Final Report
Sensitive Lakeshore Survey
Turtle Lake (31-0725-00)
Itasca County, Minnesota

January 2014

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ECOLOGICAL AND WATER RESOURCES

A Product of the
Intra-Lake Zoning to Protect Sensitive Lakeshores Project

Application of
Minnesota's Sensitive Lakeshore Identification Manual: *A Conservation Strategy for Minnesota's Lakeshores*

Prepared by
Stephanie Simon
Kristin Carlson
Donna Perleberg

Project manager
Paul Radomski

Surveys conducted by
Fish Surveys
Paul Radomski, Project Manager
Kevin Woizeschke, Nongame Wildlife Ecologist
Ben Froelich, Intern
Emmy Hauck, Intern
Nolan Schubert, Intern

Loon Nest Surveys
Kristin Carlson, Ecologist
Keri Hull, Regional Watercraft Inspection Supervisor
Emmy Hauck, Intern

Vegetation Surveys
Donna Perleberg, Aquatic Plant Ecologist
Stephanie Simon, Aquatic Biologist
Ben Froelich, Intern
Emmy Hauck, Intern
Nolan Schubert, Intern

Funding Support:
Funding for this report was provided by the State Wildlife Grants Program, Game and Fish Funds, Heritage Enhancement Funds, and by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

How to cite this document:
Simon, S., K. Carlson and D. Perleberg. 2014. Final report on the sensitive lakeshore survey for Turtle Lake (31-0725-00), Itasca County, MN. Division of Ecological and Water Resources, Minnesota Department of Natural Resources. 66 pp.

Alternative format available upon request.

Executive Summary

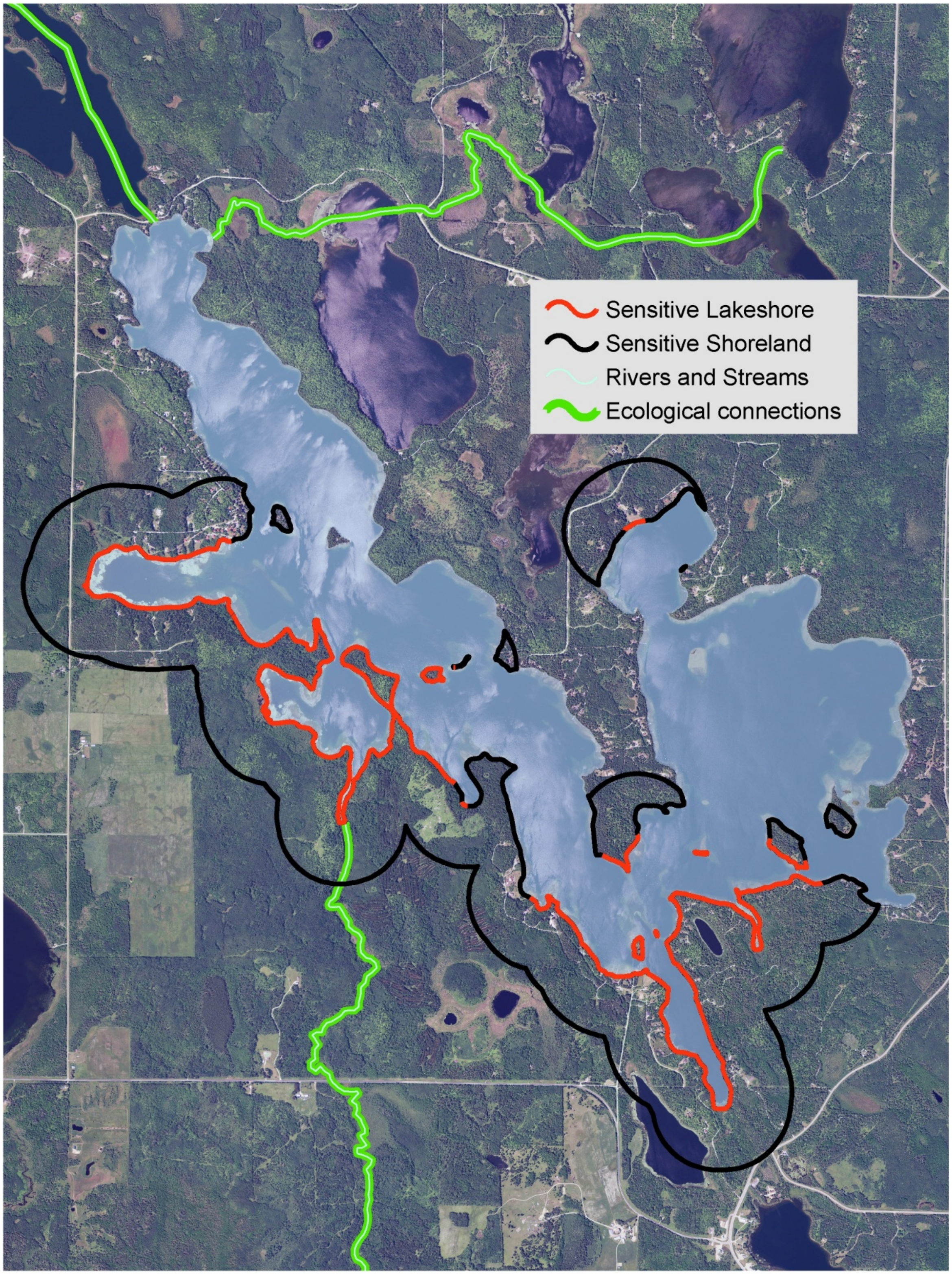
Key attributes of the flora, fauna, and physical habitat throughout the shoreline of Turtle Lake were comprehensively assessed using the Minnesota Department of Natural Resource's sensitive lakeshore identification procedures and incorporated into GIS maps. Each of the thirteen attributes was scored and combined using a standardized procedure to identify three sensitive lakeshore zones. In total, about 10 miles of lakeshore in Turtle Lake was identified as sensitive and included Moose, Sager and Newberg Bays, a significant stretch of the lake's western shore, and four islands.

A total of forty-four native aquatic plant taxa were documented in Turtle Lake, including 27 submerged, six floating-leaf and 11 emergent taxa. Submerged aquatic plants occurred around the entire perimeter of Turtle Lake and plants were found to a depth of 25 feet. Plant occurrence was greatest in depths from 0 to 15 feet, where 94% of the sites were vegetated. Common submerged plants included muskgrass, stonewort, greater bladderworts, narrow-leaf pondweeds, flat-stem pondweed, watermilfoils, and naiads. Floating-leaf plants, including white waterlily, yellow waterlily, watershield and floating-leaf pondweed, occupied about 81 acres. About 229 acres of bulrush were mapped. Six unique plant taxa were also documented in Turtle Lake.

One near-shore fish species of greatest conservation need, the pugnose shiner, was detected at several locations during the 2013 nongame fish surveys on Turtle Lake. Three proxy species, the blacknose shiner, blackchin shiner, and banded killifish, were noted at multiple survey sites. Total fish species diversity recorded during the nongame fish surveys was 19 species.

Both green frogs and mink frogs were documented during the Turtle Lake frog surveys. Green frogs were recorded more frequently than mink frogs, and were heard at approximately 36% of the survey sites. Frog locations were primarily within the protected bays and shallow non-windswept shorelines around Turtle Lake. Other anuran species documented at Turtle Lake included gray tree frogs.

The ecological model identified three primary sensitive lakeshore areas to be considered for potential resource protection districting by Itasca County. These stretches supported the greatest diversity of plant and wildlife species, including species of greatest conservation need. The ecological model displays these areas both as sensitive shoreline and as high priority shorelands. The rivers and streams connected to Turtle Lake are also an important part of the ecosystem. They provide valuable connectivity between the lakes and nearby habitat. The county may use this objective, science-based information in making decisions about districting and reclassification of lakeshore areas. The most probable highly sensitive lakeshore areas and the recommended resource protection districts are highlighted on the map:


Sensitive Lakeshore
Sensitive Shoreland
Rivers and Streams
Ecological connections

Introduction

Minnesota's lakes are one of its most valuable resources. The 12,000 lakes in the state provide various industrial, commercial, and recreational opportunities are important water supplies for some communities, and represent sites of important cultural significance. They are also home to numerous fish, wildlife, and plant species.

Among the many actions that will help protect lakes and the natural resource benefits they provide, protection of important shoreland areas is one of the most important. Shorelands are critically important because of their proximity to the lake (the outcomes from poor land management practices are delivered directly to the adjacent lake) and the diversity of habitats they provide. In particular, naturally vegetated shorelines provide critical feeding, nesting, resting and breeding habitat for many species. Common loons avoid clear beaches and instead nest in sheltered areas of shallow water where nests are protected from wind and wave action. Mink frogs and green frogs are shoreline-dependent species that prefer quiet bays and protected areas with a high abundance of aquatic plants. Fish such as the least darter, longear sunfish, and pugnose shiner are strongly associated with large, near-shore stands of aquatic plants.

Without effective protection, increasing development pressure along lakeshores may negatively impact lakes as well as their shoreline-dependent species – and Minnesota's lakeshores are being developed at a rapid rate. With this in mind, the Minnesota Department of Natural Resources developed a protocol for identifying "sensitive" areas of lakeshore. Sensitive lakeshores represent geographical areas comprised of shorelands, shorelines and the near-shore areas, defined by natural and biological features, that provide unique or critical ecological habitat. Sensitive lakeshores also include:

1. Vulnerable shoreland due to soil conditions (i.e., high proportion of hydric soils);
2. Areas vulnerable to development (e.g., wetlands, shallow bays, extensive littoral zones, etc.);
3. Nutrient susceptible areas;
4. Areas with high species richness;
5. Significant fish and wildlife habitat;
6. Critical habitat for species of greatest conservation need; and
7. Areas that provide habitat connectivity

Species of greatest conservation need are animals whose populations are rare, declining or vulnerable to decline (MN DNR 2006). They are also species whose populations are below levels desirable to ensure their long-term health and stability. Multiple species of greatest conservation need depend on lakeshore areas.

The sensitive shorelands protocol consists of three components. The first component involves field surveys to evaluate the distribution of high priority plant and animal species (focal species). Aquatic plant surveys are conducted in both submerged habitats and near-shore areas, and assess the lake-wide vegetation communities as well as describe unique plant areas. Target animal species include species of greatest conservation need as well as proxy species that represent animals with similar life history characteristics. This first component also involves the compilation of existing data such as soil type, wetland abundance, and size and shape of natural areas.

The second component involves the development of an ecological model that objectively and consistently ranks lakeshore areas for sensitive area designation. The model is based on the results of the field surveys and analysis of the additional variables. Lakeshore areas used by focal species, areas of high biodiversity, and critical and vulnerable habitats are important elements in the ecological model used to identify sensitive lakeshore areas. Because the model is based on scientific data, it provides objective, repeatable results and can be used as the basis for regulatory action.

The final component of identifying sensitive lakeshore areas is to deliver advice to local governments and other groups who could use the information to maintain high quality environmental conditions and to protect habitat for species of greatest conservation need.

This report summarizes the results of the field surveys and data analysis and describes the development of the ecological model. It also presents the ecological model delineation of Turtle Lake sensitive lakeshore areas.

Lake Description

Turtle Lake is in the Laurentian Mixed Forest Province of northeast Minnesota, about one mile north of Marcell in Itasca County (Figure 1). This region of the state is characterized by broad areas of conifer forest, mixed hardwood and conifer forests, and conifer bogs and swamps with numerous glacial lakes.

Figure 1. Location of Turtle Lake in Itasca County, Minnesota.

Turtle Lake lies within the Big Fork River watershed (Figure 1). It is a flow-through lake that receives inflow from two small streams that flow into the north bay. The lake outflows from the west bay to form the Turtle River (Figure 2). The Turtle River flows south into the Big Fork River which flows north to form the Minnesota/Canada border.

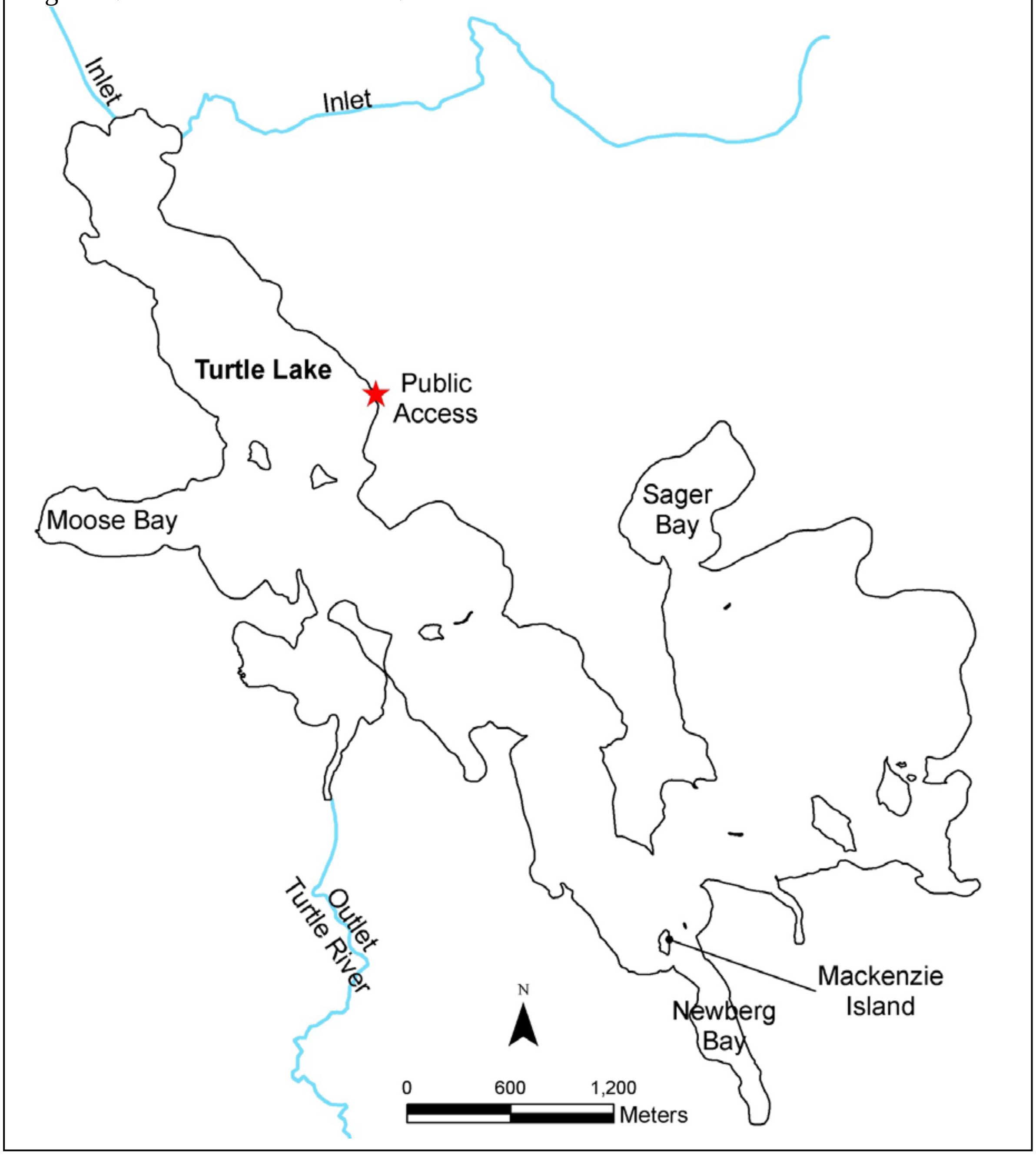
With a surface area of 2,126 acres, Turtle Lake is the 13th largest lake in Itasca County and the 6th largest lake in the watershed. Turtle Lake occurs entirely within the boundaries of the Chippewa National Forest but the surrounding shoreland ownership includes a mix of state, federal, county, and private land. About (70%) of the lakes 26 miles of shoreline is developed with residential homes and several resorts. The State of Minnesota maintains a public access on the northeast side of the northwest basin (Figure 2). The Minnesota DNR Section of Fisheries primarily manages Turtle Lake for smallmouth bass and walleye (MN DNR 2006b).

Turtle Lake has a maximum depth of 137 feet but about 25% of the lake is 15 feet or less in depth (Figure 3). The lake is a hard water lake and is characterized as mesotrophic, based on measured summer water quality conditions, phosphorus (11 ppb), chlorophyll a (2 ppb) and Secchi[1] depth (transparency). Over the last decade, 2003 to 2012, the mean summer[2] water

[1] The Secchi disc transparency measures the depth to which a person can see into the lake and provides a rough estimate of the light penetration into the water column. Water clarity is influenced by the amount of particles in the water column as well as by the water's color and can fluctuate seasonally and annually.
[2] June through September

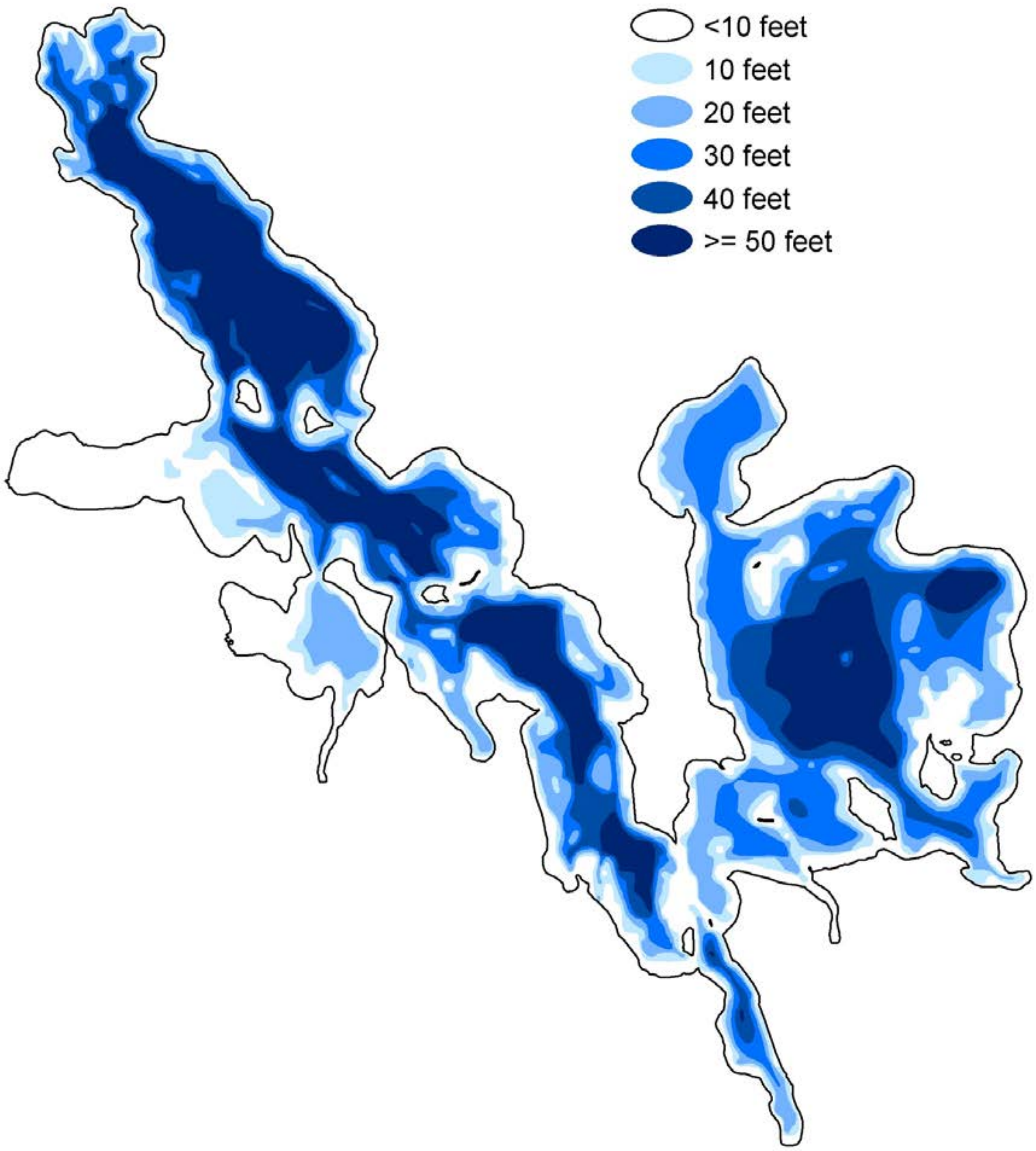
clarity was 16 feet (MPCA 2013). Based on Secchi disc measurements alone, aquatic plants have the potential to grow to depths of about 24 feet in the lake[3].

Figure 2. Features of Turtle Lake.



