Final Report
Sensitive Lakeshore Survey
Thunder Lake (11-0062-00)
Cass County, Minnesota

June 2010

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ECOLOGICAL 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*

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Executive Summary

Aquatic plants occurred around the entire perimeter of Thunder Lake. Plant surveyors recorded a total of 33 native aquatic plant taxa, including 21 submerged and free-floating taxa, four floating-leaf, and eight emergent taxa. In addition, they recorded more than 30 shoreline plant taxa and one unique submerged aquatic plant species. Submerged plants occurred to a depth of 25 feet but were most common in the shore to 15 feet depth zone, where 90% of the sample sites contained vegetation. Common submerged plants included muskgrass and multiple pondweed species. Emergent and floating-leaf plants, including bulrush and waterlilies, covered over 40 acres.

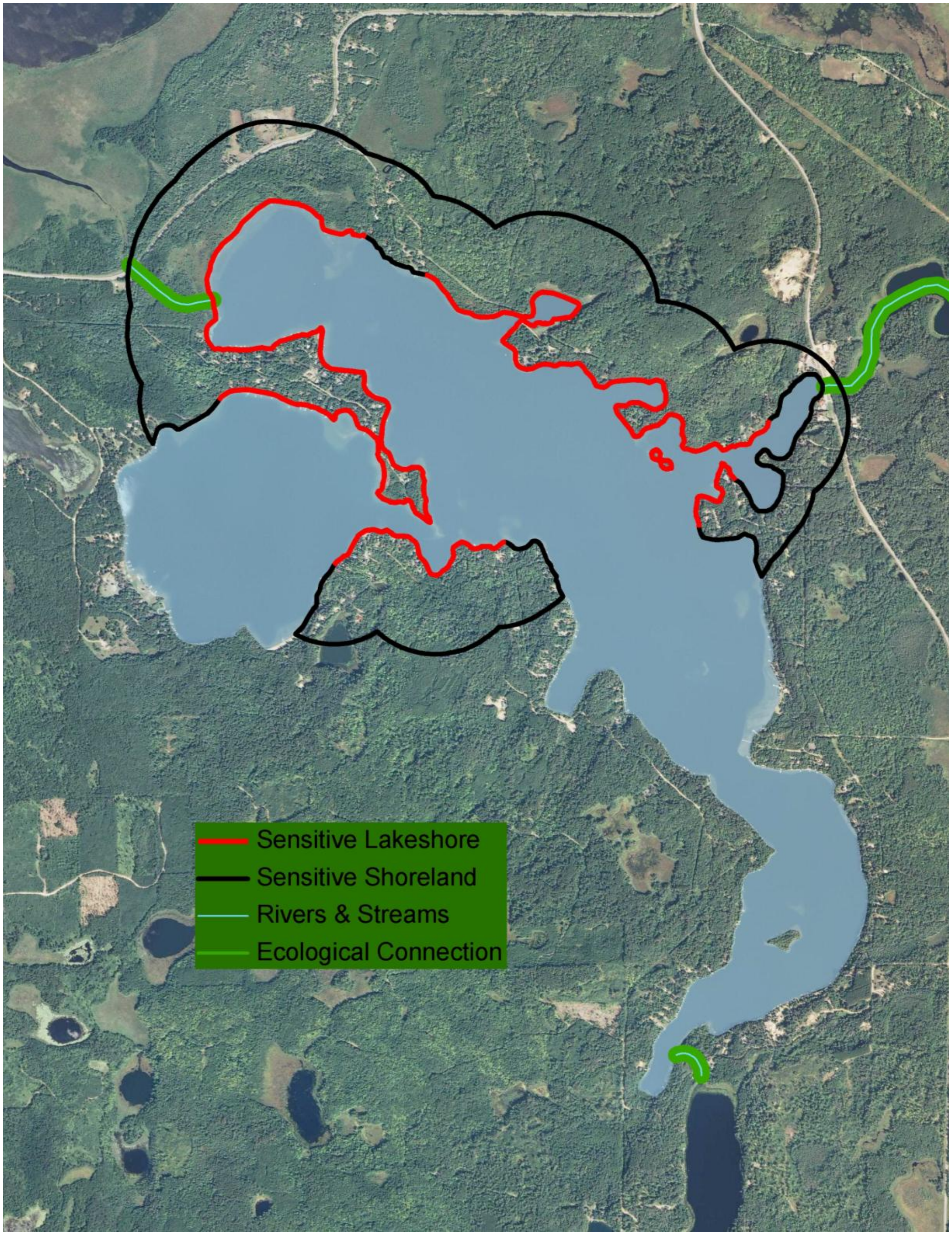
Bird surveyors documented 70 bird species at Thunder Lake, including 12 bird species of greatest conservation need. The ovenbird, found at nearly one-third of the survey stations, was the most commonly recorded species of greatest conservation need; common loons were also recorded regularly. Overall, song sparrows were the most commonly detected bird species at Thunder Lake, followed by red-eyed vireos, chipping sparrows, and the common grackle.

One fish species of greatest conservation need, the least darter, and three proxy species including the blackchin shiner, blacknose shiner, and banded killifish, were identified at Thunder Lake. Thirty different fish species were documented during the surveys, bringing the total historical observed fish community to 40 species. Eight fish species not previously documented at Thunder Lake were identified during the surveys. The newly identified species were blacknose shiner, brook stickleback, central mudminnow, creek chub, golden shiner, least darter, mottled sculpin, and northern redbelly dace. Green frogs were documented at multiple locations on Thunder Lake, particularly near or within protected bays.

An ecological model based on major conservation principles was used to assess lakeshore sensitivity. The benefit of this approach is that criteria come from the science-based surveys and the value of the lakeshore is objectively assessed. Environmental decision-making is complex and often based on multiple lines of evidence. Integrating the information from these multiple lines of evidence is rarely a simple process. Here, the ecological model used 15 attributes (hydrological conditions and documented plant and animal presence) to identify sensitive areas of shoreland. A sensitivity index was calculated for each shoreland segment by summing the scores of the 15 attributes. Lakeshore segments were then clustered by sensitivity index values using established geospatial algorithms. Sensitive lakeshore areas were buffered and important ecological connections or linkages mapped. The identification of sensitive lakeshore areas by this method is an objective, repeatable and quantitative approach to the combination of multiple lines of evidence through calculation of weight of evidence. The ecological model results are lake-specific, in that the model results are intended to recognize the most probable highly sensitive lakeshores for a specific lake. Plant and animal assemblages differ naturally between lakes, and sensitivity scores should not be compared across lakes.

The ecological model identified three primary sensitive lakeshore areas to be considered for potential resource protection districting by Cass County. The inlets and outlets of Thunder Lake were identified as ecological connections. 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:



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. They are also home to numerous fish, wildlife, and plant species. 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. Increasing development pressure along lakeshores may have negative impacts on these 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. 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 in 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 Thunder Lake sensitive lakeshore areas.

Lake Description

Thunder Lake (DOW 11-0062-00) is located about nine miles north of the city of Outing, in Cass County, north-central Minnesota (Figure 1). The lake occurs in the western corner of the Mississippi River – Grand Rapids Watershed. Thunder Lake receives flow from inlets on both the north and south ends of the lake (Figure 2). Water exits Thunder Lake on the east, and continues north and east until eventually reaching the Mississippi River.

Figure 1. Location of Thunder Lake in Cass County, Minnesota.

Thunder Lake is located near the Chippewa National Forest and Land O'Lakes State Forest. Large forested areas surround the lake, but the immediate shoreline is privately owned and developed with residential homes and several resorts. There is a public access on the west side of the lake.

Thunder Lake has a surface area of about 1,300 acres and 16 miles of shoreline. The shoreline is irregular in shape and consists of two basins: an elongated basin that makes up the main part of the lake (main basin), and a small, round basin connected to the lake by a shallow channel (west basin). There are also two small islands located in the lake. Thunder Lake has a maximum depth of 95 feet and 83% of the lake is greater than 15 feet in depth (Figure 3).

Thunder Lake is described as a mainly oligotrophic lake, with minimal nutrient enrichment. The average Secchi depth (which measures water transparency) between 1990 and 2008 was nearly 17 feet (MPCA 2008), indicating relatively high water clarity.

Figure 2. Features of Thunder Lake.

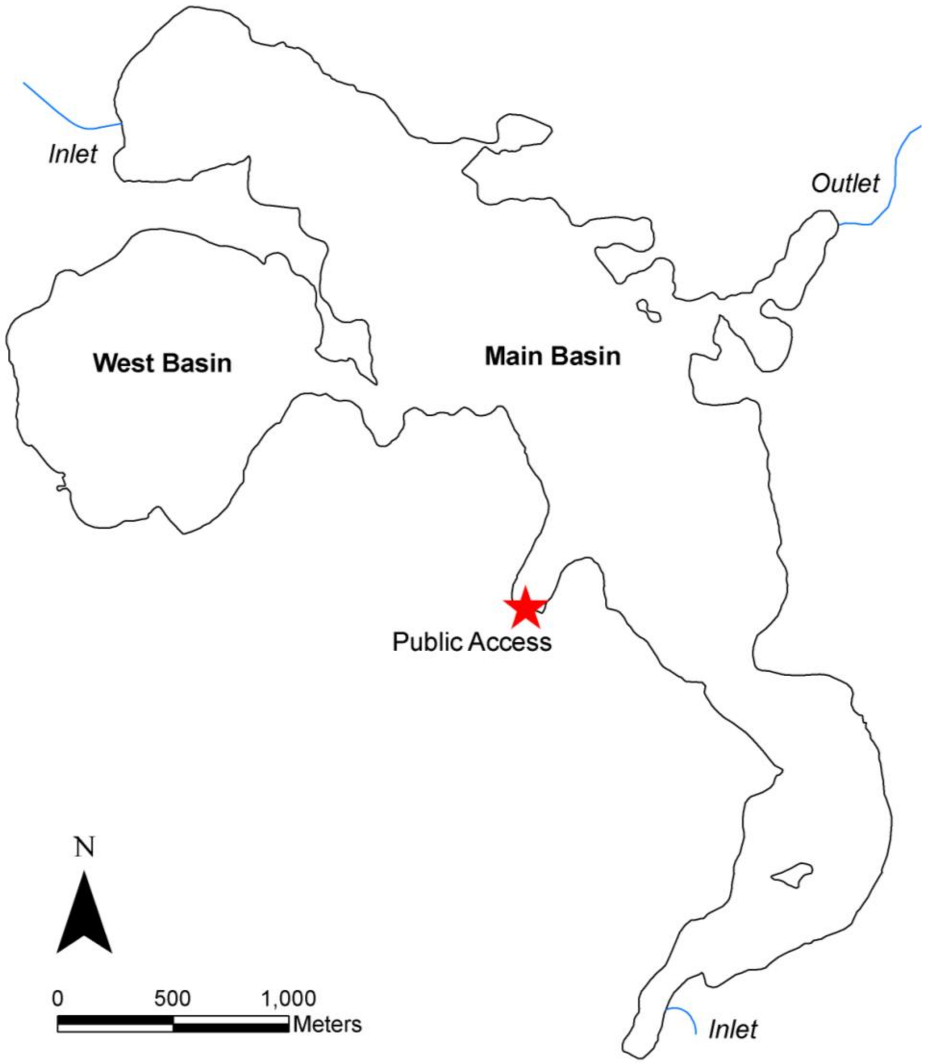
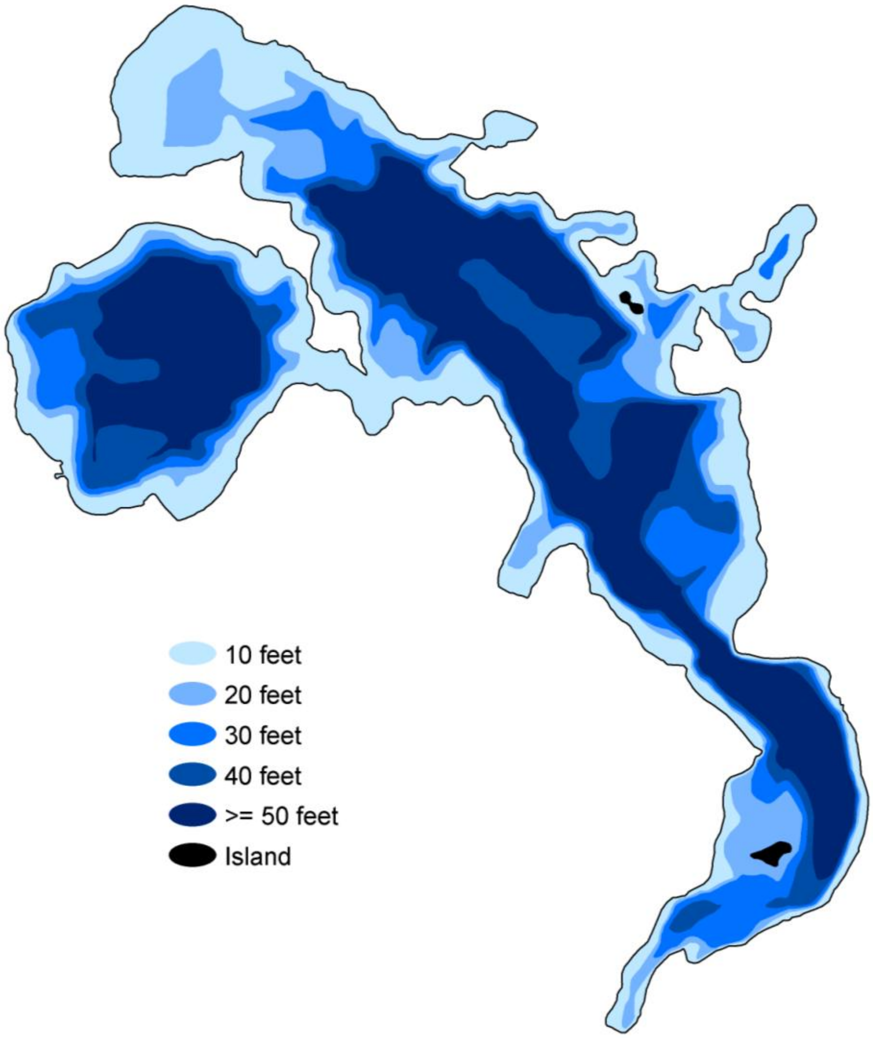


Figure 3. Depth contours of Thunder Lake.



I. Field Surveys and Data Collection

Survey and data collection followed Minnesota's Sensitive Lakeshore Identification Manual protocol (MN DNR 2008). Resource managers gathered information on 15 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, birds, bird species richness, 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

Wetlands

Objective

1. Map wetlands within the extended state-defined shoreland area of Thunder 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 Thunder Lake ordinary high water mark were excluded from this analysis.

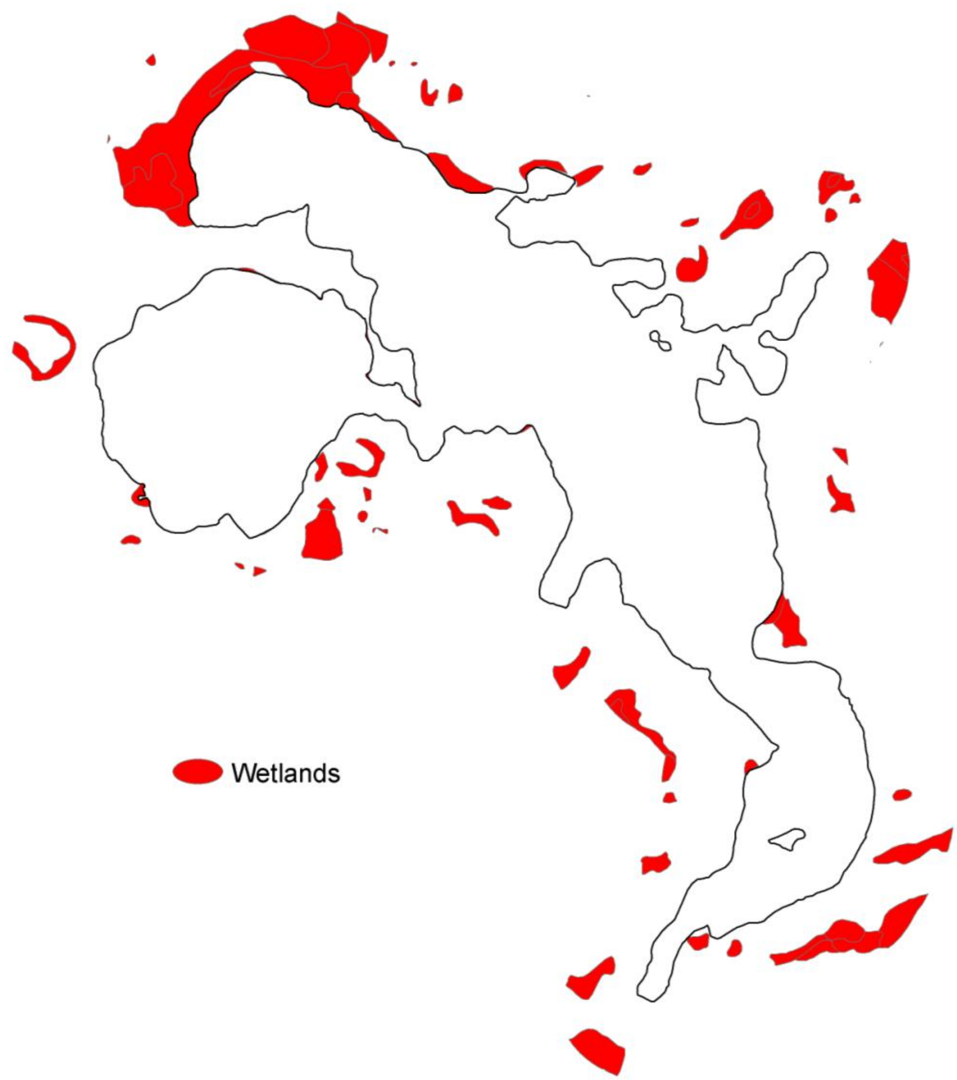
Results

Approximately 250 acres of wetlands (as defined by NWI) are located within 1320 feet of the Thunder Lake shoreline. The largest wetland complex is nearly 95 acres in size, and occurs at the northwestern tip of the lake (Figure 4). The rest of the wetlands are scattered around the shoreline of Thunder Lake, and range in size from approximately one to ten acres.

