A Management Plan for Grass Lake

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Introduction

The purpose of this document is to provide the Grass Lake Association and the Indian River Land Conservancy with a tool for the future management of Grass Lake. As a management plan, this serves many roles. It is a foundation upon which local knowledge and data can continue to collect and build. It is a guide. It provides a snapshot of Grass Lake as it exists today, ideas for how it could function in the future and management steps that can be taken to achieve the goals of the Grass Lake Association and community. And, it is a reminder. A reminder that maintaining the beauty and utility of Grass Lake demands action.

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Chapter 1: What you Have—an inventory of Grass Lake

The first step in managing a natural resource is understanding what you have. This requires inventory; thorough research on the current state of the system including its geographical, social, ecological landscape. This knowledge is essential to making management decisions as it serves as a reference point; marking where you are versus where you have been and where you want to go.

1.1 Physical Geography

Grass Lake is located in New York State on the border of Jefferson and St. Lawrence Counties in the towns of Theresa and Rossie.

Bathymetry: measuring the shape of Grass Lake

Grass Lake has a surface area of approximately 340 acres. There are two distinct regions within the lake—the main basin and what is commonly referred to as "the fingers." At its deepest point, Grass Lake is approximately 52 feet deep. It has an average depth of approximately 12 feet.

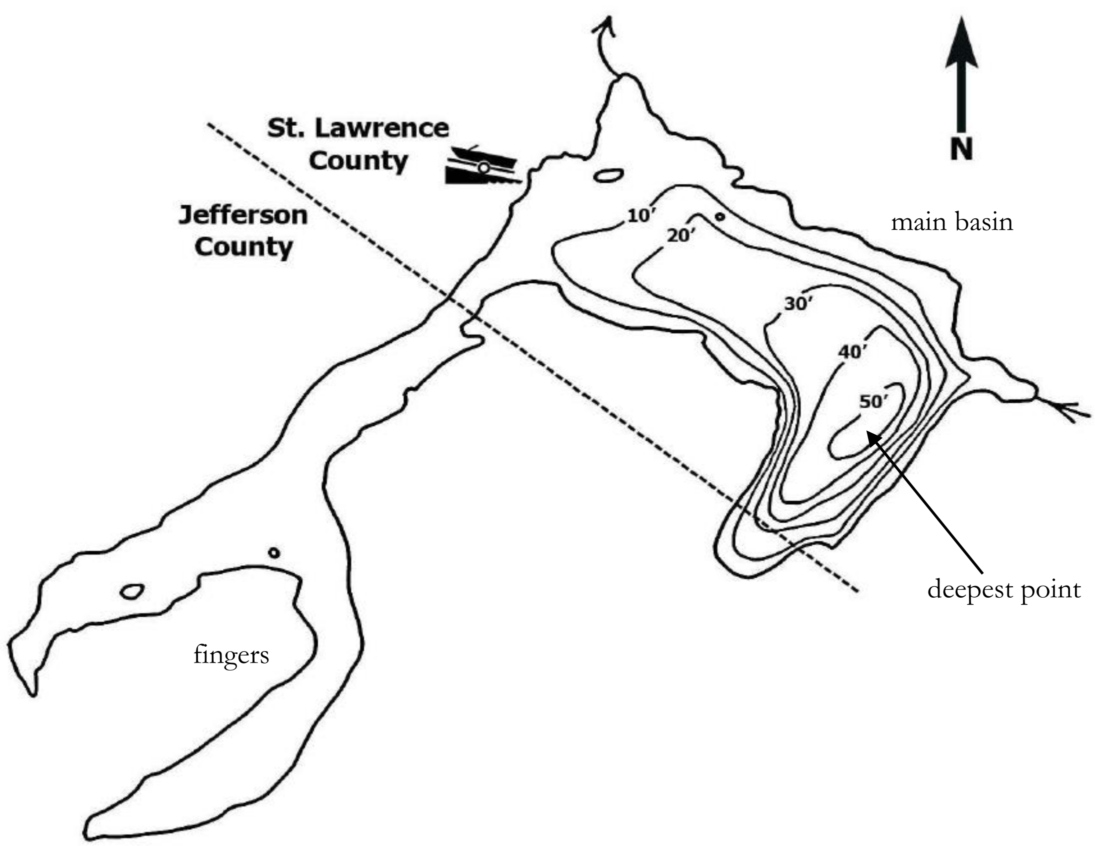
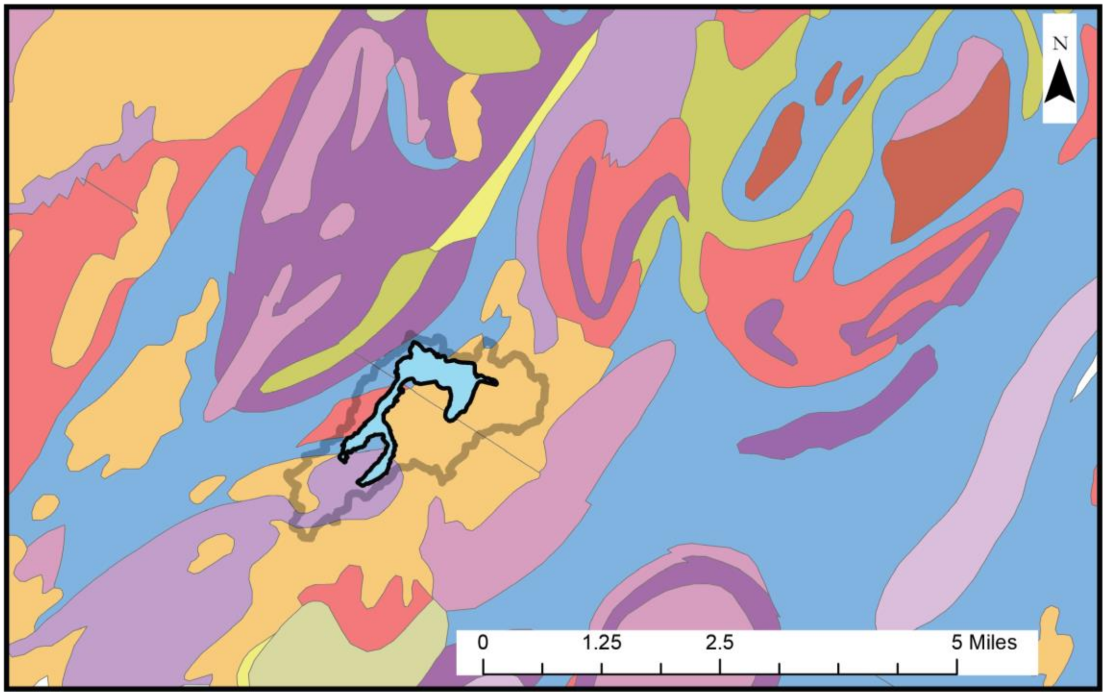


Figure 1. **Bathymetry of Grass Lake. NYSDEC Lake Map Series 2014**

Geology and Soils

The landscape surrounding Grass Lake is a product of the last glacial period, approximately 10,000 years ago. The bedrock geology of the Grass Lake watershed is comprised of Potsdam sandstone, biotite and/or horneblende granticic gneiss, calcitic and dolomitic marble, and other undivided metasedimentary rocks (Isachsen and Fisher, 1970). The surficial geology, or soils, within the watershed are mainly proglacial lake deposits, generally silty or clayey soils; and swamp deposits, comprised of peat muck, and organic silt and sand (Caldwell et al., 1986).

The soils within the Grass Lake watershed are limited in terms of their suitability for development. According to soil surveys completed by the Natural Resources Conservation Service (NRCS), soils within the watershed are rated as very limited for dwellings with basements and very limited to somewhat limited in suitability for septic tank absorption fields and dwellings without basements. These suitability ratings were developed by the NRCS. The septic tank absorption field ratings are based upon the soil percolation rate, depth to water table, flooding, slope, stoniness, and depth to impervious layer; the most common factors affecting septic tank absorption field ratings in the Grass Lake watershed were slope, depth to impervious layer, and depth to water table. The ratings for dwellings without basements are based upon depth to water table, flooding, slope, and soil shrink-swell; in the Grass Lake watershed slope and depth to water table were the most common factors contributing to the limited nature of this use within the watershed. This suggests that watershed is not amenable to residential development.



LEGEND

Grass Lake watershed

Grass Lake

Bedrock Geology

Potsdam sandstone

Underlying bedrock geology unkown

Amphibolite, commonly biotitic

Interlayered amphibolite and grantitic, charnokitic, mangeritic, or syenitic gneiss

Biotite-quartz-plagioclase gneiss and related migmatite

Calcsilicate rock, dolomitic and calcitic marble

Metagabbro, olivine metagabbro, derived amphibolite

Biotite and/or horneblende granitic gneiss

Leucogranitic gneiss

Calcitic and dolomitic marble

Undivided metasedimentary rock and related migmatite

Quartzite, quartz schist and graphitic schist

Figure 2. **Bedrock geology of the area surrounding Grass Lake**

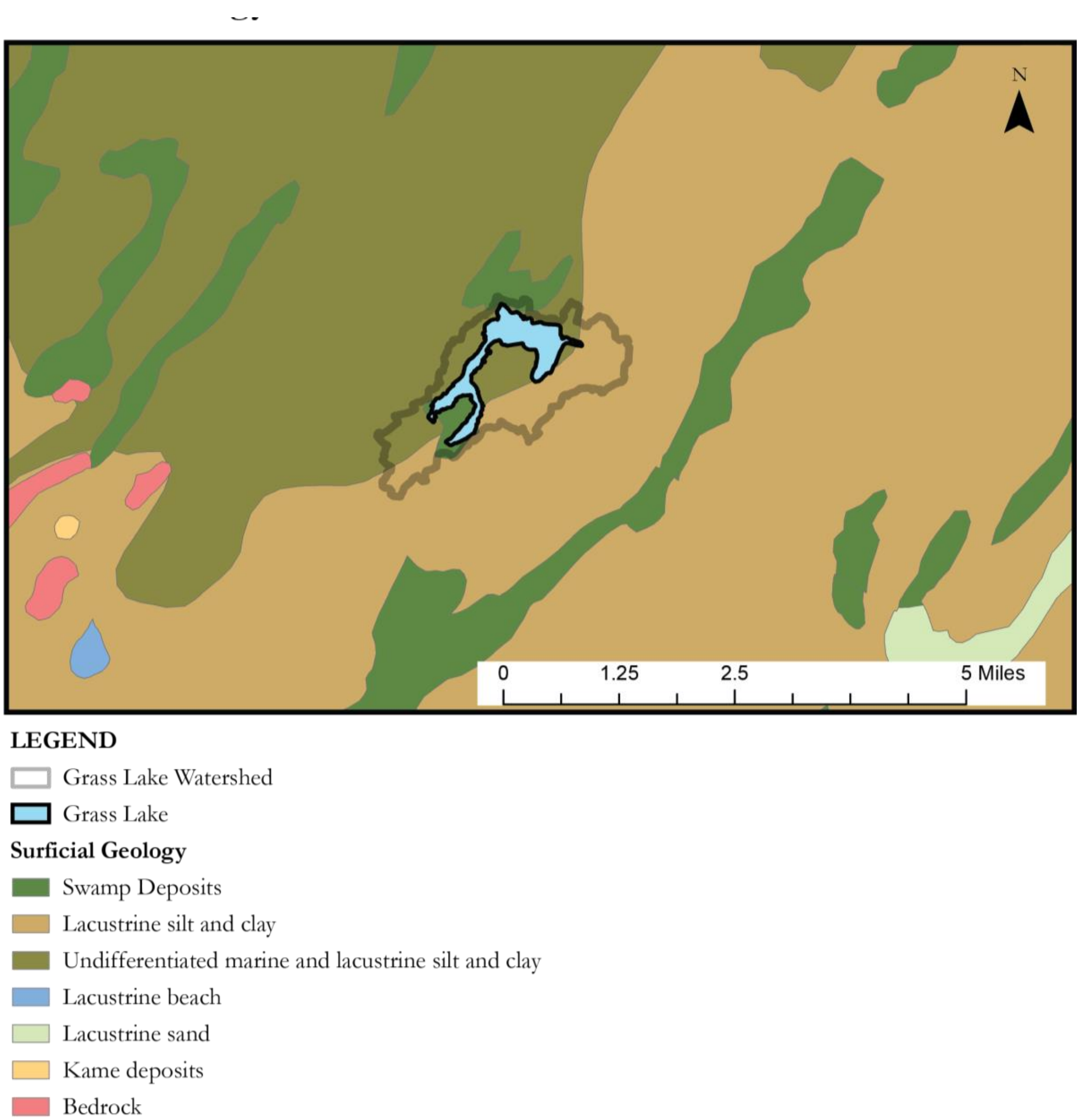


Figure 3. **Surficial geology of the area surrounding Grass Lake (Caldwell et al., 1986)**