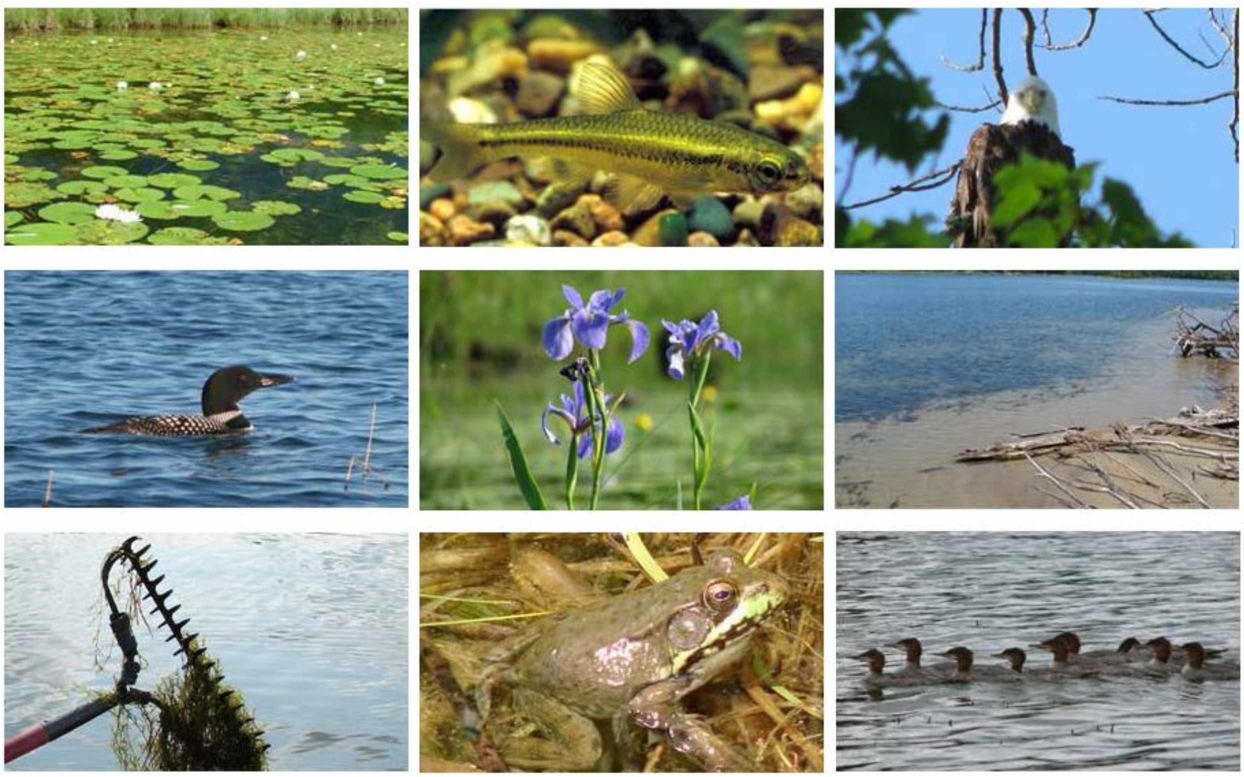
[3] As a general rule, sunlight can penetrate to a depth of two times the Secchi depth and aquatic plants can grow to a depth of one and a half times the Secchi depth.

Figure 3. Depth contours of Turtle Lake (based on 2013 data).



I. Field Surveys and Data Collection

Survey and data collection followed Minnesota's Sensitive Lakeshore Identification Manual protocol (MN DNR 2012). Resource managers gathered information on 13 different variables in order to develop the sensitive shorelands model. Sources of data included current and historical field surveys, informational databases, aerial photographs, and published literature. The variables used in this project were: wetlands, hydric soils, near-shore plant occurrence, aquatic plant richness, presence of emergent and floating-leaf plant beds, unique plant species, near-shore substrate, loon nesting areas, frogs, fish, aquatic vertebrate species richness, rare features, and size and shape of natural areas.



Pugnose shiner photo courtesy of Konrad Schmidt

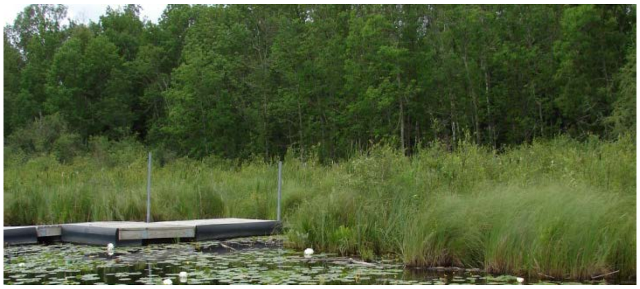
The following pages summarize the methods used to assess each of the thirteen attributes, the results obtained, and the GIS map derived to display the spatial location of variables of interest.

Wetlands

Objective

1. Map wetlands within the extended state-defined shoreland area (within 1320 feet of shoreline) of Turtle Lake

Introduction



Wetlands are important habitat types that provide a variety of services to the environment, to plants and animals, and to humans. Wetland vegetation filters pollutants and fertilizers, making the water cleaner. The roots and stems of wetland plants trap sediments and silt, preventing them from entering other water bodies such as lakes. They protect shorelines against erosion by buffering the wave action and by holding soil in place. Wetlands can store water during heavy rainfalls, effectively implementing flood control. This water may be released at other times during the year to recharge the groundwater. Wetlands also provide valuable habitat for many wildlife species. Birds use wetlands for feeding, breeding, and nesting areas as well as migratory stopover areas. Fish may utilize wetlands for spawning or for shelter. Numerous plants will grow only in the specific conditions provided by wetlands. Finally, wetlands provide a variety of recreational opportunities, including fishing, hunting, boating, photography, and bird watching.

Although the definitions of wetlands vary considerably, in general, wetlands are lands in which the soil is covered with water all year, or at least during the growing season. This prolonged presence of water is the major factor in determining the nature of soil development and the plants and animals that inhabit the area. The more technical definition includes three criteria:

1. Hydrology – the substrate is saturated with water or covered by shallow water at some time during the growing season of each year
2. Hydrophytes – at least periodically, the land supports predominantly hydrophytes (plants adapted to life in flooded or saturated soils)
3. Hydric soils – the substrate is predominantly undrained hydric soil (flooded or saturated soils) (adapted from Cowardin et al. 1979)

Methods

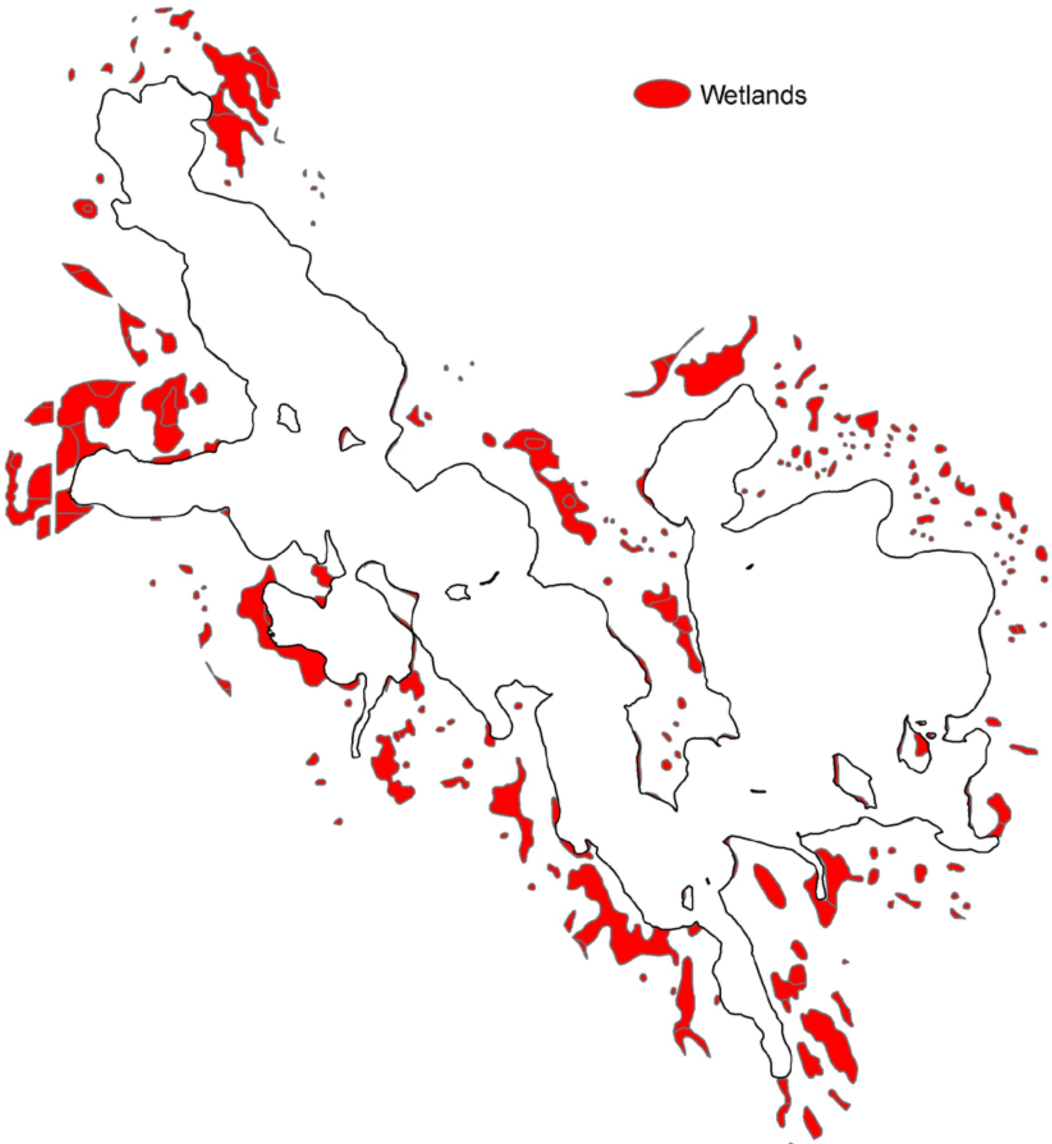
Wetland data were obtained from the National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service (USFWS). The NWI project was conducted between 1991 and 1994 using aerial photography from 1979 – 1988. Wetland polygons obtained from the NWI were mapped in a Geographic Information System (GIS) computer program. Only wetlands occurring within the extended state-defined shoreland area (i.e., within 1320 feet of the shoreline) were considered in this project. Wetlands classified as lacustrine or occurring lakeward of the Turtle Lake ordinary high water (OHW) mark were excluded from this analysis.

Results

Approximately 434 acres, or 20%, of the Turtle Lake shoreland area (the area within 1320 feet of the shoreline) are described as wetlands by NWI. Turtle Lake wetlands were fairly patchy in distribution (Figure 4) and there was only one stretch of the shoreland zone where wetlands were largely absent. Many of the wetlands occurred in small pockets scattered along or near the shoreline.

The most common wetland type occurring within the Turtle Lake shoreland was wooded swamps (Cowardin et al. 1979, MN DNR 2003). Wooded swamps are often dominated by tamarack, white cedar, black spruce, balsam, red maple and/or black ash trees and this wetland type is seasonally flooded, meaning that surface water persists through the growing season or the water table is near the ground's surface (Cowardin et al. 1979). Other wetland types adjacent to Turtle Lake included emergent marshes (dominated by cattails, sedges), and shrub swamps (dominated by alder, willows).

Figure 4. Wetlands within 1320 feet of Turtle Lake shoreline.



Hydric Soils

Objective

1. Map hydric soils within the extended state-defined shoreland area (within 1320 feet of shoreline) of Turtle Lake

Introduction

Hydric soils are defined as those soils formed under conditions of saturation, flooding, or ponding. The saturation of these soils combined with microbial activity causes oxygen depletion; hydric soils are characterized by anaerobic conditions during the growing season. These conditions often result in the accumulation of a thick layer of organic matter, and the reduction of iron or other elements.

Hydric soils are one of the “diagnostic environmental characteristics” that define a wetland (along with hydrology and vegetation). Identification of hydric soils may indicate the presence of wetlands, and provide managers with valuable information on where to focus conservation efforts.

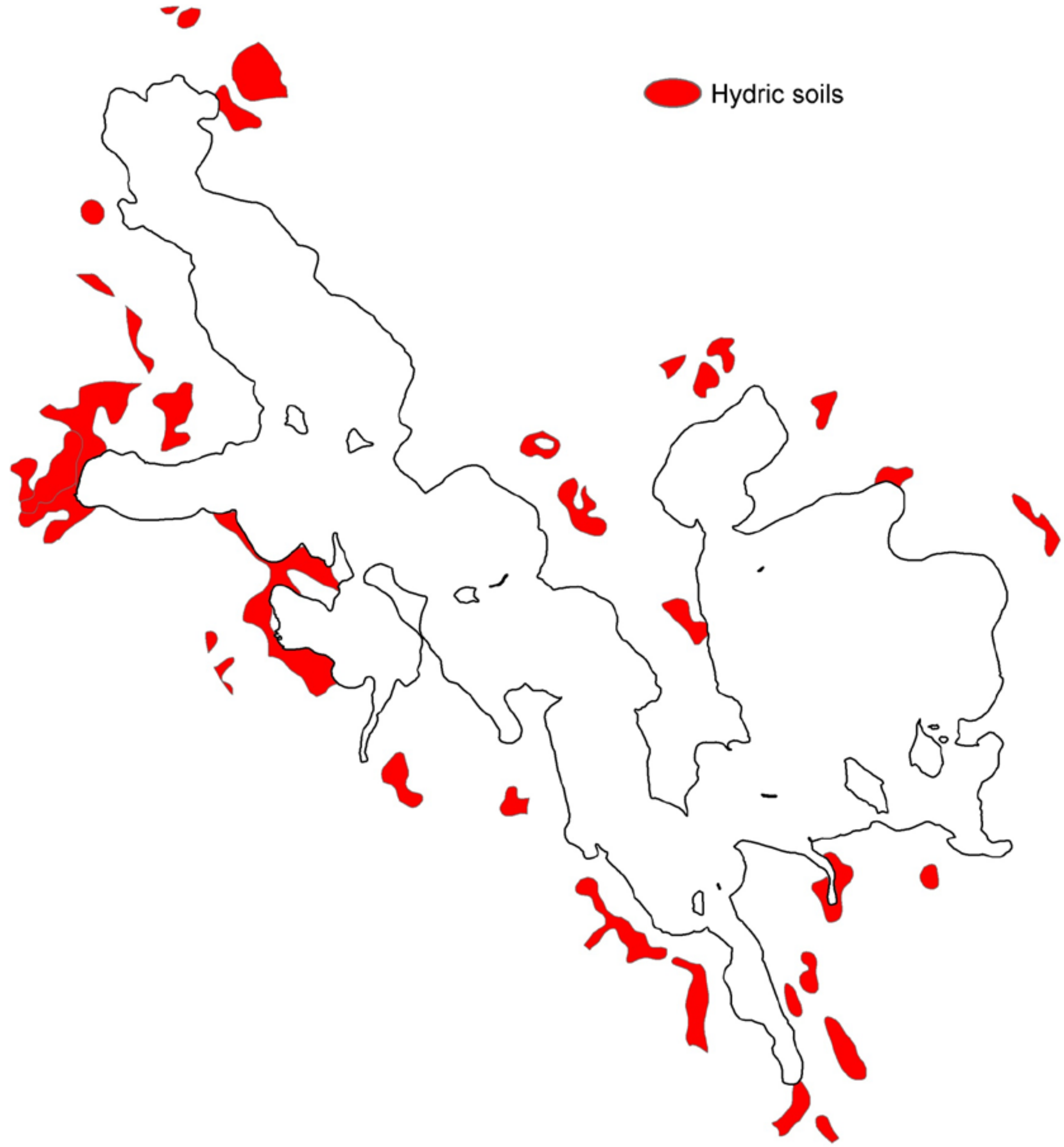
Methods

The National Cooperative Soil Survey, a joint effort of the USDA Natural Resources Conservation Service (NRCS) with other Federal agencies, State agencies, County agencies, and local participants, provided soil survey data. Polygons delineating hydric soils were mapped in a GIS computer program. Only hydric soils within 1320 feet of the shoreline were considered in this project and hydric soils occurring lakeward of the OHW for Turtle Lake were excluded.

Results

Hydric soils are scattered around the entire shoreline of Turtle Lake (Figure 5). Approximately 298 total acres of hydric soils are located within the shoreland (area within 1320 feet of the shoreline). Soil types include mucky peat and silt loam. The organic matter content of these soils ranges from low to very high, and most of the soils are very poorly drained.

Figure 5. Hydric soils within 1320 feet of Turtle Lake shoreline.



Aquatic Plant Surveys

Objectives

1. Record presence and abundance of all aquatic plant taxa
2. Describe distribution of vegetation in Turtle Lake
    a. Estimate maximum depth of plant colonization
    b. Estimate and map the near-shore occurrence of vegetation
3. Delineate and describe floating-leaf and emergent plant beds
4. Map distribution and describe habitat of unique plant species
5. Calculate and map aquatic plant taxa richness

Summary

Forty-four native aquatic plant taxa have been documented in Turtle Lake, including 27 submerged, six floating-leaved and 11 emergent taxa.

Submerged aquatic plants occurred around the entire perimeter of Turtle Lake and plants were found to a depth of 25 feet. Plant occurrence was greatest in depths from 0 to 15 feet, where 94% of the sites were vegetated. Common submerged plants included muskgrass (*Chara* sp.), stonewort (*Nitella* sp.), greater bladderwort (*Utricularia vulgaris*), narrow-leaved pondweed (*Potamogeton* sp.), flat-stem pondweed (*Potamogeton zosteriformis*), native watermilfoils (*Myriophyllum* sp.) and naiads (*Najas flexilis* and *N. guadalupensis*).

Emergent and floating-leaf plants were restricted to shallow water, 0 to 8 feet depth zone. A total of 311 acres, or 15% of the lake was occupied by emergent or floating-leaved plant beds. Approximately 229 acres of bulrush (*Schoenoplectus* sp.) beds were delineated. Floating-leaf plants covered about 81 acres and included white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*), watershield (*Brasenia schreberi*) and floating-leaf pondweed (*Potamogeton natans*).

Unique plants documented in Turtle Lake were flat-leaved bladderwort (*Utricularia intermedia*), lesser bladderwort (*Utricularia minor*), mare’s tail (*Hippuris vulgaris*), creeping spearwort (*Ranunculus flammula*), water bulrush (*Schoenoplectus subterminalis*) and quillwort (*Isoetes* sp.). These species are not widespread in Minnesota and are usually associated with undisturbed areas in clear water lakes of northern Minnesota.

Introduction

Aquatic plants help characterize lake ecosystem similar to how terrestrial ecosystems are characterized by vegetation. Lake plant communities have been referred to as the “unknown forest”. As primary producers, they help form the base of the lake food chain and provide structural habitat for a variety of fish and wildlife species. Rooted plants help stabilize the lake sediments, tamper waves and minimize shoreline erosion. The role of aquatic plants is particularly important in near-shore areas of lakes where they serve as fish spawning and nursery sites and provide food and habitat for a wide variety of wildlife.

The types and amounts of aquatic vegetation that occur within a lake are influenced by a variety of factors including water clarity, water chemistry, water depth, substrate, and wave activity. Deep or wind-swept areas may lack in aquatic plant growth, whereas sheltered shallow areas may support an abundant and diverse native aquatic plant community that in turn, provides critical fish and wildlife habitat and other lake benefits. The annual abundance, distribution and composition of aquatic plant communities may change due to environmental factors, herbivory, the specific phenology of each plant species, introductions of non-native plant or animal species, and human activities in and around the lake.

Non-native aquatic plant species, such as curly-leaf pondweed (*Potamogeton crispus*), may impact lakes, particularly if they form dense surface mats that shade out native plants. However, the mere presence of an invasive species in a lake may have little or no impact on the native plant community and the presence of a healthy native plant community may help limit the growth of non-natives.

Humans can impact aquatic plant communities directly by destroying vegetation with herbicide or by mechanical means. Motorboat activity in vegetated areas can be particularly harmful for species such as bulrush, wild rice and waterlilies. Shoreline and watershed development can also indirectly influence aquatic plant growth if it results in changes to the overall water quality and clarity or change the nature of the near-shore substrate that plants colonize. Limiting these types of activities can help protect native aquatic plant species.

Aquatic plant surveys were targeted towards five groups of aquatic plants (submerged macroalgae, submerged rooted plants, floating-leaf plants, emergent plants and unique aquatic plants). These major groupings were selected because they are the five main groups of aquatic plants that are found in most Minnesota lakes.

Submerged macroalgae
Algae are primitive forms of plants that do not form true roots, flowers or vascular tissue. They range in size from single cells to giant seaweeds. Freshwater algae that live in Minnesota lakes include tiny, free-floating planktonic algae, filamentous algae, and macroalgae. Macroalgae often resemble rooted plants and provide similar habitat and water quality benefits and were therefore included in this survey.

Figure 6. Bed of muskgrass

<u>Muskgrass</u> (*Chara* sp.; Figure 6) is a large algae that is common in many hard water Minnesota lakes. This plant resembles higher plants but does not form flowers or true leaves, stems and roots. Muskgrass grows entirely submerged, is often found at the deep edge of the plant zone (Arber 1920), and may form thick “carpets” on the lake bottom. These beds provide important habitat for fish spawning and nesting. Muskgrass has a brittle texture and a characteristic “musky” odor. It is adapted to a variety of substrates and is often the first species to colonize open areas of lake bottom where it can act as a sediment stabilizer.

Stonewort (*Nitella* sp.; Figure 7) is also a large algae but lacks the brittle texture and musky odor of muskgrass. It is often bright green in color and resembles strands of hair. Stonewort is often found in deeper water than muskgrass.

