 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 area size

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

Equipment and GIS preparation

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

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 are identified to the lowest taxonomic level possible (usually to the species level) and recorded as “present” on that transect. Surveyors also record the dominant substrate (Table 4-2) 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.

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.

Table 4-1 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

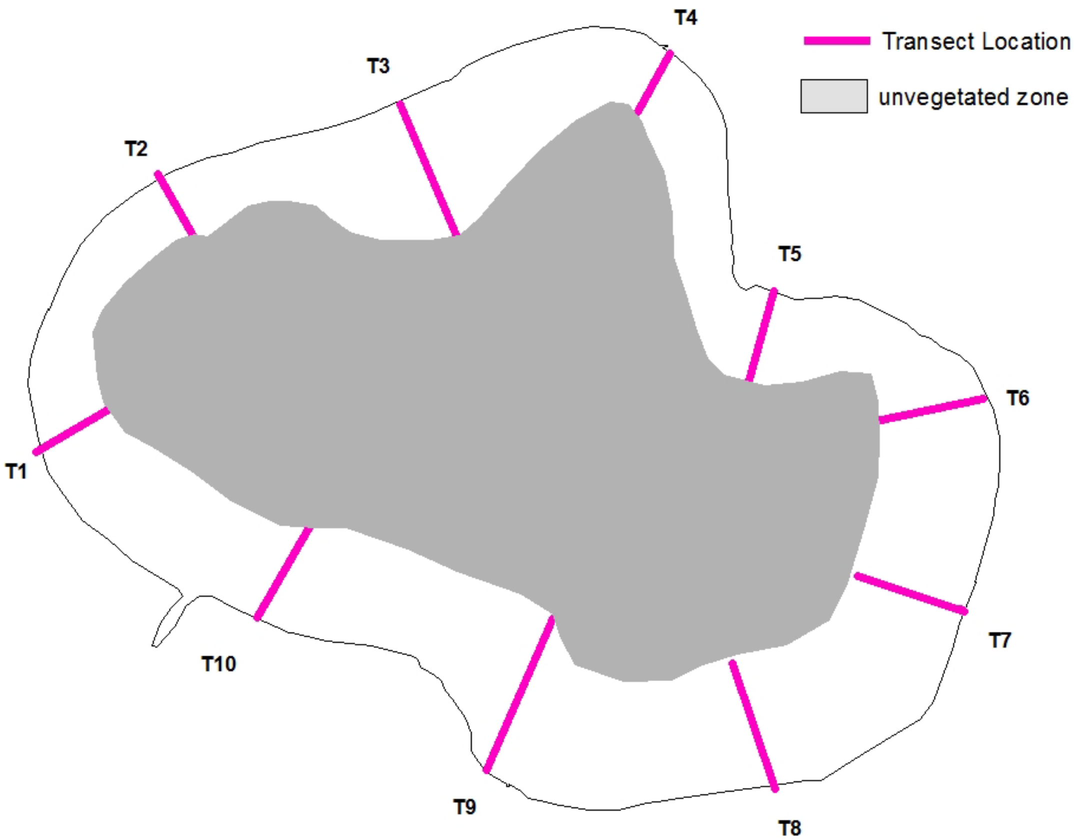
Source: MNDNR 1993 Fisheries Lake Survey Manual

Table 4-2 Shoal substrate descriptions and codes

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

Adapted from: MNDNR 1993 Fisheries Lake Survey Manual

Figure 4.1 Placement of transects at equal intervals around lakeshore



CHAPTER 5. QUANTITATIVE LAKEWIDE PLANT SURVEY: POINT-INTERCEPT

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 from a watercraft, this survey is most appropriate on lakes where the majority 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 (a large number of sample sites are 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 that occur in 30% or more of the vegetated zone) and be 95% confident that frequency estimates are within +/-20% of the estimated true value.

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 pin point 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 method 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 5.1) and accuracy varies by species (Figure 5.2).

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 the MNDNR for quantitative lake vegetation surveys conducted by Ecological and Water Resources 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).

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 points 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 5.3). In these situations, stratifying sample site placement within an area of interest (Yin et al. 2000) helps to ensure adequate sampling (Figure 5.4).

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 3 to delineate, map and describe emergent and floating-leaf habitat and other unique aquatic plant communities and in Chapter 6 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 5-1). 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%) in order to reduce sampling effort.