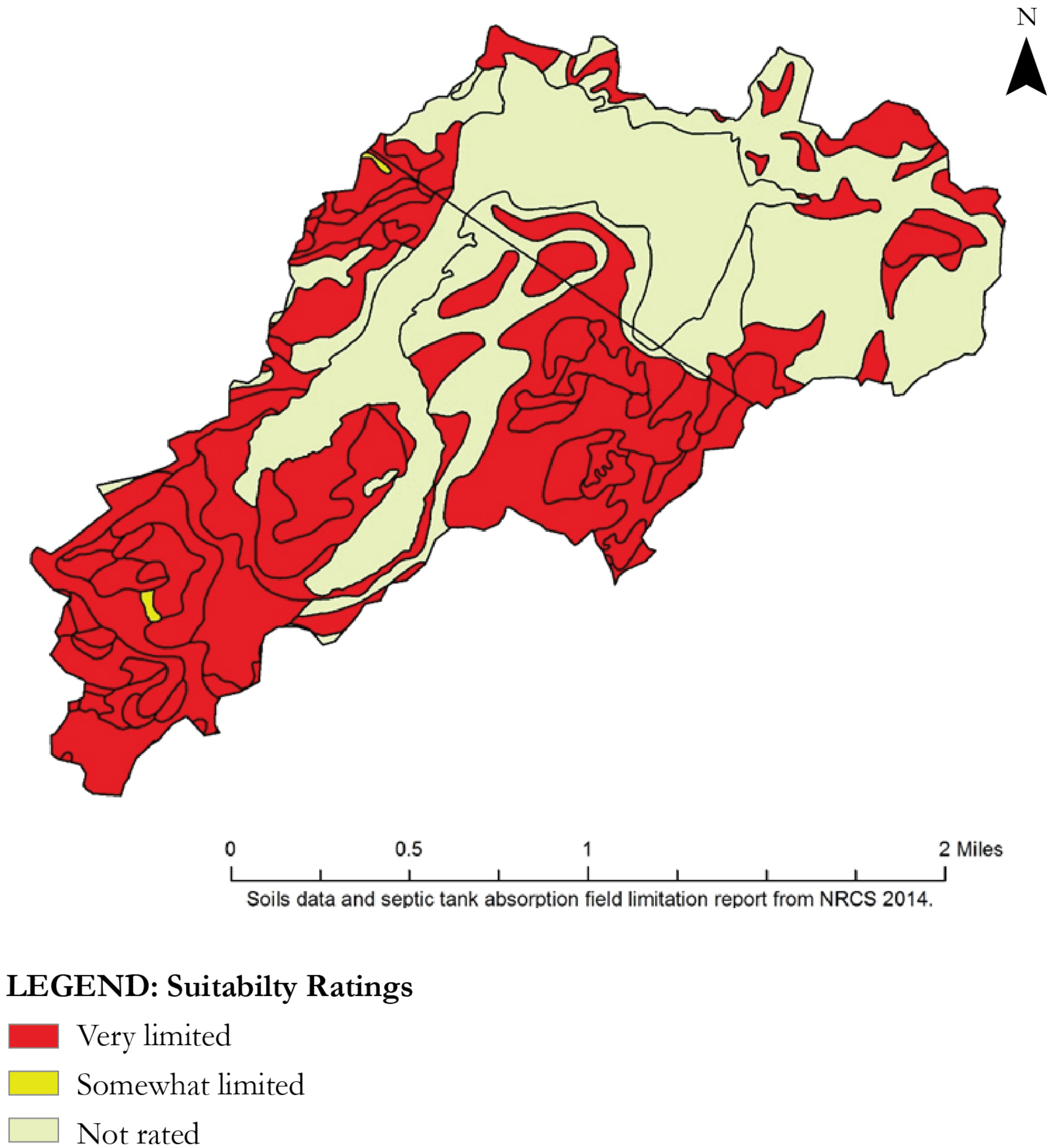


Figure 4. **Soils data and septic tank absorption field limitation map in the Grass Lake Watershed (NRCS, 2014)**

1.2 Chemical Limnology

Chemical characteristics, including temperature, dissolved oxygen, phosphorus, nitrogen, pH and alkalinity, and calcium all influence the utility and natural beauty of Grass Lake. Thus, it is important to understand how these variables function within the natural system in order to identify problems or potential threats.

Temperature

Grass Lake, like many lakes in temperate regions, is dimictic. This means that the lake stratifies twice per year; this stratification typically occurs during the winter and summer months. During these periods of stratification, the water within the lake forms distinct layers each layer differing from the others by temperature.

During the summer months, a layer of warmer water (the epilimnion) sits atop a layer of cooler water (the hypolimnion). In Grass Lake, the boundary between these two layers of water (the thermocline) is usually around 15 feet below the surface. The depth of the thermocline is dependent on water clarity and several other variables. These temperature induced density differences between these two layers of water prevent these two layers from mixing. The resistance to mixing is strongest when temperature differences between the two layers are the greatest; this occurs in mid-summer. In the fall, the surface waters begin to cool, the thermocline deepens, and stratification breaks down. At some point during this process, the lake is the same temperature from top to bottom allowing the two layers, the entire water column, to mix (in Grass Lake this occurs around November). This mixing is what is known as turn-over, a period of time at which the bottom water of the lake mixes with the top.

As fall transitions to winter and air temperatures drop, the water cools and ice begins to form, once again inducing a period of stratification. This winter temperature differentiation is referred to as inverse stratification, colder water sits atop a layer of slightly warmer water. This occurs because water is most dense at 39.2 degrees Fahrenheit. The resistance to mixing during winter months is less than that during summer due to smaller differences in temperature. However ice cover reduces the possibility of wind induced mixing. The cycle completes itself as the ice leaves, surface waters warm often resulting in turn-over (in Grass Lake this occurs around late April); and summer stratification begins to set up (in Grass Lake this occurs around May).

Temperature effects water quality; one example of this is its impact on dissolved oxygen. If winter stratification persists for too long oxygen in the water can be depleted to the extent that fish are no longer able to survive, leading to a fish kill.

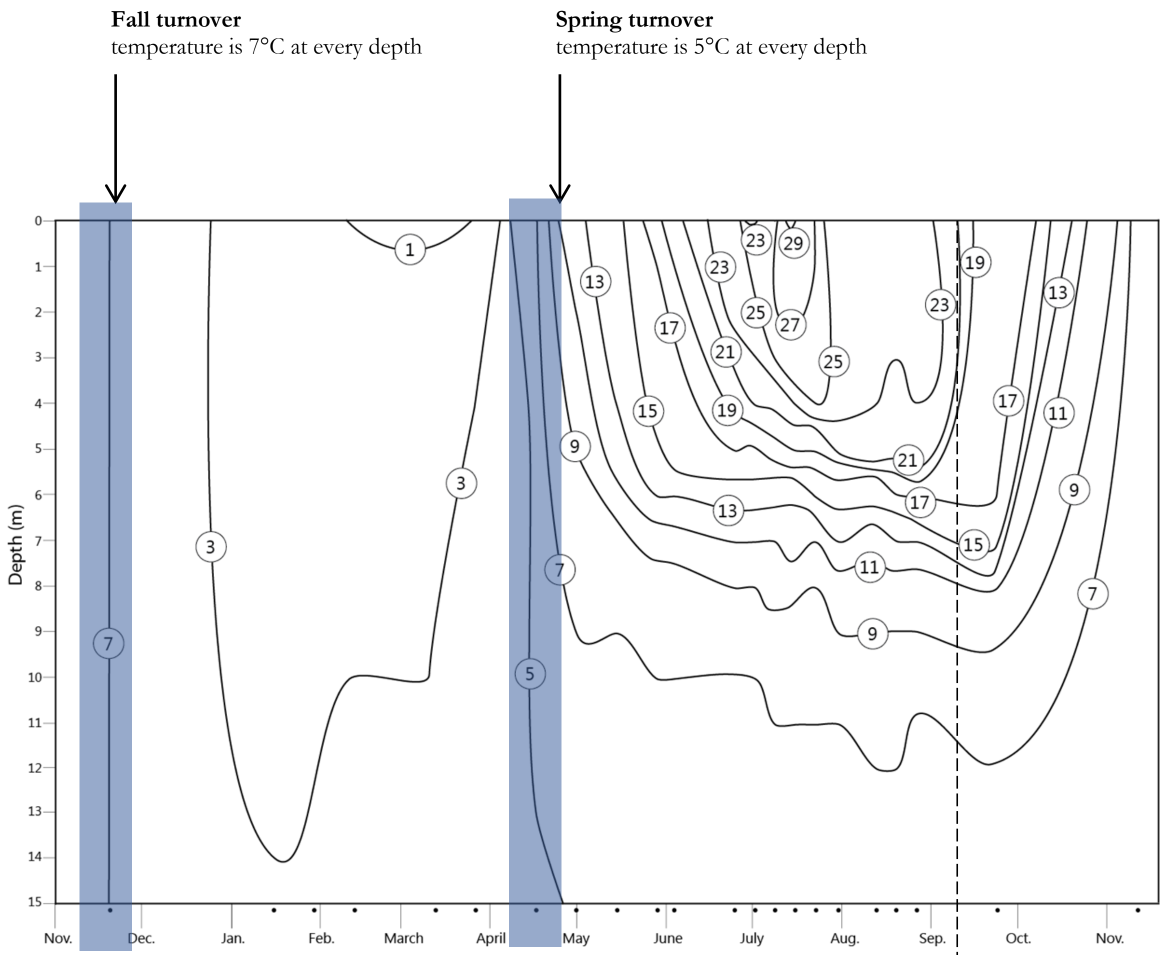


Figure 5. **Temperature Isopleth showing turn-over periods for Grass Lake 2012-2013**

To read this graph:

Each dot on the horizontal axis represents a sample date. The vertical axis represents the depth at which temperature was sampled. For example on this date in August, at around 3 meters below the surface the water temperature was about 23°C, at a depth of 7 meters it was around 11°C.