Figure 7. Stonewort

Submerged rooted plants

Submerged plants have leaves that grow below the water surface, but some species also have the ability to form floating and/or emergent leaves, particularly in shallow, sheltered sites. Submerged plants may be firmly attached to the lake bottom by roots or rhizomes, or they may drift freely with the water current. This group includes non-flowering plants such as large algae, mosses, and fern-like plants, and flowering plants that may produce flowers above or below the water surface. Submerged plants may form low-growing mats or may grow several feet in the water column with leaf shapes that include broad ovals, long and grass-like, or finely dissected.

Bladderworts (*Utricularia* spp.) are submerged plants with finely divided leaves. They produce roots but do not firmly anchor to the lake bottom. Bladderworts have specialized air bladders that regulate their position in the water column. They also act as "underwater Venus fly-traps" by catching and digesting small insects in the bladders. Bladderworts produce small but showy flowers (Figure 8) that emerge above the water surface. They prefer soft substrates (Nichols 1999b) but also float freely in the water column and may be found in protected areas such as waterlily beds. Greater bladderwort (*U. vulgaris*) is found in lakes and ponds throughout Minnesota.

Figure 8. Bladderwort flowers

Pondweeds (*Potamogeton* spp. and *Stuckenia* spp.) are one of the largest groups of submerged plants in Minnesota lakes. These plants are rooted perennials and their rhizomes may form mats on the lake bottom that help consolidate soil (Arber 1920). Pondweeds have opposite, entire leaves and form "cigar-shaped" flowers that emerge above the water surface. Some pondweeds may also form floating leaves. Many pondweed species overwinter as hardy rhizomes while other species produce tubers, specialized winter buds, or remain "evergreen" under the ice. Seeds and tubers of pondweeds are an important source of waterfowl food (Fassett 1957). The foliage of pondweeds is food for a variety of marsh birds, shore birds and wildlife and provides shelter, shade and spawning sites for a range of fish species (Borman et al. 2001). Pondweeds inhabit a wide range of aquatic sites and species vary in their water chemistry and substrate preferences and tolerance to turbidity. There are over 20

Figure 9. Robbins' pondweed

species of pondweeds in Minnesota and they vary in leaf shapes and sizes.

Pondweeds can be grouped by their leaf shape and size. Ribbon-leaf pondweeds are plants with long, narrow, grass-like leaves. This group includes flat-stem pondweed (*Potamogeton zosteriformis*) and Robbins' pondweed (*P. robbinsii;* Figure 9). Broad-leaf pondweeds are often referred to as "cabbage" by anglers and include large-leaf pondweed (*P. amplifolius*; Figure 10), Illinois pondweed (*P. illinoensis*), white-stem pondweed (*P. praelongus*), variable pondweed (*Potamogeton gramineus*) and clasping-leaf pondweed (*P. richardsonii*). Narrow-leaf pondweeds, such as sago pondweed (*Stuckenia pectinata;* Figure 11) have very narrow, almost needle-width leaves.

Figure 10. Large-leaf pondweed

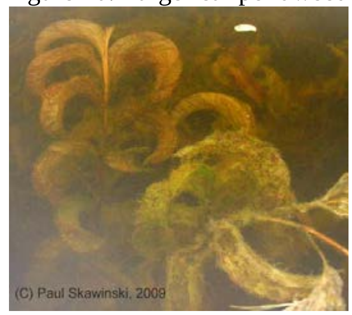
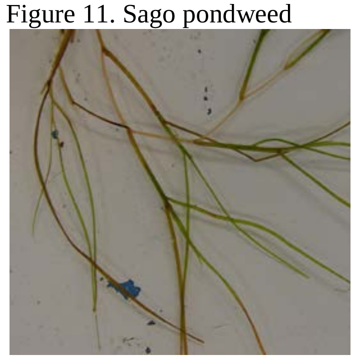


Photo by: Paul Skawindki © 2009

Figure 11. Sago pondweed



Watermilfoils are mostly submerged rooted perennial plants with finely dissected, "feather-shaped" leaves. There are several native species of watermilfoils in Minnesota and these plants are not tolerant of turbidity (Nichols 1999b) and grow best in clear water lakes. Particularly in depths less than 10 feet, watermilfoils may reach the water surface and their flower stalk will extend above the water surface (Figure 12). They spread primarily by stem fragments and over-winter by hardy rootstalks and winter buds. Two species of watermilfoils were found in Turtle Lake: Northern watermilfoil (*Myriophyllum sibiricum*) and whorled watermilfoil (*M. verticillatum*).

Figure 12. Northern watermilfoil

Photo by: Andrew Hipp (UW Madison-Wisc State Herbarium)

Naiads [bushy pondweed (*Najas flexilis*; Figure 13) and southern naiad (*Najas guadalupensis*)] are native submerged plants that often grow low in the water column and form inconspicuous flowers. The two species look very similar, but bushy pondweed is unusual because it is one of the few annual submerged species in Minnesota and must re-establish every year from seed. It prefers hard substrates and is not tolerant of turbidity (Nichols 1999b). Southern naiad may overwinter as a perennial plant or sprout from seed. The seeds and foliage of both plants are an important duck food and the foliage provides good fish cover.

Figure 13. Bushy pondweed

Photo by: Gary Fewless (UW Green Bay)

Floating-leaf and emergent plants

Floating-leaf and emergent aquatic plants are anchored in the lake bottom and their root systems often form extensive networks that help consolidate and stabilize bottom substrate. Beds of floating-leaf and emergent plants help buffer the shoreline from wave action, offer shelter for insects and young fish, and provide shade for fish and frogs. These beds also provide food, cover and nesting material for waterfowl, marsh birds and muskrat. Floating-leaf and emergent plants are most often found in shallow water to depths of about six feet and may extend lake-ward onto mudflats and into adjacent wetlands.

Figure 14. White waterlily

White and yellow waterlilies can be found in lakes in both northern and southern Minnesota. White waterlily (*Nymphaea odorata*; Figure 14) has showy white flowers and round leaves with radiating veins. Yellow waterlily (*Nuphar variegata*; Figure 15) has smaller yellow flowers and oblong leaves with parallel veins. These species often co-occur in mixed beds but yellow waterlily is generally restricted to depths less than seven feet and white waterlily may occur to depths of ten feet (Nichols1999b).

Figure 15. Yellow waterlily

Emergent aquatic plants have stems and/or leaves that extend well above the water surface. Most emergent plants are flowering plants, though their flowers may be reduced in size. Emergent plants include perennial plants as well as annual plants. Emergent plants can be grouped by leaf width as narrow-leaved, grass-leaved and broad-leaved plants.

Figure 16. Bulrush

Bulrushes (*Schoenoplectus* spp.; Figure 16) are emergent, narrow-leaved, perennial plants that occur in lakes and wetlands throughout Minnesota (Ownbey and Morley 1991). Bulrush stems are round in cross section and lack showy leaves. Clusters of small flowers form near the tips of long, narrow stalks. This emergent may occur from shore to water depths of about six feet and its stems may extend several feet above the water surface. Bulrush stands are particularly susceptible to destruction by excess herbivory and direct removal by humans.

Unique aquatic plants

Unique aquatic plant species are of high conservation importance. These species may include:

- Plant species that are not listed as rare but are uncommon in the state or locally. These may include species that are proposed for rare listing.
- Plants species with high coefficient of conservatism values (C values). These values range from 0 to 10 and represent the “estimated probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be a pre-settlement condition” (Nichols 1999a, Bourdaghs et al. 2006). Plant species with assigned C values of 9 and 10 were included as unique species.

Bladderworts (*Utricularia* spp.) are a group of submerged plants with finely divided leaves. They produce roots but do not firmly anchor to the lake bottom. Unique bladderwort species include flat-leaved bladderwort (*U. intermedia*) and lesser bladderwort (*U. minor*). Bladderworts have specialized air bladders that regulate their position in the water column. They also act as "underwater Venus fly-traps" by catching and digesting small insects in the bladders. Bladderworts produce small but showy flowers (Figure 17) that emerge above the water surface. They prefer soft substrates (Nichols 1999b) but also float freely in the water column and may be found in protected areas such as waterlily beds. They are found in protected, shallow lake areas and have been documented at scattered locations throughout northern Minnesota (Ownbey and Morley 1991).

Figure 17. Bladderwort flowers

Mare's tail (*Hippuris vulgaris*) is a submerged plant with whorls of leaves that resemble a horse's tail (Figure 18). This plant occurs primarily in northern Minnesota lakes but is relatively uncommon. It is often associated with cold-water streams or springs (Voss 1985) and its presence in a waterbody may be indicative of relatively good water quality. This submerged plant may form emergent leaves and stems in shallow water.

Figure 18. Mare's tail

Creeping spearwort (*Ranunculus flammula*) is mostly found in the northern half of Minnesota (Flora of North America 1993+). It grows on hard substrates like sand and gravel (Borman et al. 2001). Creeping spearwort often grows as a submerged plant but may grow as a short emergent on mudflats. It has linear leaves that emerge in small clusters from the arched runners or stolons. This plant is in the buttercup family and if stranded on mudflats, it may form characteristic yellow buttercup flowers (Figure 19).

Figure 19. Creeping spearwort

Photo by: Emmit Judziewicz, U of WI-Stevens Point Herbarium

Water bulrush (*Schoenoplectus subterminalis*; Figure 20) is closely related to the emergent bulrush plants but grows primarily as a submerged plant. It is a rooted perennial with fine, grass-like leaves and may form mats near the water surface. In mid to late summer its leaf tips and flower stalk may emerge above the water surface. This species once had a patchy distribution throughout North America but may now be extirpated from Illinois (Flora of North America 1993+) and its conservation status is listed as critically impaired in several other states (NatureServe 2011). It is infrequently found in Wisconsin (Nichols 1999b) and Minnesota (Ownbey and Morley 1991) lakes.

Figure 20. Water bulrush
Copyright 1996 D.W. Taylor

Quillwort (*Isoetes* sp.) (Figure 21) is a submerged plant that is primarily found in softwater lakes (Nichols 1999b) of northeastern Minnesota (Ownbey and Morley 1991). It is specially adapted to live in very low carbon environments (Bolton and Adams 1986). This is not a flowering plant but reproduces and spreads by megaspores that are produced late in the summer. Quillworts are named for their leaf-like structures that resemble "quills." Quillworts are among a specialized group of aquatic plants that are compact, slow-growing and ever-green and capable of surviving in low nutrient habitats (Madsen 1991).

Figure 21. Quillwort (*Isoetes* sp.)
Photo: C. Taylor USDA-NRCS PLANTS Database

Species richness

Species richness is defined as the number of species present in a community and is often used as a simple measure of biodiversity (Magurran 2004). In aquatic plant communities, species richness is influenced by many complex factors (Pip 1987) including water chemistry, transparency, habitat area and habitat diversity (Vestergaard and Sand-Jensen 2000, Rolon et al. 2008). In Minnesota, water chemistry strongly influences which plant species can potentially occur in a lake (Moyle 1945), and thus, indirectly influences lakewide species richness. The trophic status of a lake further influences plant species richness and eutrophic and hypereutrophic habitats have been associated with reduced species richness (Pip 1987). Within a region of Minnesota, lakewide aquatic plant species richness can be used as a general indicator of the lake clarity and overall health of the lake plant community. Loss of aquatic plant species has been associated with anthropogenic eutrophication (Stuckey 1971, Nicholson 1981, Niemeier and Hubert 1986) and shoreland development (Meredith 1983).

Within a lake, plant species richness generally declines with increasing water depth, as fewer species are tolerant of lower light levels available at deeper depths. Substrate, wind fetch, and other physical site characteristics also influence plant species richness within lakes.

Methods

The aquatic plant communities of Turtle Lake were described and measured using several techniques as found in Minnesota's Sensitive Lakeshore Identification Manual. Plant nomenclature follows MnTaxa 2013.

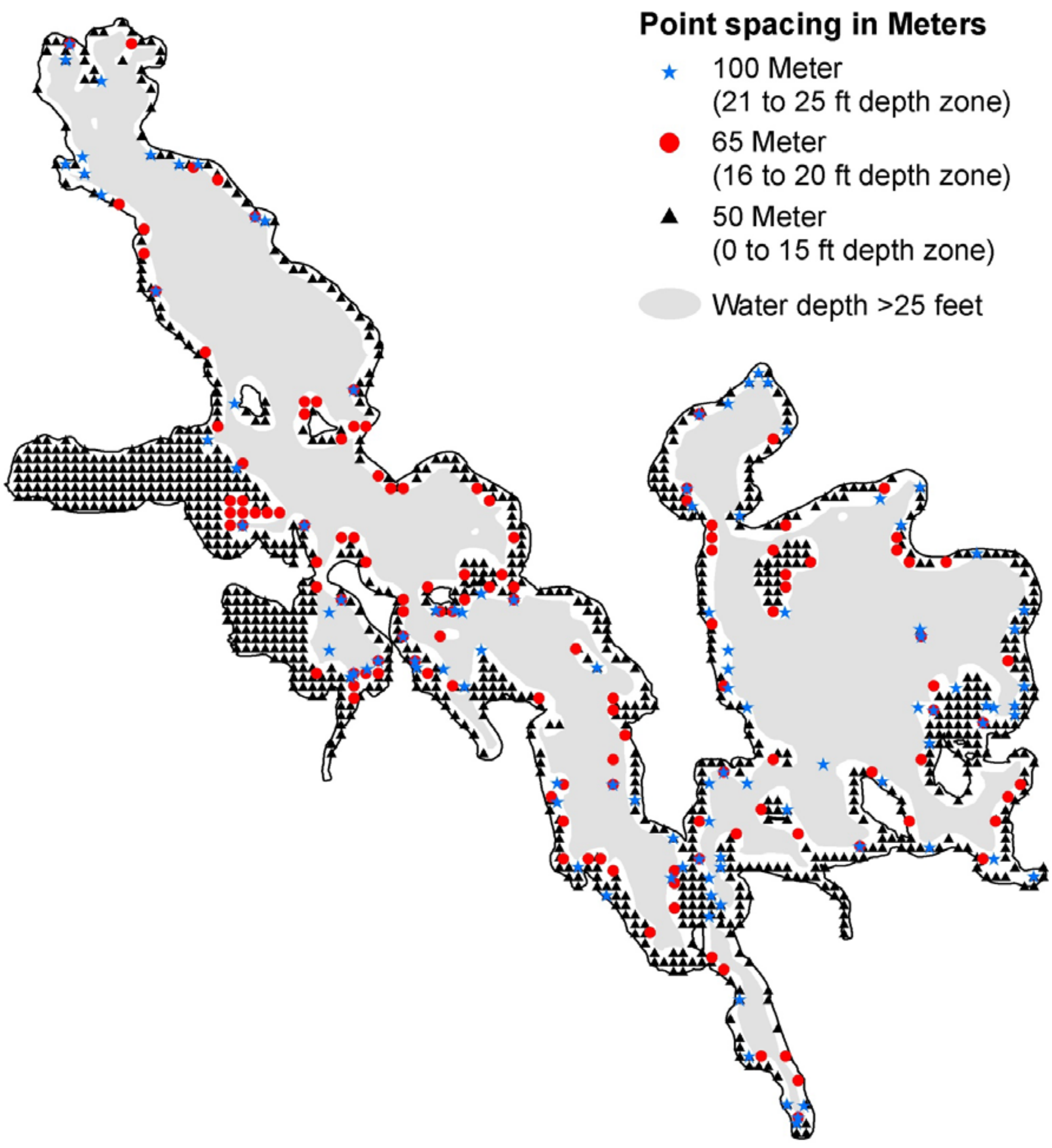
Grid point-intercept survey

The submerged plant community of Turtle Lake was assessed from July through early September, 2013, using a grid point-intercept survey (Simon and Perleberg 2014). A GIS computer program was used to establish aquatic plant survey points throughout the littoral (i.e., vegetated) zone of the lake to a depth of 25 feet. To ensure a sufficient number of sample points in the near-shore zone, survey points were stratified by water depth (Figure 22). Sample points were spaced closer together in shallow water to increase the survey effort in the area of the lake most likely to contain a high diversity of aquatic plant taxa (Table 1). In the field, surveyors sampled sites where water depth was less than 26 feet for a total of 1,066 sites within the 0-25 feet depth zone. Surveyors navigated to each site using a handheld Global Positioning (GPS) unit.

Table 1. Survey effort by depth interval.

Water depth (feet)	Point spacing in meters	Number of survey sites
0 to 5	50	535
6 to 10	50	220
11 to 15	50	110
16 to 20	65	100
21 to 25	100	101
Total		1066

Figure 22. 2013 Point-Intercept stratified survey sites on Turtle Lake.



At each sample site, water depth was measured and all vegetation within a one-meter squared area was sampled using a double-headed garden rake. All aquatic plant species present within the sample plot were recorded and frequency of occurrence was calculated for each species. Any additional plant taxa found outside of sample sites were recorded as "present" in the lake but these data were not used in frequency of occurrence calculations. Plant identification followed Crow and Hellquist (2000) and Flora of North America (1993+) and nomenclature followed MNTaxa (2013).

Frequency of occurrence was calculated for the entire vegetated zone (0-25 feet) and data were also separated into five feet increment depth zones for analysis (Table 1). Frequency estimates were also calculated for individual taxa and selected groups of plants.

Emergent and floating-leaf bed delineation
Mapping focused on plant beds that were at least 0.01 acres, or about 400 square feet, in size (generally larger than the surface area covered by a pontoon boat). Draft maps of floating-leaf and emergent plant beds were created prior to field surveys using 2010 Farm Service Administrative (FSA) true color aerial photographs. Field surveys were conducted in August and September 2013 to map plants like bulrush, which are difficult to identify from aerial photos, and to verify photo-interpretation of other plant beds. Surveyors mapped emergent and floating-leaf plant beds in the field by motoring or wading around the perimeter of each bed and recording a track with a handheld GPS unit. Field data were uploaded to a computer and a GIS software program was used to estimate acreage. Plant beds were classified by the dominant species or species-group.

Searches for unique and rare species
Prior to fieldwork, surveyors searched the Rare Features Database of the MN DNR Natural Heritage Information System for any known locations of state and federally listed rare plants within one mile of Turtle Lake. Surveyors also queried the University of Minnesota Herbarium Vascular Plant Collection database and DNR Fisheries Lake Files to determine if certain plant species had previously been documented in or near Turtle Lake.

Surveyors searched for unique and rare plant species in 2013 during the lakewide point-intercept survey and while mapping emergent and floating-leaf plant beds. A targeted search for rare aquatic vascular plants was conducted by the Minnesota County Biological Survey Program on July 24, 2001 (Myhre 2001). This search focused on sites that were most likely to contain rare plant species. Botanists used professional experience to select rare species search sites and included factors such as shoreline development, substrate type, water depth, and native plant community type in their site selection. To gain access to shallow vegetated areas, searches were conducted by slowly kayaking, canoeing and/or wading through the site. A brief habitat description and a list of all plant taxa found in the search area were recorded.

If unique or rare plant species were located, surveyors recorded the site location, the plant species found, associated plant species, approximate water depth and substrate type. When necessary, plant specimens were sent to the authority in the field for identification verification and annotation. Voucher specimens were made to document plant species and were submitted to The Herbarium of the University of Minnesota Bell Museum of Natural History, St. Paul, MN or are stored at the Brainerd Area Office of the MNDNR.

Results

Distribution of plants by water depth
Aquatic plants were found from shore to a depth of 25 feet and within that zone, 85% of the sites contained vegetation (Figure 23). The greatest occurrence of plants was in the depth zone from 0 to 15 feet, where 94% of the sample sites contained plants. Plant growth declined with

increasing water depth and in water depths of 21 to 25 feet, plant frequency was 33% (Figure 24). Sparse plant growth may have occurred in the 26 to 30 feet depth zone but this depth was not included in the survey and a significant search effort would be needed to document scattered plants in deeper water.

Aquatic plant species observed
In 2013, a total of 44 native aquatic plant taxa were recorded in Turtle Lake. These included 27 submerged, six floating-leaf and 11 emergent taxa (Table 2). Several species that can be difficult to distinguish in the field were grouped together for analysis. These species complexes are shown in the "2013" column of Table 2.

Submerged plants
The submerged plant community was dominated by macroalgae which occurred in 72% of all sites. Macroalgae often co-occurred with rooted plants; 48% of the vegetated sites contained both macroalgae and rooted plants, 24% contained only macroalgae and 13% contained only rooted plants (Figure 25).

The macroalgae present in Turtle Lake were muskgrass present in 69% of all sample sites, and stonewort occurring in 7% of the sites (Table 2). Muskgrass dominated the plant community from shore to 20 feet in depth and stonewort was common from 21 to 25 feet (Figure 26).

Numerous species of true aquatic plants (types that form true roots and flowers)were found growing in the near-shore zone of Turtle Lake and no one species or species group was dominant. In the deepest depth zone, 21 – 25 feet, few true plants were found.

Greater bladderwort was the most frequently found flowering plant and was recorded in 11% of the Turtle Lake survey sites. Other common submerged flowering plants included narrow-leaved pondweeds (10%), flat-stem pondweed (9%), native watermilfoils (8%) and naiads (8%) (Table 2). Flowering plants did not dominate at any depth zone (Figure 26) but as a group, they were an important component of the lake ecosystem and added a wide variety of submerged habitat structure.

Table 2. Historical and current aquatic plants found in Turtle Lake, 1935 - 2013.