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.

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

1. Minimum sample number for that stratum is not met (Table 5-2) (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. EWR Lakes Program 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 one meter squared 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

Equipment and GIS preparation

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

For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (Appendix D). Survey point waypoints are created (Appendix D) and uploaded to handheld GPS units. Surveyors should 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 as long as all sites within the 0-20 feet depth zone are sampled. If surveyors need to reduce sampling in the field in order 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 5.5). Instead, sampling should be based on minimum sample number by depth zone, regardless of whether vegetation is detected (Figure 5.6).

Survey site accessibility

Surveyors should attempt to sample all sample sites within the pre-designated survey area. 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.

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 4-2) are recorded. If several substrate types occur at a site, surveyors record the most common type.

Vegetation sampling

At each site, plants within the $1m^2$ area are sampled visually and with a rake sampler (see Appendix A). 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.

For each site, total plant abundance is described as one of the following 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: neither sparse nor matted
4. Abundant: matted at or near surface, making boat navigation difficult

At each site, all plants observed are recorded. Taxa are identified to the species level when feasible (see list of Minnesota aquatic plant taxa in Appendix G). Plant taxonomy follows Crow and Hellquist (2000) and nomenclature follows MNTaxa (2013).

Voucher specimens are collected according to methods provided in Appendix F and are stored at the University of Minnesota Bell Museum Herbarium or at the Minnesota Department of Natural Resources office in Brainerd.

Any additional taxa observed outside of the pre-established sample sites should be recorded as present in the lake but these data 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.

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 species richness (see Chapter 6). 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 also 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%).

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.

Table 5-1 Required sample number for frequency data based on 95% confidence limits and 10% and 20% error

	Required sample number (95% confidence interval)	
Frequency of vegetation	10% error	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

From Newman et al. 1998:

$N = (t/D)^2 * (1-p)/p$, 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 (e.g., 0.1 to estimate p within 10%)

Table 5-2 Recommended minimum sample number by depth strata for Minnesota lakewide 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
		>150	≥65
6 to 10	75	<50	<65
		75-150	65
		>150	≥65
11 to 15	50	<50	<65
		50-150	65
		>150	>65
16 to 20	50	<50	<65
		50-150	65
		>150	≥65
21 to 30	tbd	<50	<65
		50-150	65
		>150	≥65

Figure 5.1 Usefulness of frequency data as proxy for cover is scale dependent

Large sample plots
Frequency = 10/25 = 40%
Frequency is greater than actual cover

Small sample plots
Frequency = 30/100 = 30%
Frequency is good proxy for cover

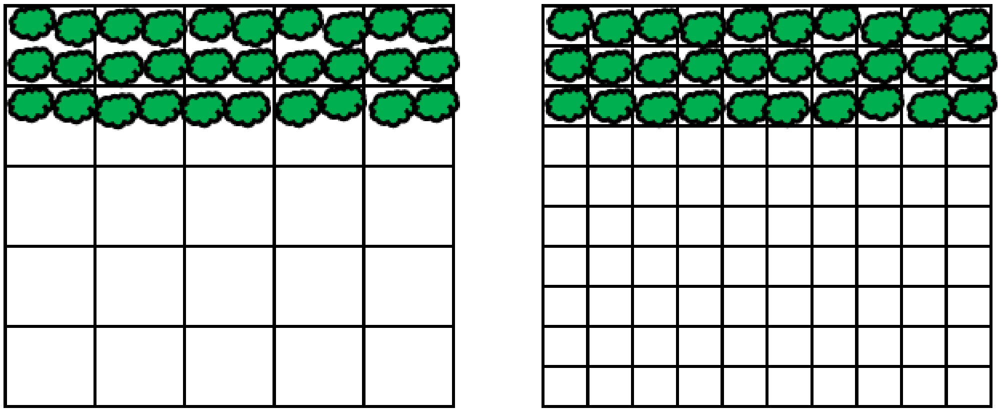


Figure 5.2 Usefulness of frequency data as proxy for cover is species and life-form dependent