The most common wetland types are palustrine scrub-shrub (Cowardin et al. 1979) or wetland shrublands (MN DNR 2003), emergent (Cowardin et al. 1979) or marsh (MN DNR 2003) systems, and forested wetlands (Cowardin et al. 1979, MN DNR 2003). Deciduous and evergreen shrubs dominate the palustrine scrub-shrub wetlands, while the emergent wetlands systems are characterized by herbaceous vegetation. Deciduous and evergreen trees are present in the forested wetlands.

The water regime varies among the different wetland systems. Many of the emergent wetlands are semipermanently flooded, with surface water that often persists throughout the growing season. The substrate of most palustrine scrub-shrub and forested systems is saturated, but surface water is seldom present. These systems may also be seasonally flooded.

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



Hydric Soils

Objective

1. Map hydric soils within the extended state-defined shoreland area of Thunder 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.

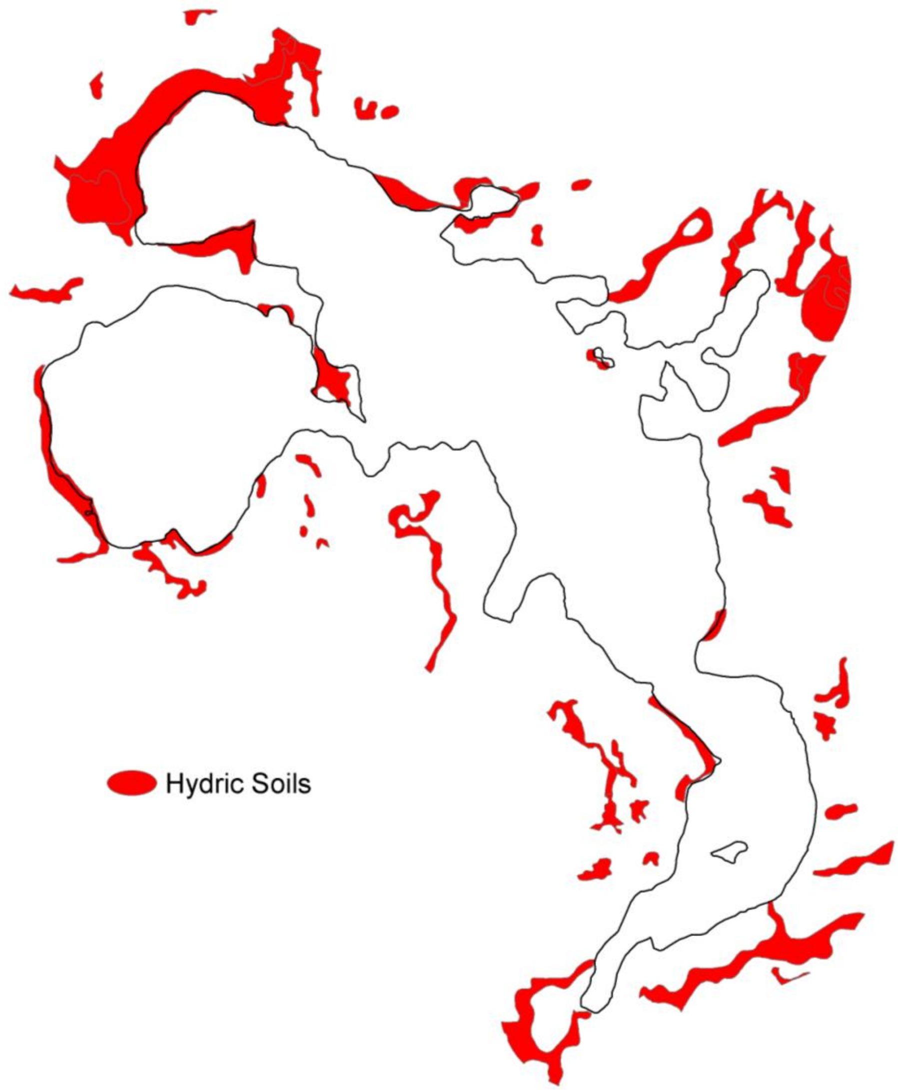
Methods

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.

Results

Nearly 324 acres of the Thunder Lake shoreland are comprised of hydric soils. These soils are located around the entire Thunder Lake shoreline, but occur in the greatest quantities along the northwestern lake edge (Figure 5). The specific soil types vary, and include muck, peat, and loamy sand. The majority of these soils have a very high organic matter content and are very poorly drained.

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



Plant Surveys

Objectives

1. Record presence and abundance of all aquatic plant taxa
2. Describe distribution of vegetation in Thunder 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

A total of 33 native aquatic plant taxa were recorded in Thunder Lake. These included 21 submerged and free-floating taxa, four floating-leaf, and eight emergent taxa. More than 30 shoreline plants were also found.

Aquatic plants occurred around the entire perimeter of Thunder Lake. Submerged plants occurred to a depth of 25 feet but were most common in the shore to 15 feet depth zone, where 90% of the sample sites contained vegetation. Common submerged plants included muskgrass (*Chara* sp.), coontail (*Ceratophyllum demersum*), Fries' pondweed (*Potamogeton friesii*), flat-stem pondweed (*Potamogeton zosteriformis*), and broad-leaf pondweeds (*Potamogeton* spp.).

Emergent and floating-leaf plants were generally restricted to depths of five feet and less. This depth zone was a narrow band in Thunder Lake and covered only 125 acres, or 10% of the lake. Within this shallow zone, 31% of the sample sites contained at least one emergent or floating-leaf plant. Floating-leaf plants, including white waterlily (*Nymphaea odorata*), yellow waterlily (*Nuphar variegata*), and floating-leaf pondweed (*Potamogeton natans*), occupied about nine acres and the largest beds were located in the northwest tip of the lake. Thirty-six acres of hard-stem bulrush (*Schoenoplectus acutus*) were mapped, with the largest beds occurring at the north end of the lake.

The unique submerged aquatic plant flat-leaved bladderwort (*Utricularia intermedia*) was documented for the first time in the lake.

Introduction

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, predation, 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 have not been documented in Thunder Lake. However, if they invade the lake, they may directly or indirectly impact the native plant community. Non-native plant species, such as Eurasian watermilfoil (*Myriophyllum spicatum*) or curly-leaf pondweed (*Potamogeton crispus*) may form dense surface mats that shade out native plants. The impact of these invasive species varies among lakes but the presence of a healthy native plant community may help mitigate the harmful effects of these exotics.

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 and wild rice. Shoreline and watershed development can also indirectly influence aquatic plant growth if it results in changes to the overall water quality and clarity. Limiting these types of activities can help protect native aquatic plant species.

Submerged 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 flowering plants that may produce flowers above or below the water surface, as well as non-flowering plants such as large algae.

Figure 6. Bed of muskgrass

Muskgrass (*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.

Figure 7. Coontail

Coontail (*Ceratophyllum demersum*; Figure 7) is the most common submerged flowering plant in Minnesota lakes. It grows entirely submerged and is adapted to a broad range of lake conditions, including turbid water. Coontail is a perennial and can overwinter as a green plant under the ice before beginning new growth early in spring. Because it is only loosely rooted to the lake bottom it may drift between depth zones (Borman et al. 2001). Coontail provides important cover for young fish, including bluegills, perch, largemouth bass and northern pike. It also supports aquatic insects beneficial to both fish and waterfowl.

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

Figure 8. Fries’ pondweed

<u>Fries' pondweed</u> (*Potamogeton friesii*; Figure 8) is fairly common within Midwestern lakes. This rooted, perennial submerged plant has small, thin leaves that grow entirely below the water surface but flowers that extend above the water. This plant overwinters as rhizomes and winter buds. There are several species of narrow-leaf pondweeds and they can be difficult to identify if not found in flower or fruit. Fries’ pondweed was positively identified in the lake, but additional narrow-leaf species may have also been present.

Figure 9. Flat-stem pondweed

<u>Flat-stem pondweed</u> (*Potamogeton zosteriformis*; Figure 9) is a perennial plant that is anchored to the lake bottom by underground rhizomes. It is named for its flattened, grass-like leaves. Depending on water clarity and depth, these plants may reach the water surface and may produce flowers that extend above the water. The flowers are small and green-brown in color. Flat-stem pondweed prefers to grow in soft sediments. These pondweeds overwinter by winter buds.

Figure 10. Illinois pondweed

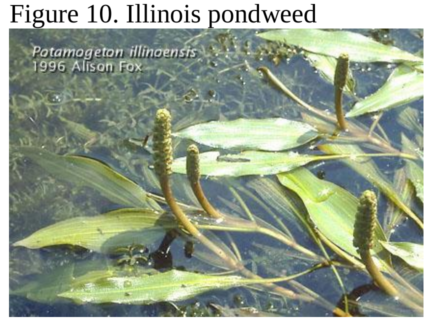


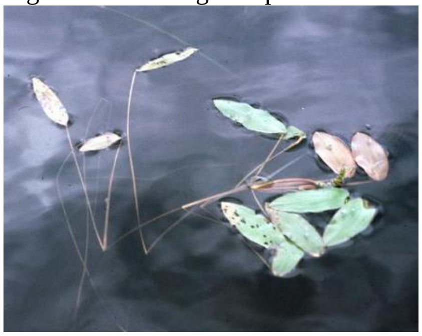
Photo by: Allison Fox, U. of Florida © 1996

<u>Illinois pondweed</u> (*Potamogeton illinoensis*; Figure 10) is a rooted, perennial plant with broad leaves. It is one of several pondweeds that are often called “cabbage” plants by anglers. These plants are primarily submerged but many will form floating leaves in shallower water. The fruits of pondweeds are a favorite duck food and the broad leaves provide food and shelter for fish. Illinois pondweed is found scattered throughout central Minnesota (Ownbey and Morley 1991).

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 11. Floating-leaf pondweed



Floating-leaf pondweed (*Potamogeton natans*; Figure 11) occurs in lakes throughout the state. It may co-occur with other vegetation or may be found on the deep end of bulrush beds. This plant forms very narrow submerged leaves and oval-shaped floating-leaves. The fruits of floating-leaf pondweed are eaten by geese and ducks, including scaup and blue-winged teal (Borman et al. 2001).

Figure 12. White waterlily

White and yellow waterlilies can be found in lakes in both northern and southern Minnesota. White waterlily (*Nymphaea odorata*; Figure 12) has showy white flowers and round leaves with radiating veins. Yellow waterlily (*Nuphar variegata*; Figure 13) 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 (Nichols 1999b).

Figure 13. 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.

Hard-stem bulrush (*Schoenoplectus acutus*) is an emergent, perennial plant that occurs in lakes and wetlands throughout Minnesota (Ownbey and Morley 1991). Bulrush stems are round in cross section and lack showy leaves (Figure 14). 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.

Figure 14. Bulrush bed

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.

Figure 15. Bladderwort in flower among watershield

Bladderworts (*Utricularia* spp.) are a group of submerged plants that produce roots but do not firmly anchor to the lake bottom. Greater bladderwort (*U. vulgaris)* is found in lakes and ponds throughout Minnesota but several other species are much less common. The unique bladderwort species documented in Thunder Lake was flat-leaved bladderwort (*U. intermedia*). This small submerged plant is often confused as algae because of its fine stems and leaves. 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 15) 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).

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 Thunder Lake were described and measured using several techniques as found in Minnesota's Sensitive Lakeshore Identification Manual (MN DNR 2008). Plant nomenclature follows MNTaxa 2009.

Grid point-intercept survey
A grid point-intercept survey was conducted in Thunder Lake on July 23, 24, 28, 29 and 30, 2008 (Perleberg and Loso 2008). 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. Points were spaced 40 meters apart and 1160 sites were sampled within the shore to 25 feet depth zone. An additional nine sites were surveyed in the 26 to 30 feet depth zone but since no vegetation was found, these deeper water sites were not used in analyses. Surveyors navigated to each site using a handheld Global Positioning (GPS) unit. At each sample site, water depth and all vegetation within a one-meter squared sample 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 species found outside the sample plots were recorded as present in the lake. Voucher specimens were collected for most species and were submitted to The Herbarium of the University of Minnesota Bell Museum of Natural History, St. Paul, MN.

Emergent and floating-leaf bed delineation
Protocol for mapping plant beds were based on the procedures documented in the DNR draft Aquatic Vegetation Mapping Guidelines (MN DNR 2005). They included a combination of aerial photo delineation and interpretation, field delineation, ground-truthing and site specific surveys. Waterlily beds were delineated using 2003-2004 and 2008 Farm Service Administration (FSA) true color aerial photos. Black and white aerial photos from 1999 were used to help distinguish the true shoreline from mats of perennial vegetation. In 2008, reconnaissance surveys were conducted of the largest beds to verify species composition and if needed, modify boundary lines. Field mapping focused on bulrush beds, which were difficult to see on aerial photos. Bulrush beds were mapped in 2008 using handheld GPS technology.

Near-shore vegetation survey
Near-shore vegetation surveys were conducted at three plots. Plots were selected based on the presence of non-game fish. Each plot measured 15 meters along the shoreline and 16 meters lakeward, and 30 (one-meter squared) sites were sampled within each plot. Surveyors recorded plant species present, water depth, substrate and presence of woody debris.

Searches for unique and rare species
Prior to fieldwork, surveyors obtained known locations of state and federally listed rare plants within one mile of Thunder Lake from the Rare Features Database of the MN DNR Natural Heritage Information System. 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 Thunder Lake.

Surveyors searched for unique and rare plant species in 2008 during the lakewide point-intercept surveys and during the near-shore plot surveys. 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. Any new sites of rare plant species were documented and entered into the MN DNR Natural Heritage Information System.

A targeted search for rare aquatic vascular plants in Thunder Lake was conducted by the Minnesota County Biological Survey Program on July 22, 2008 (Myhre 2008). 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. When necessary, plant specimens were sent to the authority in the field for identification verification and annotation. Voucher specimens were collected to document county records and some other species, and were submitted to The Herbarium of the University of Minnesota Bell Museum of Natural History, St. Paul, MN.

Results

Aquatic plant species observed

A total of 33 native aquatic plant taxa were recorded in Thunder Lake. These included 21 submerged and free-floating taxa, four floating-leaf, and eight emergent taxa (Table 1). More than 30 shoreline emergent plants were also recorded (Appendix 1).

Distribution of plants

Aquatic plants occurred around the entire lake perimeter and the most extensive beds were in the northern-most bay where vegetation extended lakeward at least 1000 feet. Plant growth was also common in the channel to the western basin and along the north shore of the western basin (Figure 16).

Submerged plants were found to a water depth of 25 feet. This vegetated zone includes about one-third of the lake surface and within this area, 71% of the survey sites contained vegetation. Plant occurrence was greatest in depths from shore to 15 feet, where 90% of the sites were vegetated. Percent of vegetated sites decreased with increasing water depth. In depths of 23 to 25 feet, only five percent of sites were vegetated.

Emergent and floating-leaf plants were most often found in depths of five feet and less. Within this shallow zone, 31% of the sample sites contained at least one emergent or floating-leaf plant. The main areas of emergent and floating-leaf vegetation were along the northern shores (Figure 16). A total of 45 acres of emergent and floating-leaf plant beds were delineated.

Table 1. Aquatic plants recorded in Thunder Lake, 2008.