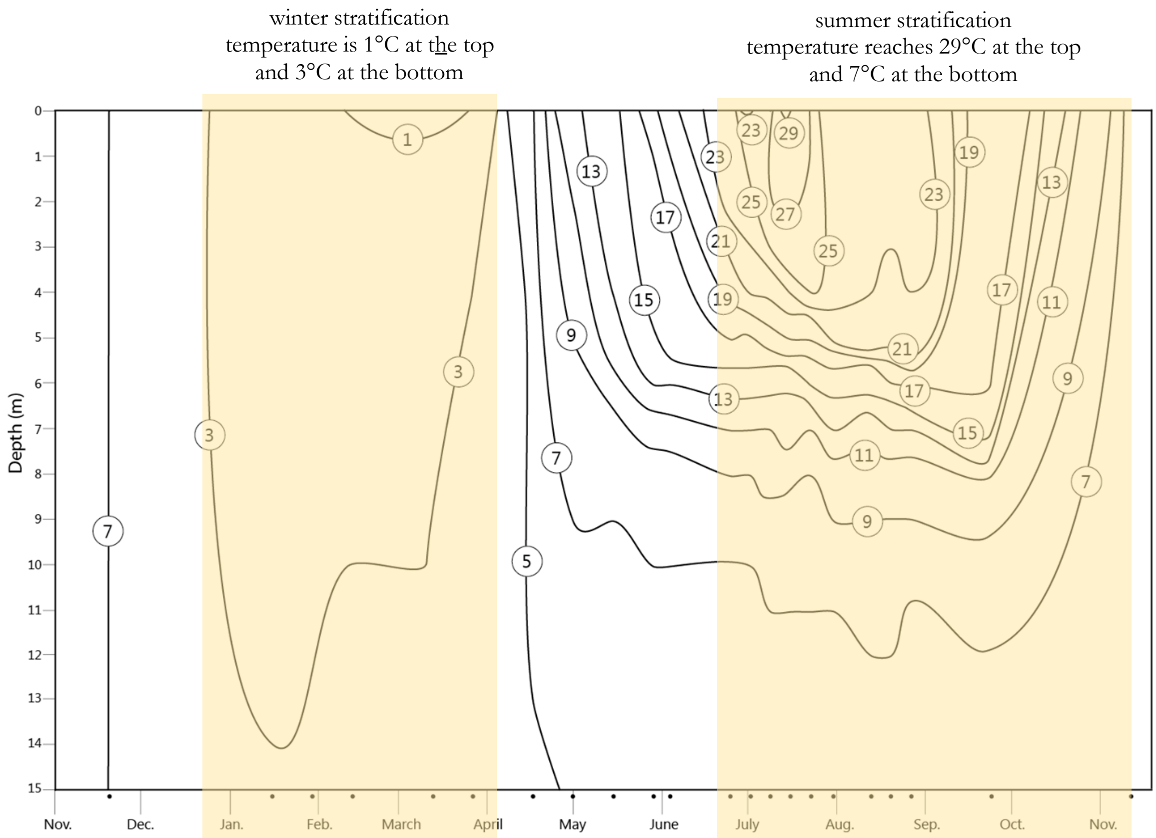


Figure 6. **Temperature Isopleth showing stratification for Grass Lake 2012-2013**

Dissolved Oxygen

Dissolved oxygen (DO) is essential for fish and other aquatic fauna. New York State has identified standards used to protect water quality; the NYS water quality standard for dissolved oxygen in non-trout waters, such as Grass Lake, is "the minimum daily average shall not be less than 5.0 mg/L, and at no time shall the DO concentration be less than 4.0 mg/L" (NYCRR §703.3). Meeting this standard ensures that invertebrates and early life stages of fish have available habitat; and that production of other life stages of fish are not more than moderately impaired (EPA 1986). During 2012-2013 sampling found that Grass Lake failed to meet this water quality standard on multiple occasions.

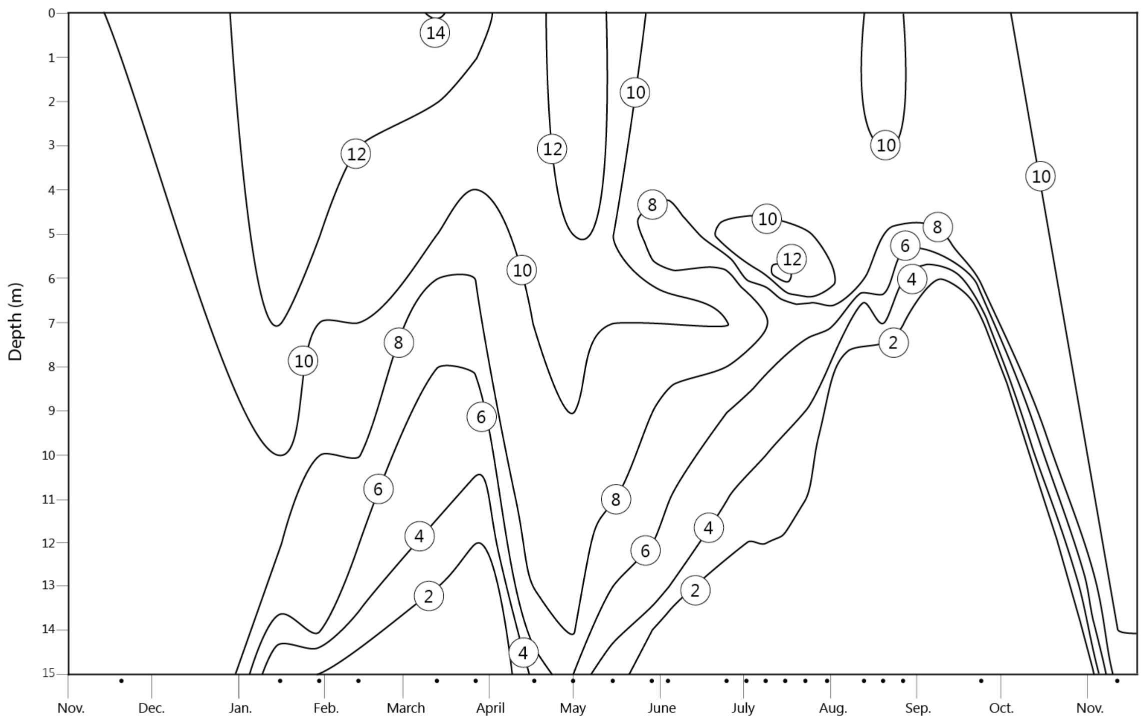


Figure 7. **Dissolved oxygen isopleth above deepest point in Grass Lake 2012-2013**

***Table 1.* Dissolved Oxygen criteria for aquatic life. Values given in mg L^{-1}. Adapted from EPA Quality Criteria for Water 1986.**

	Fish		Invertebrates
	Early Life Stages	Other Life Stages	
No Production Impairment	6.5	6	8
Slight Production Impairment	5.5	5	-
Moderate Production Impairment	5	4	5
Severe Production Impairment	4.5	3.5	-
Limit to Avoid Acute Mortality	4	3	4

There are two main sources of dissolved oxygen within Grass Lake (1) interactions with the atmosphere, such as diffusion and surface turbulence; and (2) as a byproduct of photosynthesis carried out by algae and higher plants. Dissolved oxygen is consumed through decomposition of organic matter and respiration by plants and animals. The oxygen dynamics within Grass Lake are influenced by the extent and duration of stratification. During periods of stratification there is a spatial separation between the input and consumption of oxygen. The sources of oxygen are limited to the epilimnion, while the hypolimnion is dominated by consumption of oxygen.

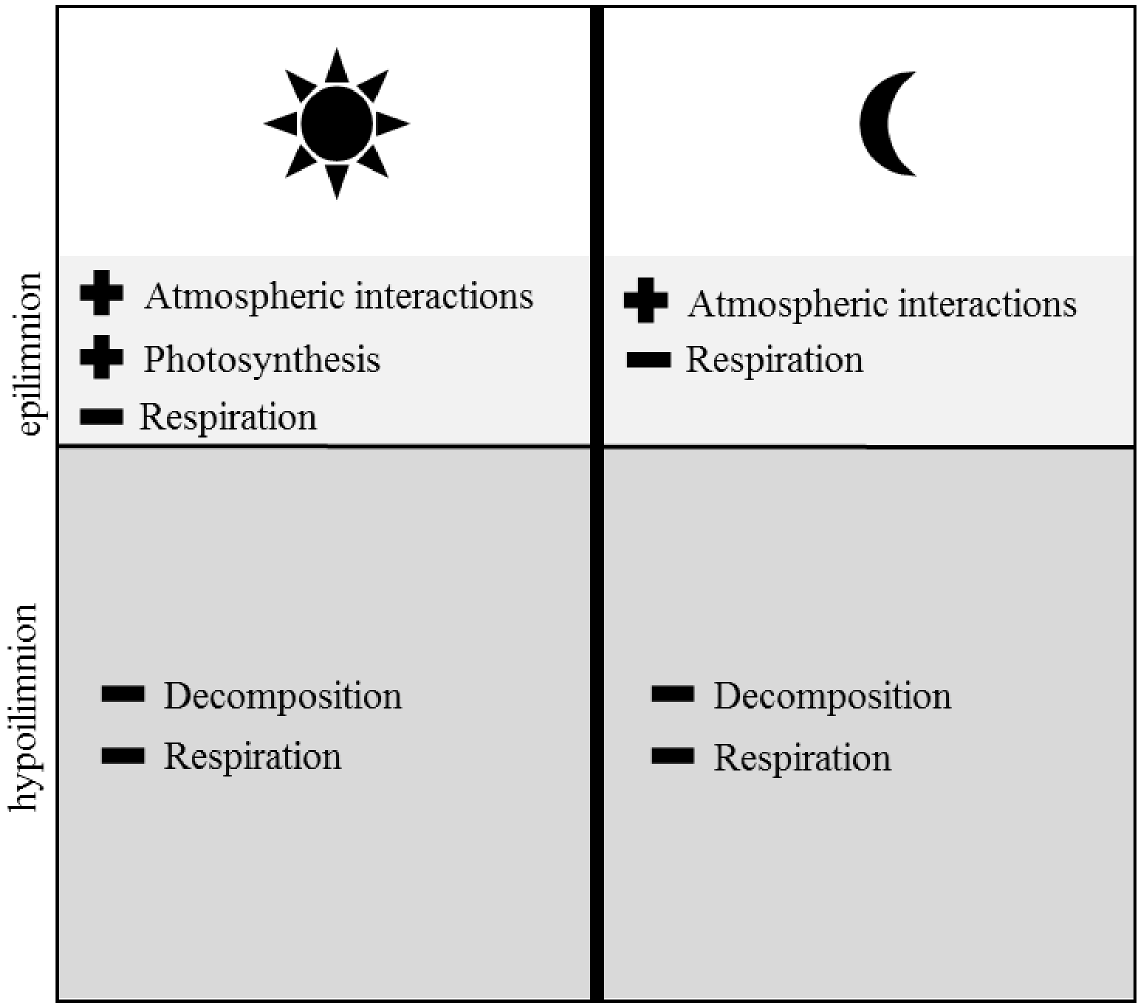


Figure 8. **Simplified oxygen sources and consumption during day and night time**

Since mixing between the epilimnion and hypolimnion is restricted, this results in the depletion of oxygen within the hypolimnion. Oxygen begins to deplete at the sediment/water interface where decomposition processes are concentrated; the zone of low oxygen will then expand into the water column. If the rate of oxygen depletion is high and stratification persists throughout the summer the entire hypolimnion can become completely devoid of oxygen. As shown in figure 7, the hypolimnion of Grass Lake is almost entirely unsuitable for aquatic life in late summer; it is during this period that the lake fails to meet the NYS water quality standard. During turn-over events oxygen concentrations are high and well distributed throughout the lake. A similar situation can occur during the winter; when ice covers the lake the sources of oxygen to the water – atmospheric interaction and photosynthesis – are limited, while consumption processes continue. If the rate of oxygen depletion is high and ice cover persist the possibility that the entire lake can become unsuitable for aquatic life; this can result in a winter fish kill. Though a zone of low oxygen exists in the deep waters during winter in Grass Lake, it is not yet widespread enough to cause a fish kill.

The rate of oxygen depletion within the hypolimnion is dependent on the amount of organic matter present for decomposition; the amount of organic matter present for decomposition is directly related to nutrient concentration.