Plant community 1
Frequency = 30/100 = 30%
Frequency is good proxy for cover

Plant community 2
Frequency = 30/100 = 30%
Frequency is greater than cover

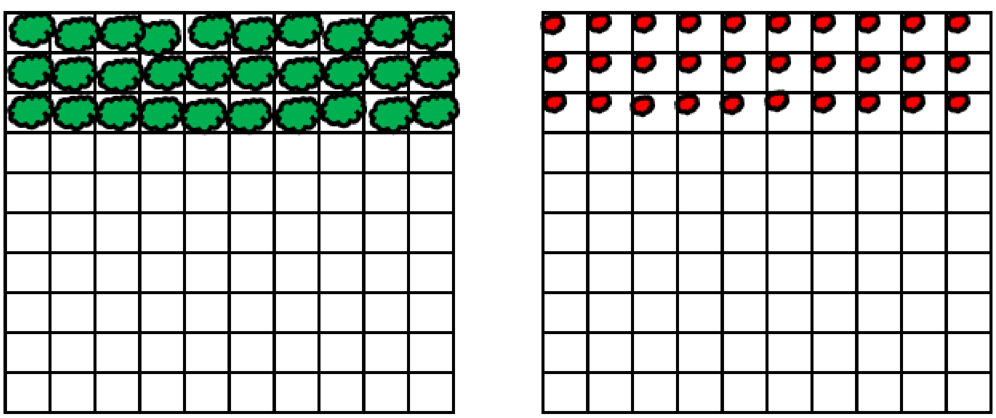


Figure 5.3 Simple grid placement of sample points

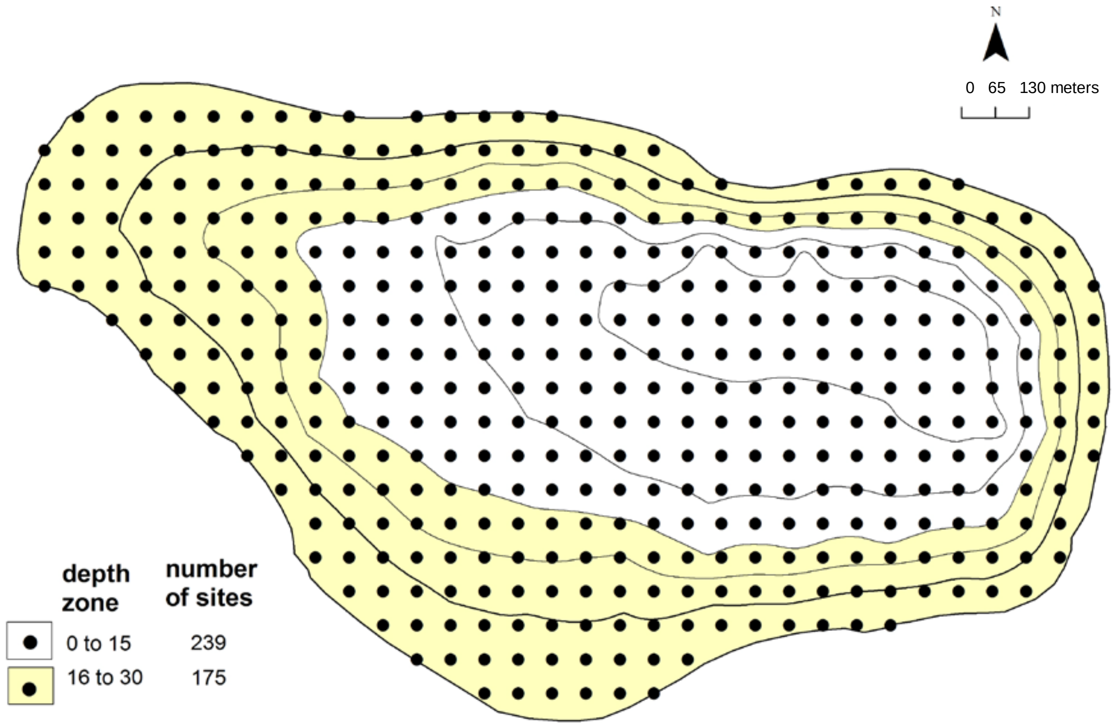