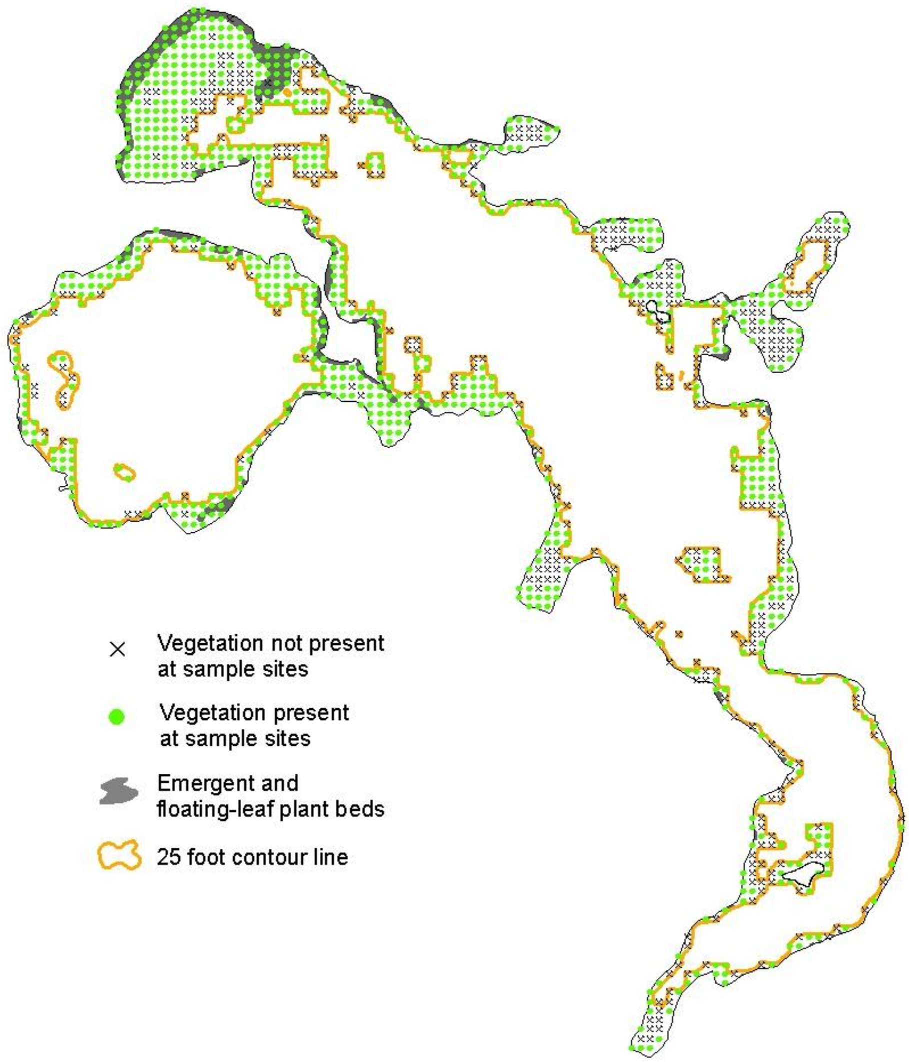
Description			Common Name	Scientific Name	Frequency[a]
SUBMERGED and/or FREE-FLOATING	Large Algae		Muskgrass	*Chara* sp.	49
	Rooted plants		Coontail	*Ceratophyllum demersum*	27
		Narrow-leaf pondweeds	Fries' pondweed	*Potamogeton friesii*	18
			Flat-stem pondweed	*Potamogeton zosteriformis*	14
			Sago pondweed	*Stuckenia pectinata*	4
		Broad-leaf pondweeds	Illinois pondweed	*Potamogeton illinoensis*	7
			White-stem pondweed	*Potamogeton praelongus*	3
			Large-leaf pondweed	*Potamogeton amplifolius*	1
			Clasping-leaf pondweed	*Potamogeton richardsonii*	1
			Variable pondweed	*Potamogeton gramineus*	<1
		Other	Northern watermilfoil	*Myriophyllum sibiricum*	3
			Bushy pondweed	*Najas* sp.	2
			Canada waterweed	*Elodea canadensis*	1
			Wild celery	*Vallisneria americana*	<1
			Water stargrass	*Zosterella dubia*	<1
			Water marigold	*Bidens beckii*	Present[b]
			White water buttercup	*Ranunculus aquatilis*	Present
	Free-drifting		Greater bladderwort	*Utricularia vulgaris*	2
			Flat-leaved bladderwort	*Utricularia intermedia*	<1
			Star duckweed	*Lemna trisulca*	1
			Greater duckweed	*Spirodela polyrhiza*	<1
FLOATING-LEAF			Floating-leaf pondweed	*Potamogeton natans*	2
			White waterlily	*Nymphaea odorata*	1
			Yellow waterlily	*Nuphar variegata*	Present
			Watershield	*Brasenia schreberi*	Present
EMERGENT			Hard-stem bulrush	*Schoenoplectus acutus*	7
			Needlegrass	*Eleocharis acicularis*	<1
			Spikerush	*Eleocharis* sp.	<1
			Horsetail	*Equisetum palustris*	<1
			Arrowhead	*Sagittaria latifolia*	<1
			Giant burreed	*Sparganium eurycarpum*	<1
			Broad-leaf cattail	*Typha latifolia*	<1
			Narrow-leaf cattail	*Typha angustifolia*	Present

[a]Frequency values are provided for taxa that were observed within point-intercept survey sample stations (N = 1160). They represent the percent of the sample stations that contained a plant taxon.

[b]Present = present in lake but not found at point-intercept sample stations.

Nomenclature follows MNTaxa 2009.

Figure 16. Aquatic plant distribution in Thunder Lake, 2008.



Submerged plants

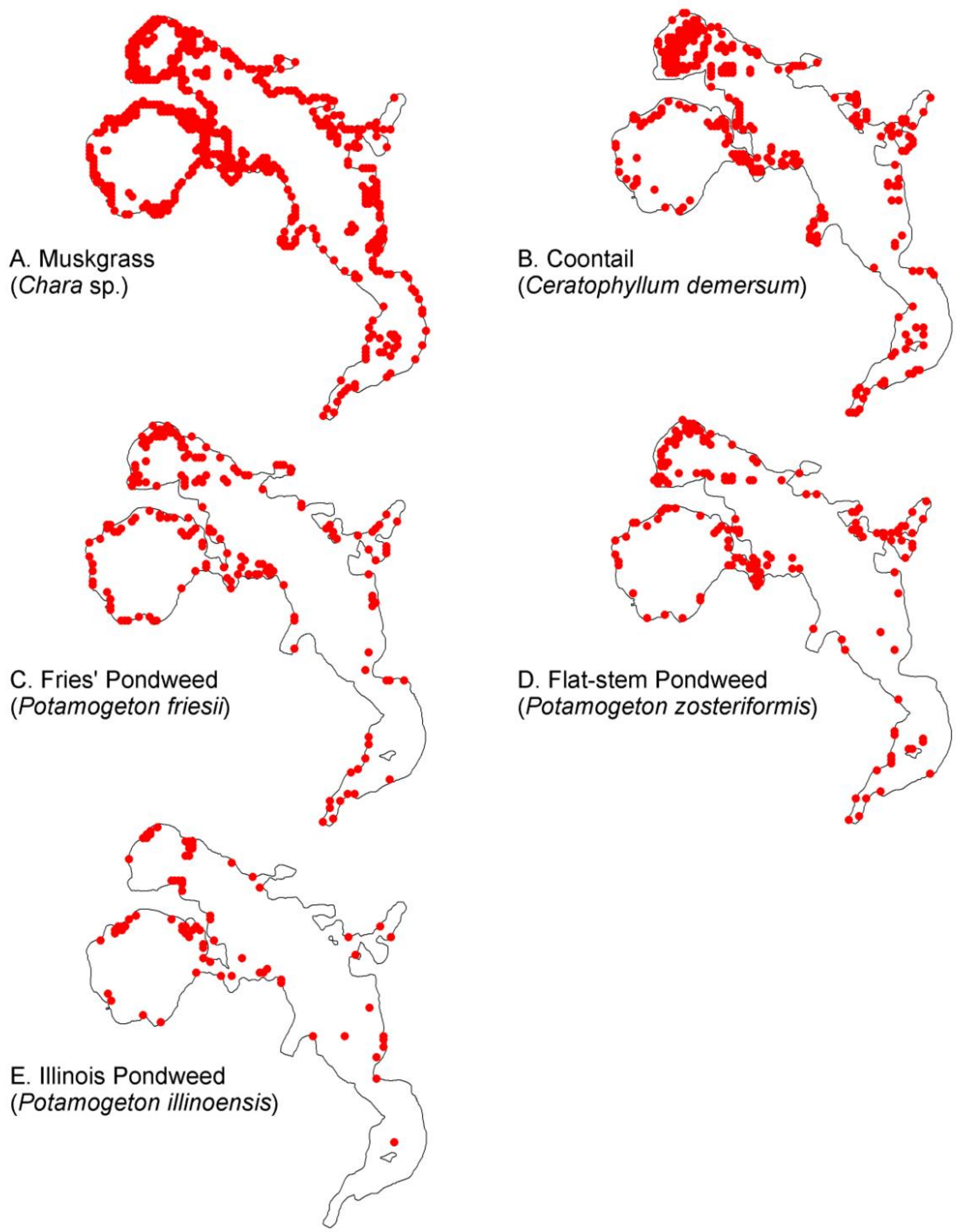
Submerged plants occurred in 71% of Thunder Lake sample sites. The plant community included leafy plants that are anchored to the lake bottom by roots as well as large algae that may resemble leafy plants but are weakly anchored to the lake bottom.

Muskgrass was found in 49% of all sample sites (Table 1, Figure 17A). It was an important plant throughout the littoral zone and was most frequent within the shore to 15 feet depth zone where it occurred in 69% of the sites (Figure 17A).

Coontail was found in 26% of all sample sites. It occurred throughout the vegetated zone (Figure 17B) and was the dominant species in the 11 to 20 feet depth zone where it occurred in 52% of the sites. The deep water portion in the northern tip of the lake was dominated by coontail.

Nine different pondweed species (*Potamogeton* spp. and *Stuckenia* spp.) were found in Thunder Lake and they were distributed throughout the lake (Figure 17C, D, E). Fries' pondweed and flat-stem pondweed were most commonly documented in the six to 15 feet depth zone and were found in 18% and 14% of the sample sites, respectively. Illinois pondweed was more common in shallow water of five feet or less and was recorded in seven percent of all sample sites.

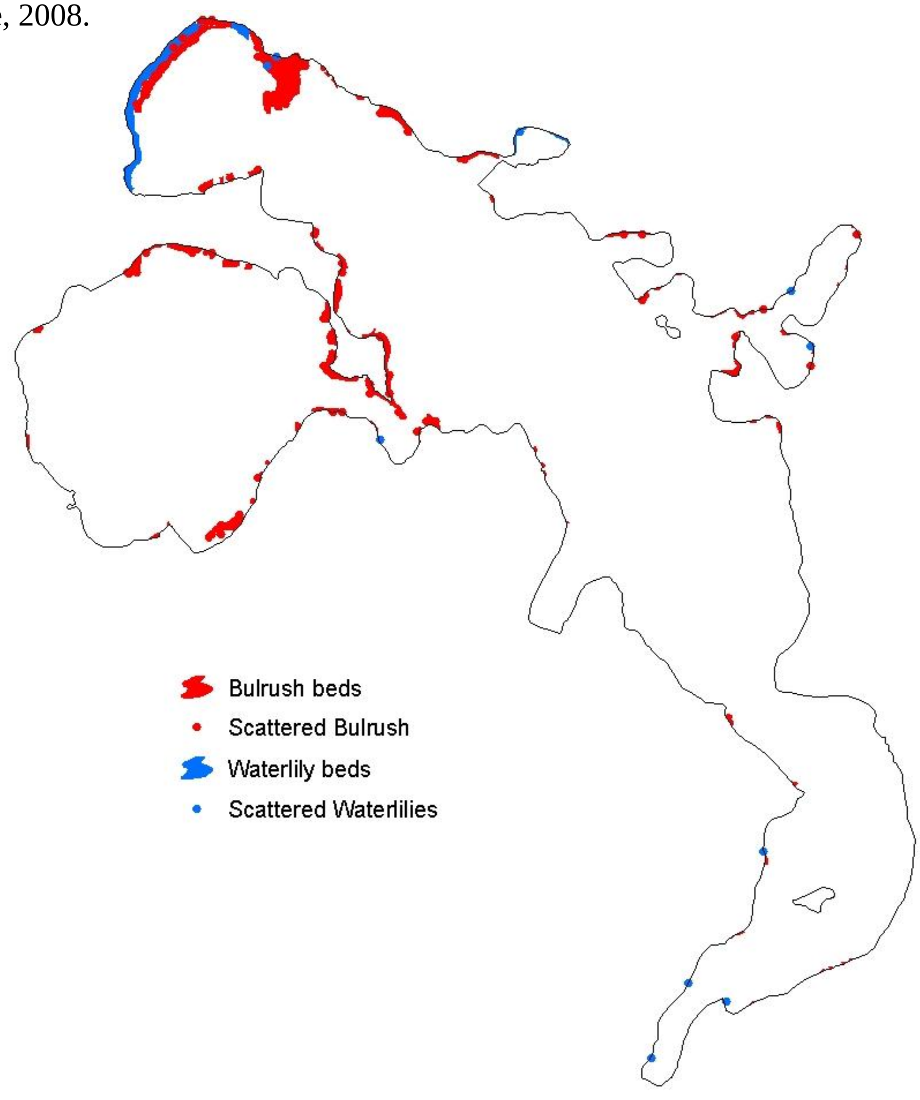
Figure 17. Distribution of common aquatic plants in Thunder Lake, 2008.



Floating-leaf and emergent plants
A total of 45 acres of emergent and floating-leaf plant beds were delineated in Thunder Lake. About nine acres of floating-leaf plant beds were mapped and the largest beds occurred along the northwest tip of the lake (Figure 18). The most common species were white waterlily, yellow waterlily, and floating-leaf pondweed. Because surveyors avoided motoring into floating-leaf plant beds, the frequency values obtained for these taxa (Table 1) were lower than the actual lakewide occurrence. Frequency values for floating-leaf taxa represent the occurrence of these taxa only within the sites that were surveyed. Waterlily beds often contained scattered bulrush plants as well as submerged plants and were usually associated with muck sediments.

Bulrush was the most common emergent plant and surveyors delineated approximately 36 acres (Figure 18). Other emergent plants occurred within bulrush beds or at scattered locations around the lake and included spikerush (*Eleocharis* sp.), broad-leaved arrowhead (*Sagittaria latifolia*), and horsetail (*Equisetum* sp.). Numerous additional native emergents occurred in wetlands adjacent to the lake, but this survey did not include an exhaustive wetland species inventory.

Figure 18. Distribution of emergent and floating-leaf plant beds in Thunder Lake, 2008.



Waterlilies in Thunder Lake, 2008

Bulrush in Thunder Lake, 2008

Unique plants

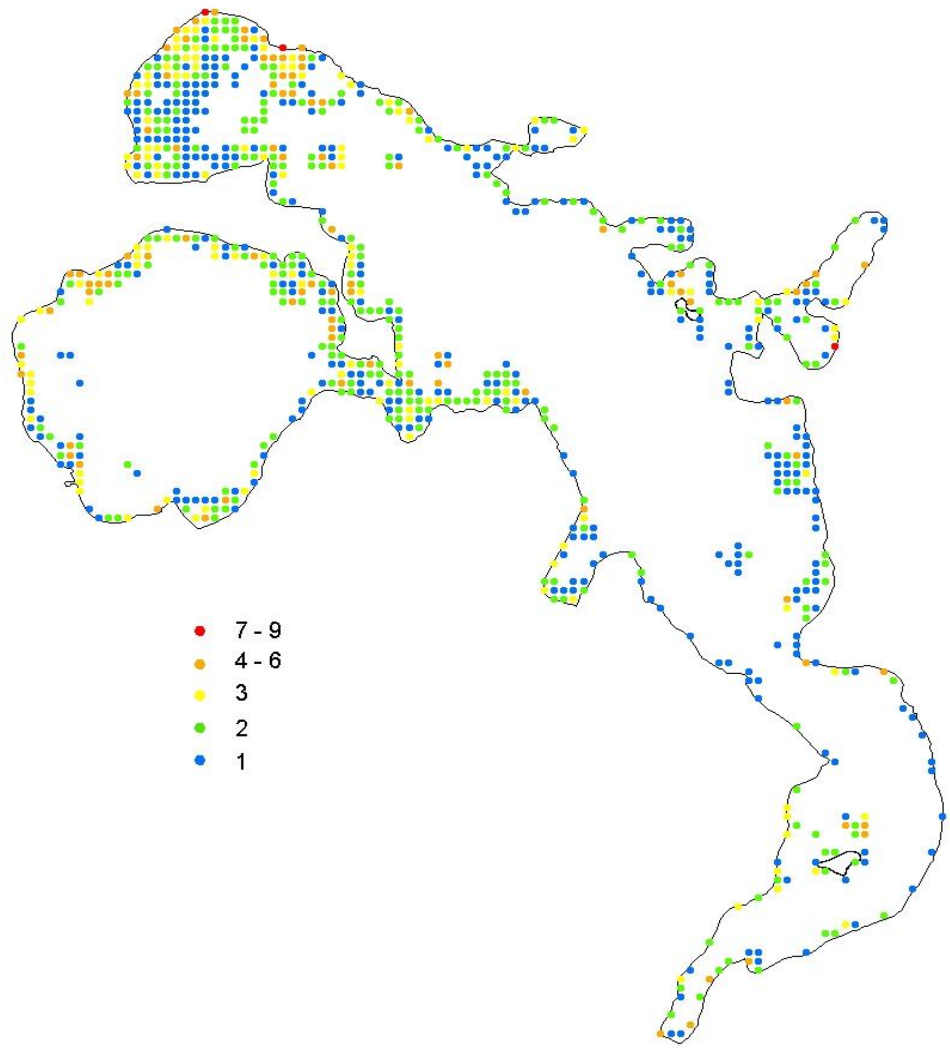
In addition to the commonly occurring plants in Thunder Lake, the unique submerged plant, flat-leaved bladderwort, was documented for the first time in the lake. It was found along the southwestern shore of Thunder Lake at a depth of five feet, within a bed of muskgrass (Figure 19).

Figure 19. Unique aquatic plants in Thunder Lake, 2008.

Species richness

The number of plant taxa found in each one-square meter sample site ranged from zero to nine (Figure 20). Sites with the highest number of species occurred near shore, within mixed beds of emergent, floating-leaf and submerged plants. In water depths greater than 15 feet, the mean number of species found per site was less than one.

Figure 20. Aquatic plant richness (number of species per sampling station) in Thunder Lake, 2008.