Phosphorus

Phosphorous is a major nutrient that is essential for plant and algal growth. In Grass Lake, the amount of phosphorous available in the water column drives amount of algal production. The New York State water quality standard for phosphorus is in narrative form, and states that there shall be "none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYCRR §703.2). A commonly suggested numerical guideline for phosphorus concentration in surface waters is 20 $\mu g\ L^{-1}$. During 2012-2013 water quality monitoring it was found that Grass Lake failed to meet the NYS water quality standard for phosphorus; this was evidenced by blue-green algae blooms in Sept-Oct 2013. The high algal production driven by phosphorus concentrations likely increased the rate of hypolimnetic oxygen depletion – resulting in a reduction of the volume of fishery habitat. The 20 $\mu g\ L^{-1}$ guideline was also violated at several other times throughout the year.

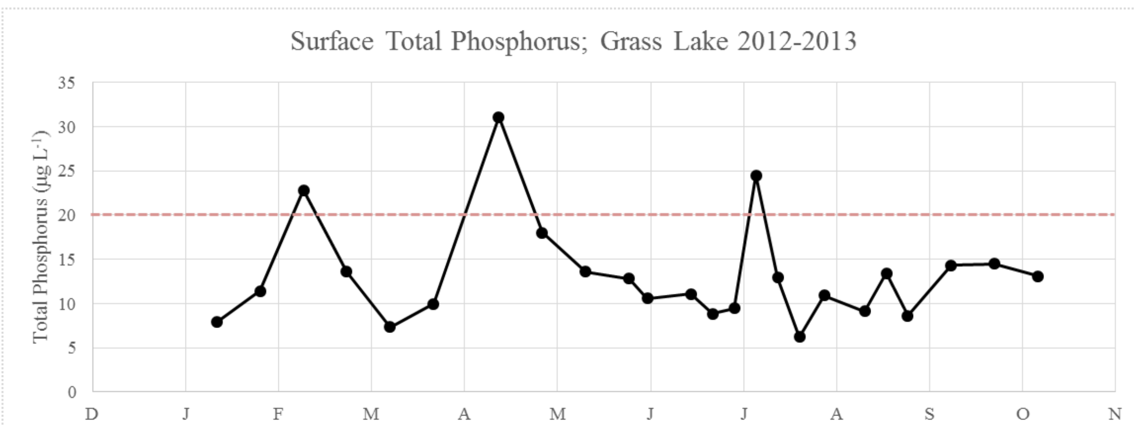


Figure 9. **Total Phosphorus from surface samples in Grass Lake at center lake sample point 2012-2013**

The landscape position, basin shape, and other characteristics of the outlet on Grass Lake do not encourage a high volume of outflow; this means that once phosphorus enters the system there is limited possibility of it exiting the system through the outlet. Once available phosphorus is utilized by plants and algae and is incorporated into their bodies it has two possible fates. The plants/algae could die; in this case the phosphorus may become sequestered in the sediments or released into the water column during the decomposition process. The plants/algae could be consumed; in this case the phosphorus enters the food chain where it is biologically sequestered until the death of the consumer.

Sources of phosphorus to Grass Lake can be broken down into two major categories; external and internal sources. External phosphorus loading can originate from a variety of sources and activities within the watershed. Phosphorus is often adsorbed to soil particles, therefore soil erosion can be a major source of phosphorus to lakes. Many activities within the watershed can cause increased soil erosion such as agriculture, forestry, and construction. Human, animal, and household waste also contain high concentrations of phosphorus; thus many aspects of a human activities within the watershed can increase phosphorus loading into thelLake. Preliminary monitoring of one inlet to Grass Lake showed that external loading of phosphorus is occurring within Grass Lake.

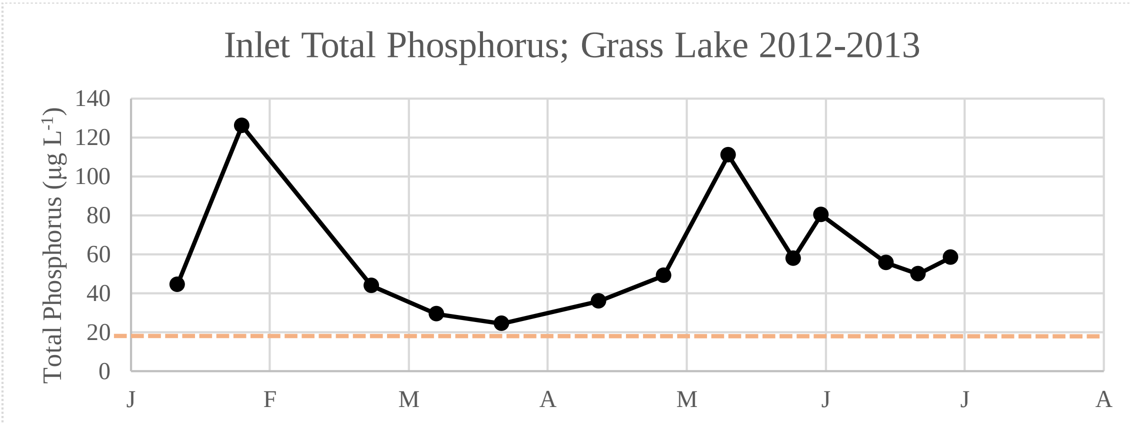


Figure 10. **Total Phosphorus concentrations of inlet to Grass Lake; 2012-2013**

Internal phosphorus loading is a recycling of the phosphorus that is already within the lake. Not all lakes exhibit internal loading; but there is evidence that internal loading may be occurring within Grass Lake. Phosphorus is often sequestered in the sediments at the bottom of the lake. In late summer, when the lake is stratified and there is little oxygen at the bottom of the lake phosphorus is released from the sediments into the water column. Once the release of phosphorus from the sediments into the water column begins it can reinforce itself; increased phosphorus can lead to increased algal growth, increase algal growth can lead to increased organic matter for decomposition at the bottom of the lake, this can increase the rate of oxygen depletion at the lake bottom and provide the environment for phosphorus release. High concentrations of phosphorus were found at the bottom of Grass Lake on several occasions; this indicates that internal phosphorus loading is occurring. The extent to which this increased hypolimnetic phosphorus concentration impacts primary production and algal dynamics within Grass Lake is unknown; however in many lakes this results in increased primary production and a shift toward unfavorable algal species.

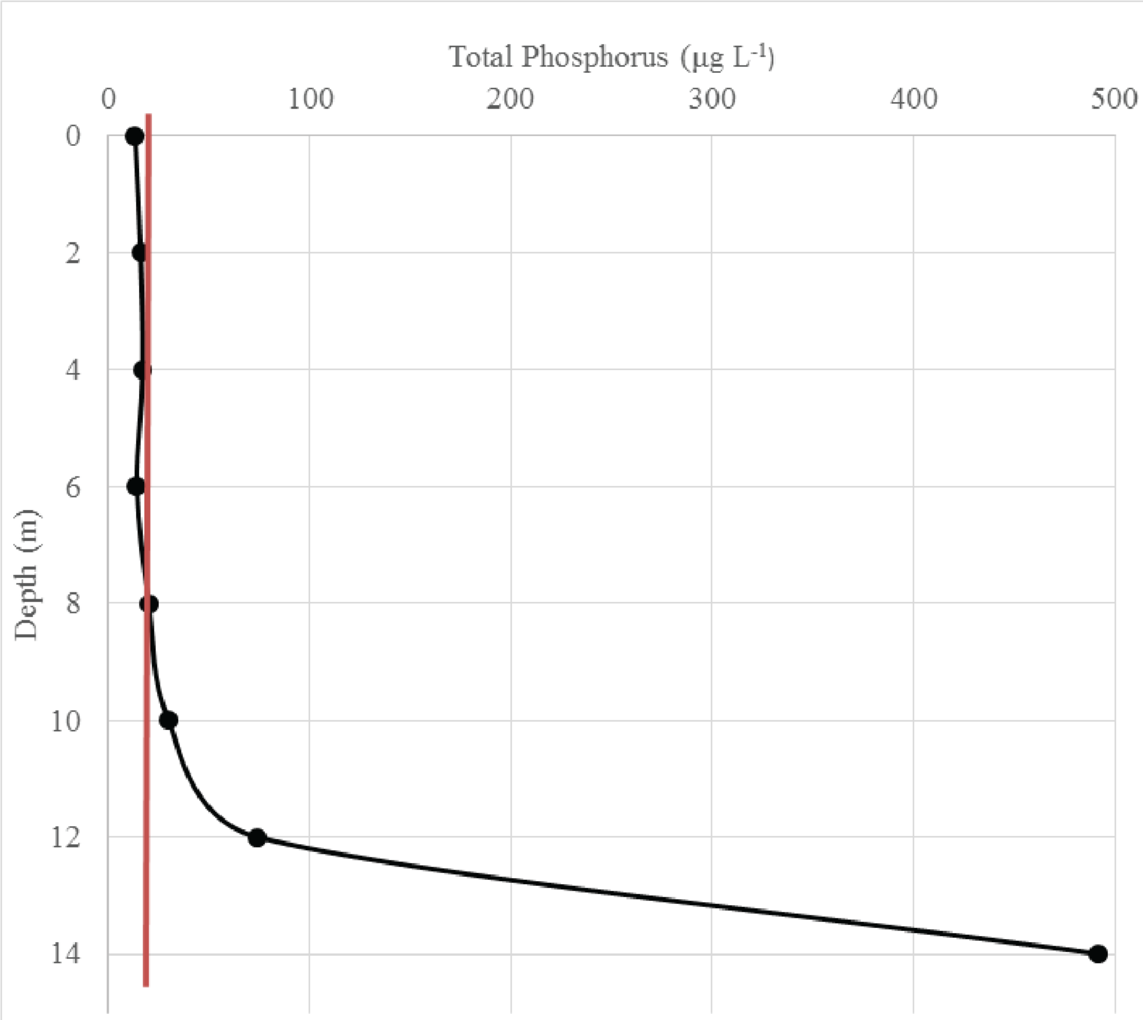


Figure 11. **Depth profile of total phosphorus concentrations within Grass Lake. August 2013. High phosphorus concentrations at depth indicate phosphorus release from sediments (i.e. internal loading of phosphorus)**

Nitrogen

Nitrogen is an important nutrient required for aquatic life. The NYS water quality standard for nitrogen is the same as the phosphorus standard. It states that there should be "none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYCRR §703.2)."

There are several forms of nitrogen that occur within lakes naturally; nitrate (NO_3), nitrite (NO_2), and ammonium (NH_4) are all common forms of nitrogen that can be utilized by plants and algae. Nitrogen can enter Grass Lake through a variety of external sources. Nitrogen within the atmosphere can enter the lake through the biological process of nitrogen fixation; this process is carried out by some types of algae. Nitrogen can be stored in and recycled through the aquatic food chain. Nitrogen can exit the lake system much more easily than phosphorus. This is because nitrogen has a gaseous phase; thus through a process called denitrification nitrogen gas can leave the lake and enter the atmosphere. Nitrogen is much more soluble than phosphorus and is thus more likely to be flushed out of the system through the outlet.

Ammonia is a form of nitrogen that can be toxic to aquatic life. It is a waste product of plants and animals and is released as part of the decomposition of organic matter. The NYS water quality standard for ammonia is dependent upon pH and water temperature. During 2012-2013 water quality monitoring it was found that Grass Lake failed to meet this standard on several occasions.

pH and alkalinity

pH is a measure of acidity. The NYS water quality standard for pH states that it "shall not be less than 6.5 nor more than 8.5" (NYCRR §703.3); this range is where pH is most suitable to aquatic life. During 2012-2013 water quality monitoring there were several occasions on which there were spatially localized pH values that were in violation of the NYS water quality standard; on both the high end and low end. Though at no time was the water column average in violation of the NYS water quality standard.