Submerged plants

	Common Name	**Scientific Name**	**1935**	**1950**	**1975**	**2001**	**2013**
Lg Algae	Muskgrass	*Chara* sp.			X		69
	Stonewort	*Nitella* sp.		X			4
Moss	Watermoss	Not identified to genus					3
Monocots	Needlerush	*Eleocharis acicularis*					P
	Canada waterweed	*Elodea canadensis*				X	4
	Water star-grass	*Heteranthera dubia*					<1
	Quillwort	*Isoetes* sp.					P
	Naiads	*Najas flexilis*				X	[B]8
		Najas guadalupensis					
	Slender naiad	*Najas gracillima*[A]		?			--
	Large-leaf pondweed	*Potamogeton amplifolius*			X		2
	Narrow-leaf pondweed group	*Potamogeton friesii*				X	[B]10
		Potamogeton pusillus				X	
		Potamogeton obtusifolius		X			
		Potamogeton strictifolius				X	
	Variable pondweed	*Potamogeton gramineus*				X	3
	Illinois pondweed	*Potamogeton illinoensis*				X	7
	White-stem pondweed	*Potamogeton praelongus*				X	2
	Clasping-leaf pondweed	*Potamogeton richardsonii*		X	X	X	4
	Robbin's pondweed	*Potamogeton robbinsii*				X	1
	Flat-stem pondweed	*Potamogeton zosteriformis*		X	X	X	9
	Widgeon grass	*Ruppia occidentalis*[A]			?		--
	Water bulrush	*Schoenoplectus subterminalis*					1
	Sago pondweed	*Stuckenia pectinata*			X	X	2
	Wild celery	*Vallisneria americana*	X			X	4
Dicots	Water marigold	*Bidens beckii*				X	<1
	Coontail	*Ceratophyllum demersum*		X		X	4
	Northern watermilfoil	*Myriophyllum sibiricum*		X		[B]X	[B]8
	Whorled watermilfoil	*Myriophyllum verticillatum*					
	Marestail	*Hippuris vulgaris*				X	P
	White water buttercup	*Ranunculus aquatilis*				X	--
	Creeping spearwort	*Ranunculus flammula*				X	P
	Greater bladderwort	*Utricularia vulgaris*		X		X	11
	Flat-leaved bladderwort	*Utricularia intermedia*					2
	Lesser bladderwort	*Utricularia minor*					2
		Total	1	8	6	20	27

Floating-leaved plants

Common Name	**Scientific Name**	**1935**	**1950**	**1975**	**2001**	**2013**
Watershield	*Brasenia schreberi*					2
Yellow waterlily	*Nuphar variegata*	X	X		X	6
White waterlily	*Nymphaea odorata*	X	X		X	9
Floating-leaf smartweed	*Persicaria amphibia*					P
Floating-leaf pondweed	*Potamogeton natans*		X		X	8
Floating-leaf burreed	*Sparganium fluctuans*					<1
	Total	2	3	0	3	6

Emergent plants

Common Name	**Scientific Name**	**1935**	**1950**	**1975**	**2001**	**2013**
Sweet flag	*Acorus americanus*					P
River bulrush	*Bolboschoenus fluviatile*					<1
Sedge	*Carex* sp.					<1
Spikerush	*Eleocharis palustris*				X	1
Horsetail	*Equisetum fluviatilis*				X	<1
Baltic rush	*Juncus articus var. balticus*					P
Giant cane	*Phragmites australis*					P
Broad-leaf arrowhead	*Sagittaria latifolia*	[B]X			X	[B]<1
Bulrush	*Schoenoplectus* sp.[C]		X		X	24
Giant burreed	*Sparganium eurycarpum*					[B]<1
Narrow-leaf cattail	*Typha angustifolia*					[B]<1
Broad-leaf cattail	*Typha latifolia*					
	Total	1	1	0	4	11

Wetland emergent plants

Common Name	**Scientific Name**	**1935**	**1950**	**1975**	**2001**	**2013**
Purple loosestrife (I)	*Lythrum salicaria*				X	P
Reed Canary Grass (I)	*Phalaris arundinacea*				X	P
	Total	0	0	0	2	2

(I)= Introduced to Minnesota

[A] *Najas gracillima* and *Ruppia occidentalis* are rare species that were reported, but not officially confirmed, in Turtle Lake in 1950 and 1975. These plants closely resemble several other submerged plants and without a voucher specimen it is not possible to confirm these plants in the lake.
[B]some plants were only identified to the genus level in this lake. It is possible that additional species of this genus were present in the lake, but only one species was positively identified.
[C]species of bulrush (*Schoenoplectus* sp.) was used to record bulrush plants that were hard-stem bulrush (*Schoenoplectus acutus*), soft-stem bulrush (*S. tabernaemontani*) or the hybrid.

2013 (July 9, 10, 11, 22, 23, 24, 25, 30, 31, August 14-15, September 3)
Perleberg, Simon, Hauck, Froelich, Schubert, MNDNR EWR Lakes and Rivers Unit
2001 (July 24) Karen Myhre, MNDNR County Biological survey
1975 survey (July 21-25) Marc Olson, MNDNR Division of Game and Fish: Major bulrush stands grew on North shore of main basin and heavy stands of bulrush in southwest bay of lake. Submerged vegetation found to a depth of 17 feet.
1950 (August 16-23) Robert Erickson, Robert Farmes, MN Department of Conservation Division of game and fish.
1935 (September 4) Chippewa National Forest survey.

Figure 23. Aquatic plant distribution in Turtle Lake, 2013.

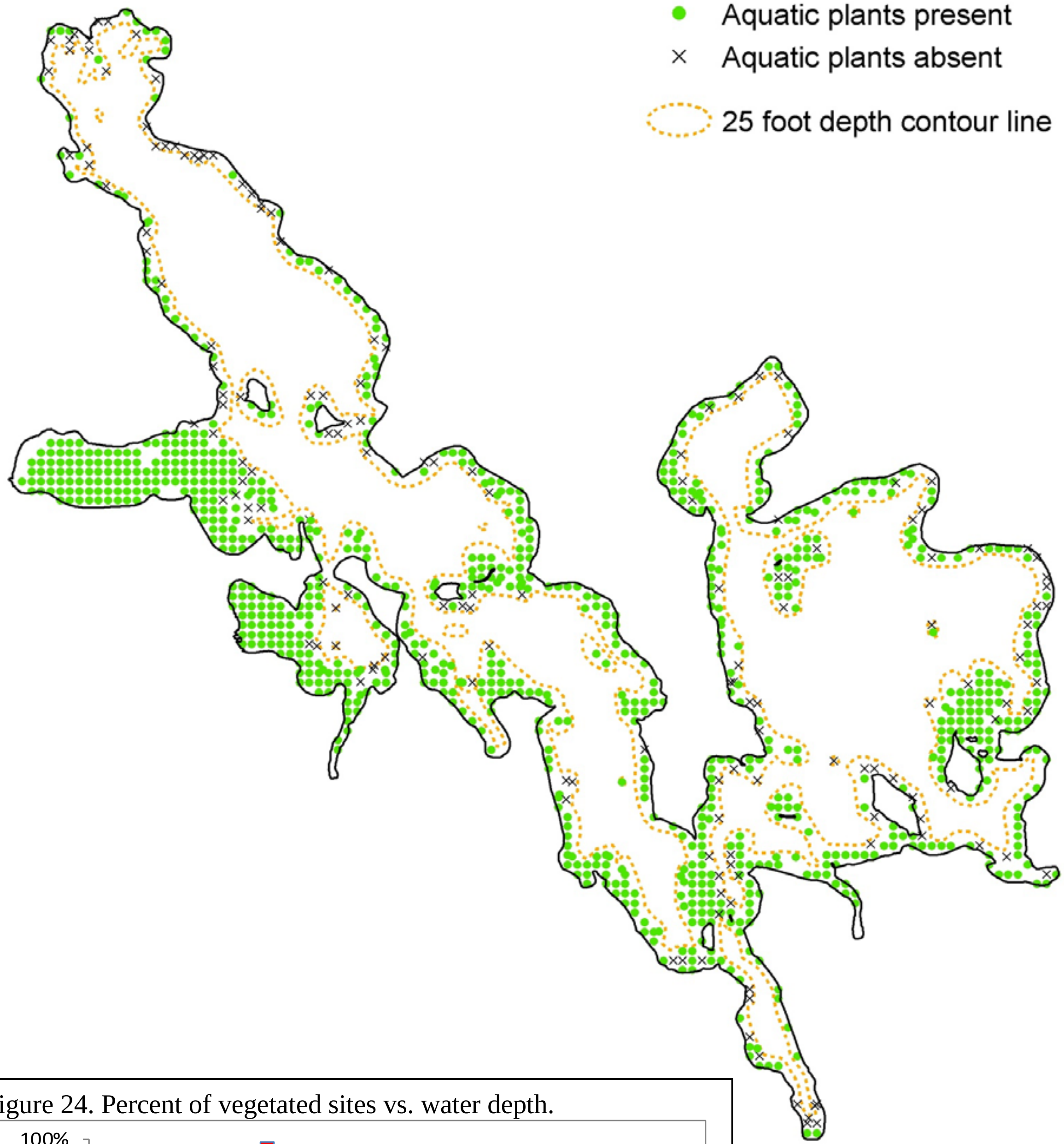


Figure 24. Percent of vegetated sites vs. water depth.

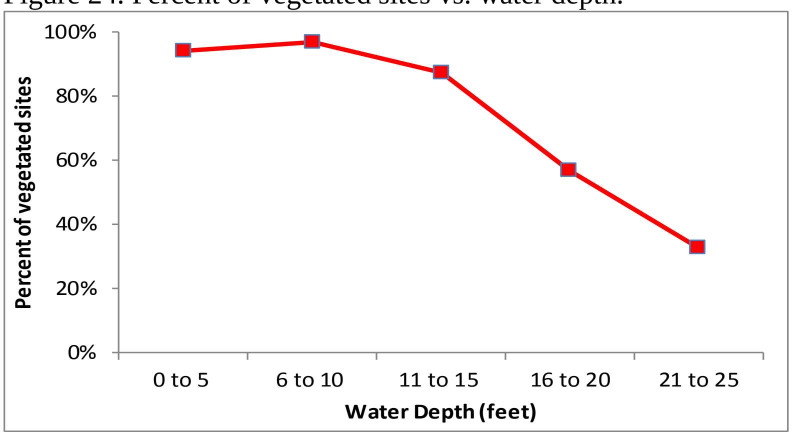


Figure 25. Macroalgae and rooted plants in Turtle Lake, 2013.

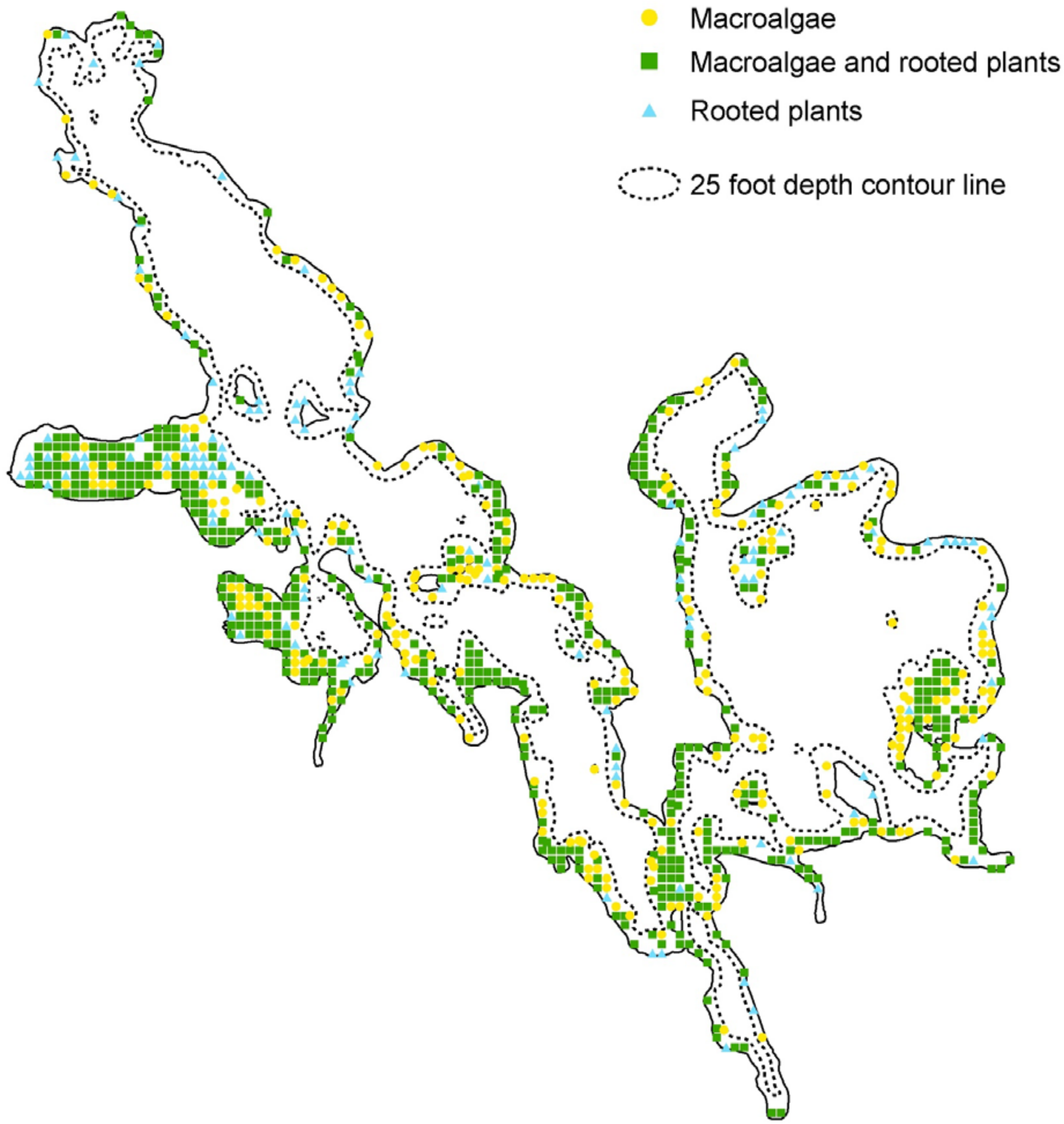
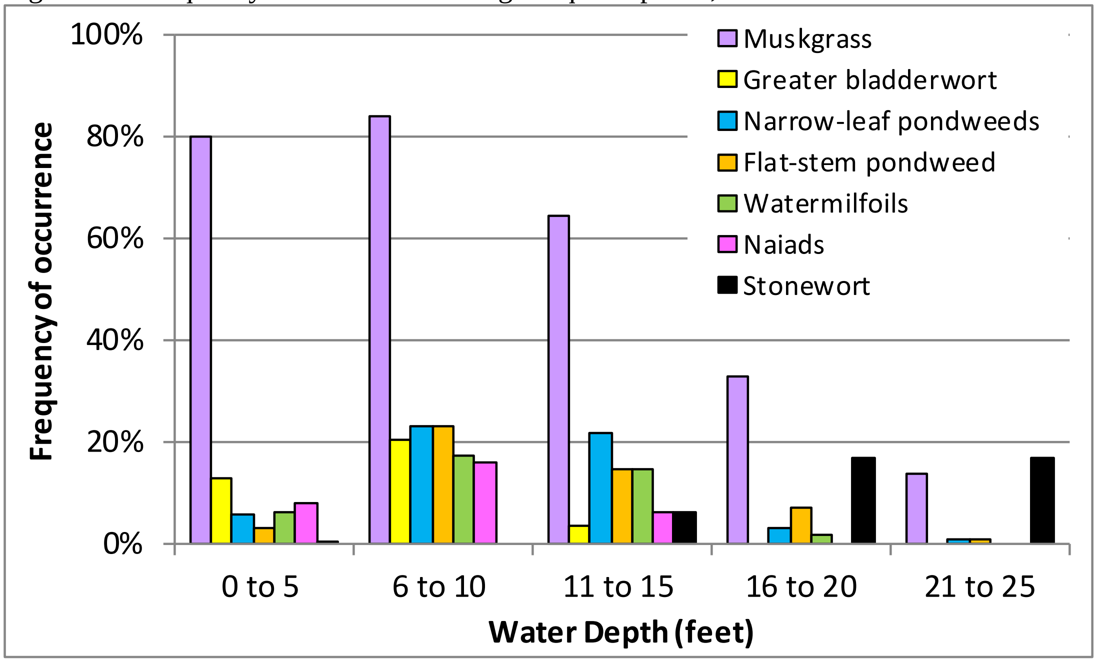


Figure 26. Frequency of common submerged aquatic plants, Turtle Lake 2013.



Floating-leaf and emergent plants

Floating-leaf (Figure 27) and emergent plants (Figure 28) occurred in water depths of 10 feet and less.

Figure 27. Waterlilies in Turtle Lake, 2013.

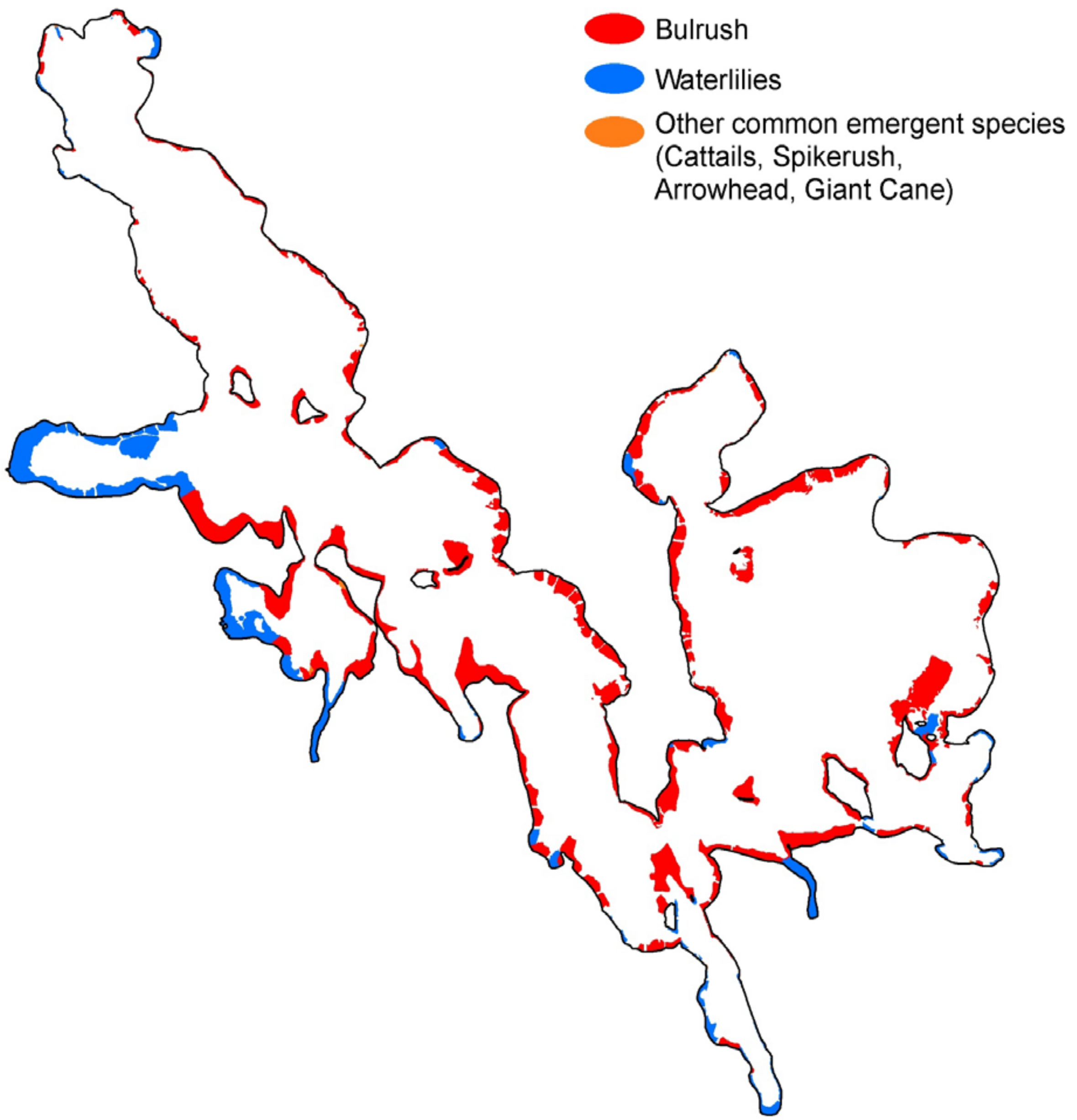
About 81 acres of floating-leaf plant beds were mapped and the largest beds occurred in Moose Bay. The most common floating-leaf plant species were white waterlily, yellow waterlily, floating-leaf pondweed and watershield. Waterlily beds often contained scattered bulrush plants as well as submerged plants and were usually associated with muck sediments.

Figure 28. Bulrush bed in Turtle Lake, 2013.

Surveyors delineated approximately 229 acres of emergent plants and the most common species was bulrush. Bulrush was found on sandy sites in water depths from shore to seven feet. The largest bulrush beds occurred along shorelines in the southern two-thirds of the lake, including shorelines around islands (Figure 29).

Other emergent plants occurred at scattered locations around the lake and included spikerush, arrowhead, giant cane and cattails. Many of these emergent plants occupied the transitional zone between the lake and adjacent wetlands. Numerous additional native emergents occurred in these adjacent wetlands but this survey did not include an exhaustive wetland species inventory.