Near-shore Substrates

Objective

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

Introduction

Substrate type can have an effect on species make-up and richness. 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 Thunder Lake was evaluated at a total of 654 sampling stations set up in the grid point-intercept aquatic plant surveys and near-shore fish surveys. Plant sample stations were 40 meters apart and occurred in a grid from shore to a depth of 25 feet; substrate was documented at stations where the water depth was seven feet 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 64 of these stations.

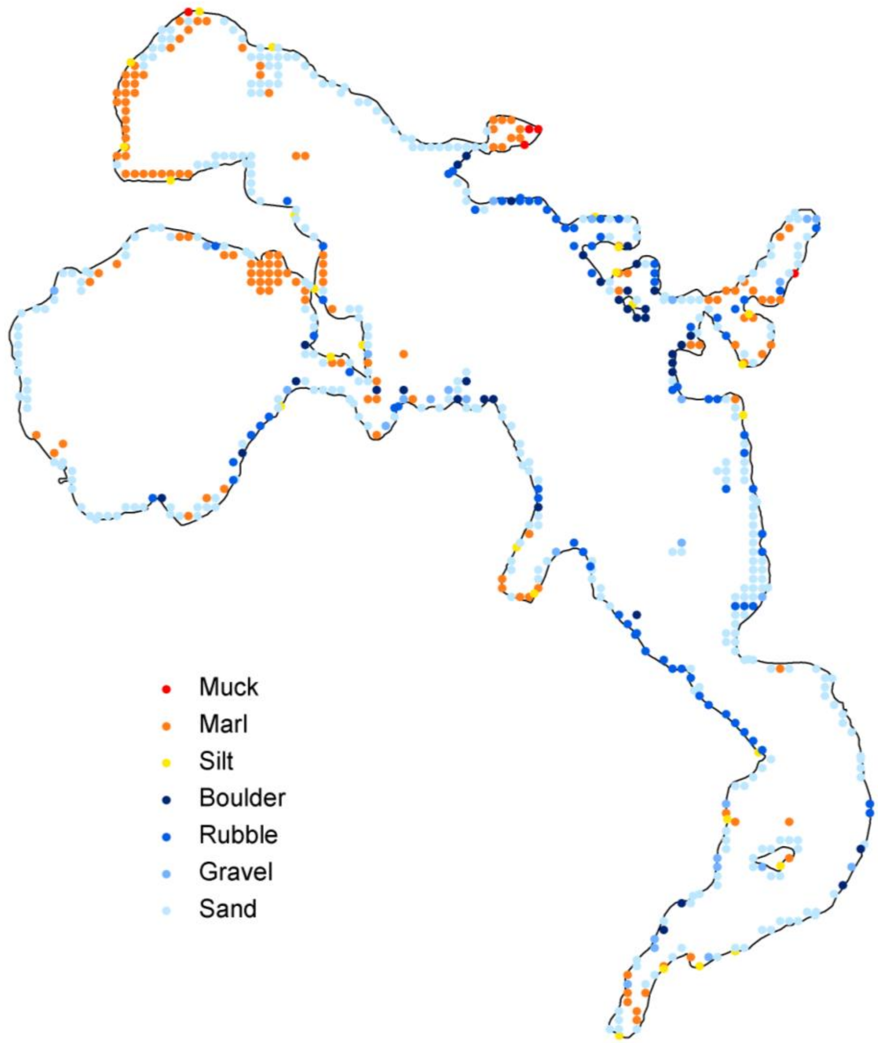
Surveyors evaluated substrate by tapping a pole into the lake bottom; soft substrate could usually be brought to the surface on the pole or sampling rake for evaluation. If this was not feasible, substrate was evaluated by visual observation. Standard lake substrate classes were based on the DNR Fisheries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

Hard bottom substrates of boulder and rubble were common, especially in the main basin of Thunder Lake (Figure 21). The east shore of the main basin and a large portion of the west basin shore had extensive areas of sand. Natural sand beaches were the most common near-shore substrate. There were large but scattered areas dominated by marl substrate, notably the northwestern portion of the main basin, portions of protected bays, and along the north shore of the west basin. Muck and silt were limited to protected bays.

Figure 21. Distribution of Thunder Lake near-shore substrates, 2008.



Bird Surveys

Objectives

1. Record presence of all bird species detected during point count surveys
2. Record presence of marsh birds detected with call-playback surveys
3. Document all non-survey observations of birds
4. Develop distribution maps for species of greatest conservation need

Introduction

Bird Species of Greatest Conservation Need
There are 97 bird species of greatest conservation need (SGCN) in Minnesota. Species of greatest conservation need are documented in Minnesota's State Wildlife Action Plan, Tomorrow's Habitat for the Wild and Rare (2006). Twelve of these species were identified at Thunder Lake.

Figure 22. Bald eagle

Photo by: Carrol Henderson

Bald eagles (*Haliaeetus leucocephalus*; Figure 22) are an increasingly common sight in Minnesota. Once listed as an endangered species, bald eagle numbers have rebounded due to effective environmental protection laws and conservation efforts. Adult bald eagles are easily identified by the white head and tail, although these colors don't appear until birds are 4 or 5 years old. Prior to that, eagles are generally dark brown with white feathers scattered along the wings, head, tail and back. With a wingspan of up to 7 feet, bald eagles are one of the largest birds in North America. They are found in forested areas near large, open bodies of water. Although bald eagle numbers are increasing, these birds still face threats from environmental contaminants and destruction of habitat. Bald eagles are listed as a species of Special Concern in the state of Minnesota.

Figure 23. Cape May warbler

Photo by: S. Maslowski, USFWS

The Cape May warbler (*Dendroica tigrina*; Figure 23) is a small, active warbler. Breeding plumage is striking, with a bright yellow rump, throat, and breast streaked with black. The face is orange-brown with a black eyestripe. Cape May warblers breed across the northern United States and into Canada, where large expanses of coniferous woodland are present. Numbers of Cape May warblers rise and fall somewhat regularly, in response to availability of spruce budworms, a main food source. However, loss of mature, boreal forest through logging and loss of winter habitat may lead to long-term population declines in Cape May warblers.

Common loons (*Gavia immer*; Figure 24) are one of Minnesota's most recognizable birds. They are found from northeastern to central Minnesota, and numbers are higher here than in any other state except Alaska. These large diving birds possess red eyes and a large, dark pointed bill that is well-adapted for catching fish. Loons spend most of their time in water, and go ashore only to mate and incubate eggs. Summer plumage is spotted black and white, while in winter the colors are gray above and white below. Loon populations are closely monitored in Minnesota; however, these birds still face threats, particularly in the form of human disturbance and lead poisoning.

Figure 24. Common loon

Photo by: Carrol Henderson

Common terns (*Sterna hirundo*; Figure 25) are the most widespread terns in North America. In the breeding season common terns have a solid black cap with gray back and underparts. The gray wings have dark edges. The rump is white, and the legs and bill are orange-red in color. Common terns nest in colonies, often on sandy substrates of islands or peninsulas of large lakes. Populations of common terns declined in the the late 1800s, when their feathers were used to adorn clothing, and again in the 1970s, likely due to poisoning by pesticides. Habitat loss, nest predation, and disturbance by humans may also negatively affect common terns.

Figure 25. Common tern

Photo by: Carrol Henderson

Eastern wood-pewees (*Contopus virens*; Figure 26) are medium-sized, nondescript birds common in Eastern forests. They utilize multiple habitat types, including deciduous forests, mixed woods, and suburban areas. This bird gets its name from its call, a slurred "pee-ah-wee." Eastern wood-pewees are grayish-olive above, with a paler throat and belly and whitish wingbars. They forage throughout the canopy, often flying out from their perch to catch insects before returning to the same perch. Populations of eastern wood-pewees are declining throughout much of their range. One possible cause of the decline is the increase in white-tailed deer, which browse and decrease the lower-canopy foraging area available to the pewee.

Figure 26. Eastern wood-pewee

Photo by: J.A. Spendelow

Least flycatchers (*Empidonax minimus*; Figure 27) are the smallest flycatchers found in Minnesota. Like many other flycatchers, they are olive to gray in color with two white wingbars and whitish underparts. They have a small bill and a prominent white eye ring. The best way to distinguish least flycatchers from other flycatchers is the call, a harsh "che-bek." These birds are often found along water edges in mature, open woods. Least flycatchers are common throughout most of their range where habitat is suitable. However, they are sensitive to human disturbance and require large areas of forest to survive.

Figure 27. Least flycatcher

Photo by: J.A. Spendelow

Ovenbirds (*Seiurus aurocapillus*; Figure 28) are rarely seen birds of the forest. However, their loud "teacher, teacher, teacher" song is commonly heard during the summer months. They dwell on the ground, and build a covered nest that resembles a Dutch oven. Ovenbirds are olive-brown with a boldly streaked breast. Two black stripes border an orange crown. They have a thin bill and a white eye ring. They breed in mature deciduous and mixed forests, especially those with minimal undergrowth. Ovenbird numbers appear to be stable, but the birds are vulnerable to forest fragmentation and parasitism by brown-headed cowbirds (*Molothrus ater*).

Figure 28. Ovenbird

Photo source: U.S. Fish and Wildlife Service

Rose-breasted grosbeaks (*Pheucticus ludovicianus*; Figure 29) are summer visitors to Minnesota bird feeders. The males are easily identified by a red triangle on a white breast, with a black head and back and a large bill. Females are more difficult to identify, and resemble a large sparrow with brown and white streaks. Rose-breasted grosbeaks are found in open woodlands near water, edges of marshes, meadows and woodlands, and suburban parks and gardens. The winter range spans from southern Mexico to South America and the Caribbean. Significant regional declines in rose-breasted grosbeak populations have been noted. Protection of large, unfragmented areas of hardwood forest would be beneficial to the rose-breasted grosbeak.

Figure 29. Rose-breasted grosbeak

Photo by: J.A. Spendelow

The swamp sparrow's (*Melospiza georgiana*; Figure 30) slow trill is a familiar sound in swampy areas in the summer. Other wetlands, such as bogs and meadows, may also harbor populations of this species. Swamp sparrows eat mainly seeds and fruits, but may also be adventurous feeders, wading in the water and putting their heads underneath in order to capture aquatic insects. This rusty-colored bird has black streaks on the back and an unstreaked gray breast and neck. A reddish cap is easily visible during the breeding season. Swamp sparrows thrive in suitable habitat; however, destruction of wetlands has put this species at risk.

Figure 30. Swamp sparrow

Photo by: Jim Stasz

The veery (*Catharus fuscescens*; Figure 31) is one of the most easily identifiable thrushes. It has faint dark spots on a buffy breast and a reddish brown back and head. The legs are pink and the eyes are dark with an indistinct light eye ring. The veery was named after its most common call, a "vee-er" sound. Riparian areas with dense vegetation and wetlands within large forests are good places to find the veery. The veery is suffering declines throughout many parts of its range. Destruction of winter habitat and parasitism by brown-headed cowbirds are major reasons cited for the decline.

Figure 31. Veery

Photo by: Deanna Dawson

White-throated sparrows (*Zonotrichia albicollis*; Figure 32) are common in Minnesota during their spring and fall migrations. They are recognizable by the white patch on the throat and their characteristic "Old Sam Peabody Peabody Peabody" song. The head is striped with black and tan or white, and has a yellow spot above the eye. The chest is gray and the back is streaked with brown and black. They inhabit coniferous or mixed forests, and prefer areas with multiple openings and abundant low-growing vegetation. During winter and migration, they may also be found in woodlots, city parks, and backyards. Nests are often build on or near the ground. Although white-throated sparrows are widespread, they are declining over portions of their breeding range. Large blocks of mixed forest with multiple age classes and semi-open wetlands provide important habitat, and should be protected to benefit white-throated sparrows.

Figure 32. White-throated sparrow

Photo by: Dave Herr

The yellow-bellied sapsucker's (*Sphyrapicus varius*; Figure 33) name describes it well. This medium-sized woodpecker exhibits a yellow underside, and feeds primarily on sap it harvests from trees. The forehead and crown are red, and the throat is also red in the male. The back and sides are striped with black and white. Deciduous forests and riparian areas along streams characterize the breeding habitat of this species. Yellow-bellied sapsuckers create a food source for many other species when they drill holes for sap, and are therefore considered an important part of the ecosystem. Populations currently appear stable, and care should be taken to ensure they remain that way.

Figure 33. Yellow-bellied sapsucker

Photo by: J.A. Spendelow

Methods

Surveyors used several techniques to collect information on bird species. Point counts were conducted at 64 stations, located 400 meters apart along the lakeshore. Surveyors listened for five minutes per station and recorded all species detected (heard or seen) within that time. Point count surveys were conducted in the early morning hours, when birds were most likely to be singing. Call-playback surveys were conducted at survey stations that had appropriate habitat. At each station, surveyors played a tape that included the calls of six marsh birds (least bittern (*Ixobrychus exilis*), yellow rail (*Coturnicops noveboracensis*), sora (*Porzana carolina*), Virginia rail (*Rallus limicola*), American bittern (*Botaurus lentiginosus*), and pied-billed grebe (*Podilymbus podiceps*)) and listened for a response. Call-playback surveys generally took place in the early evening. Both survey techniques were dependent on good listening conditions, and surveys were stopped if inclement conditions prevented the ability to hear bird vocalizations. Casual observations of birds seen or heard on the lake or on the lakeshore were also recorded.

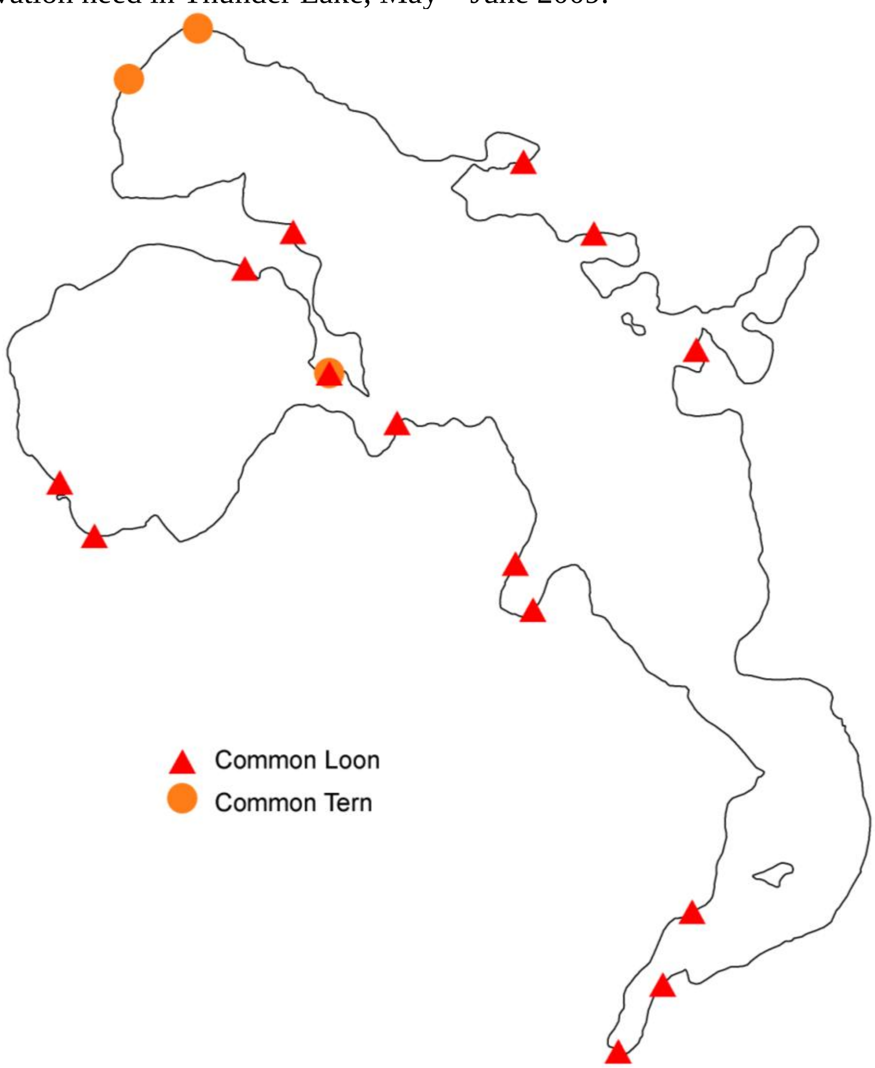
Results

Thunder Lake bird surveys were conducted in May and June 2009. During this time, surveyors documented 70 bird species, including 12 bird species of greatest conservation need. The majority of the species (68 species), including all species of greatest conservation need, were documented during the point count and call-playback surveys (Table 2); several additional species were recorded through casual observation of the lake (Appendix 2). The ovenbird, documented at nearly one-third of the survey stations, was the most commonly recorded species of greatest conservation need. Common loons were identified at nearly 25% of the survey stations (N = 14), and the veery and yellow-bellied sapsucker were each detected at more than five survey stations. The Cape May warbler and swamp sparrow were detected rarely; each of these species was found at only one survey station. The remaining species of greatest conservation need identified during the surveys were bald eagle, common tern, eastern wood-pewee, least flycatcher, rose-breasted grosbeak, and white-throated sparrow.

Overall, song sparrows were the most commonly detected bird species at Thunder Lake. Surveyors found this species at 80% of the survey stations. American robins were second in overall abundance, and were documented at 42 of the 64 stations. Red-eyed vireos, chipping sparrows, and the common grackle rounded out the top five most commonly documented species.