Figure 5.4 Stratified placement of sample points within water depth zones

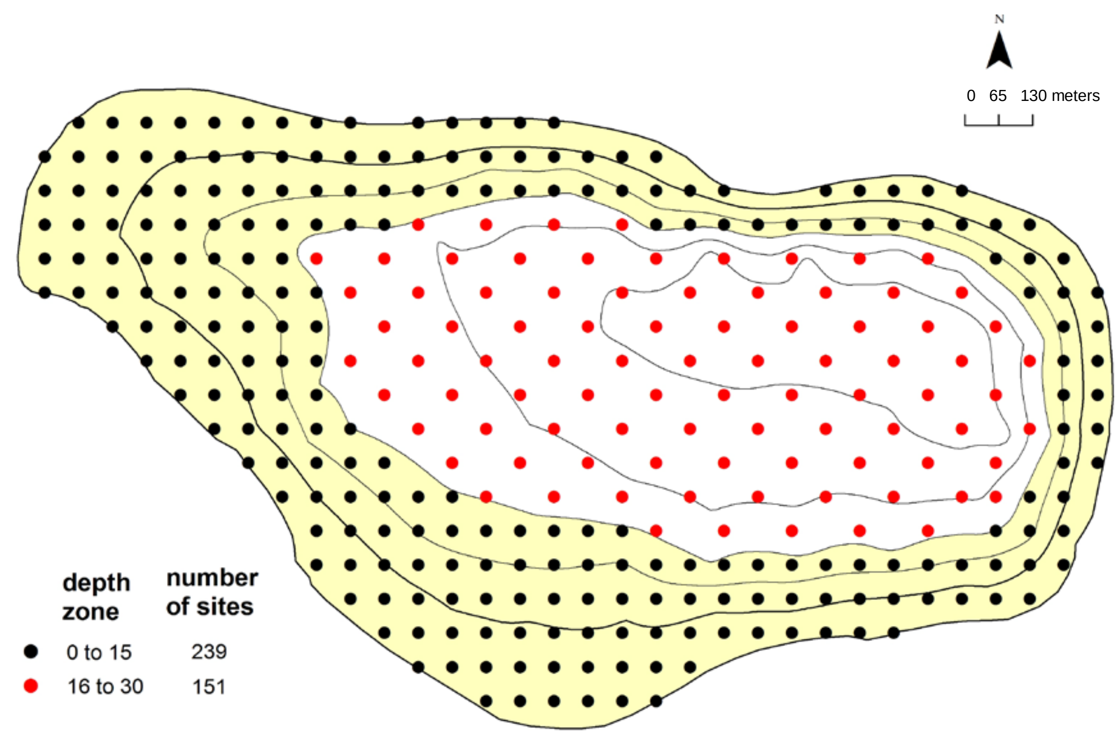


Figure 5.5 Sampling based on detection of vegetation at adjacent site may result in inadequate sampling of important zones (note - only some sites in the 6 to 10 feet and 11 to 15 feet strata are sampled with this design)