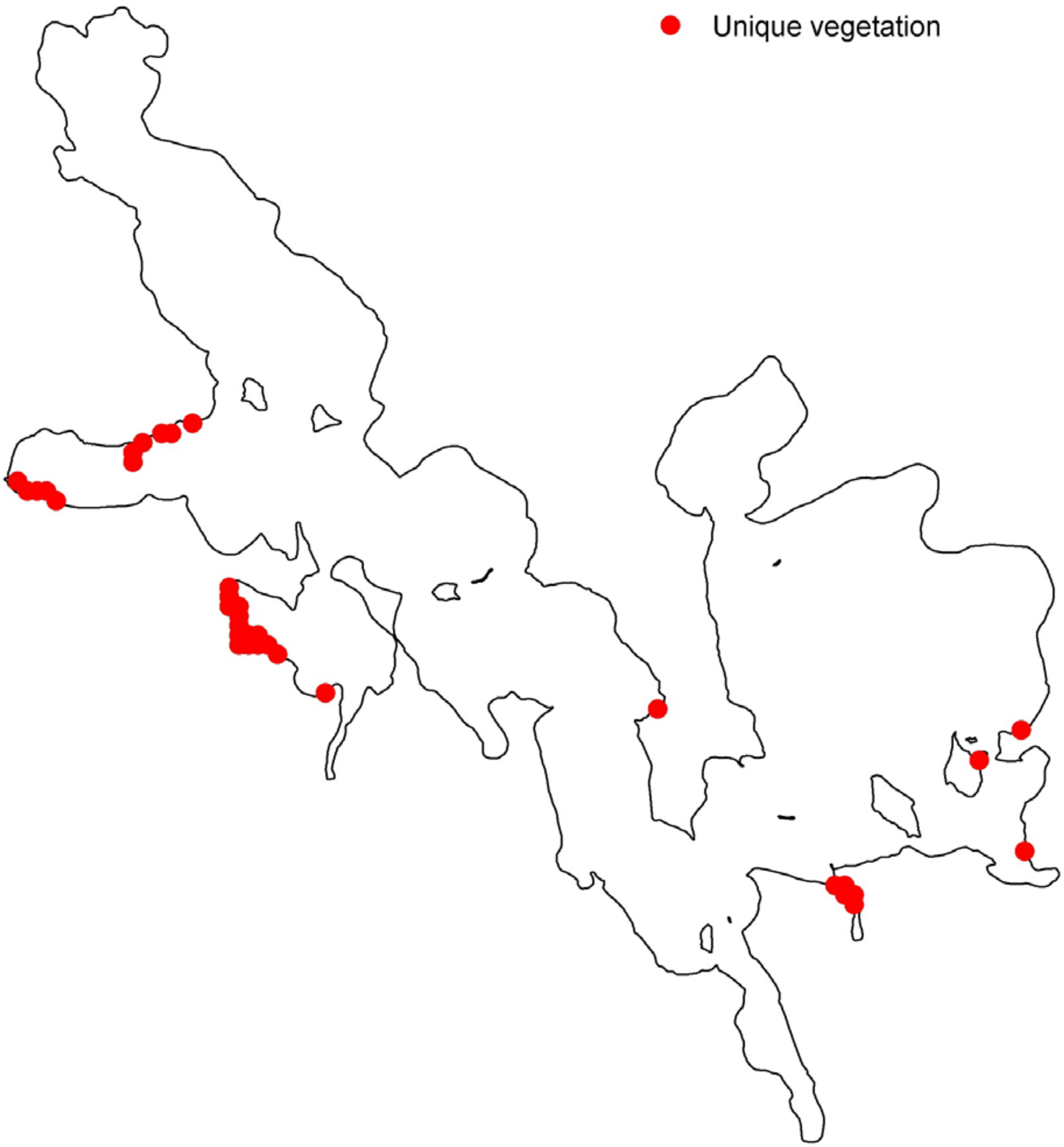
Figure 29. Distribution of floating-leaf and emergent plant beds in Turtle Lake, 2013.



Unique plants

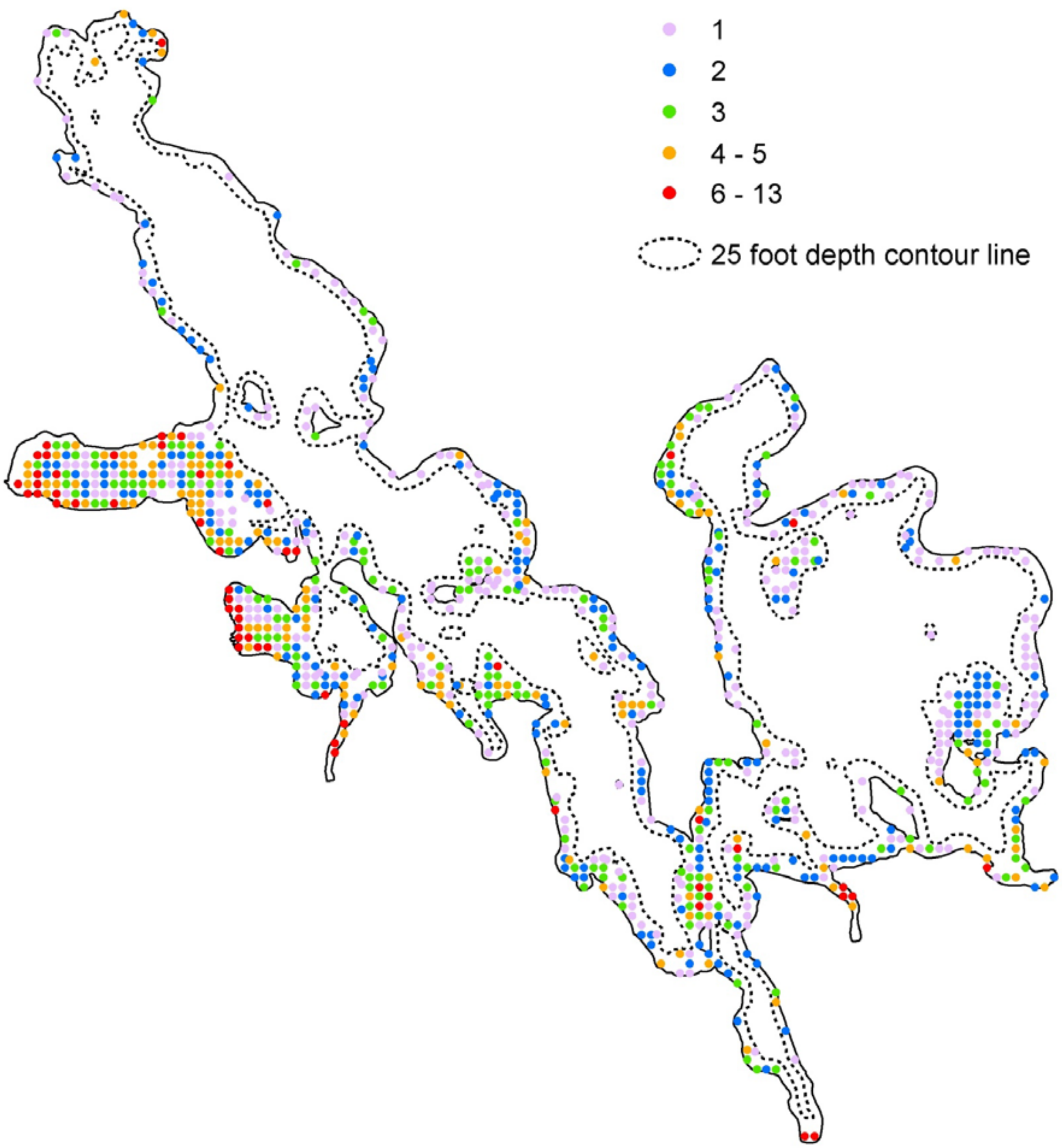
In addition to the commonly occurring plants in Turtle Lake, six submerged unique plant species were located. These species were found in undisturbed, shallow areas (depth less than five feet) throughout Turtle Lake (Figure 30). These species are not widespread in Minnesota but their presence is indicative of relatively undisturbed native plant beds in Turtle Lake.

Figure 30. Unique aquatic plants in Turtle Lake, 2013.



Species richness
The number of plant taxa found in each one square meter sample site ranged from zero to 13 with a mean of two species per site (Figure 31). The greatest number of species was found in protected bays and within areas of thick bulrush that protect species from wave activity.

Figure 31. Aquatic plant richness (number of taxa per sampling station), 2013.



Near-shore Substrates

Objective

1. Describe and map the near-shore substrates of Turtle Lake

Introduction

Substrate type can influence the plant and animal community found along a particular stretch of shoreline. Some fish, such as the pugnose shiner, least darter, and longear sunfish, prefer small diameter substrates, such as silt, muck, and sand. Other species, such as walleye, prefer hard bottom substrates with a larger diameter, such as gravel and rubble. A diverse substrate will also allow plants with different habitat requirements to exist within a system. For example, bulrush may occur on sand or gravel whereas yellow waterlily prefers soft substrates (Nichols 1999b).

Methods

Near-shore substrate in Turtle Lake was evaluated at a total of 846 sampling stations set up in the grid point-intercept aquatic plant surveys and near-shore fish surveys. Plant sample stations were stratified by water depth and occurred in a grid from shore to a depth of 25 feet (see figure 22); substrate was evaluated at sample sites in seven feet of water or less. To increase sample coverage at near-shore sites not covered by the grid sampling, substrate was also evaluated at near-shore fish sample stations. Fish sample stations were located every 400 meters around the perimeter of the lakeshore and substrate was evaluated at 102 of these stations.

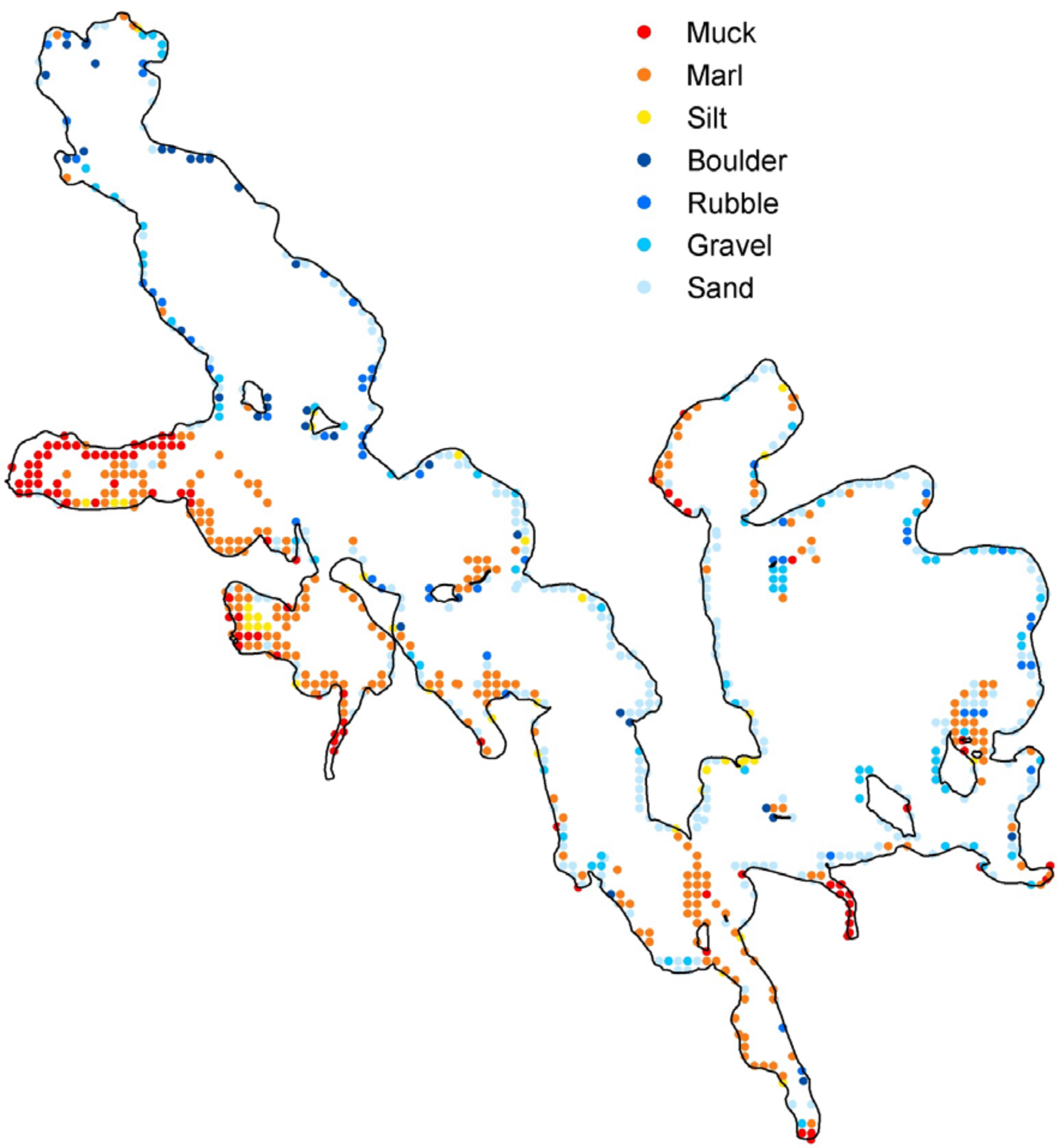
Surveyors evaluated substrate by tapping a pole into the lake bottom; soft substrate could usually be brought to the surface on the pole or sampling rake for evaluation. If this was not feasible, substrate was evaluated by visual observation. Standard lake substrate classes were based on the DNR Fisheries Survey Manual (MN DNR 1993):

Substrate Group	**Type**	**Description**
Hard Bottom	Boulder	Diameter over 10 inches
	Rubble	Diameter 3 to 10 inches
	Gravel	Diameter 1/8 to 3 inches
	Sand	Diameter less than 1/8 inch
Soft Bottom	Silt	Fine material with little grittiness
	Marl	Calcareous material
	Muck	Decomposed organic material

Results

Substrate types documented at Turtle Lake ranged from soft (muck, marl and silt) to hard (gravel, rubble and boulders) (Figure 32). Muck and silt substrates were present in shallow protected areas. Sand substrates occurred along the deep, windswept shorelines of the main lake basin, and were interspersed with scattered boulders, rubble and gravel. Overall, sand was the most common substrate type, and occurred at nearly 37% of the sample locations.

Figure 32. Distribution of Turtle Lake near-shore substrates, 2013.



Loon Nesting Areas

Objectives

1. Map current and historical loon nesting areas
2. Identify loon nests as natural or manmade

Introduction

The Volunteer LoonWatcher survey began in 1979 as a way for the DNR to obtain information on loon numbers and nesting success on a variety of lakes in Minnesota. Each year volunteer loon watchers observe the loons on a selected lake and fill out a report, noting information such as number of loons, number of nests, and number of chicks. Locations of loon nests, if known, are also documented in the report. Volunteers began reporting on Turtle Lake loons in 2006.

Loon pair with chick

Photo by: Paul Bolstad

Common loons may be easily disturbed by human presence, and tend to avoid nesting where development has occurred. They prefer protected areas such as bays and islands, especially those areas with quiet shallow water and patchy emergent vegetation that provides cover. Identification of these loon nesting sites will help managers prevent degradation and destruction of these sensitive areas.

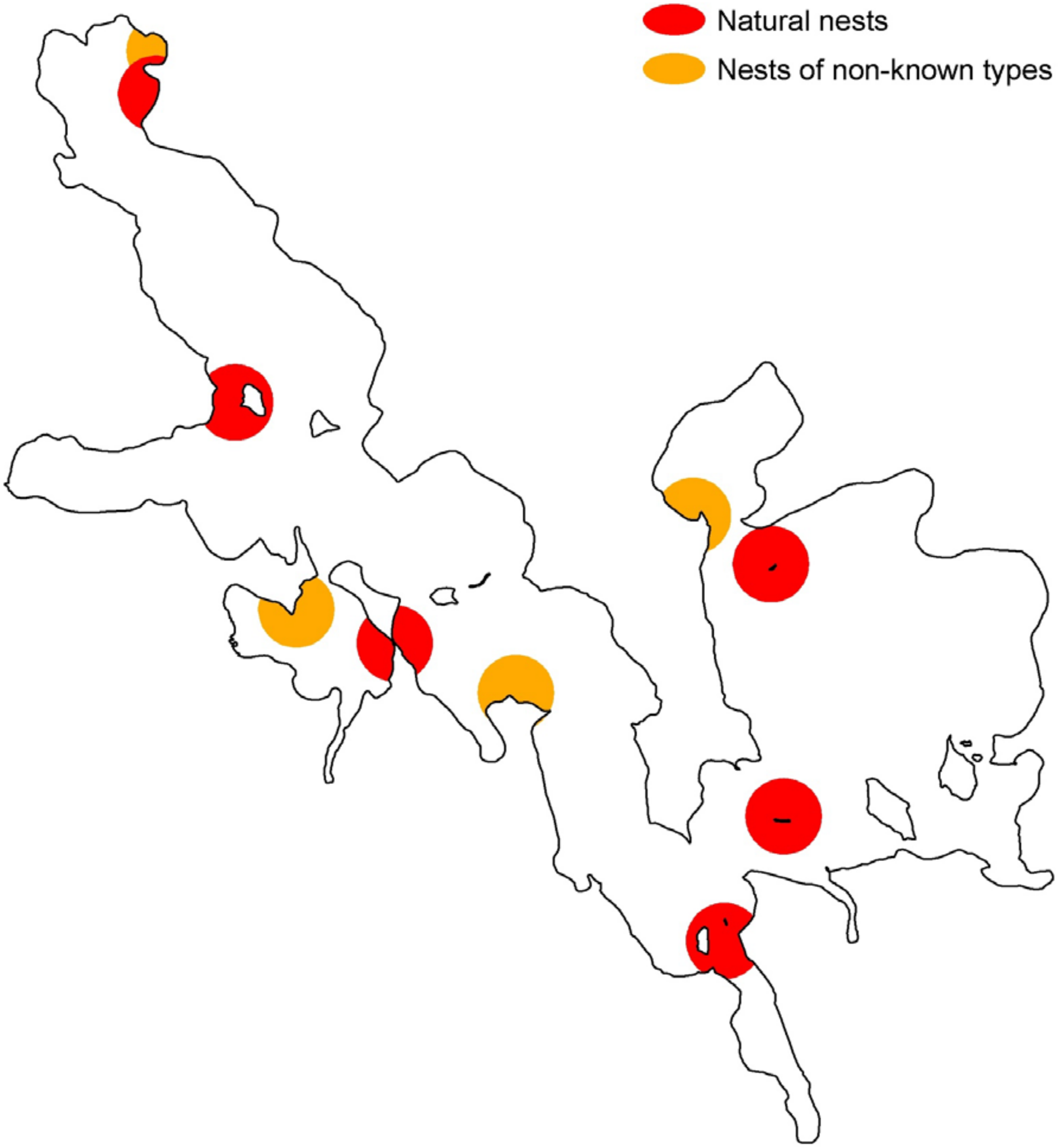
Methods

Using information from LoonWatcher reports and bird, fish, and vegetation survey crews, researchers mapped loon nesting locations in GIS. Mapped nests were buffered by 200 meters to account for locational uncertainty. Nests were identified as either natural or manmade (artificial platforms). All former and current natural nesting locations and artificial platforms used by loons were included in the maps and analysis; artificial platforms not utilized by loons were not included.

Results

Since 2006, 10 loon nesting areas have been identified on Turtle Lake (Figure 33). Six natural nests have been recorded scattered around Turtle Lake. One natural loon nest was found during the 2013 survey and the other five were found in 2007. Four additional nesting areas were reported in 2006; it is unknown whether these nests were natural nests or artificial platforms.

Figure 33. Location of natural loon nests and nests of non-known types (*it is unknown whether these nests were natural nests or artificial platforms) recorded on Turtle Lake between 2006 and 2013.



Aquatic Frog Surveys

Objectives

1. Record index of abundance for all frogs and toads
2. Estimate actual abundance of green and mink frogs
3. Develop distribution maps for green and mink frogs

Introduction

Amphibians are ideal indicator species of lakeshore habitats. Although population declines may be caused by a number of factors, including predation, competition, and introduction of exotic species, amphibians are particularly prone to local extinctions resulting from human-caused alteration and fragmentation of their habitat. Removal of vegetation and woody debris, retaining wall construction, and other common landscaping practices all have been found to negatively affect amphibian populations.

Target species for the frog surveys were mink frog (*Rana septentrionalis*) and green frog (*Rana clamitans*). These frogs, which are strongly associated with larger lakes, are easily surveyed during their breeding season, which extends from May until August. During this time they establish and defend distinct territories, and inhabit vegetated areas along the lakeshore.

Figure 34. Mink frog

Photo by: Jeff LeClere, www.herpnet.net

Mink frogs (Figure 34) are typically green in color with darker green or brown mottling. They emit an odor similar to that of a mink when handled. They inhabit quiet waters near the edges of wooded lakes, ponds, and streams, and are considered the most aquatic of the frogs found in Minnesota. Populations of mink frogs have potentially been declining recently, and the numbers of observed deformities have been increasing.