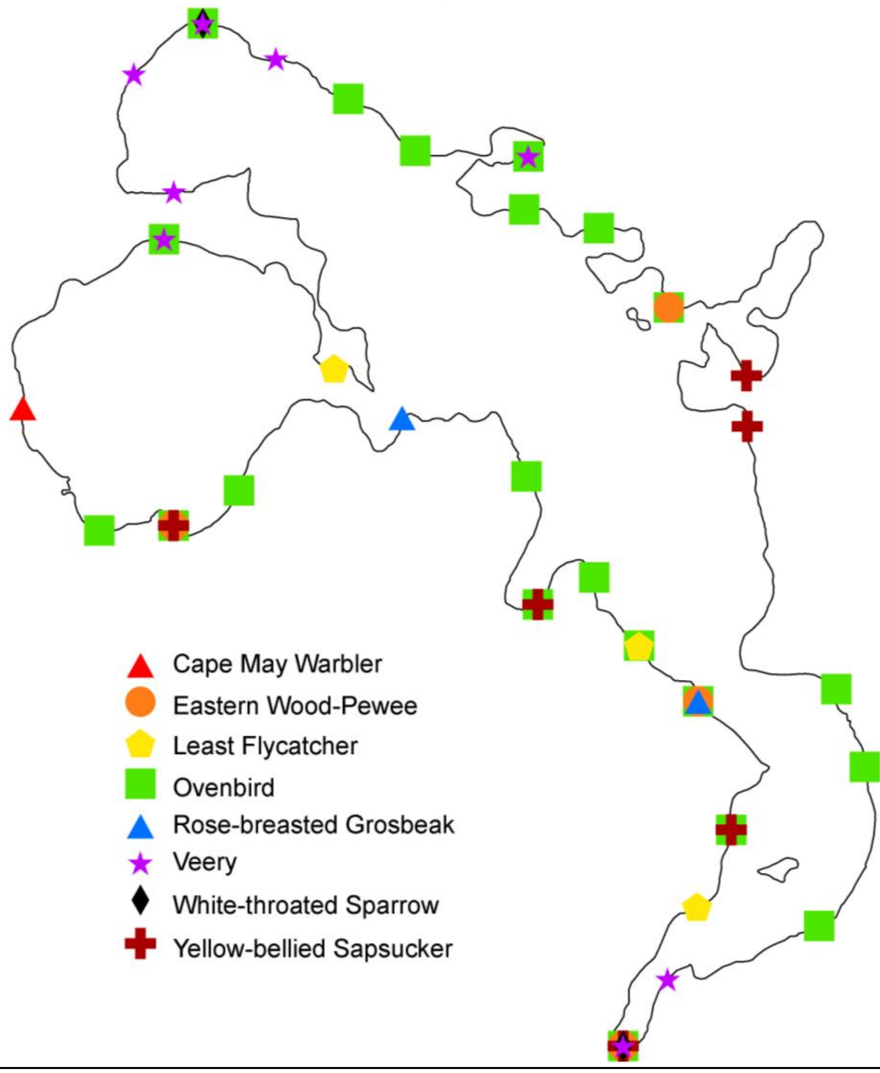
The common loon was documented at multiple locations along the Thunder Lake shoreline (Figure 34). Although many of the sightings were within small bays, loons were also detected along the main shoreline of the lake. The common tern was detected at three survey stations on Thunder Lake. Two of these stations were within the large wetland complex at the northern end of the main basin.

Figure 34. Distribution of aquatic habitat-dependent bird species of greatest conservation need in Thunder Lake, May – June 2009.



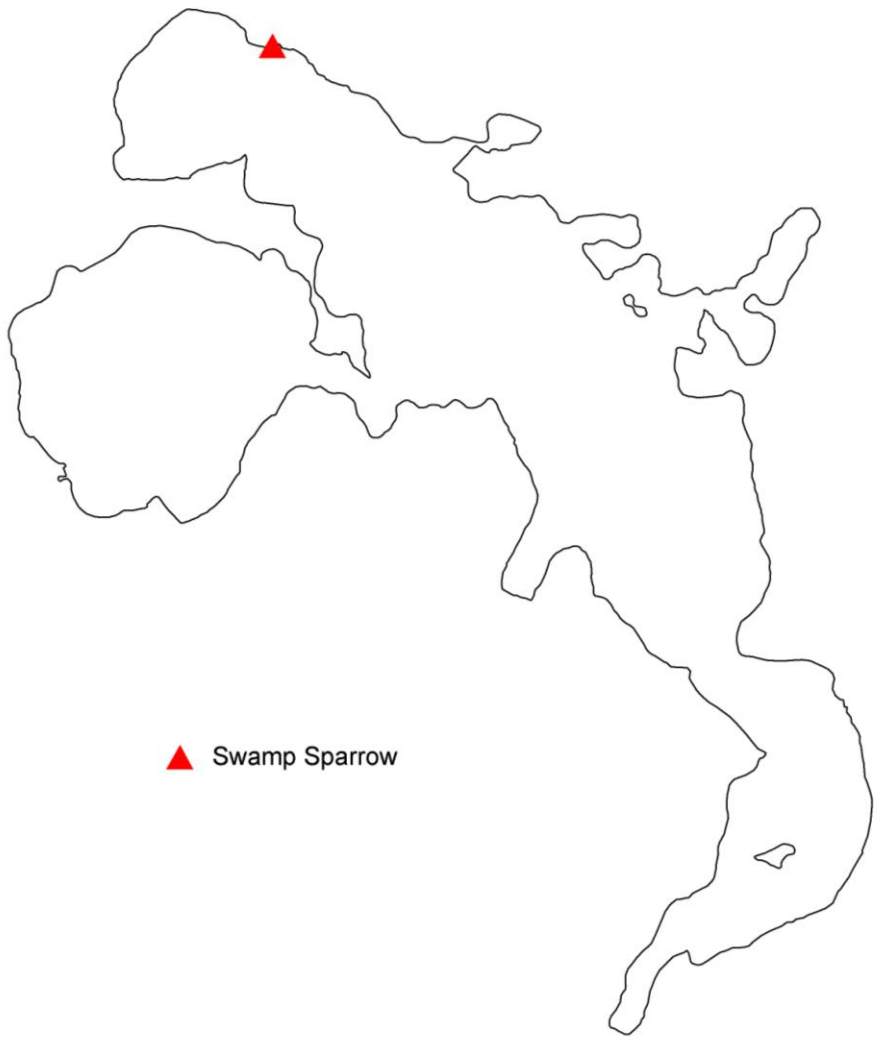
The majority of the bird species of greatest conservation need documented at Thunder Lake were forest-dwelling species (Figure 35). The three most common forest-dwelling species of greatest conservation need (ovenbird, veery, yellow-bellied sapsucker) were found scattered along the entire shoreline, in both the main basin and the western basin. The least flycatcher and rose-breasted grosbeak detections were limited to the western half of Thunder Lake. The only Cape May warbler detected was along the western shoreline of the west basin.

Figure 35. Distribution of forest habitat-dependent bird species of greatest conservation need in Thunder Lake, May – June 2009.



The only highly wetland habitat-dependent species of greatest conservation need identified at Thunder Lake was the swamp sparrow (Figure 36). This species was documented at one survey station, within the large wetland complex located at the north end of the lake.

Figure 36. Distribution of wetland habitat-dependent bird species of greatest conservation need in Thunder Lake, May – June 2009.



The bald eagle, which can occupy a variety of habitat types, was found at four different survey stations on Thunder Lake (Figure 37). Two of these locations were near the southern end of the lake, one was along the western shoreline, and one was on the northwestern tip of the lake.

Figure 37. Distribution of bird species of greatest conservation need that occupy a variety of habitats in Thunder Lake, May – June 2009.

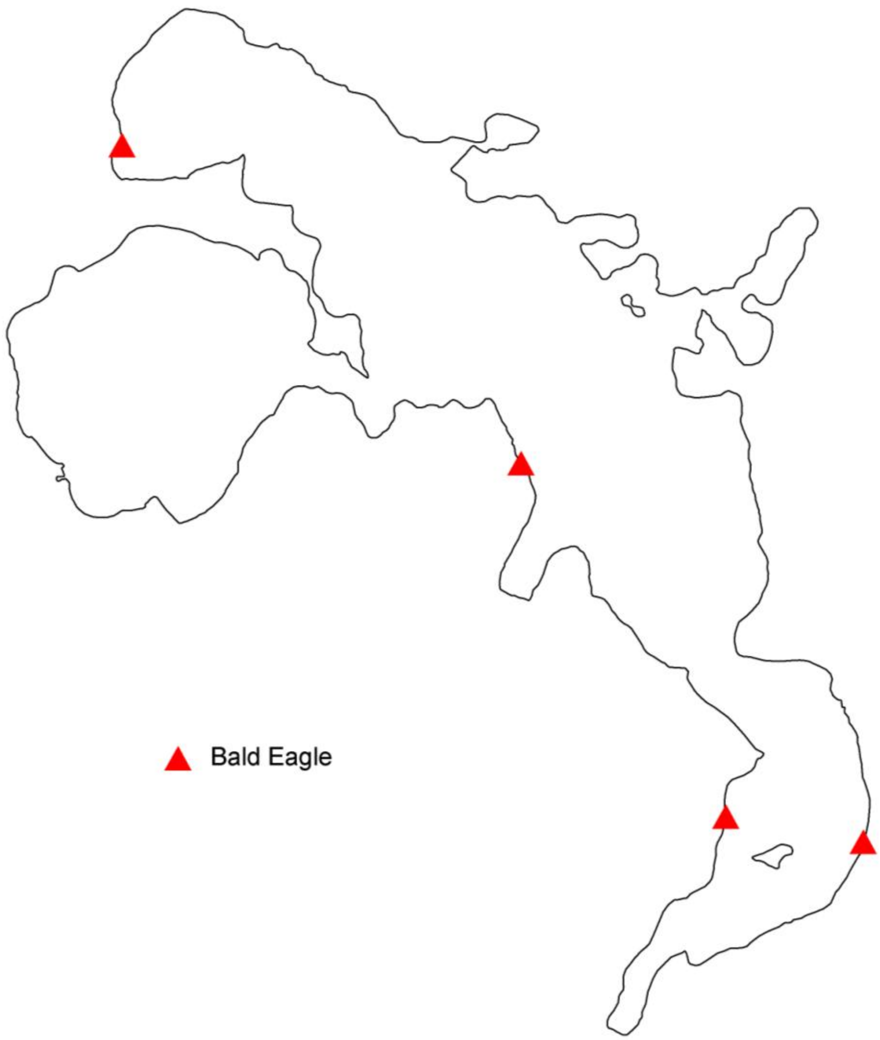


Table 2. Species list and frequency of occurrence of bird species identified during point count and call-playback surveys, May – June 2009. * denotes a species of greatest conservation need.

Description	Common Name	Scientific Name	%[a]
Waterfowl	Canada Goose	*Branta canadensis*	2
	Wood Duck	*Aix sponsa*	3
	Mallard	*Anas platyrhynchos*	17
	Common Goldeneye	*Bucephala clangula*	14
	Common Merganser	*Mergus merganser*	6
Loons	Common Loon*	*Gavia immer*	22
Herons/bitterns	Great Blue Heron	*Ardea herodias*	13
	Green Heron	*Butorides virescens*	11
Hawks/eagles	Osprey	*Pandion haliaetus*	3
	Bald Eagle*	*Haliaeetus leucocephalus*	6
Gulls/terns	Ring-billed Gull	*Larus delawarensis*	3
	Caspian Tern	*Hydroprogne caspia*	2
	Common Tern*	*Sterna hirundo*	5
Kingfishers	Belted Kingfisher	*Megaceryle alcyon*	14
Woodpeckers	Red-bellied Woodpecker	*Melanerpes carolinus*	3
	Yellow-bellied Sapsucker*	*Sphyrapicus varius*	9
	Downy Woodpecker	*Picoides pubescens*	2
	Hairy Woodpecker	*Picoides villosus*	5
	Northern Flicker	*Colaptes auratus*	8
	Pileated Woodpecker	*Dryocopus pileatus*	2
Flycatchers	Eastern Wood-Pewee*	*Contopus virens*	6
	Alder Flycatcher	*Empidonax alnorum*	2
	Least Flycatcher*	*Empidonax minimus*	5
	Eastern Phoebe	*Sayornis phoebe*	28
	Great Crested Flycatcher	*Myiarchus crinitus*	11
	Eastern Kingbird	*Tyrannus tyrannus*	27
Vireos	Warbling Vireo	*Vireo gilvus*	5
	Red-eyed Vireo	*Vireo olivaceus*	55
Jays/crows	Blue Jay	*Cyanocitta cristata*	25
	American Crow	*Corvus brachyrhynchos*	19
Swallows	Purple Martin	*Progne subis*	2
	Tree Swallow	*Tachycineta bicolor*	13
	Barn Swallow	*Hirundo rustica*	20
Chickadees	Black-capped Chickadee	*Poecile atricapilla*	28
Nuthatches	Red-breasted Nuthatch	*Sitta canadensis*	20
	White-breasted Nuthatch	*Sitta carolinensis*	6
Wrens	House Wren	*Troglodytes aedon*	5

Table 2, continued.

Description	**Common Name**	**Scientific Name**	**%** [a]
Thrushes	Eastern Bluebird	*Sialia sialis*	2
	Veery*	*Catharus fuscescens*	13
	Hermit Thrush	*Catharus guttatus*	2
	American Robin	*Turdus migratorius*	66
Mockingbirds	Gray Catbird	*Dumetella carolinensis*	11
Waxwings	Cedar Waxwing	*Bombycilla cedrorum*	25
Warblers	Nashville Warbler	*Vermivora ruficapilla*	2
	Yellow Warbler	*Dendroica petechia*	34
	Chestnut-sided Warbler	*Dendroica pensylvanica*	14
	Cape May Warbler*	*Dendroica tigrina*	2
	Yellow-rumped Warbler	*Dendroica coronata*	5
	Blackburnian Warbler	*Dendroica fusca*	2
	Pine Warbler	*Dendroica pinus*	3
	Black-and-white Warbler	*Mniotilta varia*	25
	American Redstart	*Setophaga ruticilla*	25
	Ovenbird*	*Seiurus aurocapilla*	33
	Northern Waterthrush	*Seiurus noveboracensis*	8
	Common Yellowthroat	*Geothlypis trichas*	6
Tanagers	Scarlet Tanager	*Piranga olivacea*	2
Sparrows/allies	Chipping Sparrow	*Spizella passerina*	38
	Song Sparrow	*Melospiza melodia*	80
	Swamp Sparrow*	*Melospiza georgiana*	2
	White-throated Sparrow*	*Zonotrichia albicollis*	3
Cardinals/allies	Rose-breasted Grosbeak*	*Pheucticus ludovicianus*	3
Blackbirds	Red-winged Blackbird	*Agelaius phoeniceus*	25
	Common Grackle	*Quiscalus quiscula*	36
	Brown-headed Cowbird	*Molothrus ater*	5
	Baltimore Oriole	*Icterus galbula*	27
Finches	Purple Finch	*Carpodacus purpureus*	2
	Pine Siskin	*Spinus pinus*	3
	American Goldfinch	*Spinus tristis*	28

[a] % – Percent of surveyed sample sites in which a bird species occurred (N=64)

Bird Species Richness

Objective

1. Calculate and map bird richness around the shoreline of Thunder Lake

Introduction

Bird species richness is affected by a number of factors, including habitat diversity and area, habitat composition, fragmentation, competition, and presence of exotic species. Species richness is generally highest in non-fragmented habitats with a variety of vegetation types. Anthropogenic disturbance, in particular, may negatively affect bird species richness in a variety of ways. Human presence in an area may result in the loss or destruction of critical habitat. Elimination of vegetation and use of pesticides may reduce the food base for a number of bird species. Human activity in an area may also disturb breeding or nesting birds. Maintaining large areas of natural habitat will be beneficial to maintaining diversity of bird species.

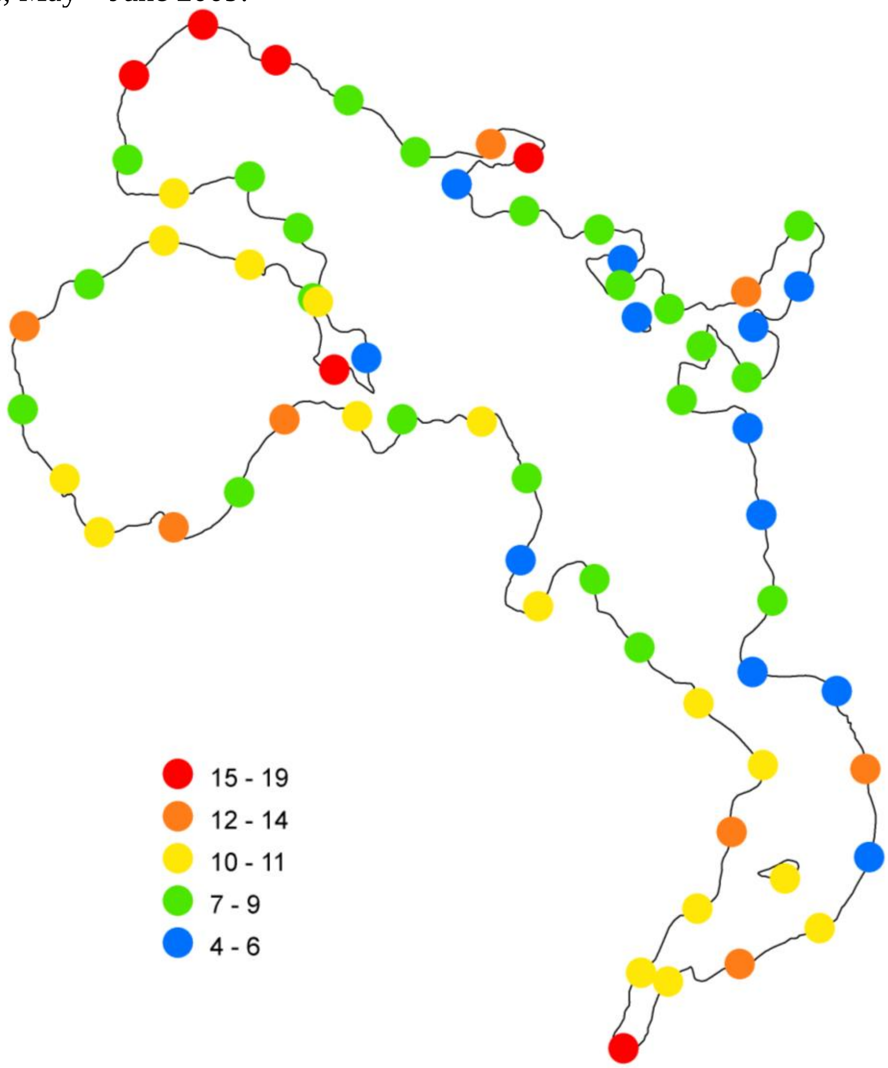
Methods

Bird species were documented during the point count and call-playback sampling surveys. At each sample station, surveyors identified and recorded the number of species found.