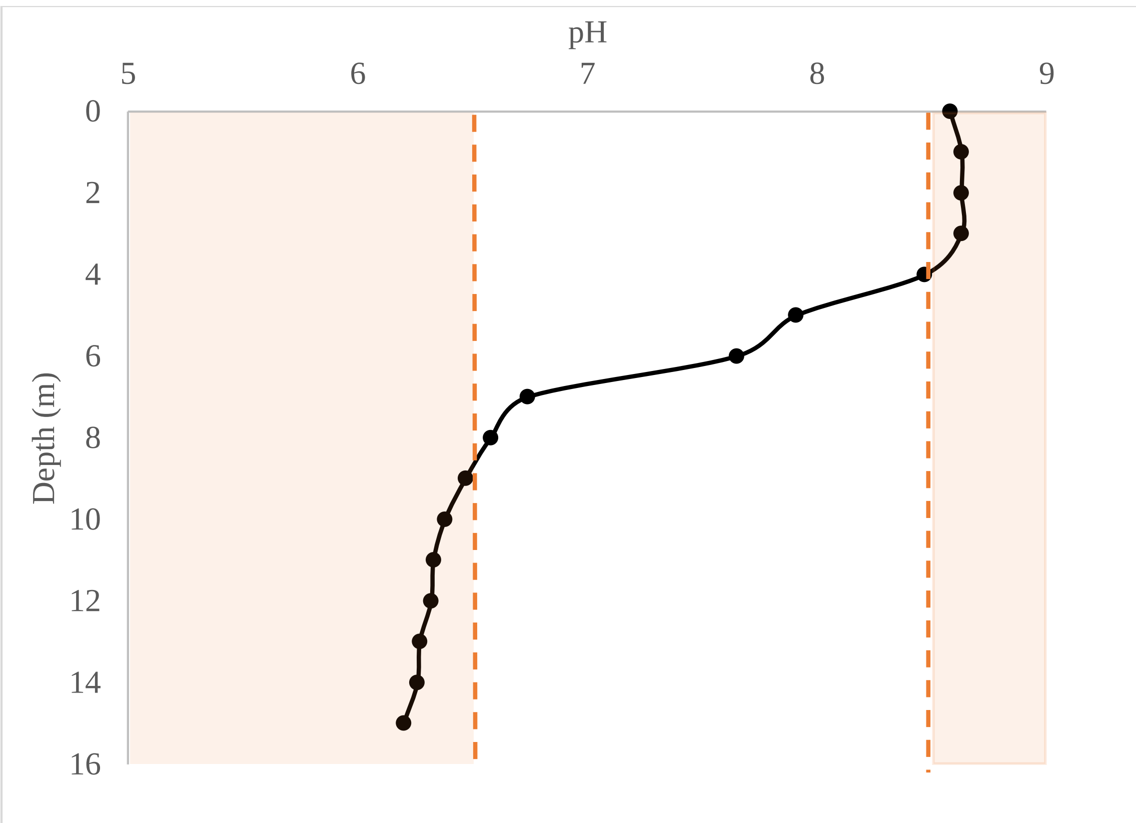


Figure 12. **Depth profile of pH within Grass Lake in August 2013. Red areas indicate a localized violation of NYS water quality standards**

Alkalinity is a measure of how susceptible a system is to a change in pH; there is no NYS state water quality standard regarding alkalinity. Hardwater lakes, those with high alkalinity, are much less susceptible to pH changes than those softwater lakes with low alkalinity. Grass Lake is on the lower end of the alkalinity spectrum and would be considered a softwater lake; the alkalinity of Grass Lake was found to be around 34 mg L^{-1} $CaCO_3$ during 2012-2013 water quality monitoring. Even though Grass Lake is considered a softwater lake the alkalinity is high enough that it is relatively unsusceptible to whole lake acidification (Jenkins et al 2007).

Shifts in pH can be caused by internal or external pressures. Acid rain, ultimately caused by burning fossil fuels, has acidified many Adirondack lakes; the impacts of acid rain on Grass Lake are unknown. High primary productivity can lead to areas localized high and low pH. High pH within the epilimnion can be a result of high rates of photosynthesis; and low pH within the hypolimnion can be a result of high rates of decomposition. This is what is most likely occurring within Grass Lake.

Calcium

There is no NYS water quality standard for calcium concentrations in surface waters. Calcium concentrations can be used as a measure of how suitable a system is to zebra mussel colonization. Zebra mussels are a non-native nuisance species that can impair lake use. A lake is said to be suitable for zebra mussel colonization if calcium concentrations are greater than 20 mg L^{-1}; borderline suitability range is between 15-20 mg L^{-1}; calcium concentrations below 15 mg L^{-1} are said to be unsuitable (Cohen 1998). Calcium concentrations were sampled mid-summer 2013 at four sites around Grass Lake. The calcium concentration of these four samples ranged from 8-14 mg L^{-1} and averaged 11.6 mg L^{-1}. These results suggest that zebra mussel colonization within Grass Lake is a minimal risk; however a more intensive study and continual monitoring may find localized calcium concentrations that may allow zebra mussel colonization.

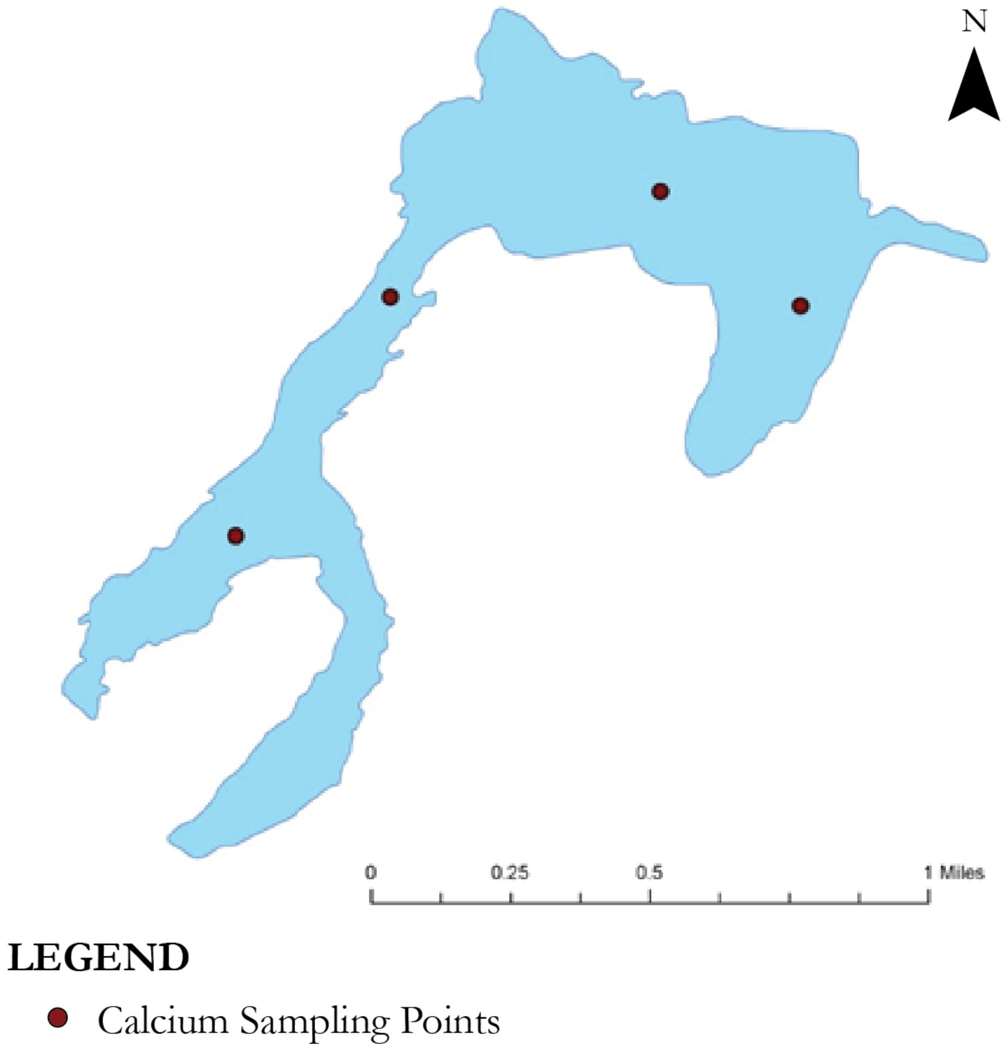


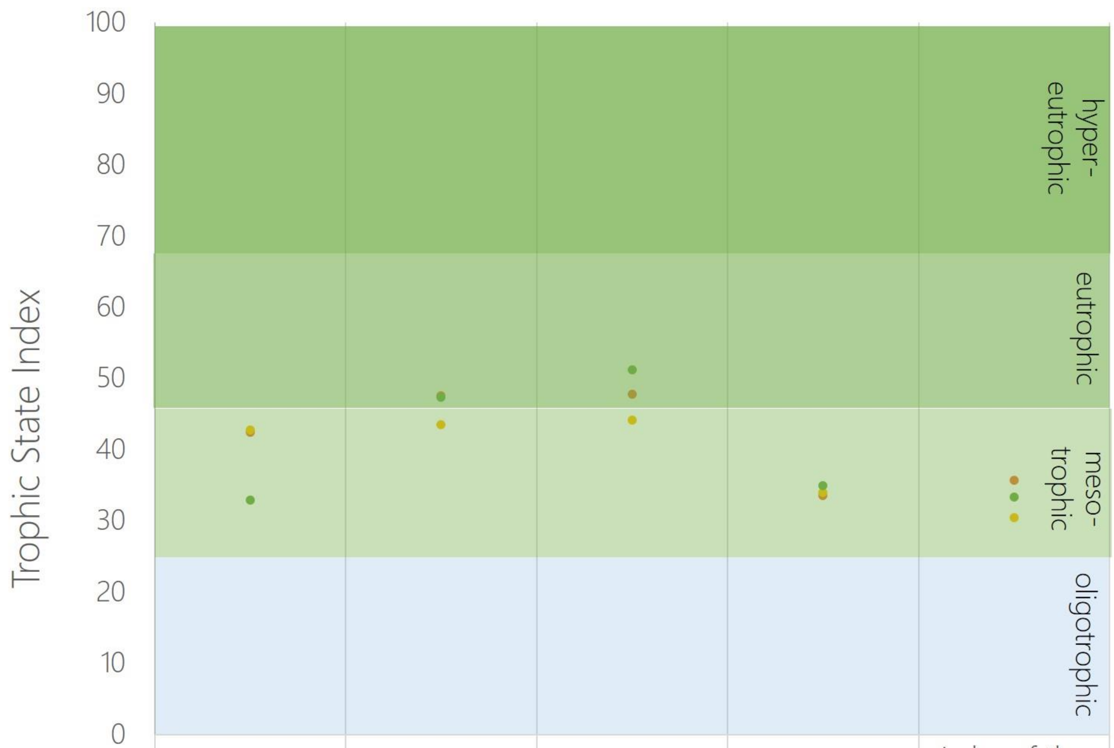
Figure 13. **Calcium sampling points within Grass Lake, 2013**

1.3 Ecology

Trophic State

Biological productivity refers to the rate at which biomass is generated. Biomass refers to any biological material and can include algal cells, plant tissues, zooplankton, and fish. A more productive system will likely have higher biomass of plants and algae; it will also likely be able to support more or larger zooplankton and fish. Lakes with low productivity are called oligotrophic. Lakes with medium productivity are called mesotrophic. Lakes with high productivity are called eutrophic. Lakes move toward a more productive state through time; the rate of eutrophication is dependent on many variables including watershed characteristics, climate, and human impacts. It is important to note that a lake naturally changes through time. The theory of aquatic succession states that as an aquatic system, such as a lake, moves through time it slowly fills with sediment and organic matter; this process is directly related to eutrophication. Increased productivity will increase the rate at which a system fills with organic matter. Thus the system moves from an open water system, to a wetland, to a terrestrial system; the lifespan of each state of the system varies but can be on the scale of thousands of years. Cultural eutrophication refers to an increased rate of eutrophication caused by human development.