Figure 35. Green frog

Photo by: Jeff LeClere, www.herpnet.net

Green frogs (Figure 35) are medium-sized, greenish or brownish frogs with small dark spots. The belly is often brighter in color than the back. A large tympanum (eardrum) helps identify the green frog. They can be found in a variety of habitats surrounding lakes, streams, marshes, and swamps, but are strongly associated with the shallow water of lakeshores. Although green frog populations are generally stable, regional declines and local extinctions have been noted.

Methods

The aquatic frog survey methodology followed the Minnesota Frog and Toad Calling Survey (MFTCS) protocol (see Minnesota's Sensitive Lakeshore Identification Manual for additional information on how this protocol was adjusted for water routes). Frog survey points were located around the entire lake, spaced 400 meters apart. Surveys were conducted between sunset and 1:00 AM. At each station surveyors listened for up to five minutes for all frog and toad calls. An estimate of abundance and a calling index were recorded for both green and mink frogs. For other species, only calling index was recorded. If survey conditions such as rain or wind noticeably affected listening ability, the survey was terminated.

Results

Target species

Both green frogs and mink frogs were documented during the Turtle Lake frog surveys (Figure 36). Green frogs were recorded most frequently; they were heard at 61 of 113 survey stations. Green frogs were also heard at several scattered locations along the west side and in the protected areas of the larger east basin. Mink frogs were heard less frequently than green frogs; surveyors recorded this species at 21 survey stations. All 21 survey stations were located in Moose Bay, the bay south of Moose Bay, and Sager Bay.

At survey stations where green frogs were present, abundance estimates ranged from one frog to 100 frogs (Figure 37). At the majority of these stations, individual frog calls were distinguishable, although no more than 20 mink frogs were heard at a single Turtle Lake survey station (Figure 38).

Figure 36. Distribution of green and mink frogs heard during Turtle Lake frog surveys, July 2013.

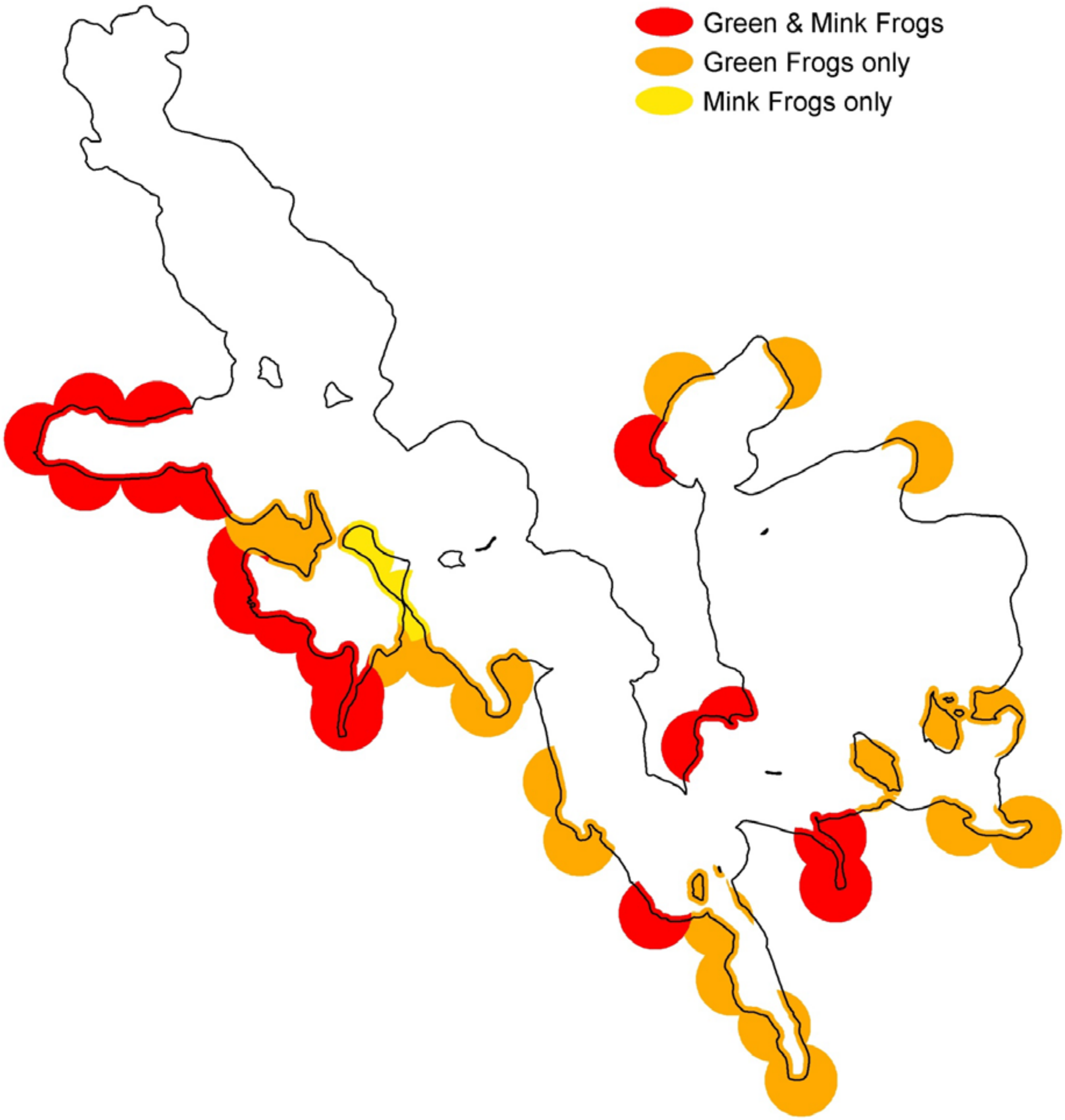


Figure 37. Abundance of green frogs heard during Turtle Lake frog surveys, July 2013.

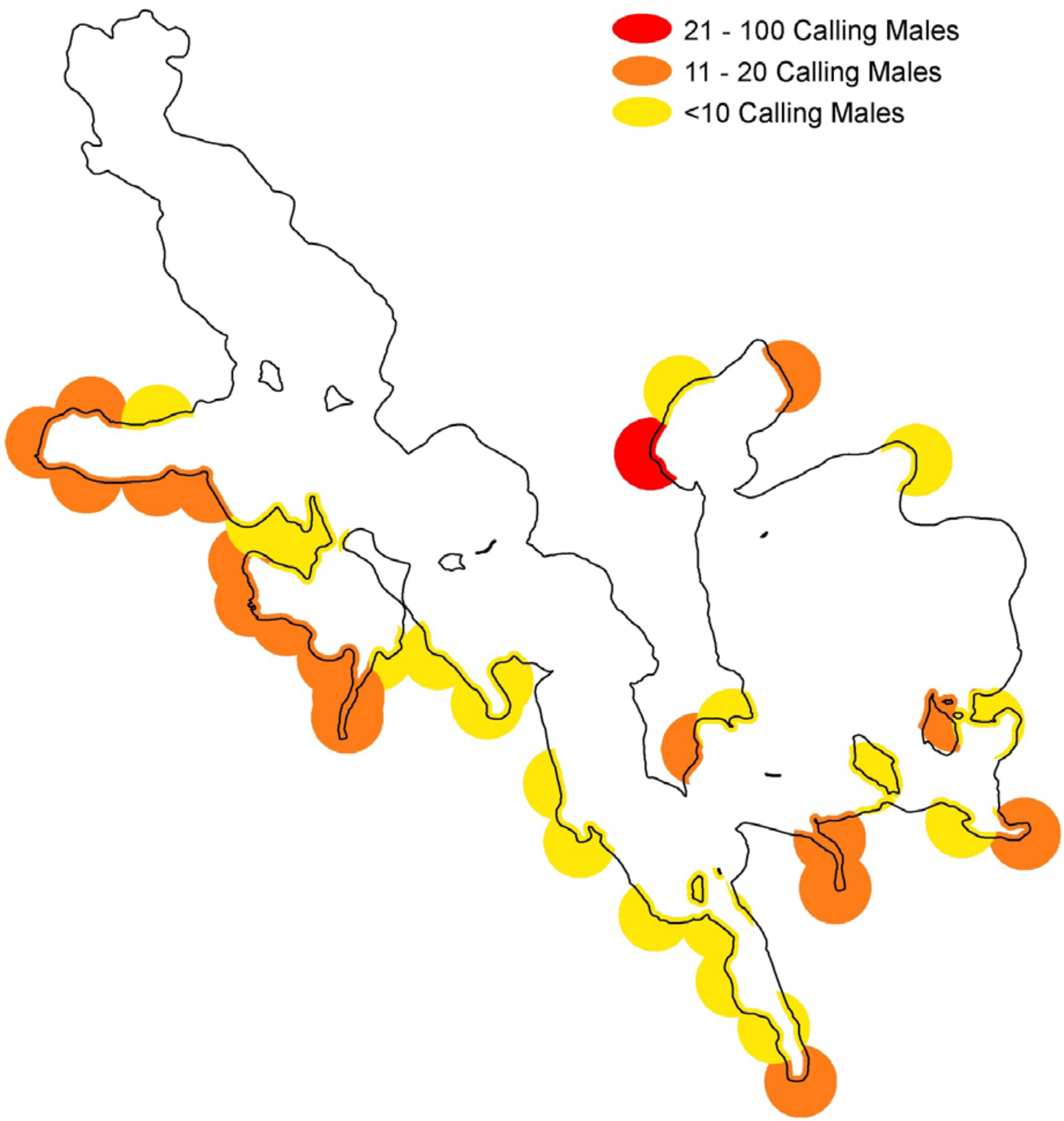
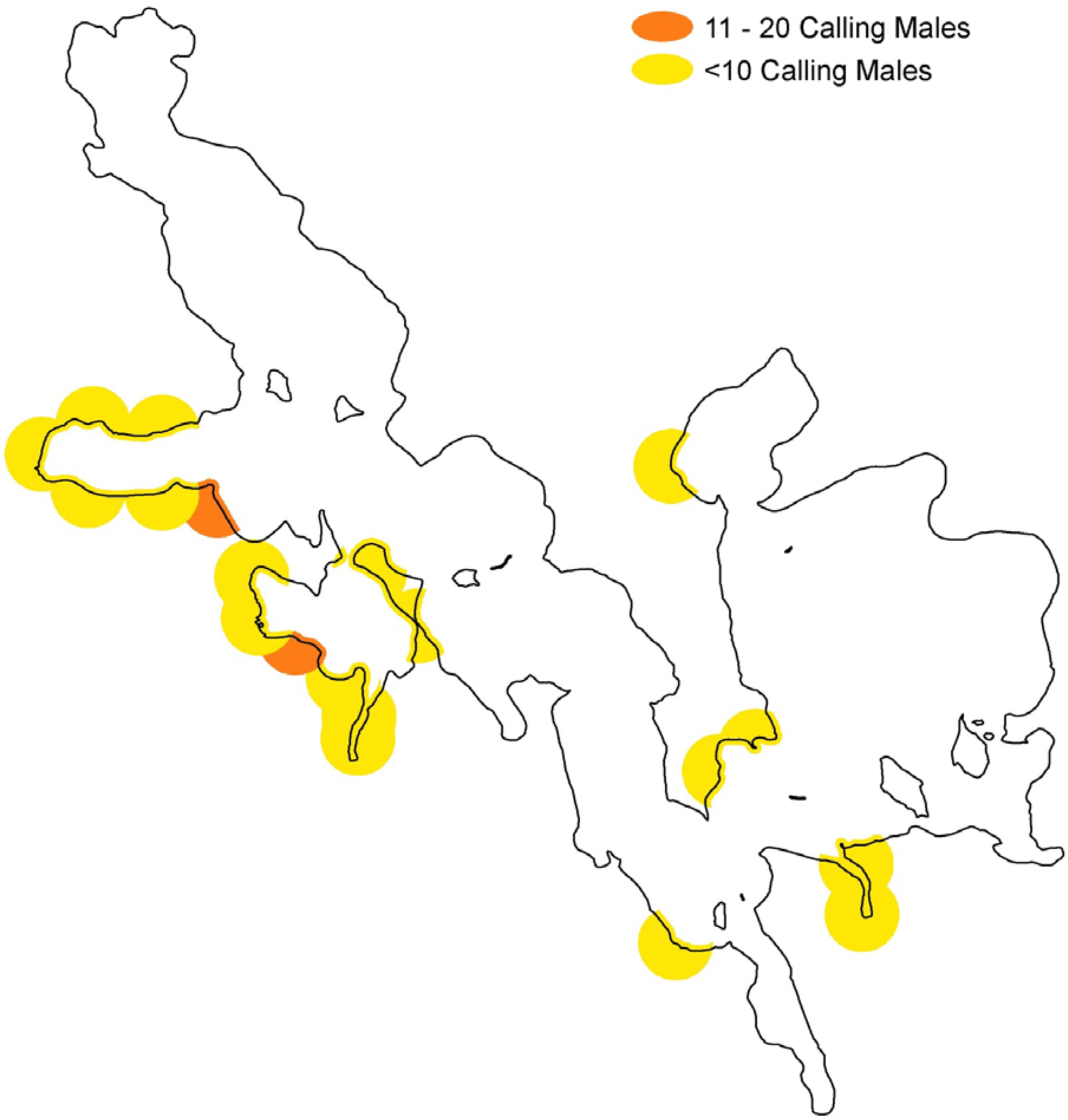


Figure 38. Abundance of mink frogs heard during Turtle Lake frog surveys, July 2013.



Nongame Fish Surveys

Objectives

1. Record presence and abundance of near-shore fish species of greatest conservation need
2. Record presence and abundance of proxy species
3. Develop distribution maps for species of greatest conservation need and proxy species
4. Identify habitat (substrate and aquatic vegetation biovolume) associated with presence of species of greatest conservation need and proxy species
5. Identify commonly occurring near-shore fish species

Introduction

Fish Species of Greatest Conservation Need
There are 47 fish species of greatest conservation need (SGCN) within the state of Minnesota. Of these 47 species, three are near-shore species found within Itasca County. The pugnose shiner and least darter are listed as species of Special Concern in the State of Minnesota. The longear sunfish exhibits a spotty distribution, and is listed as threatened in Wisconsin.

Pugnose shiners (*Notropis anogenus*; Figure 39) are small (38 – 56 mm), slender, silverish-yellow minnows. They possess large eyes and a distinctively upturned mouth that gives them a "pugnose" appearance. They are secretive minnows, and are found often in schools of 15 to 35 individuals. Pugnose minnows inhabit clear lakes and low-gradient streams and are extremely intolerant of turbidity. Vegetation, particularly pondweed, coontail, and bulrush, is an important habitat component.

Figure 39. Pugnose shiner

Photo by: Konrad Schmidt

Least darters (*Etheostoma microperca*; Figure 40) are Minnesota's smallest fish, averaging only 25 – 38 mm in length. They are olive-brown in color with scattered dark brown spots and markings and four dark bars radiating from the eye. Males possess an extremely long pectoral fin. Least darters are found in clear, shallow areas of low-gradient streams or lakes. Extensive beds of muskgrass (*Chara* spp.) are a preferred habitat feature. Removal of vegetation, riparian area modification, and poor water quality all pose threats to the least darter.

Figure 40. Least darter

Photo by: Konrad Schmidt

Longear sunfish (*Lepomis megalotis*; Figure 41) are a deep-bodied fish reaching a length of 71 – 94 mm. These colorful fish have a belly that is orange-red, and the sides are speckled with turquoise. Adults have an elongated opercular “ear flap” that is trimmed in white. Like the other species of greatest conservation need, the longear sunfish prefers clear, shallow, vegetated areas and is intolerant of turbidity.

Figure 41. Longear sunfish

Photo by: Konrad Schmidt

Proxy species

Proxy species have similar life history characteristics and occupy habitat similar to species of greatest conservation need; they represent indicator species for those SGCN.

Blackchin shiners (*Notropis heterodon*; Figure 42) are small (50 – 75 mm) fish with a bronze-colored back and silver sides and belly. A dark lateral band extends through the chin. Like the species of greatest conservation need, the blackchin shiner inhabits clear water with abundant submerged aquatic vegetation; it also prefers a clean sand or gravel substrate. This species cannot tolerate turbidity or loss of aquatic vegetation.

Figure 42. Blackchin shiner

Photo by: Konrad Schmidt

Blacknose shiners (*Notropis heterolepis*; Figure 43) are similar in size and coloration to blackchin shiners. However, the dark lateral line does not extend through the lips or chin. Scales on the back are outlined in a dark color, giving them a crosshatch appearance. Blacknose shiners are sensitive to turbidity and pollution, and their range has contracted since the beginning of the century. Habitat includes clean, well-oxygenated lakes and streams with plentiful vegetation and low turbidity and pollution.

Figure 43. Blacknose shiner

Photo by: Konrad Schmidt

Banded killifish (*Fundulus diaphanus*; Figure 44) are slender fish with slightly flattened heads. The mouth, which opens dorsally, is an adaptation for surface feeding. Dark vertical bars are present along the sides. Size ranges from about 50 – 100 mm. Calm, clear, shallow water with abundant aquatic vegetation and a sandy or gravely substrate is preferred by the killifish.

Figure 44. Banded killifish

Photo by: Konrad Schmidt

Methods

Fish surveys were conducted using Minnesota's Sensitive Lakeshore Survey Protocol. Fish survey stations were located 400 meters apart, and were the same stations used for surveying aquatic frogs. At each station, fish were sampled using two different methods: shoreline seining, and electrofishing. At several locations, excessive vegetation, depth, or soft substrate prevented surveyors from using seines or trapnets. However, electrofishing samples were still collected, from a boat if necessary. All species captured using the different sampling methods were identified and counted. Target fish species included near-shore species of greatest conservation concern (pugnose shiner, least darter, and longear sunfish) and proxy species (blackchin shiner, blacknose shiner, and banded killifish). These species are associated with large, near-shore stands of submerged grass leaved plants and macrophytes. They are intolerant to disturbance, and have been extirpated from lakes where extensive watershed and lakeshore development has occurred.

In addition to the fish data, habitat data were collected at each sampling station. Substrate data were recorded using standard near-shore classes. Aquatic vegetation biovolume was also estimated at each station; this represented the volume (percent) of a sampling area that contained submerged aquatic vegetation.

Results

There was one near-shore fish species of greatest conservation need detected during the 2013 nongame fish surveys on Turtle Lake. The pugnose shiner was documented at one survey location on the lake, on the southeast point (Figure 45). Three pugnose shiners were collected at one survey location on the lake, on the southeast point.

All three proxy fish species were also documented in Turtle Lake (Figure 46). Banded killifish were identified in the greatest numbers; surveyors counted 85 individuals. Banded killifish were found in shallow, protected areas of Turtle Lake. Six blackchin shiners were found at two survey stations around Newburg Bay. One blacknose shiner was recorded at one survey station within Moose Bay.

Habitat conditions where pugnose shiners and proxy species were collected were similar. The substrate was characterized as small-diameter substrate, and included silt, sand and muck. Aquatic vegetation biovolume was over twice as high at sites that contained SGCN and proxy species and sites that did not.

The presence of these sensitive fish species may indicate minimal disturbance in several areas of the lake. However, because populations of these species are vulnerable across their ranges, continued monitoring and maintenance of these shoreline habitats is necessary to ensure continued existence of these populations. Limiting macrophyte removal, pesticide and herbicide use, and modification of the riparian zone will help maintain good water quality and a healthy aquatic plant community.

In total, surveyors identified 19 fish species at Turtle Lake in 2013 (Table 3). Bluegills and smallmouth bass, each recorded at 40 or more (of 87) survey stations, were the most frequently documented species. Largemouth bass were also common, and identified at over 30% of the survey sites; surveyors estimated over 230 individuals were captured. Bluegills and smallmouth bass were found in numbers greater than 200. Brook stickleback, mimic shiners and pumpkinseed sunfish were detected at only one station each.

Figure 45. Distribution of fish species of greatest conservation need documented during Turtle Lake fish surveys, July and August 2013.