Results

Bird richness (the number of bird species at a single survey station) in Thunder Lake ranged from four to 19 species (Figure 38). Six stations, primarily in the northern half of Thunder Lake, had 15 or more bird species recorded. Twenty-four additional stations contained between 10 and 14 species; these sites were scattered along the entire Thunder Lake shoreline. The maximum number of species of greatest conservation need recorded at a single survey station was six. This survey station was located at the very southern tip of the lake. Approximately one-third of the survey stations did not have any species of greatest conservation need recorded.

Figure 38. Bird species richness (number of species per sample site) in Thunder Lake, May – June 2009.



Loon Nesting Areas

Objectives

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

Introduction

Loon pair with chick

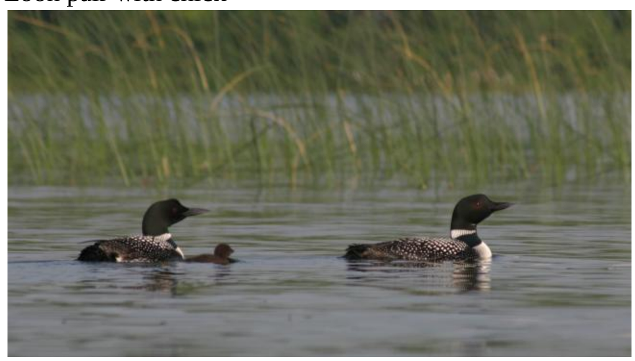


Photo by: Paul Bolstad

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.

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.

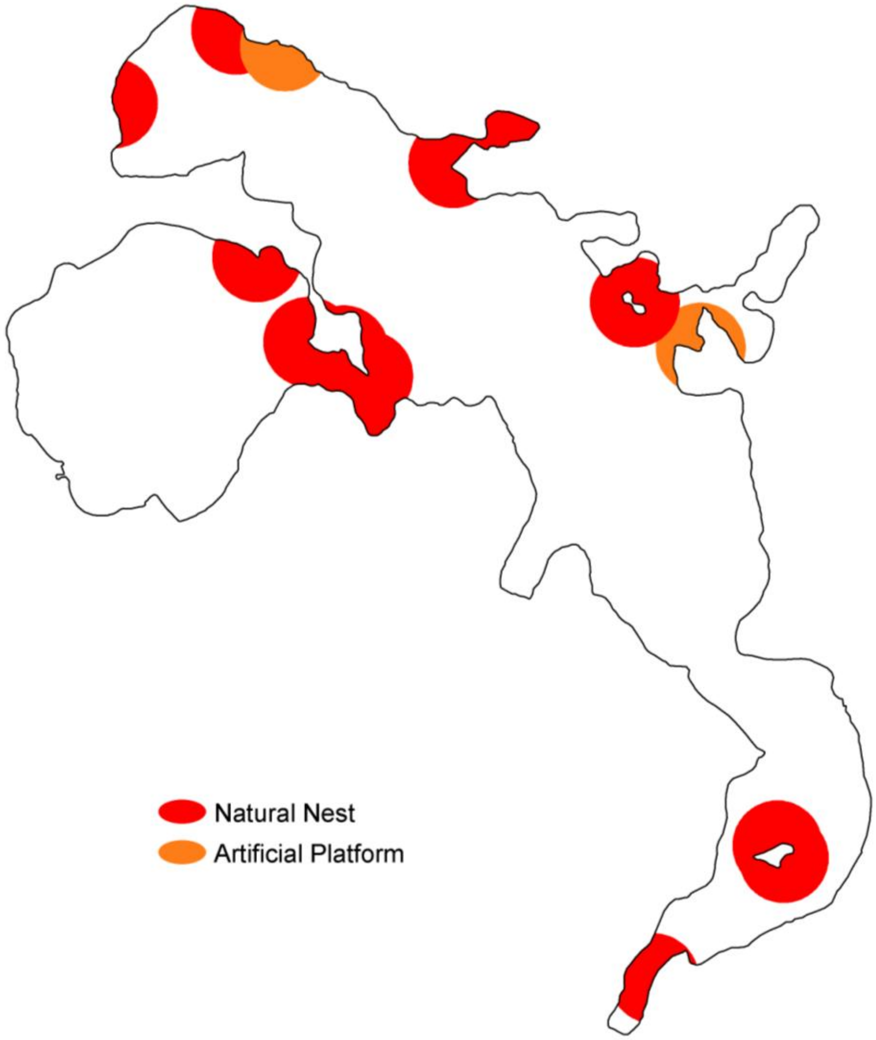
Methods

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. Volunteers have been reporting on Thunder Lake loons since 1979.

Results

Since 1979, fifteen probable loon nesting areas have been identified on Thunder Lake (Figure 39). The majority of the nests are natural nests, but loons have also been documented nesting on two artificial platforms in the lake. Nesting areas have been located in the main lake basin, the west basin, and the channel connecting the two basins. At least one of the nesting areas, the island in the southern portion of the lake, has been used by loons since the 1980s. In 2009, several natural nests and at least one artificial platform were utilized by loons.

Figure 39. Location of natural loon nests and manmade loon platforms recorded on Thunder Lake between 1979 and 2009.



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 40. Mink frog

Photo by: Jeff LeClere, www.herpnet.net

Mink frogs (Figure 40) 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 41. Green frog

Photo by: Jeff LeClere, www.herpnet.net

Green frogs (Figure 41) 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

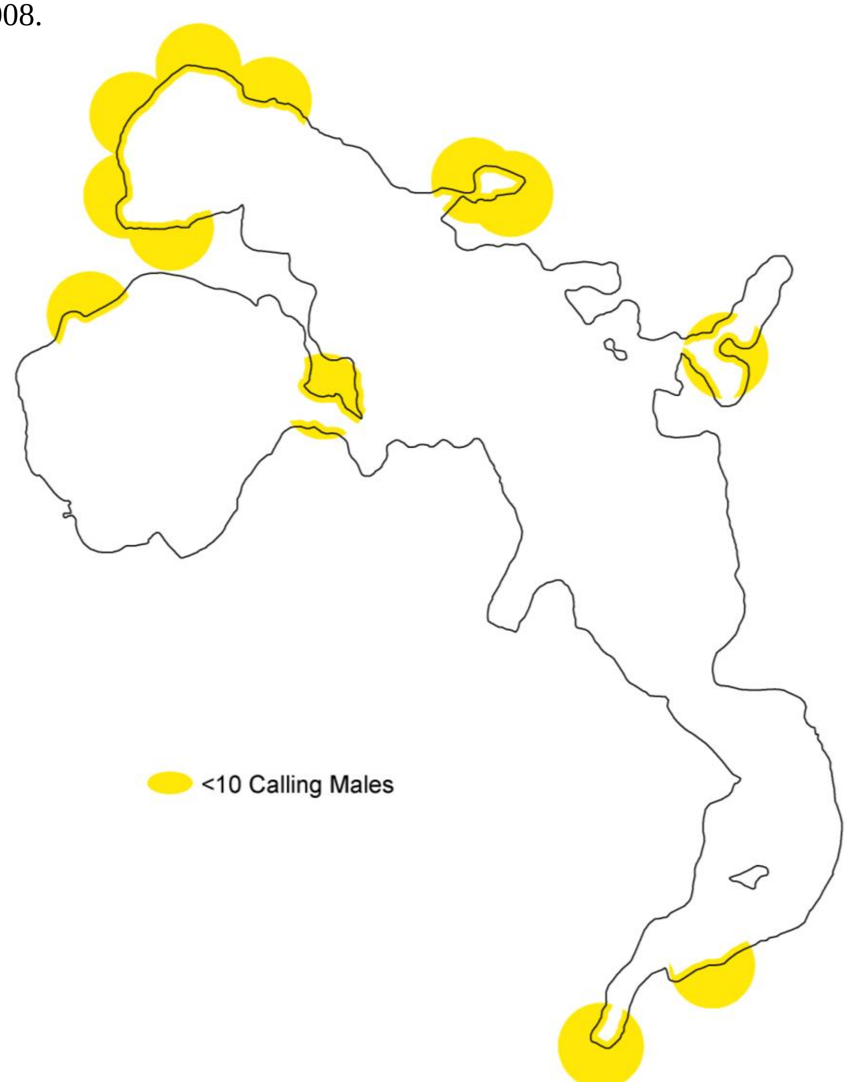
The aquatic frog survey methodology followed the Minnesota Frog and Toad Calling Survey (MFTCS) protocol (see Minnesota's Sensitive Lakeshore Identification Manual for additional information on how this protocol was adjusted for water routes). Frog survey points were located around the entire lake, spaced 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
Green frogs were the only target frog species documented during the Thunder Lake frog surveys. Surveyors heard green frogs at eleven survey stations on the lake (Figure 42). They occurred along both the northern and southern shorelines of the main basin as well as within the western lake basin. Most green frog locations were near or within protected bays. Surveyor estimates of the number of frogs calling at each survey station ranged between one and ten.

Other species
In addition to green frogs, frog surveyors also documented gray treefrogs (*Hyla versicolor*) and a leopard frog (*Rana pipiens*) on Thunder Lake. Gray treefrogs were recorded at nearly one-third (N = 21) of the lake's 64 survey stations. They were heard along the northern shoreline of the west basin, the northwestern shoreline of the main basin, within the small bay on the eastern lake shoreline, and near the public access. Index values for gray treefrogs ranged from two (individual frog calls were distinct, but overlapped) to three (full chorus; frog calls were continuous and overlapping). Frog surveyors also recorded one leopard frog within the west lake basin. Other frog or toad species that may be found near Thunder Lake, including wood frog (*Rana sylvatica*), spring peeper (*Pseudacris crucifer*), chorus frog (*Pseudacris triseriata*) and American toad (*Bufo americanus*), breed earlier in the year and are not strongly associated with larger lakes.

Figure 42. Abundance of green frogs heard during Thunder Lake frog surveys, June 2008.



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 near-shore fish assemblages

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 Cass 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 43) 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 43. Pugnose shiner

Photo by: Konrad Schmidt

Least darters (*Etheostoma microperca*; Figure 44) 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* sp.) are a preferred habitat feature. Removal of vegetation, riparian area modification, and poor water quality all pose threats to the least darter.

Figure 44. Least darter

Photo by: Konrad Schmidt

Longear sunfish (*Lepomis megalotis*; Figure 45) 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 45. 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 46) 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 46. Blackchin shiner

Photo by: Konrad Schmidt

Blacknose shiners (*Notropis heterolepis*; Figure 48) 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 47. Blacknose shiner

Photo by: Konrad Schmidt

Banded killifish (*Fundulus diaphanus*; Figure 49) 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 49. 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 birds and aquatic frogs. At each station, fish were sampled using three different methods: trapnetting, 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 aquatic grasses 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

Only one fish species of greatest conservation need was identified at Thunder Lake. Surveyors found least darters at 16 sampling sites (Figure 50). Pugnose shiners and longear sunfish were not found at Thunder Lake. All three proxy species were documented during the surveys (Figure 51). Banded killifish were by far the most abundant proxy species. Surveyors counted over 2700 individuals at 35 sampling locations. Blackshin and blacknose shiners were similar in abundance; surveyors documented ten or fewer individuals at a few sites.

Least darters were generally located at sites with small diameter substrate, such as silt or sand. Biovolume at these sites was on average higher than at sites that did not contain least darters.

The presence of least darters and the proxy fish species at Thunder Lake may indicate minimal disturbance along several sections of shoreline. However, because these species are declining or vulnerable across much of their range, 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.

Thirty different fish species were documented during the nongame fish surveys (Table 3). The most abundant species collected was the mimic shiner, which was found at 42 sampling stations. Bluegills were the most frequently found species, and were documented at 60 stations. Species richness at the sample sites ranged from 1 to 15 species. Thirty-seven of the 64 stations contained 10 or more fish species. Eight fish species not previously documented at Thunder Lake were identified during the surveys, bringing the total historical observed fish community to 40 species. The newly documented species were blacknose shiner, brook stickleback, central mudminnow, creek chub, golden shiner, least darter, mottled sculpin, and northern redbelly dace.

Figure 50. Distribution of fish species of greatest conservation need documented during Thunder Lake fish surveys, June – July 2008.

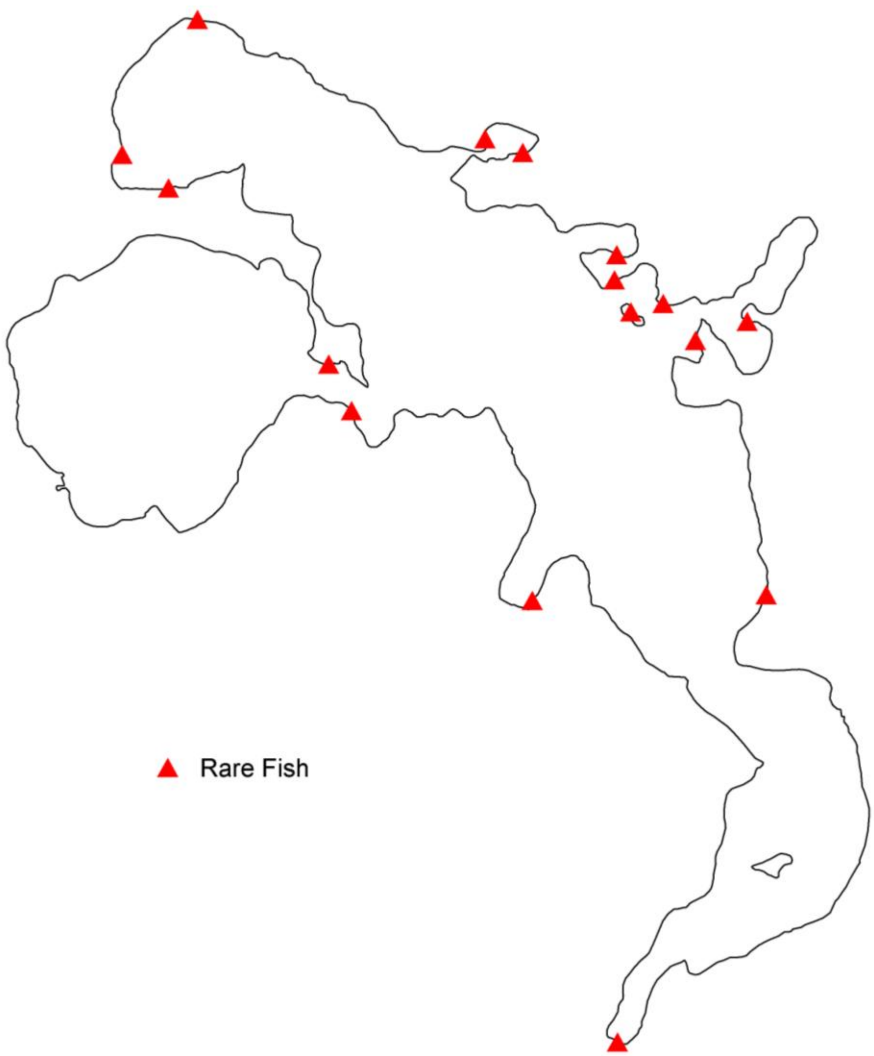


Figure 51. Distribution of fish proxy species documented in during Thunder Lake fish surveys, June – July 2008.