The trophic state index was developed to classify lakes in terms of productivity. Based upon 2007-2011 CSLAP data, Grass Lake is classified as mesotrophic; this is similar to many other of the lakes within the region.



	Grass Lake	Butterfield	Hyde	Millsite	Lake of the Woods
• TSI(SD)	42	48	48	34	36
• TSI(TP)	43	44	44	34	30
• TSI(CHL)	33	47	51	35	33

Figure 14. **The trophic state index calculated for Grass Lake and several nearby lakes. Calculations were made using CSLAP data from 2007-2011. SD refers to secchi depth, TP refers to total phosphorus, CHL refers to Chlorophyll a.**

Primary productivity refers to any biomass generated through energy derived from sunlight, such as algal production and plant production; this is the main pathway of biological materials into the lake. Algae and plants serve as the base of the food web within Grass Lake; sustaining zooplankton, macroinvertebrate and fish populations.

Algae

Algae are diverse group of organisms; some species of algae are microscopic free-floating organisms, while others can are similar in form to plants. All algae are photosynthetic primary producers and contain the photosynthetic pigment chlorophyll *a*. Algae utilize nutrients, such as phosphorus and nitrogen, and sunlight to grow. Water temperature, availability of sunlight and nutrients drives algal abundance and species composition. Algae can influence water quality, fish abundance, and possibly impede lake use. High algal abundance can increase the amount of organic matter available for decomposition which can potentially lead to hypolimnetic oxygen depletion, localized shifts in pH, and increased ammonia concentrations. Some species of algae are undesirable as food for zooplankton; this can reduce fish production if the algal community is dominated by these undesirable species. Some algae, mainly blue-green algae (cyanobacteria), often form blooms in late summer; an algae bloom is characterized by a rapid increase in algal abundance which is often dominated by a single species or type of algae. Blue-green algae blooms may contain toxins which impede lake uses and can impact fish production (Malbrouck and Kestemount 2006).

Chlorophyll *a* is a photosynthetic pigment present in all algae; it is measured as a proxy for algal abundance. Chl. *a* was measured periodically within the main basin of Grass Lake. Results showed that algae are widely distributed throughout the water column

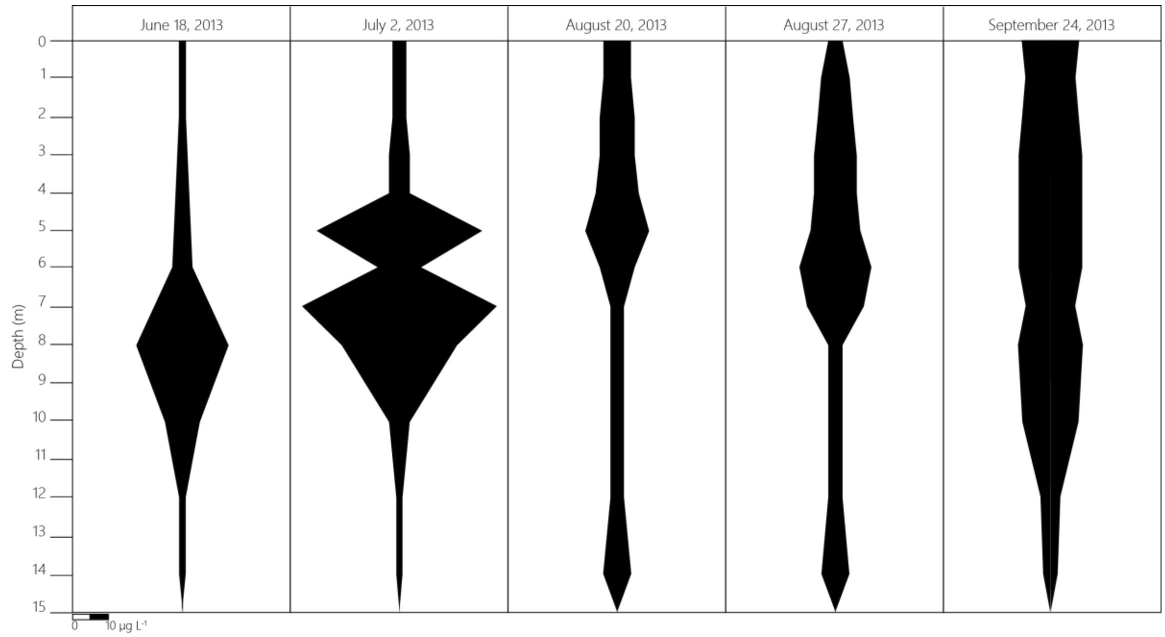


Figure 15. **Depth-abundance profiles of *Chlorophyll* a. concentrations within Grass Lake during 2013**

Grass Lake has experienced several algae blooms in recent years. A prolonged bloom which lasted from late August to early October 2013 was dominated by the blue-green algae *Anabaena spp.* and *Gleotrichia echinulata*. Many blue-green algae species have the ability to produce toxins; Grass Lake was screened for algal toxins during this bloom; results were positive for the presence of the algal toxin microcystin. Exposure to microcystins, a liver toxin, can cause skin irritation and gastrointestinal distress in humans and has been attributed to several canine deaths throughout New York State. Recent research suggests that exposure to algal toxins may be related to some chronic illnesses in humans (Li et al., 2012, Caller et al, 2009).

Plants

Aquatic plants are often viewed as a nuisance as they can impede lake use; however they are a natural and essential part of the lake ecosystem. They provide habitat for aquatic organisms, seasonally sequester nutrients, stabilize lake sediments, and are an important source of food for wildlife. Grass Lake has a diverse plant community comprised of many native, and a few nonnative, species.

Table 2. **Aquatic Plants of Grass Lake in order of estimated abundance according to 2013 survey**

**macro-algae*
ł *invasive*

Common Name	**Scientific Name**
Richardson's pondweed	*Potamageton richardsonii*
Eurasian Water-milfoil ł	*Myriophyllum spicatum*
Largeleaf pondweed	*Potamageton ampifolius*
Coonstail	*Ceratophyllum demersum*
Common waterweed	*Elodea canadensis*
White water lily	*Nymphaea odorata*
Yellow pond-lily	*Nuphar advena*
European Frogsbit ł	*Hydrocharis morsus-ranae*
Common bladderwort	*Utrichularia macrorhiza*
Stonewort *	*Chara spp.*
Water shield	*Brasenia schreberi*
Water Bulrush	*Schoenoplectus subterminalis*
Sago Pondweed	*Stuckenia spp.*
Variable leaved milfoil ł	*Myriophyllum heterophyllum*
Flatleaf pondweed	*Potamageton zosteriformus*
Flatleaf bladderwort	*Utrichularia intermedia*
Wild celery, eelgrass	*Valisneria americana*
Ribbonleaf pondweed	*Potamageton epihydrus*
Variableleaf pondweed	*Potamageton gramineus*
Waterthread pondweed	*Potamageton diversifolius*
Curlyleafed pondweed ł	*Potamageton crispus*

There are several invasive aquatic plants that have been identified within Grass Lake. Figure 16 shows abundance of plants at sampling locations throughout Grass Lake differentiating between native and invasive plants. Eurasian Watermilfoil is an invasive aquatic plant that can impede many lake uses by forming dense beds that extend to the lakes surface; there are several such beds of Eurasian watermilfoil within Grass Lake. European frogsbit it a small floating leafed plant that has caused problems in other lakes. It is abundant and widely distributed along the periphery of the fingers and within the wetlands associated with Grass Lake; currently, it does not seem to have an impact on lake use. Variable leaved milfoil has been found in several locations throughout Grass Lake. Currently the variable leaved milfoil population within Grass Lake is small and it seems to be interspersed within the native vegetation; it does not currently pose a threat to lake use. A single specimen of curlyleafed pondweed was found floating within Grass Lake in 2013; there has been no observation of any established populations of curlyleafed pondweed within Grass Lake.

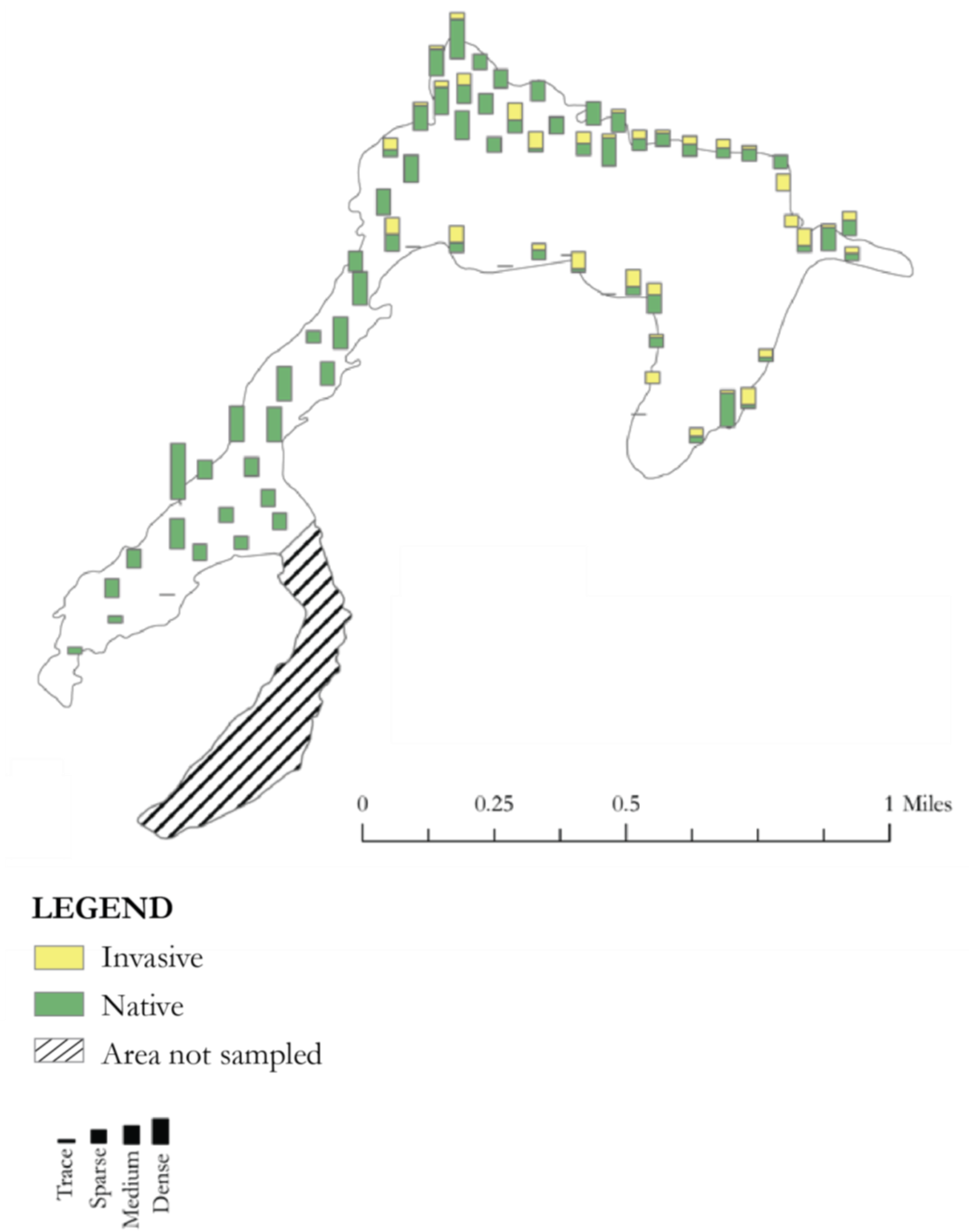


Figure 16. **Aquatic plant abundance in Grass Lake, summer 2013 differentiating between native and invasive**

There are several different species of floating leafed plants common around the periphery of Grass Lake; they include the white water lily, yellow pond lily, watershield, and European frogsbit. Within the fingers there are mats, or floating islands, that seasonally appear, present during the summer months. These mats cut off access to the east finger during the summer months. The mats are comprised of organic sediments that rest upon a tangled mass of the underwater stems of the yellow water lily. The mechanism that causes the seasonality of the appearance of these floating mats is unknown. The mats likely provide important habitat and food for water fowl.