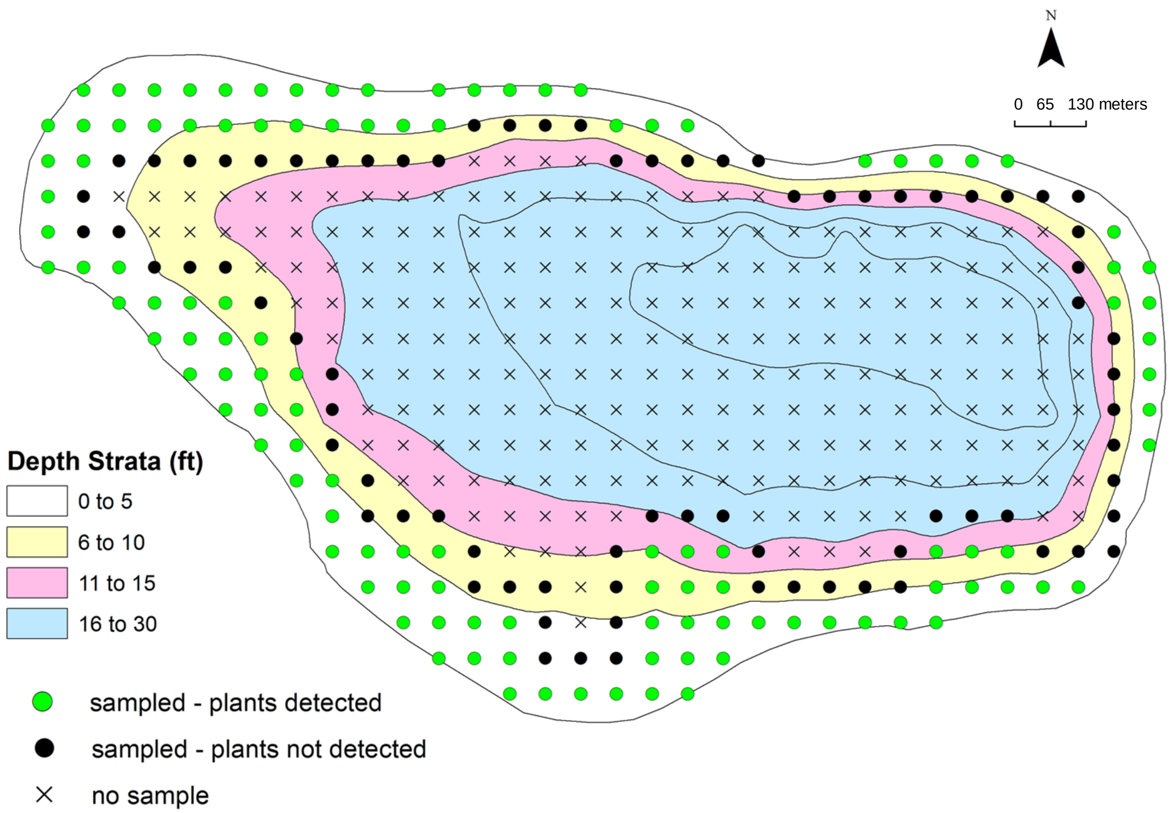
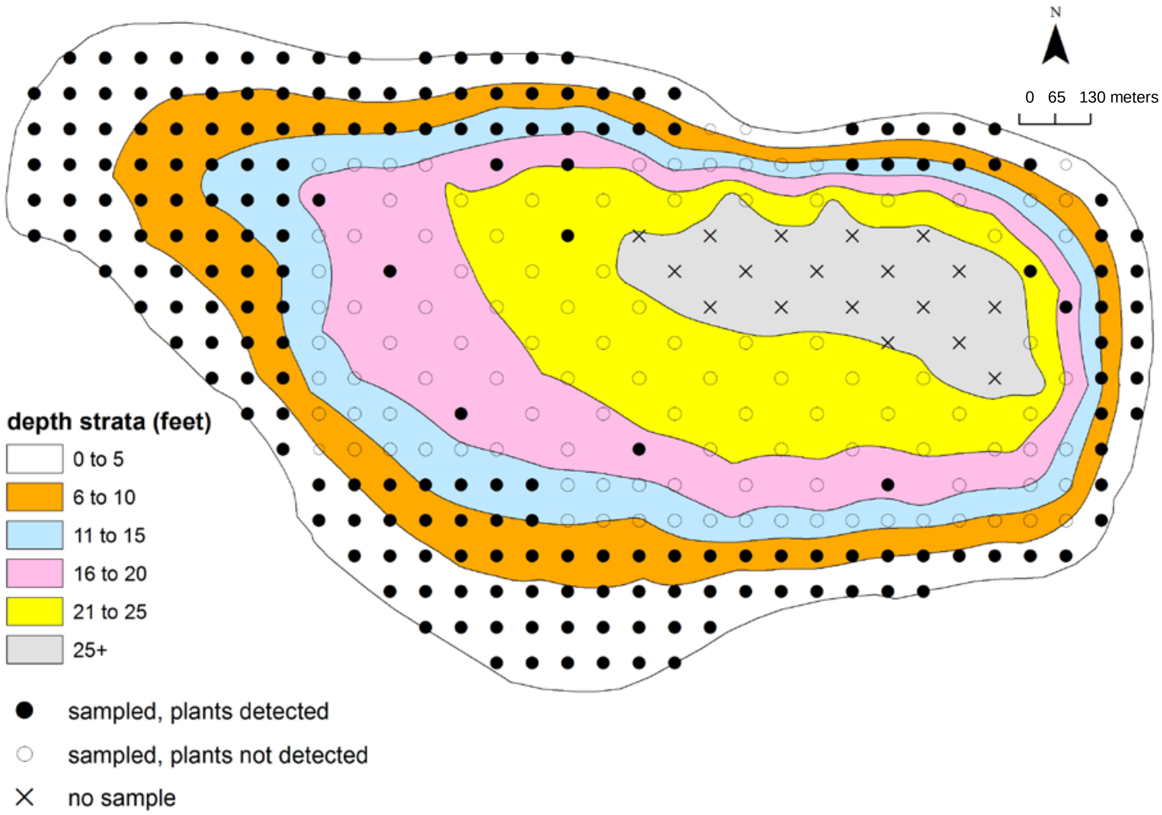