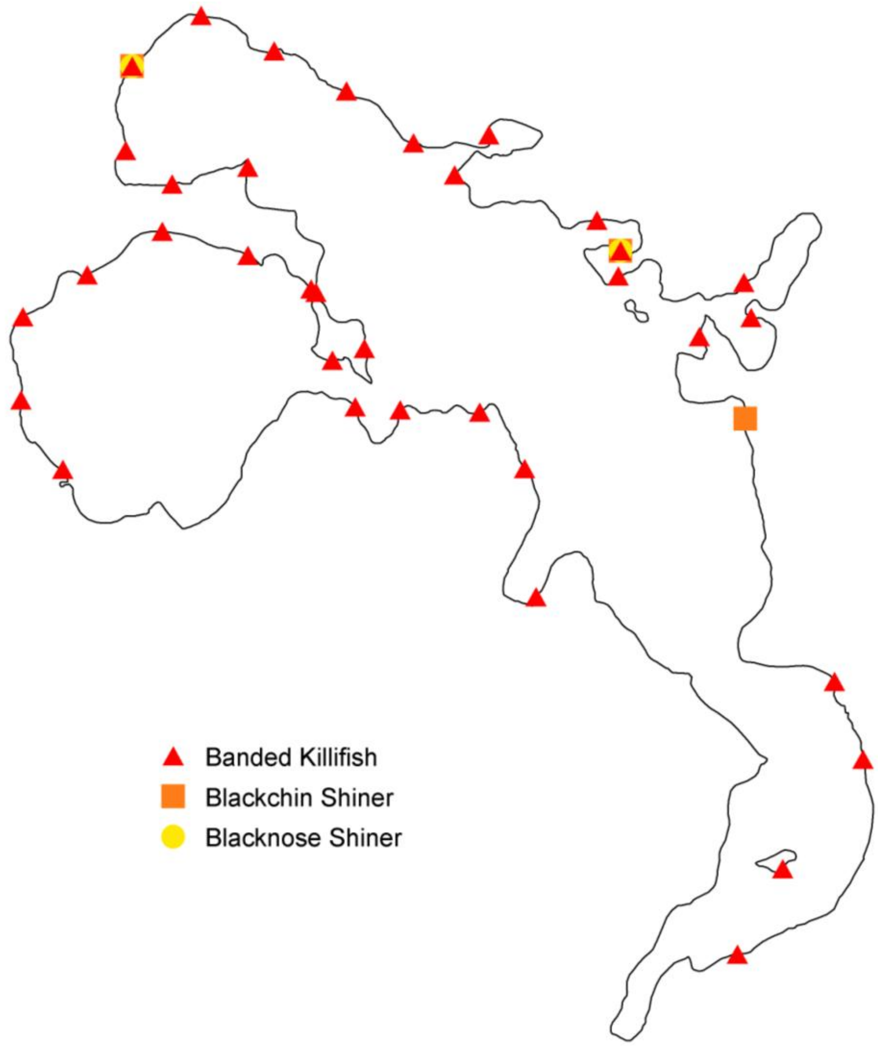


Table 3. Abundance and frequency of fish species identified during Thunder Lake fish surveys, June – July 2008. * denotes species of greatest conservation need

Description	Common Name	Scientific Name	#[a]	%[b]
Bowfins	Bowfin	*Amia calva*	9	13
Minnows	Common shiner	*Luxilus cornutus*	101	28
	Golden shiner	*Notemigonus crysoleucas*	9	8
	Blackchin shiner	*Notropis heterodon*	8	5
	Blacknose shiner	*Notropis heterolepis*	10	3
	Spottail shiner	*Notropis hudsonius*	6	5
	Mimic shiner	*Notropis volucellus*	~169,000	66
	Northern redbelly dace	*Phoxinus eos*	1	2
	Bluntnose minnow	*Pimephales notatus*	~1100	61
	Creek chub	*Semotilus atromaculatus*	1	2
Suckers	White sucker	*Catostomus commersonii*	1	2
Catfishes	Yellow bullhead	*Ameiurus natalis*	12	6
	Tadpole madtom	*Noturus gyrinus*	20	22
Mudminnows	Central mudminnow	*Umbra limi*	4	3
Killifishes	Banded killifish	*Fundulus diaphanus*	~2700	55
Sticklebacks	Brook stickleback	*Culaea inconstans*	2	3
Sculpins	Mottled sculpin	*Cottus bairdii*	31	22
Sunfishes	Rock bass	*Ambloplites rupestris*	689	91
	Pumpkinseed	*Lepomis gibbosus*	169	63
	Bluegill	*Lepomis macrochirus*	~1100	94
	Smallmouth bass	*Micropterus dolomieu*	36	28
	Largemouth bass	*Micropterus salmoides*	14	19
	Black crappie	*Pomoxis nigromaculatus*	60	34
Perches	Iowa darter	*Etheostoma exile*	286	78
	Johnny darter	*Etheostoma nigrum*	147	59
	Least darter*	*Etheostoma microperca*	44	25
	Logperch	*Percina caprodes*	159	27
	Yellow perch	*Perca flavescens*	~62,000	64
	Walleye	*Sander vitreus*	8	11
Trouts	Cisco	*Coregonus artedi*	1	2

[a] # – Total number of individuals found. Numbers above 1000 were rounded to the nearest 100. Numbers above 10000 were rounded to the nearest 1000.

[b] % – Percent of surveyed sample sites in which a species occurred (N=63)

Aquatic Vertebrate Richness

Objective

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

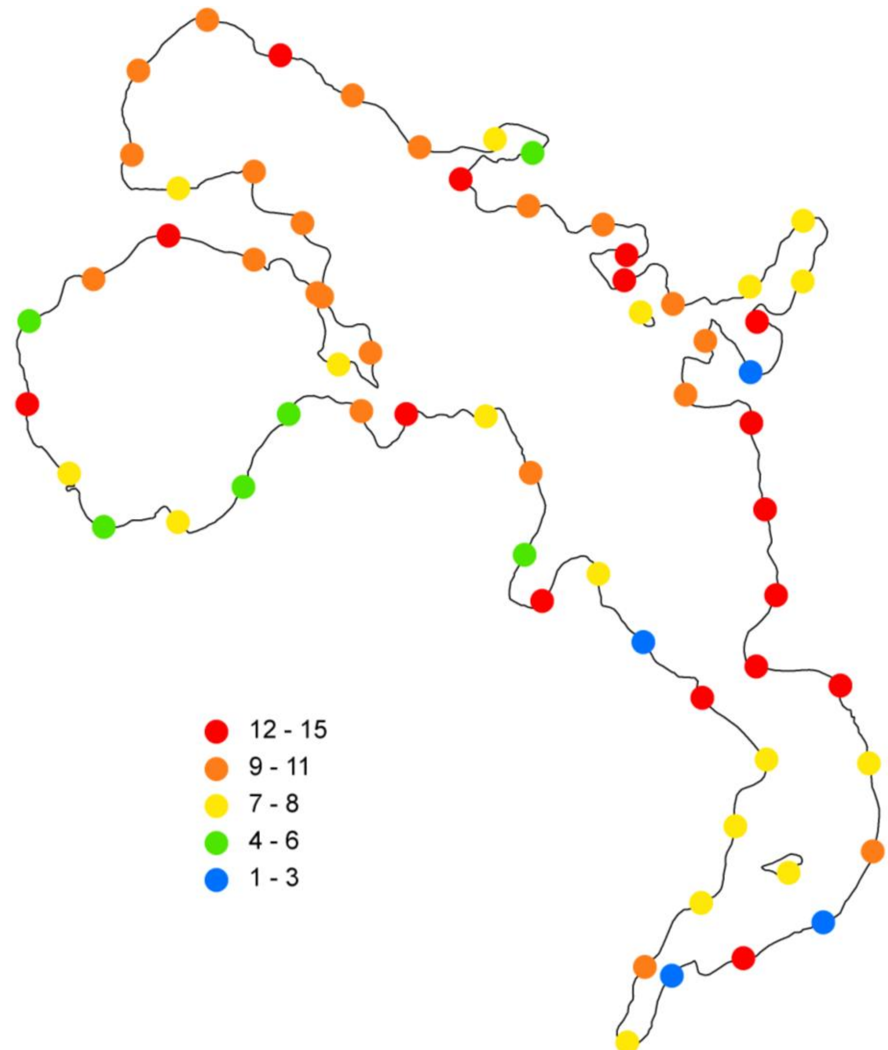
Methods

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

Maximum aquatic vertebrate species richness at a sampling station was 15 species, and 30 stations had ten or more species (Figure 52). The majority of the documented species were fish, although painted and snapping turtles and green and mink frogs were also identified. All aquatic vertebrate species documented during the survey were native.

Figure 52. Aquatic vertebrate species richness (number of species per sample site) in Thunder Lake, June – July 2008.



Other Rare Features

Objective

1. Map rare features occurring within the extended state-defined shoreland area of Thunder 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 Federally 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

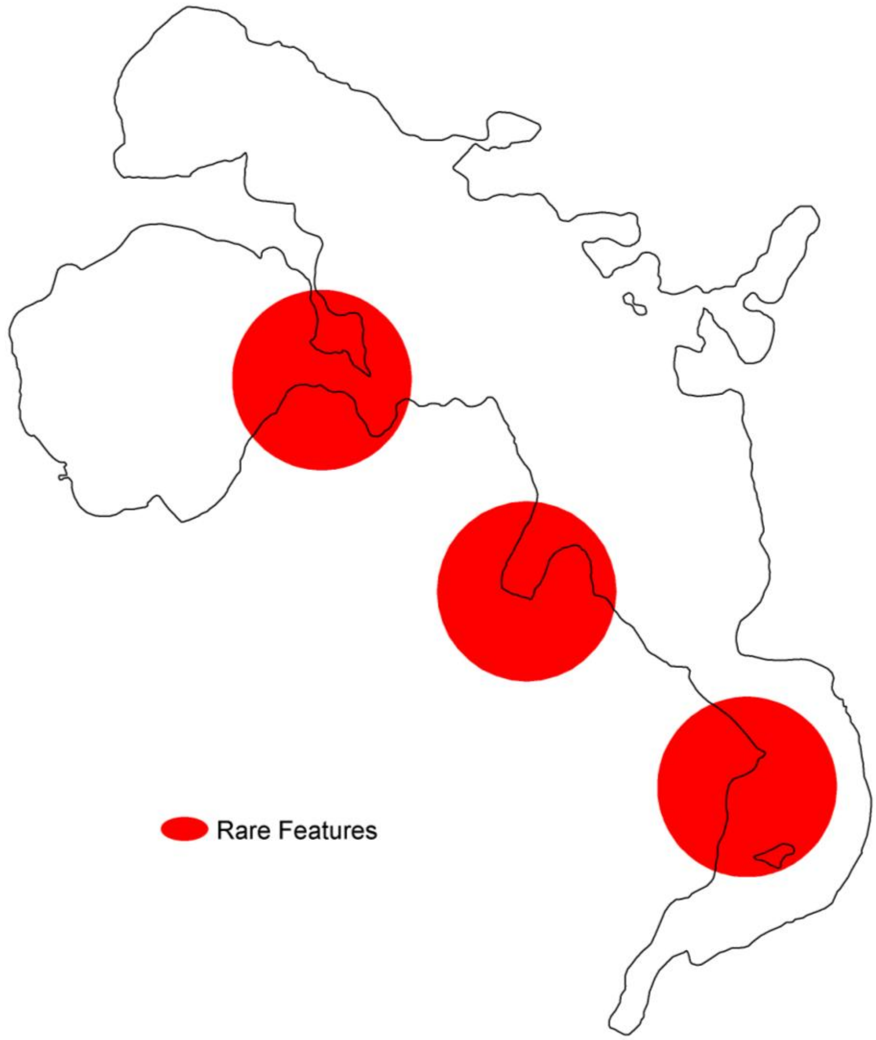
Researchers obtained locations of rare features from the Rare Features Database. Only "listed" plant and animal species (Federal or State endangered, threatened, or special concern) were considered in this project; non-listed unique plant species were included in the "Unique Plant Species" section of 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

Three rare features have been documented at Thunder Lake (Figure 53). They include one location of a fish species of Special Concern and two locations of a bird species of Special Concern status. 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 Thunder Lake, practices that maintain good water quality and the integrity of the shoreline will be beneficial to all species involved.

Figure 53. Natural Heritage Database rare features (Federal or State-listed endangered, threatened, or special concern species) located within 1320 feet of Thunder Lake shoreline.



 Rare features data have been provided by the Division of Ecological Resources, Minnesota Department of Natural Resources (MNDNR) and were current as of November 24, 2009. 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

Objectives

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.

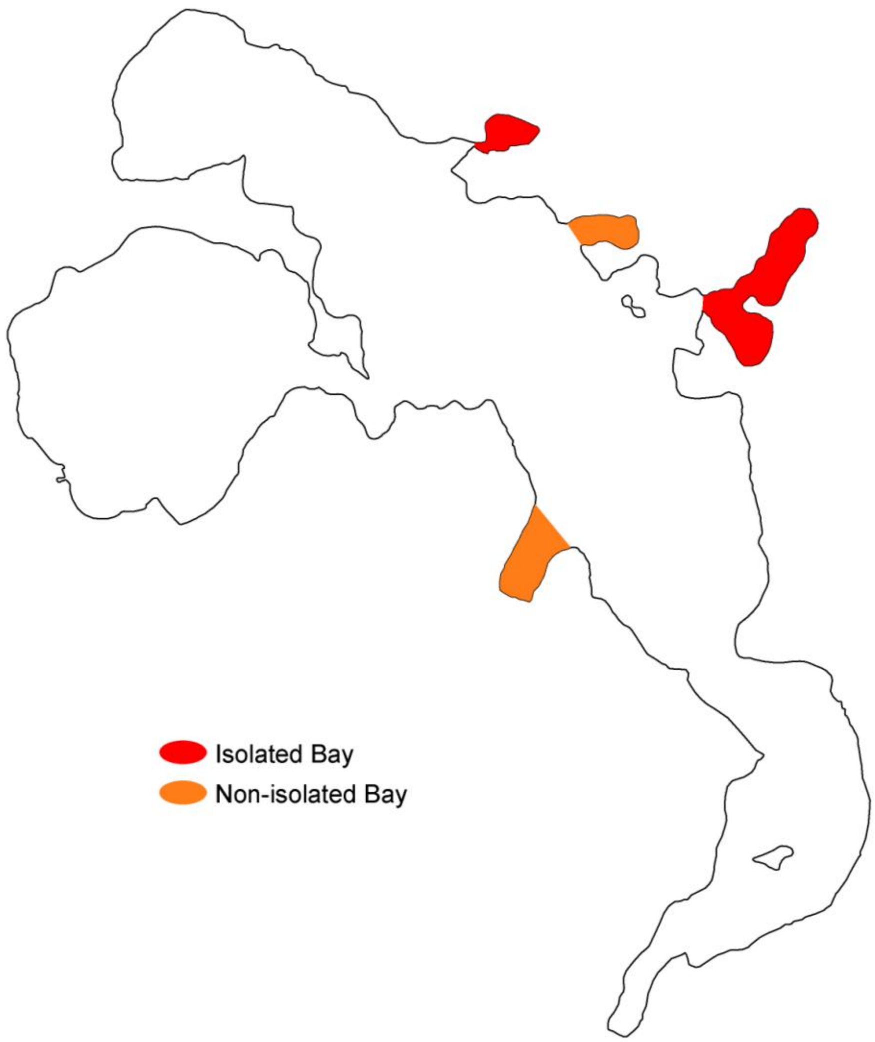
Methods

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

Two isolated and two non-isolated bays were identified on Thunder Lake (Figure 54). Green frogs and several bird and fish species of greatest conservation need were located within or near delineated bays.

Figure 54. Location of isolated and non-isolated bays in Thunder 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 15 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 55). 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 56). 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 57).

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

Variable	**Score**	**Criteria**
Wetlands	3	> 25% of analysis window is in wetlands
	2	12.5 – 25% is in wetlands
	1	< 12.5% is in 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 present
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

Table 4, continued.

Variable	Score	Criteria
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 or Rare Plant Species	3	Presence of 2 or more unique or rare 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 (i.e., > 50% of points within analysis window consisted of soft substrate)
	2	Frequency of occurrence is 25 – 50% soft substrate
	1	Frequency of occurrence < 25% soft substrate
	0	No soft substrate present
Birds	3	Presence of 3 or more SGCN within analysis window
	2	Presence of 2 SGCN
	1	Presence of 1 SGCN
	0	No SGCN present
Bird Richness	3	Total number of bird species within analysis window > 25
	2	Total number of bird species 11 – 25
	1	Total number of bird species 1 – 10
	0	No bird species observed
Loon Nesting Areas	3	Presence of natural loon nest within analysis window
	2	Presence of loon nest on artificial platform
	0	No loon nesting observed
Frogs	3	Presence of both mink and green frogs within analysis window
	2	Presence of mink or green frogs
	0	Neither mink nor green frogs present

Table 4, continued.

Variable	Score	Criteria
Fish	3	Presence of one or more SGCN within analysis window
	2	Presence of one or more proxy species
	0	Neither SGCN nor proxies present
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 a Natural Heritage feature
	0	No Natural Heritage feature present
Bays	3	Protected or isolated bay within analysis window
	2	Non-protected or non-isolated bay
	0	Not a distinctive bay

Figure 55. Total score layer created by summing scores of all 15 variables. Highest total scores represent most sensitive areas of shoreline.