Zooplankton

Zooplankton are microscopic animals that are important in the aquatic food chain; they can have a significant impact on algal abundance as well as species composition. There has been no in-depth study on the zooplankton of Grass Lake to date. Presence of cladocerans, copepods, and several species of rotifers have been observed. This is an area that requires further study.

Fish

Fish play significant role in the ecological function of Grass Lake; they are also important to the recreational use. The fishery within Grass Lake was surveyed by the NYSDEC in June of 2006; found the black bass population was satisfactory and there was currently no need for additional management of that fishery. In 2007 there was an illegal gill-net found in Grass Lake; the NYSDEC suspects that this was detrimental to the bass fishery. A boat electrofishing survey was conducted in June 2014; by SUNY Oneonta in cooperation with SUNY Cobleskill.

Boat electrofishing is a common method used by professionals to survey a fish population. An electric current generated in the water immediately surrounding the boat. The electric current stuns the fish for 20-30 seconds so they float to the surface where they are netted and placed into a live-well on the boat. The survey is conducted in several segments or "runs". Each run typically lasts between 10-15 minutes. After each run, the captured fish are identified, counted, measured, and returned to the lake.

Figure 17 shows the areas that were sampled during the 2014 survey. Only shallow or near shore areas are able to be effectively sampled with boat electrofishing surveys. Sample areas were selected in an attempt to encompass all the different habitat types within the lake.

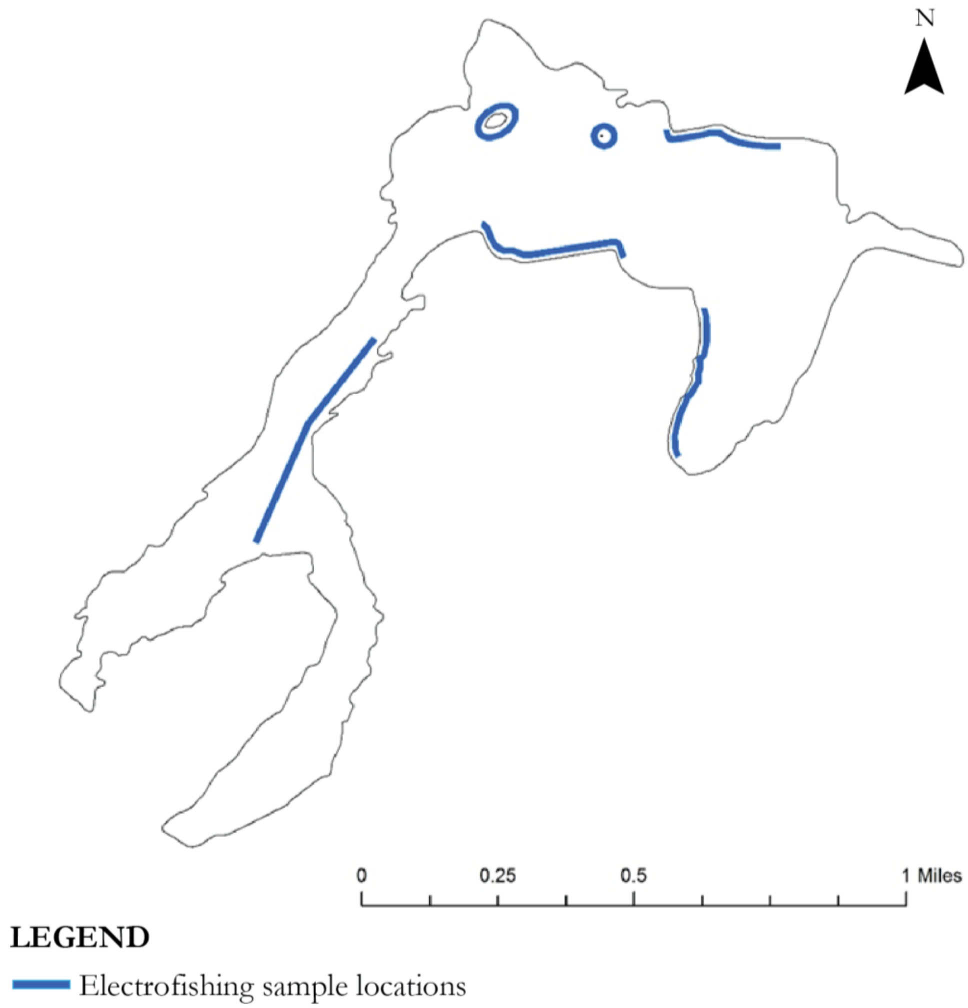


Figure 17. **Sample location for June 2014 electrofishing survey**

Twelve different species of fish were collected. Table 3 gives an overview of the data collected in the survey. Figure 18 shows the relative number of each fish species collected within the survey. Bluegill were the most abundant fish comprising over 70% of the fish collected were bluegill.

Table 3. **Results from 2014 electrofishing survey. Proportional Stock Density (PSD) calculations in red note small sample size that may not accurately describe the population. 95% confidence intervals are included for PSD calculations (Gustafason 1988)**

Species	Count	Relative Abundance (% by #)	CPUE (#/hr)	Averge Size (in)	Size Range (in)	PSD
Banded Killifish	7	0.48%	6.7	2.5	1.6-3.1	--
Black Bullhead	33	2.26%	31.5	9.1	6.1-11.8	48.5 (+/- 21)
Black Crappie	4	0.27%	3.8	7.6	6.1-8.9	--
Bluegill	1024	70.14%	977.8	4.1	0.4-8.0	10.6 (+/- 2)
Golden Shiner	17	1.16%	16.2	4.0	2.6-5.1	--
Largemouth Bass	80	5.48%	76.4	8.3	1.2-20.0	51.3 (+/- 19)
Northern Pike	10	0.68%	9.5	18.6	15.1-23.4	20
Pumpkinseed	206	14.11%	196.7	4.5	1.4-8.74	12.8 (+/- 5)
Smallmouth Bass	2	0.14%	1.9	10.1	5.3-14.9	--
Spottail Shiner	2	0.14%	1.9	2.4	2.2-2.7	--
Walleye	3	0.21%	2.9	9.3	8.7-10.3	--
Yellow Perch	72	4.93%	68.8	5.1	3.1-10.0	12.5
TOTAL	**1460**	100.00%	1394.2			

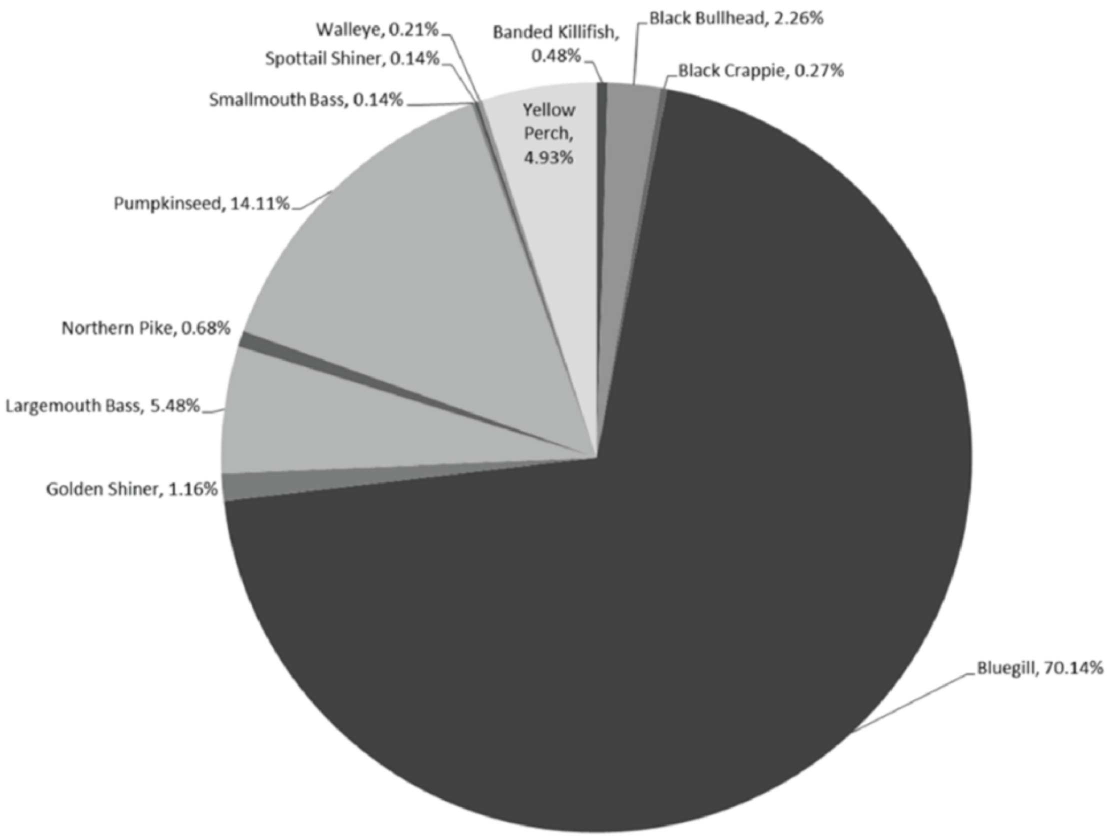


Figure 18. **Relative Abundance of Fish Found in Grass Lake, 2014**

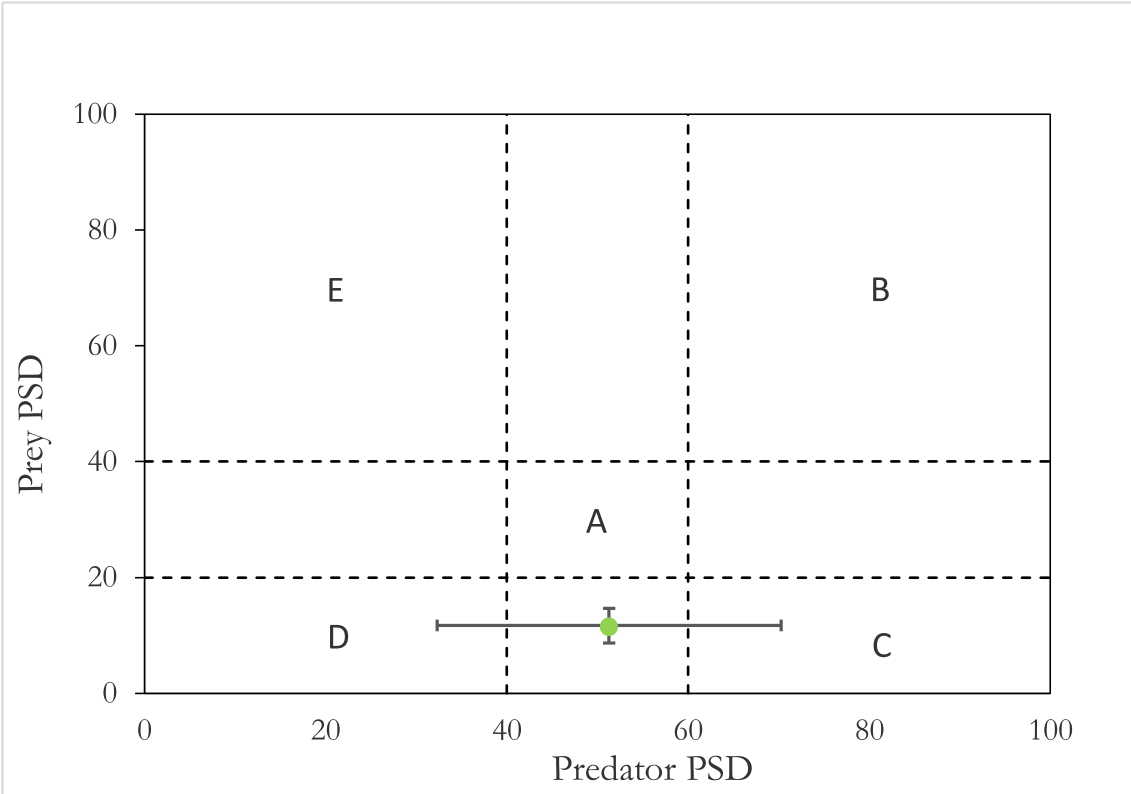


Figure 19. **Predator:Prey PSD Tic-Tac-Toe adapted from Ney 1999. Current state of Predator:Prey PSD in Grass Lake plotted with 95% confidence intervals.**

Proportional Stock Density (PSD) is an index of population size structure. It can be used to judge whether a population is balanced, or meets management objectives, in terms of predator:prey population size structure. Figure 19 is a tic-tac-toe grid of predator-prey PSD where different ratios of predator- prey PSD relate to specified scenarios. Those scenarios are: (**A**) Mutual balance for satisfactory fishing, **(B)** community comprised of large, old specimens, **(C)** stunted prey population interfering with predator production, **(D)** overfishing of predators and stunting of prey, **(E)** high population of small predators excessively cropping young prey (Ney 1999).