Figure 5.6 Stratified sampling with minimum sample number by depth zone, regardless of whether vegetation is detected (all sites within a targeted depth zone are sampled)



CHAPTER 6. QUANTITATIVE NEAR-SHORE SAMPLING

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 the majority of 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. EWR 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 watermoss. 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".

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 a distance of 5 meters. Within this zone, survey sites, measuring 5 meters along the shore by 5 meters lakeward (Figure 6.1) 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 2.1). If a Score The Shore survey has or will be conducted on the lake, those survey site locations should be used for the near-shore sites.

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 6-1). 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 50 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.

Pre-survey preparation

Equipment and GIS preparation

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

For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (Appendix D). Survey point waypoints are created (Appendix D) 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 6.1). 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 6.1). 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 within the shallow zone (0 to 4 feet) of the survey site 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 4-2) 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 frequency of occurrence estimates.

For each site, total plant abundance is described as one of the following categories:

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

At each site, all plants observed are recorded. Taxa are identified to the species level when feasible (see list of Minnesota aquatic plant taxa in Appendix G). Plant taxonomy follows Crow and Hellquist (2000) and nomenclature follows MNTaxa (2013).

Data management and analysis

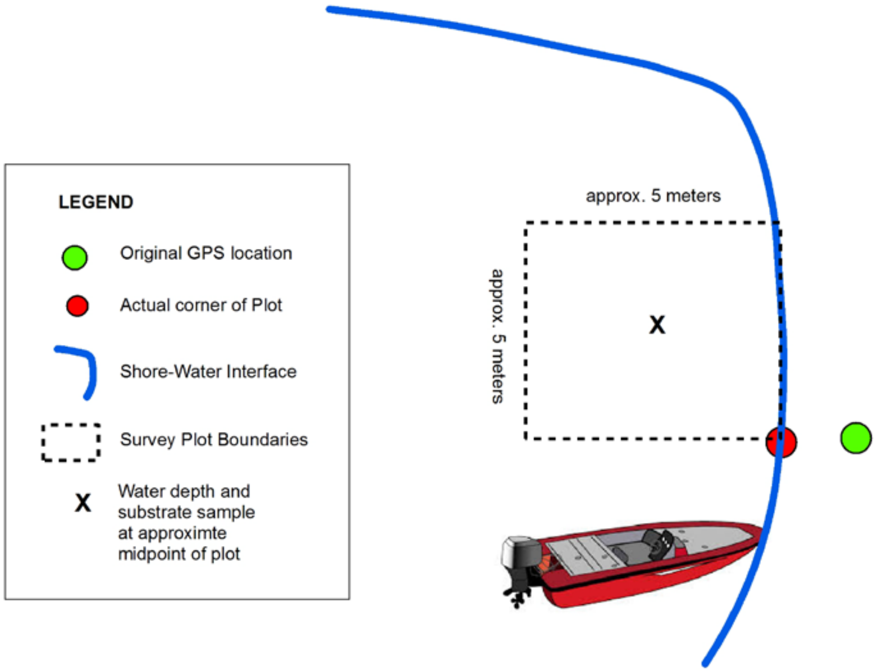
Data collected with this method can also be used to:

- 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

Table 6-1 Determining spacing for near-shore sites

Shoreline length (miles)	Spacing of sites (meters)	Number of points 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

Figure 6.1 Near-shore sample site



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.

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.

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.

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

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 Mmacrophytes. In: Research Management Findings, Bureau of Research – Wisconsin Department of Natural Resources, No. 32, March 1992.

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

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.

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.

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

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.

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.

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

MNTaxa. 2013. Minnesota State checklist of vascular plants. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, St. Paul. Updated April 2011. Available on Internet: MNTaxa

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

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.

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.

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. In press.

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.

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.

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. 675:187-195.

MNDNR