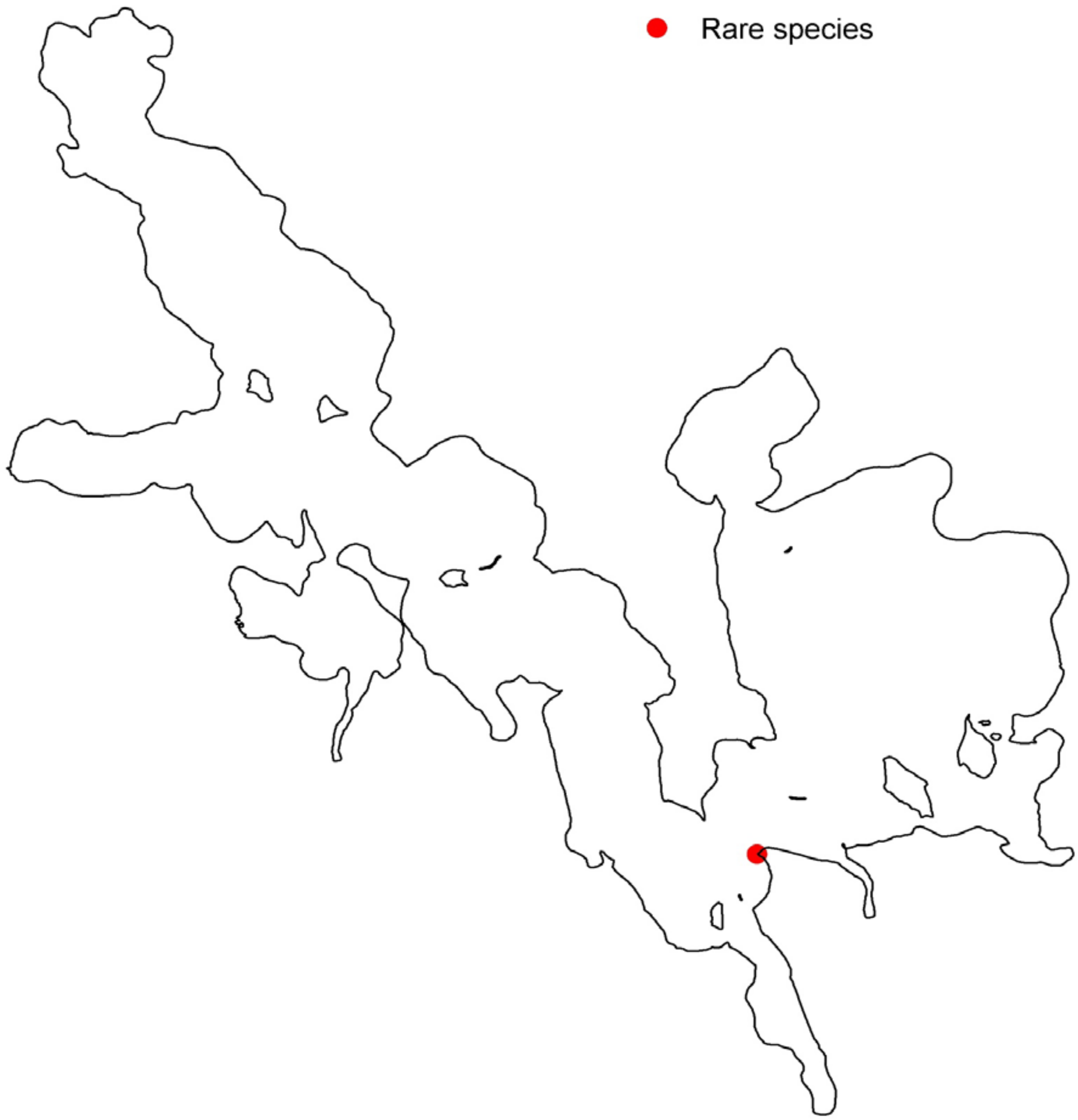


Figure 46. Distribution of fish proxy species documented during Turtle Lake fish surveys, July and August 2013.

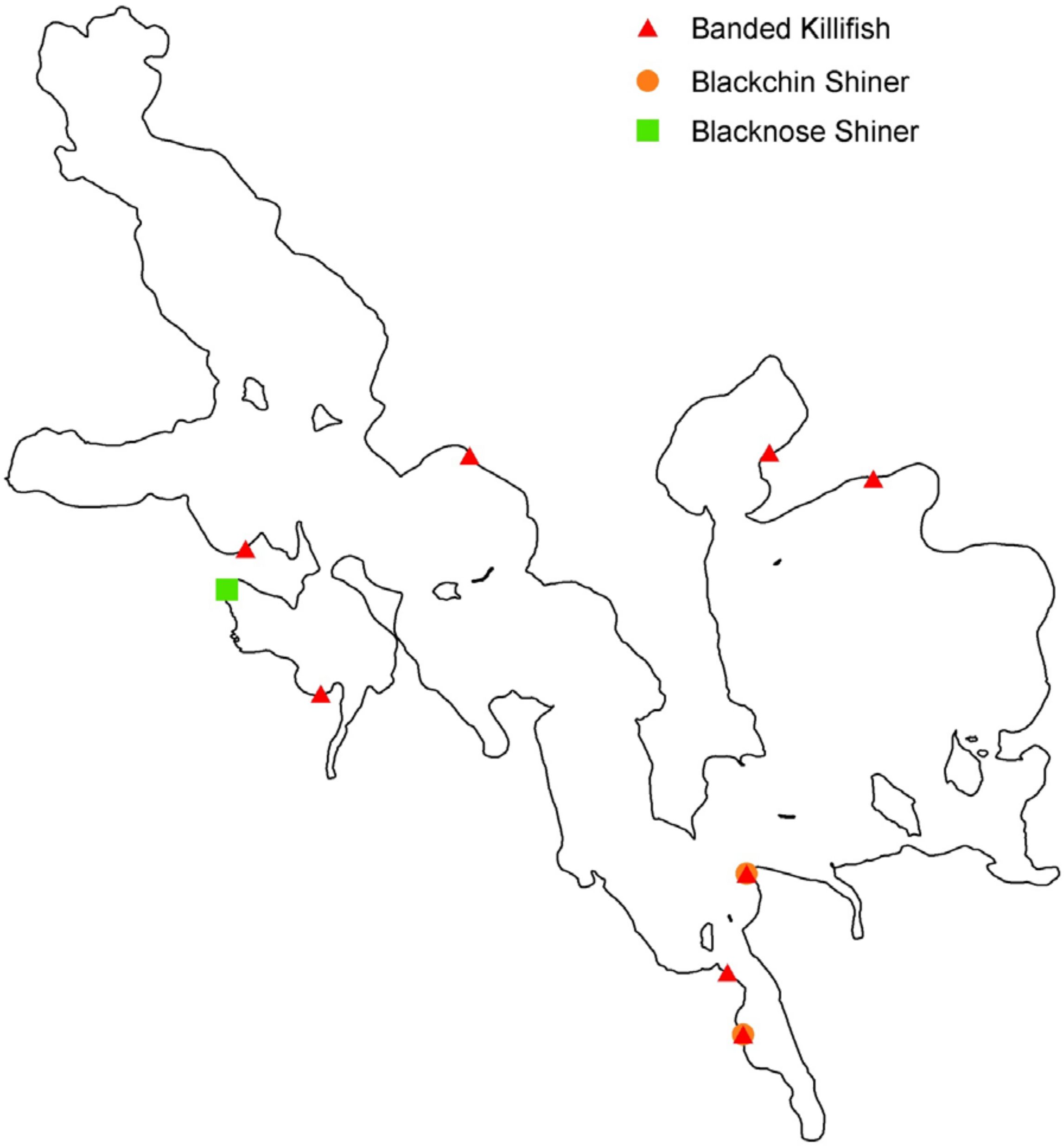


Table 3. Abundance and frequency of fish species identified during Turtle Lake fish surveys, July and August 2013. * denotes species of greatest conservation need

Description	Common Name	Scientific Name	# [a]	% [b]
Minnows/carps	Pugnose shiner*	*Notropis anogenus*	3	1
	Blackchin shiner	*Notropis heterodon*	6	2
	Blacknose shiner	*Notropis heterolepis*	1	1
	Mimic shiner	*Notropis volucellus*	15	3
	Bluntnose minnow	*Pimephales notatus*	40	10
N. American freshwater catfish	Yellow bullhead	*Ameiurus natalis*	6	7
	Tadpole madtom	*Noturus gyrinus*	5	5
Mudminnows	Central mudminnow	*Umbra limi*	55	18
Killifishes	Banded killifish	*Fundulus diaphanus*	85	9
Sticklebacks	Brook stickleback	*Culaea inconstans*	1	1
Sculpins	Mottled sculpin	*Cottus bairdi*	1	1
Sunfishes	Rock bass	*Ambloplites rupestris*	34	26
	Pumpkinseed	*Lepomis gibbosus*	1	1
	Bluegill	*Lepomis macrochirus*	204	56
	Largemouth bass	*Macropterus salmoides*	237	33
	Smallmouth bass	*Micropterus dolomieu*	240	46
Perches	Iowa darter	*Etheostoma exile*	25	21
	Johnny darter	*Etheostoma nigrum*	7	8
	Yellow perch	*Perca flavescens*	145	25

[a] # – Total number of individuals found.

[b] % – Percent of surveyed sample sites in which a species occurred (N=87).

Aquatic Vertebrate Richness

Objective

1. Calculate and map aquatic vertebrate richness around the shoreline of Turtle Lake

Introduction

A variety of factors may influence aquatic vertebrate richness, including habitat diversity, water chemistry, flow regime, competition, and predation. High aquatic vertebrate richness indicates a healthy lakeshore community with diverse habitat, good water quality, varied flow regimes, and a sustainable level of competition and predation. A diverse aquatic vertebrate community will also help support diversity at higher trophic levels.

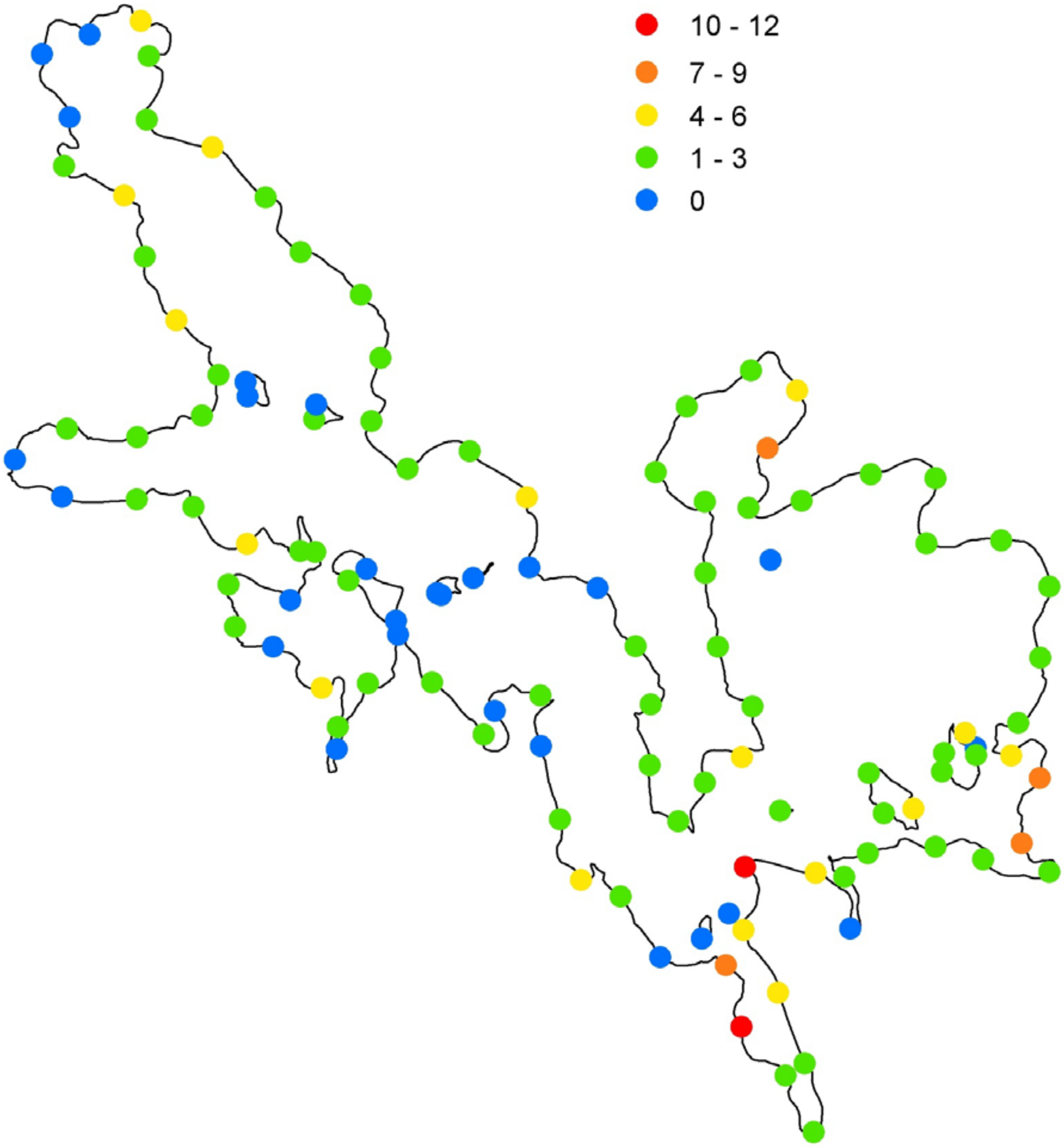
Methods

Aquatic vertebrate species were documented during the nongame fish sampling surveys. All aquatic vertebrates, including fish, frogs, and turtles, captured during trapnetting, seining, and electrofishing surveys were identified to the species level. Young-of-year animals that could not be identified to the species level and hybrids were not used in the analysis.

Results

The number of species per Turtle Lake sample site ranged from one to 12 (Figure 47). The sites with the highest recorded aquatic vertebrate diversity (10 or more species documented) were all located in/or near Newman Bay. Only six of the surveyed sites had seven or more species, and over half of the sites had less than four species. The majority of the species observed during the nongame fish surveys were fish, although gray tree frogs were also identified. At a number of the zero-fish sites, seining was not conducted because of excessive vegetation or soft substrate; these sites may have had fish present but surveyors were not able to document them.

Figure 47. Aquatic vertebrate species richness (number of species per sample site) in Turtle Lake, July and August 2013.



Other Rare Features

Objective

1. Map rare features occurring within the extended state-defined shoreland area (within 1320 feet of shoreline) of Turtle Lake

Introduction

The Minnesota Natural Heritage Information System provides information on Minnesota's rare animals, plants, native plant communities, and other features. The Rare Features Database includes information from both historical records and current field surveys. All Federal and State-listed endangered and threatened species and state species of special concern are tracked by the Natural Heritage program. The program also gathers information on animal aggregations, geologic features, and rare plants with no legal status.

Methods

Researchers obtained locations of rare features from the Rare Features Database. Only "listed" plant and animal species (Federal or State endangered, threatened, or special concern) were considered in this project; non-listed unique plant species were included in the "Unique Plant Species" section of this report. Rare features within 1320 feet of the shoreline were mapped using GIS. Varying buffer sizes around rare feature locations represent locational uncertainty and do not indicate the size of the area occupied by a rare feature.

Results

Two rare feature locations have been identified at Turtle Lake (Figure 48). The rare features include a bird species of special concern. The publication of exact descriptive and locational information is prohibited in order to help protect these rare species.

Although specific management recommendations will vary depending on the rare features that are present at Turtle Lake, practices that maintain good water quality and the integrity of the shoreline will be beneficial to all species involved.

Figure 48. Natural Heritage Database rare features (Federal or State-listed endangered, threatened, or special concern species) located within 1320 feet of Turtle Lake shoreline.

 Rare features data have been provided by the Division of Ecological and Water Resources, Minnesota Department of Natural Resources (MNDNR) and were current as of October, 2013. These data are not based on an exhaustive inventory of the state. The lack of data for any geographic area shall not be construed to mean that no significant features are present.

Bay Delineation

Objective

1. Determine whether areas of the lake are in isolated bays, non-isolated bays, or not within bays

Introduction

Bays are defined as bodies of water partially enclosed by land. They often offer some degree of protection from the wind and waves to those species living within them. These protected areas provide habitat for a number of aquatic plant species, and bays are frequently characterized by abundant vegetation. These areas of calm water and plentiful vegetation, in turn, provide habitat for a number of fish and wildlife species. Protecting these areas will be beneficial to a variety of plant and animal species.

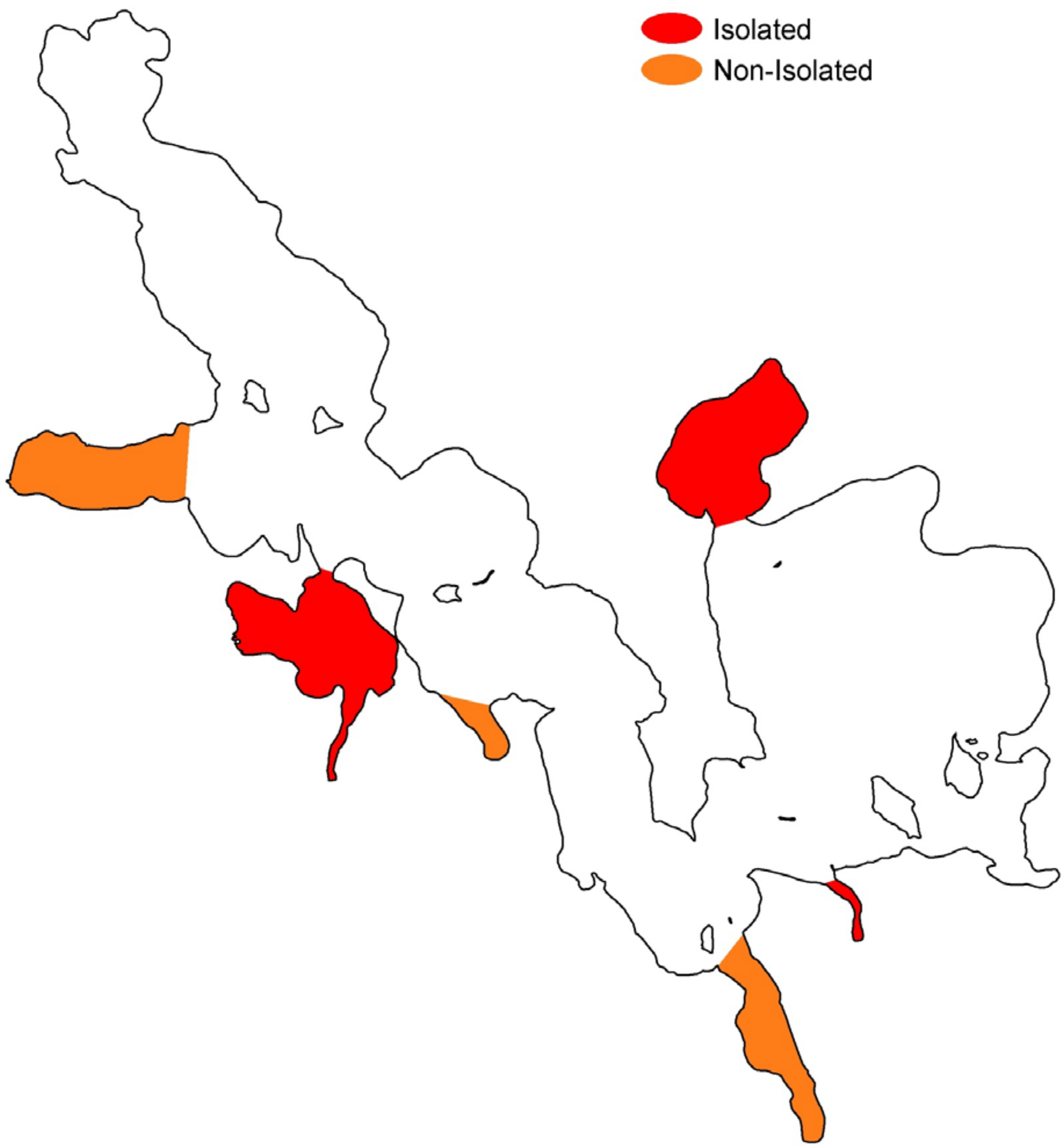
Methods

Bays were delineated using lake maps and aerial photos. Obvious bays (e.g., significant indentations of shoreline, bodies of water set off from main body or enclosed by land) were mapped based on inspection of lake maps. Additional bays were identified using aerial photos. Underwater shoals or reefs that offset a body of water from the main body were visible only in these photographs. Non-isolated bays were open to the main water body by a wide mouth. Isolated bays had a narrower connection to the main water body, or were offshoots of non-isolated bays.

Results

Three isolated bays and three non-isolated bays were identified in Turtle Lake (Figure 49). The isolated bays included Sager Bay, the bay where the Turtle River outflows and a small bay on the southeast side of Turtle Lake. Non-isolated bays included Newburg Bay, Moose Bay and a smaller bay to the northwest of Newburg Bay.

Figure 49. Location of isolated and non-isolated bays in Turtle Lake.



II. Ecological Model Development

The second component of the sensitive lakeshore area protocol involved the development of an ecological model. The model scored lakeshore areas based on calculations of sensitivity. The model incorporated results of the field surveys and analysis of additional data, so included information on plant and animal communities as well as hydrological conditions.

In order to develop a continuous sensitivity score along the shoreline, the ecological model used a moving analysis window that included both shoreland and near-shore areas. Resource managers developed a system to score each of the 13 variables. These scores were based on each variable's presence or abundance in relation to the analysis window (Table 4). Each analysis window was assigned a score, which was equal to the highest score present within a window. On occasion, point data were buffered by a set distance and converted to polygons to account for locational uncertainty before inclusion in the model.

Scores for each of the layers were summed (Figure 50). This map represents an index of sensitivity; those points with higher total scores are highly sensitive, whereas points with lower total scores have lower sensitivity.

Once the total score index was developed for the shoreline, clusters of points along the shoreline with similar values were identified using GIS (Figure 51). Due to the narrow bands of shoreline on Turtle Lake the GIS analysis was made with a distance of 1000 feet instead of 2000 feet. The clusters with high values (i.e., areas of highly sensitive shoreline) were buffered by ¼ mile. These buffered areas were defined as most likely highly sensitive lakeshore areas. These areas will be forwarded to the local government for potential designation as resource protection areas (Figure 52).