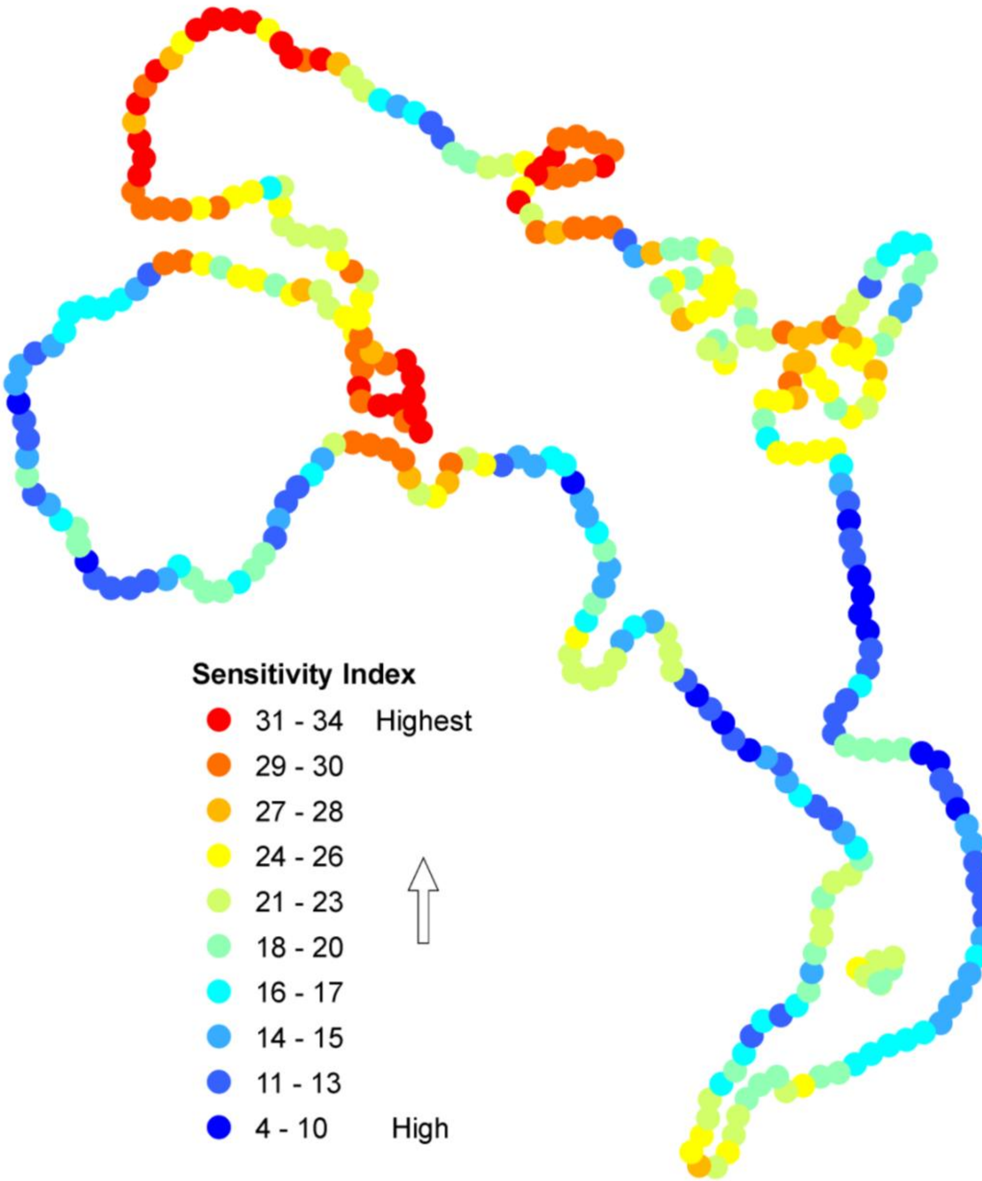


Figure 56. GIS-identified clusters of points with similar total scores. Red areas are those with high scores (i.e., areas of highly sensitive shoreland).

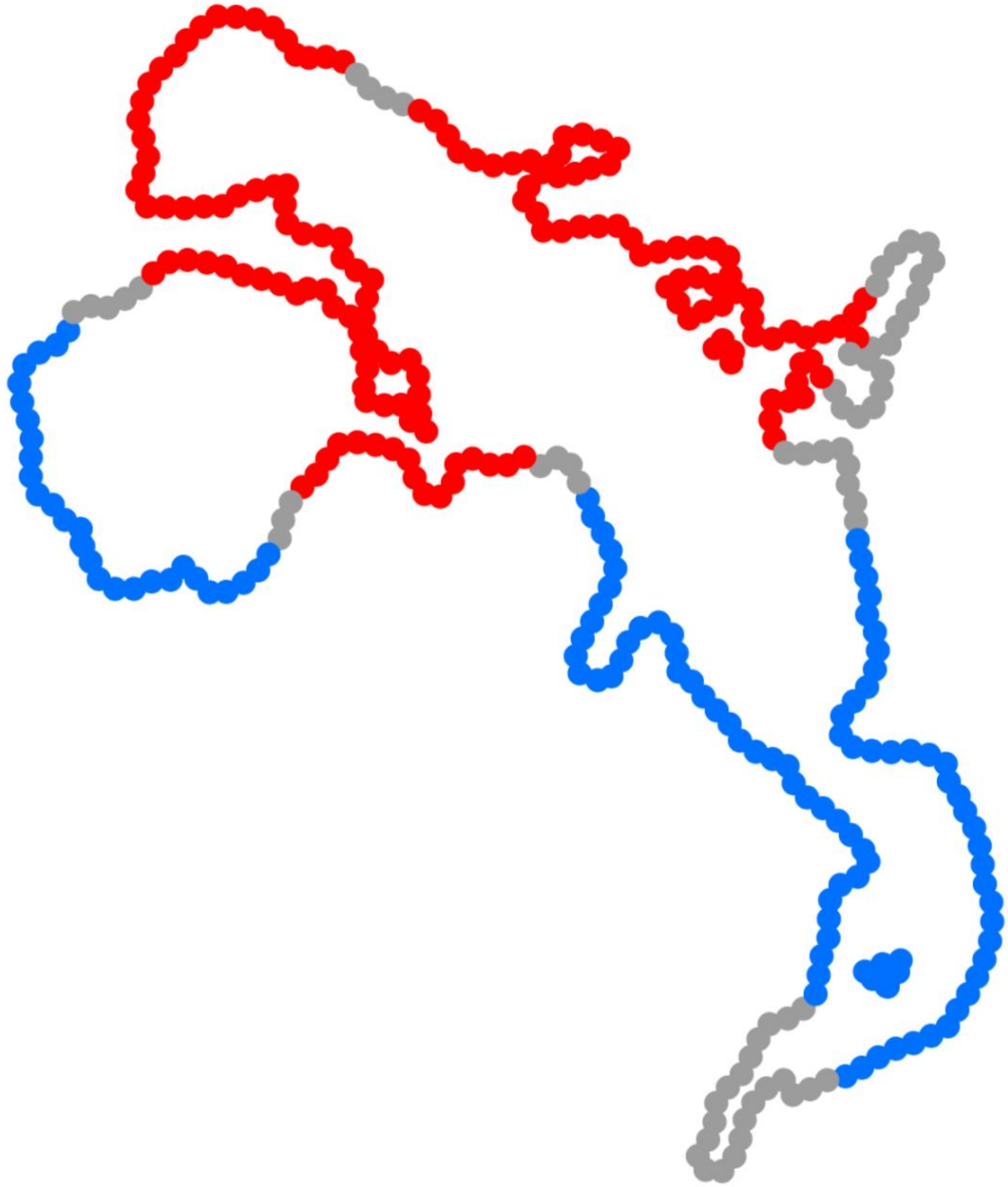
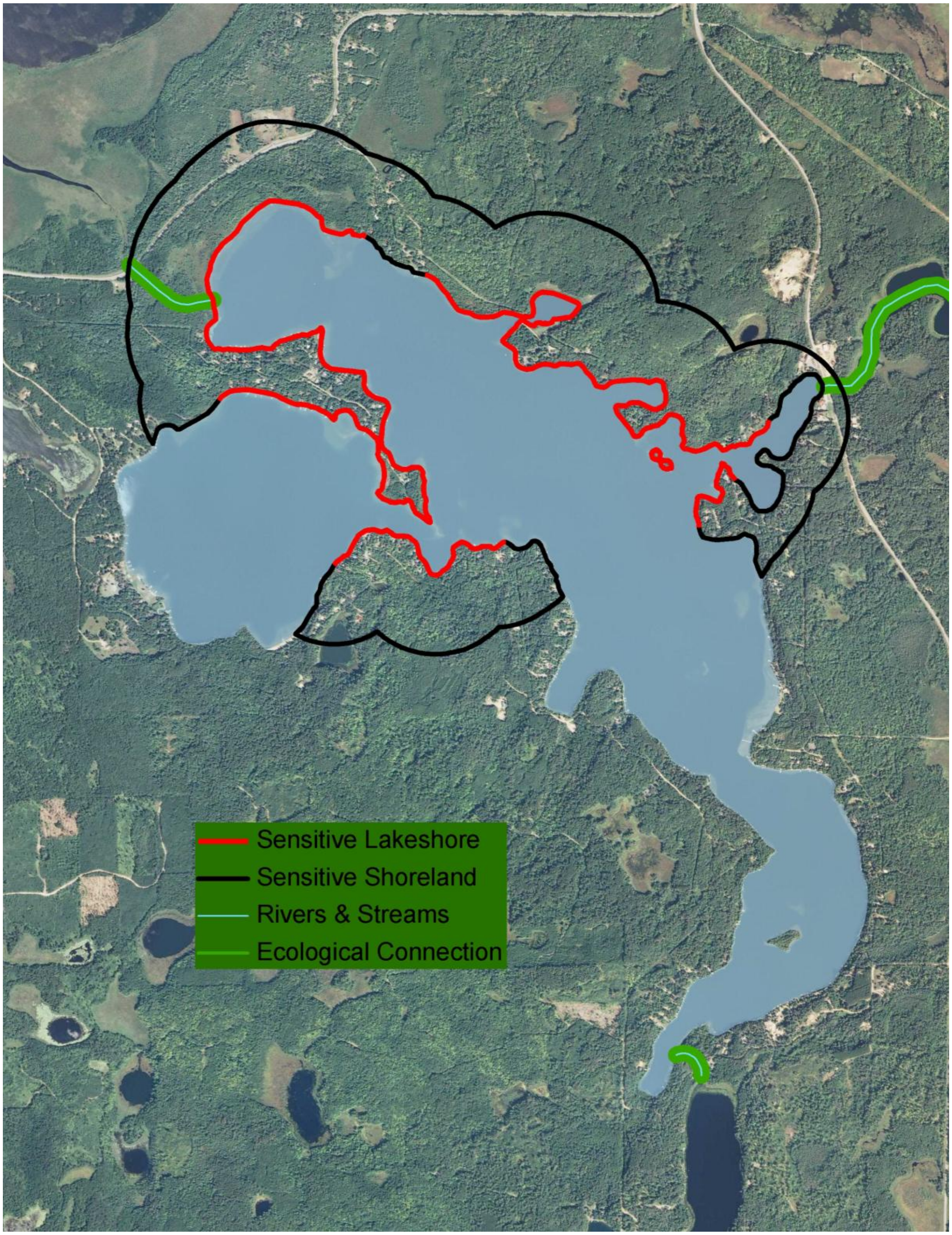


Figure 57. The sensitive lakeshore areas identified by the ecological model.



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. The inlets and outlet of Thunder Lake were identified as important ecological connections. The inlets connect to Laura Lake in the northwest and Kidney Lake in the south, while the outlet flows into Little Thunder and then into Pughole Lake. Depending on the existing shoreland classification of these rivers, the County may use the ecological connection recommendation to consider reclassifying to a more protective river class.

Other Areas of Ecological Significance
There are additional aquatic areas of ecological significance in Thunder 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 Thunder 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. 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.

Submerged beds of muskgrass are also significant in Thunder Lake. Muskgrass may form continuous submerged mats where other plant species are not present. Despite the low plant species richness in these sites, this habitat is unique and valuable. Certain rare fish species, such as pugnose shiners, have been associated with muskgrass beds (Becker 1983).

Other sites of ecological significance include emergent and floating-leaf plant beds that may occur outside of the sensitive shoreland areas. 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. 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 northern half of Thunder 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. The inlets and outlet of Thunder Lake are also an important part of the lake ecosystem. They provide habitat connectivity between Thunder Lake and nearby habitat. They allow movement of animals from various populations, increasing diversity. Habitat connectivity also allows animals with different vegetation requirements during different life stages to access those habitats. 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 Thunder Lake, and the value of the lake itself.

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Appendix 1. Shoreline emergent aquatic plants recorded in Thunder Lake, 2008.

Description	Common Name	Scientific Name	Survey type
Shoreline Emergents	Swamp milkweed	*Asclepias incarnata*	1, 2
	Canada bluejoint grass	*Calamagrostis canadensis*	2
	Marsh bellflower	*Campanula aparinoides*	2
	Sedge	*Carex* sp.	1
	Bristly sedge	*Carex comosa*	1
	Porcupine sedge	*Carex hystricina*	2
	Pennsylvania sedge	*Carex pensylvanica*	2
	Bulb-bearing water hemlock	*Cicuta bulbifera*	2
	Horsetail	*Equisetum* sp.	2
	Joe-pye weed	*Eupatorium maculatum*	2
	Boneset	*Eupatorium perfoliatum*	2
	Jewelweed	*Impatiens capensis*	2
	Blue flag iris	*Iris versicolor*	2
	Water horehound	*Lycopus uniflorus*	2
	Tufted loosestrife	*Lysimachia thyrsiflora*	2
	Wild mint	*Mentha arvensis*	2
	Reed canary grass	*Phalaris arundinacea*	1
	Water dock	*Rumex* sp.	1
	Dark green bulrush	*Scirpus atrovirens*	1,2
	Marsh skullcap	*Scutellaria galericulata*	2
Shoreline Trees and Shrubs	Paper birch	*Betula papyrifera*	2
	Red osier dogwood	*Cornus sericeus*	2
	Ash	*Fraxinus* sp.	2
	Tamarack	*Larix laricina*	2
	Black spruce	*Picea mariana*	2
	Red pine	*Pinus resinosa*	2
	White pine	*Pinus strobus*	2
	Aspen	*Populus* sp.	2
	Bur oak	*Quercus macrocarpa*	2
	White cedar	*Thuja occidentalis*	2
	Basswood	*Tilia americana*	2

1. Myhre, K. July 22, 2008 (MN DNR Minnesota County Biological Survey)
2. Perleberg, D. and S. Loso. August 11, 2008 (Nearshore vegetation plots)

Nomenclature follows MNTaxa 2009.

Appendix 2. Bird species list. Includes all species within Thunder Lake and shoreland recorded during surveys and casual observation, May – June 2009.

Common Name	**Scientific Name**
Canada Goose	*Branta canadensis*
Wood Duck	*Aix sponsa*
Mallard	*Anas platyrhynchos*
Common Goldeneye	*Bucephala clangula*
Common Merganser	*Mergus merganser*
Ruffed Grouse	*Bonasa umbellus*
Common Loon	*Gavia immer*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides virescens*
Osprey	*Pandion haliaetus*
Bald Eagle	*Haliaeetus leucocephalus*
Ring-billed Gull	*Larus delawarensis*
Caspian Tern	*Hydroprogne caspia*
Common Tern	*Sterna hirundo*
Ruby-throated Hummingbird	*Archilochus colubris*
Belted Kingfisher	*Megaceryle alcyon*
Red-bellied Woodpecker	*Melanerpes carolinus*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Downy Woodpecker	*Picoides pubescens*
Hairy Woodpecker	*Picoides villosus*
Northern Flicker	*Colaptes auratus*
Pileated Woodpecker	*Dryocopus pileatus*
Eastern Wood-Pewee	*Contopus virens*
Alder Flycatcher	*Empidonax alnorum*
Least Flycatcher	*Empidonax minimus*
Eastern Phoebe	*Sayornis phoebe*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Kingbird	*Tyrannus tyrannus*
Warbling Vireo	*Vireo gilvus*
Red-eyed Vireo	*Vireo olivaceus*
Blue Jay	*Cyanocitta cristata*
American Crow	*Corvus brachyrhynchos*
Purple Martin	*Progne subis*
Tree Swallow	*Tachycineta bicolor*
Barn Swallow	*Hirundo rustica*
Black-capped Chickadee	*Poecile atricapilla*
Red-breasted Nuthatch	*Sitta canadensis*
White-breasted Nuthatch	*Sitta carolinensis*
House Wren	*Troglodytes aedon*
Eastern Bluebird	*Sialia sialis*
Veery	*Catharus fuscescens*
Hermit Thrush	*Catharus guttatus*
American Robin	*Turdus migratorius*
Gray Catbird	*Dumetella carolinensis*
Cedar Waxwing	*Bombycilla cedrorum*

Appendix 2, continued.

Common Name	Scientific Name
Nashville Warbler	*Vermivora ruficapilla*
Yellow Warbler	*Dendroica petechia*
Chestnut-sided Warbler	*Dendroica pensylvanica*
Cape May Warbler	*Dendroica tigrina*
Yellow-rumped Warbler	*Dendroica coronata*
Blackburnian Warbler	*Dendroica fusca*
Pine Warbler	*Dendroica pinus*
Black-and-white Warbler	*Mniotilta varia*
American Redstart	*Setophaga ruticilla*
Ovenbird	*Seiurus aurocapilla*
Northern Waterthrush	*Seiurus noveboracensis*
Common Yellowthroat	*Geothlypis trichas*
Scarlet Tanager	*Piranga olivacea*
Chipping Sparrow	*Spizella passerina*
Song Sparrow	*Melospiza melodia*
Swamp Sparrow	*Melospiza georgiana*
White-throated Sparrow	*Zonotrichia albicollis*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Red-winged Blackbird	*Agelaius phoeniceus*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
Baltimore Oriole	*Icterus galbula*
Purple Finch	*Carpodacus purpureus*
Pine Siskin	*Spinus pinus*
American Goldfinch	*Spinus tristis*