Table 4. Criteria for assigning scores to analysis windows for each variable

Variable	Score	Criteria
Wetlands	3	> 25% of analysis window contains wetlands
	2	12.5 – 25% contains wetlands
	1	< 12.5% contains wetlands
	0	No wetlands present
Hydric Soils	3	> 25% of analysis window is hydric soils
	2	12.5 – 25% hydric soils
	1	< 12.5% hydric soils
	0	No hydric soils observed
Near-shore Plant Occurrence	3	Frequency of occurrence is > 75% (> 75% of points within analysis window contained vegetation)
	2	Frequency of occurrence is 25 – 75%
	1	Frequency of occurrence < 25%
	0	No vegetation present
Aquatic Plant Richness	3	Total number of plant taxa per analysis window > 10
	2	Total number of plant taxa 5 – 10
	1	Total number of plant taxa 1 – 4
	0	No vegetation present
Presence of Emergent and Floating-leaf Plant Beds	3	Emergent and/or floating-leaf plant stands occupy > 25% of the aquatic portion of the analysis window
	2	Stands occupy 5 – 25%
	1	Stands present but occupy less than 5%
	0	No emergent or floating-leaf plant beds present
Unique Plant Species	3	Presence of 2 or more unique plant species within analysis window
	2	Presence of 1 unique plant species
	0	No unique plant species present
Near-shore Substrate	3	Frequency of occurrence is > 50% soft substrate (> 50% of points within analysis window consist of soft substrate)
	2	Frequency of occurrence is 25 – 50% soft substrate
	1	Frequency of occurrence < 25% soft substrate
	0	No soft substrate present
Loon Nesting Areas	3	Presence of natural loon nest within analysis
	2	Presence of artificial loon nest (nesting platform)
	0	No loon nesting observed
Frogs	3	Presence of both mink frogs and green frogs within
	2	Presence of mink frogs or green frogs
	0	Neither mink frogs nor green frogs present

Table 4, continued.

Variable	**Score**	**Criteria**
Fish	3	Presence of one or more species of greatest conservation need (SGCN) within analysis window
	2	Presence of one or more proxy species
	0	Neither SGCN nor proxies observed
Aquatic Vertebrate Richness	3	Total number of aquatic vertebrate species within analysis window > 10
	2	Total number of aquatic vertebrate species 5 – 10
	1	Total number of aquatic vertebrate species 1 – 4
	0	No aquatic vertebrate species observed
Rare Features	3	Presence of multiple Natural Heritage features within analysis window
	2	Presence of one Natural Heritage feature
	0	No Natural Heritage feature present
Bays	3	Isolated bay within analysis window
	2	Non-isolated bay
	0	Not a distinctive bay

Figure 50. Total score layer created by summing scores of all 13 variables. Highest total scores represent most sensitive areas of shoreline.

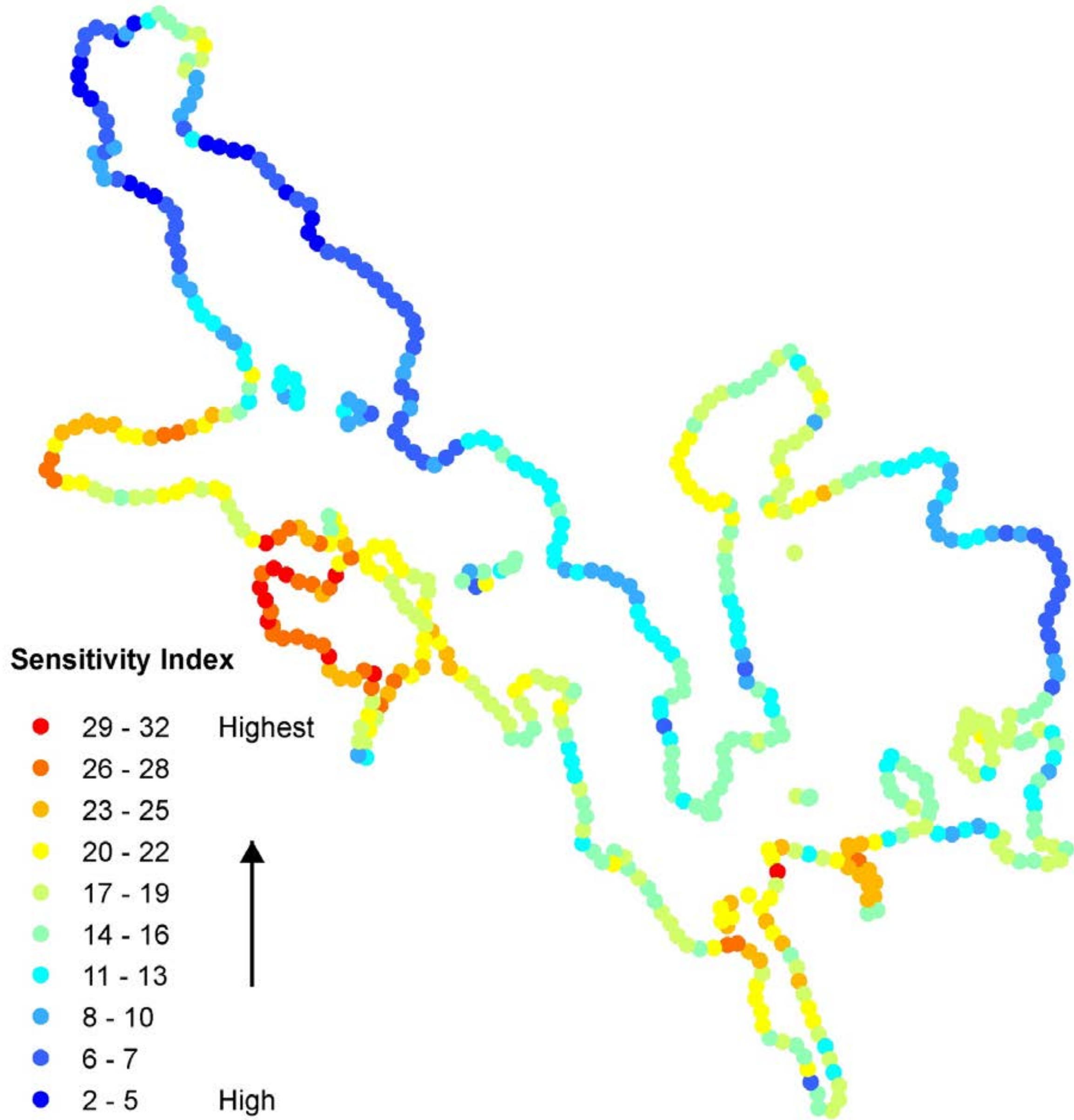


Figure 51. GIS-identified clusters of points with similar total scores. Red areas are those with high scores (i.e., areas of highly sensitive shoreland).

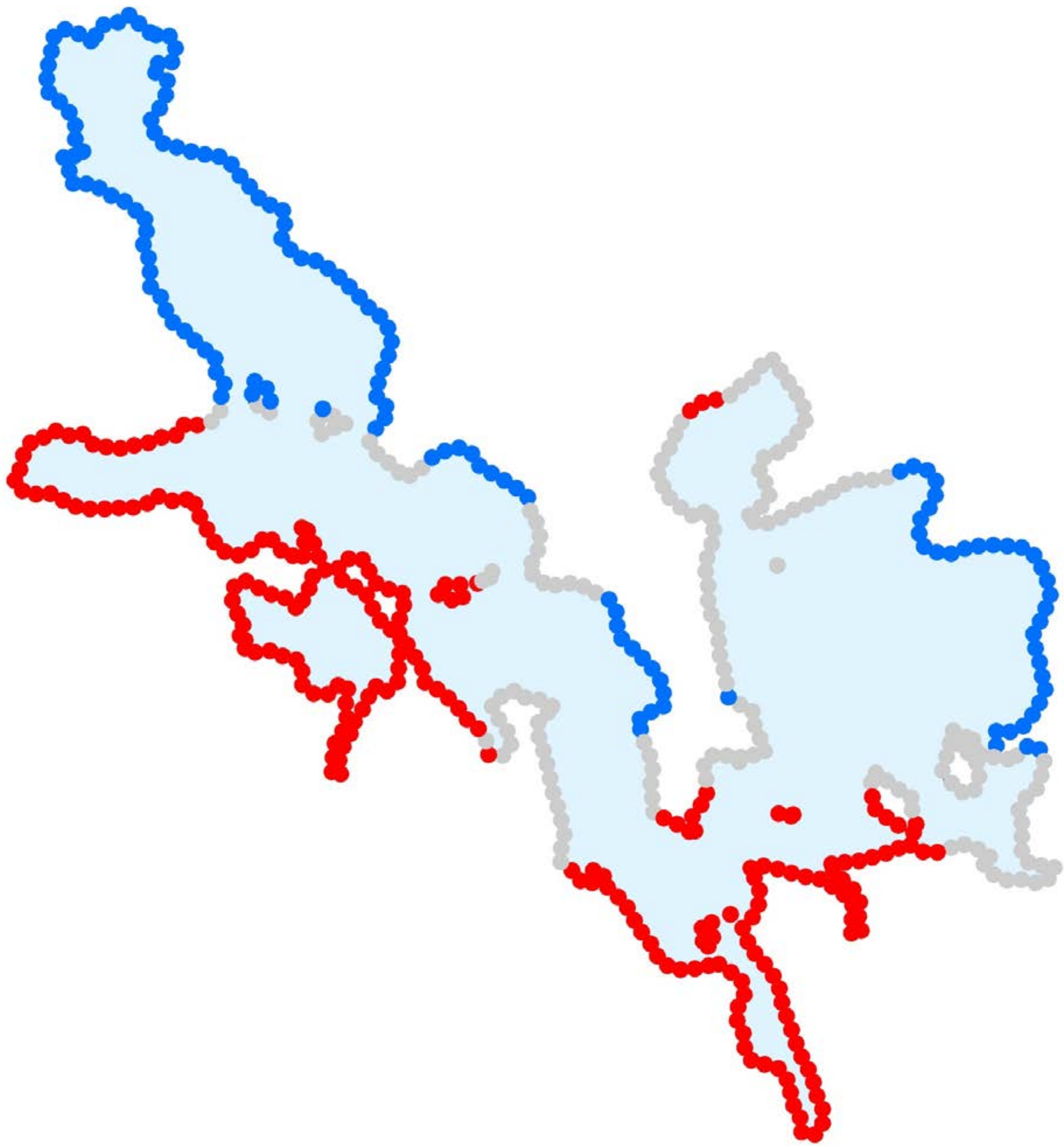
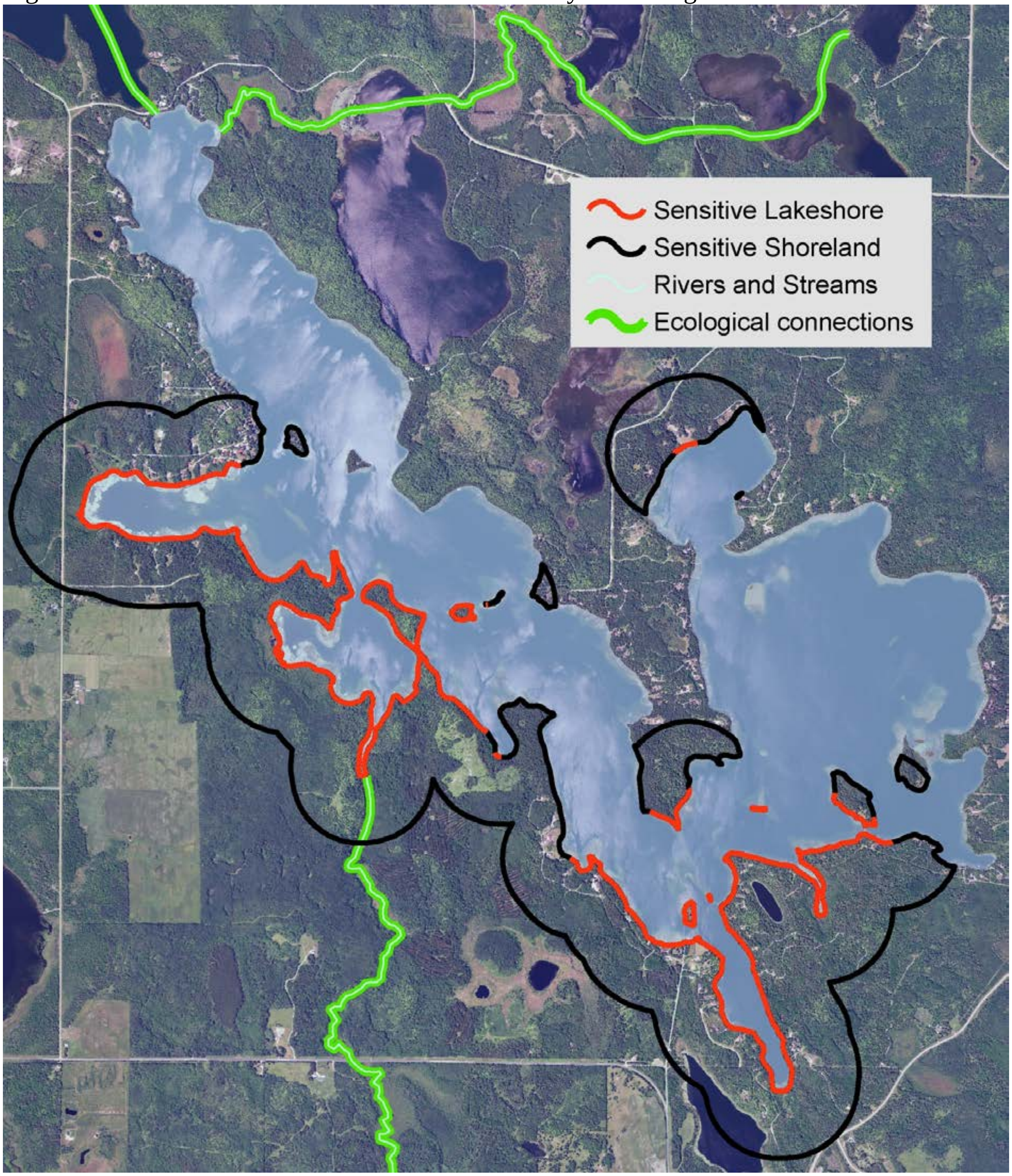


Figure 52. The sensitive lakeshore areas identified by the ecological model.



Habitat Connectivity
In addition to the sensitive shorelands identified through the GIS model, surveyors considered adjacent river shorelines that provide habitat connectivity to and from the lake shorelands. Aquatic habitat connectivity allows for the movement of organisms within a watershed. Organisms can move between existing habitats, colonize new areas, or recolonize former habitat in the wake of local extinctions. Two unnamed streams flow into Turtle Lake on the north side.

Other Areas of Ecological Significance
There are additional aquatic areas of ecological significance in Turtle Lake that contain important aquatic plant communities but these sites are not necessarily associated with priority shoreland features. Identifying these sites is important, although exact delineation of their boundaries can be difficult because they occur in the water and may be patchy in distribution.

In Turtle Lake, sites containing a high diversity of native submerged plants are considered sites of ecological significance. These include broad underwater zones that contain numerous types of submerged plants (Figure 31). Not only do these species-rich sites provide a diverse habitat mix for fish and wildlife, but they may also help mitigate the potentially harmful impacts if invasive plants occur in the lake.

Other sites of ecological significance are emergent and floating-leaf plant beds that may occur outside of the sensitive shoreland districts. Often, these sites are too small to warrant inclusion as part of a shoreline protection district, but their small size is a defining feature that adds to their importance within the lake (Figure 29). Emergent and floating-leaf plant beds continue to be fragmented as shorelines are developed. Protecting remaining areas of these plant communities and preventing further fragmentation is important.

One of the primary threats to these sites is the direct destruction of plant beds through aquatic plant management and recreational boating activities. Planning efforts, such as the development of a Lake Vegetation Management Plan, can be used to set specific management practices within these types of sites.

Sensitive Lakeshore
The bays, four of the islands and the western and southern shorelines of Turtle Lake contained a great diversity of plant and animal species, including species of greatest conservation need. Critical habitat, such as emergent and floating-leaf vegetation, was also present in high quantities. The ecological model displays these areas both as sensitive shoreline and as high priority shorelands. Although the shoreline itself is important, development and land alteration nearby may have significant negative effects on many species. Fragmented habitats often contain high numbers of invasive, non-native plants and animals that may out-compete native species. The larger a natural area is, the more likely it is to support populations of native plants and animals. Large natural areas that support a diversity of species and habitats help comprise a healthy ecosystem. Protection of both the shoreline itself and the habitat surrounding the shoreline will be the most effective way to preserve the plant and animal communities in and around Turtle Lake, and the value of the lake itself.

References

Arber, A. 1920. Water plants: A study of aquatic angiosperms. Cambridge University Press. 436 pp.

Bolton, H.L. and M.S. Adams. 1986. The contribution of crassulacean acid metabolism to the annual productivity of two aquatic vascular plants. Oecologia. vol. 68. (615-622).

Borman, S., R. Korth and J. Temte. 2001. Through the looking glass: A field guide to aquatic plants. The Wisconsin Lakes Partnership, Stevens Point, Wisconsin. 248 pp.

Bourdaghs, M., C.A. Johnston, and R.R. Regal. 2006. Properties and performance of the floristic quality index in Great Lakes coastal wetlands. Wetlands 26(3):718–735.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 131 pp.

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

Fassett, N.C. 1957. A manual of aquatic plants. The University of Wisconsin Press. 405 pp.

Flora of North America Editorial Committee, eds. 2007. Flora of North America north of Mexico. 12+ vols. New York and Oxford. Flora of North America

Madsen, J. D. 1991. Resource allocation at the individual plant level. Aquatic Botany 41:67-86.

Magurran, A.E. 2004. Measuring biological diversity. Blackwell Science, Oxford.

Meredith, T.C. 1983. The effects of shorezone development on the nature of adjacent aquatic plant communities in Lac St. Louis, Quebec. Lake and Reservoir Management Proceedings. 3rd Annual Nalms Conference. North American Lake Management Society. October 1983. Washington, D.C. pp.527-530.

MnDNR Fisheries Lake Files. Minnesota Department of Natural Resources. Division of Fish and Wildlife, Section of Fisheries, Lake Survey Program. St. Paul, MN.

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 Biological Survey, and Natural Heritage and Nongame Research Program, St. Paul.

Minnesota Department of Natural Resources. 2005. Aquatic vegetation mapping guidelines. Working version, May 2005. Section of Fisheries, St. Paul.

Minnesota Department of Natural Resources. 2006. Tomorrow's habitat for the wild and rare: An action plan for Minnesota wildlife, comprehensive wildlife conservation strategy. Division of Ecological Services, Minnesota Department of Natural Resources.

Minnesota Department of Natural Resources. 2006b. Turtle Lake Management Plan. May 2006. Section of Fisheries, Grand Rapids.

Minnesota Department of Natural Resources. 2012. Minnesota's sensitive lakeshore identification manual: A conservation strategy for Minnesota lakeshores (version 2). Division of Ecological and Water Resources, Minnesota Department of Natural Resources.

Minnesota Pollution Control Agency. 2013. Clean lake monitoring program. Minnesota Pollution Control Agency, St. Paul. Water quality data

MnTaxa. 2013. Minnesota state checklist of vascular plants. Division of Ecological and Water Resources, Minnesota Department of Natural Resources.

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

Myhre, K. 2001. Plant survey of Turtle Lake (31-0725-00), Itasca County, Minnesota, July 24, 2001. Division of Ecological and Water Resources, Minnesota Department of Natural Resources. Minnesota County Biological Survey Program. Unpublished data.

NatureServe. 2011. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Nature Serve website

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

Nichols, S.A. 1999b. Distribution and habitat descriptions of Wisconsin lake plants. Wisconsin Geological and Natural History Survey. Bulletin 96. Madison. 266 pp.

Nicholson, S.A. 1981. Changes in submersed macrophytes in Chautaqua Lake, 1937-1975. Freshwater Biology 11:523-530.

Niemeier, P.E. and W.A. Hubert. 1986. The 85-year history of the aquatic macrophyte species composition in a eutrophic prairie lake (United States). Aquatic Botany 25:83-89.

Ownbey, G.B. and T. Morley. 1991. Vascular plants of Minnesota: a checklist and atlas. University of Minnesota Press, Minneapolis. 307 pp.

Pip, E. 1987. Species richness of aquatic macrophyte communities of Central Canada. Hydrobiological Bulletin 21(2):159-165.

Rolon, A.S., T. Lacerda, L. Maltchik, and D.L. Guadagnin. 2008. Influence of area, habitat and water chemistry on richness and composition of macrophyte assemblages in southern Brazilian wetlands. Journal of Vegetation Science 19:221-228.

Simon, S. and D. Perleberg, 2014. Aquatic vegetation of Turtle Lake (DOW 31-0725-00), Itasca County, Minnesota, 2013. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, Brainerd.

Stuckey, R.L. 1971. Changes of vascular aquatic flowering plants during 70 years in Put-in-Bay Harbor, Lake Erie, Ohio. The Ohio Journal of Science 71:321-342.

Vestergaard, O. and K. Sand-Jensen. 2000. Aquatic macrophyte richness in Danish lakes in relation to alkalinity, transparency, and lake area. Canadian Journal of Fisheries and Aquatic Sciences 57:2022-2031.

Voss, E.G. 1985. Michigan Flora: a guide to the identification and occurrence of native and naturalized seed-plants of the state. Part II: Dicots (Saururaceae-Cornaceae). Cranbrook Institute of Science Bulletin 59 and University of Michigan Herbarium. 724 pp.