Grass Lake falls somewhere between scenario D and scenario C. The predator PSD calculation only included largemouth bass – due to the low sample size of both northern pike, smallmouth bass, and walleye. If we were to include the PSD for northern pike, Grass Lake would fall within scenario D. This suggests that the fishery is not in balance; there are many small prey fish and fewer large predators. Management decisions should not be made based solely on the predator:prey PSD relationship due to high variability within the fish population. However, it can be useful in tracking the effectiveness of management activities (Ney 1999).

The bluegill population in Grass Lake is stunted; a large proportion of the bluegill within Grass Lake is below the quality length and PSD is 10.6 (+/- 2). Stunting occurs through overpopulation. When a species is overpopulated food resources can grow scarce; slowing the growth rate of that population leaving it stunted.

Catch per unit effort (CPUE) is a metric that can be used to estimate abundance of fish within a population. It can be compared between surveys assuming that the methods used to collect the data were the same. The CPUE for bluegill in Grass Lake was 977.8 (number per hour).

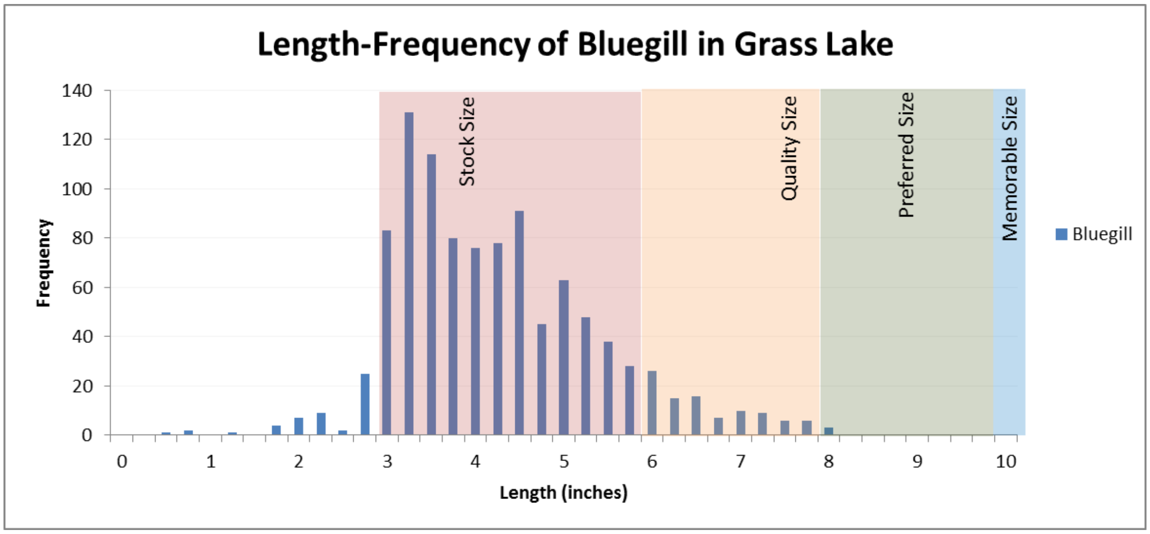


Figure 20. **Size and Abundance of Bluegill in Grass Lake, 2014**

The pumpkinseed population, like the bluegill population, is stunted (PSD = 12.8); although they are not as abundant as bluegill. The CPUE for pumpkinseed in Grass Lake was 196.7 (number per hour)

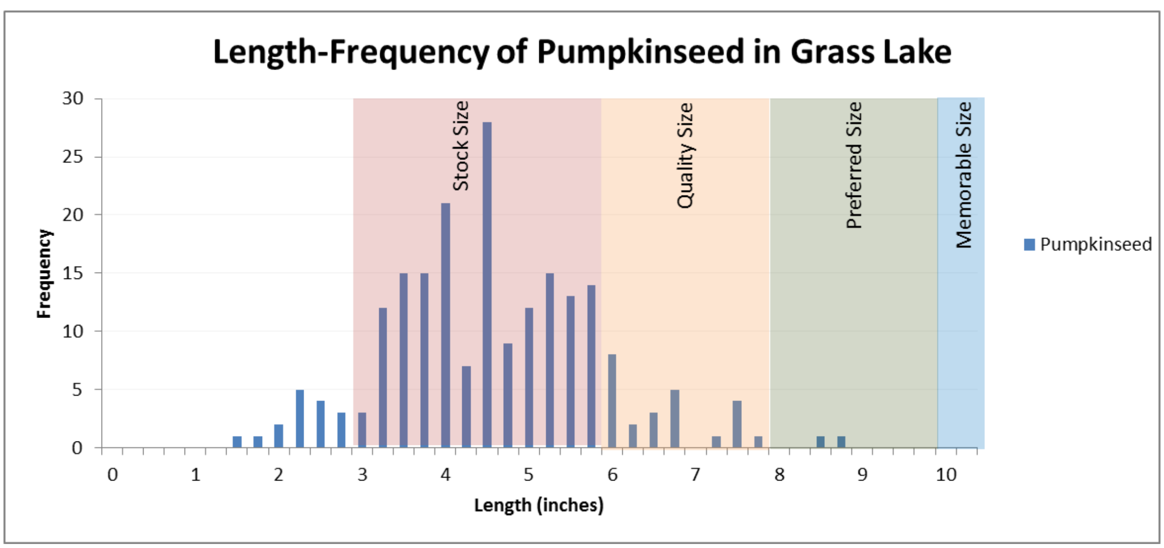


Figure 21. **Size and Abundance of Pumpkinseed in Grass Lake, 2014**

There were few black crappie caught in the survey. The CPUE for black crappie was 3.8 (number per hour).

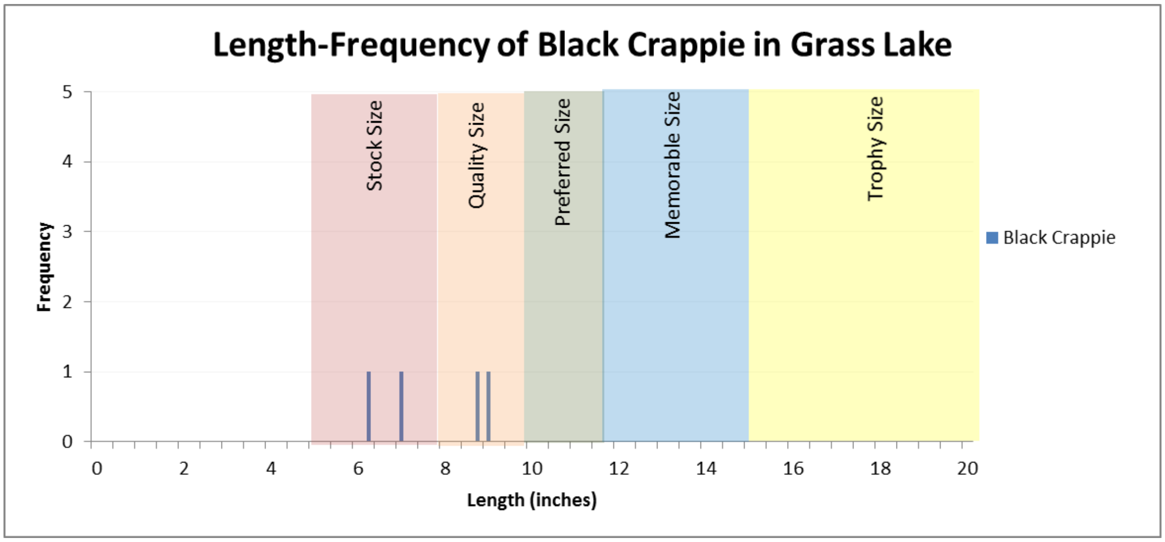


Figure 22. **Size and Abundance of Black Crappie in Grass Lake, 2014**

There were very few smallmouth bass caught in the survey. This could suggest a decline in the smallmouth fishery within Grass Lake. The CPUE for smallmouth bass was 1.9 (number per hour).

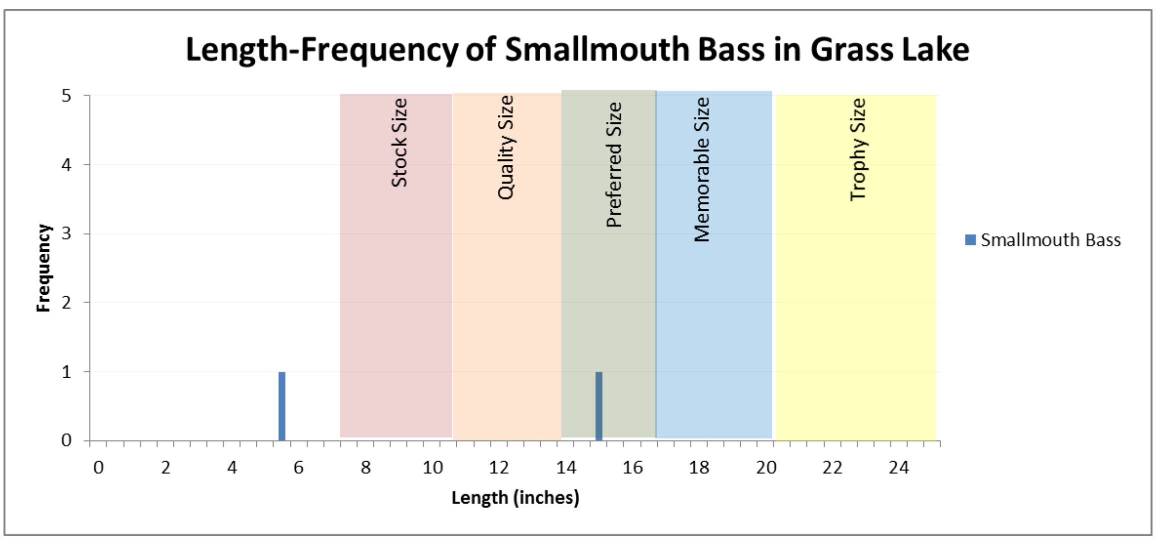


Figure 23. **Size and Abundance of Smallmouth Bass in Grass Lake, 2014**

With a PSD of 51.3 (+/- 19), the largemouth bass population seems to be balanced within Grass Lake. This is similar to the NYSDEC survey done in 2006. The CPUE for largemouth bass in Grass Lake was 76.4 (number per hour).

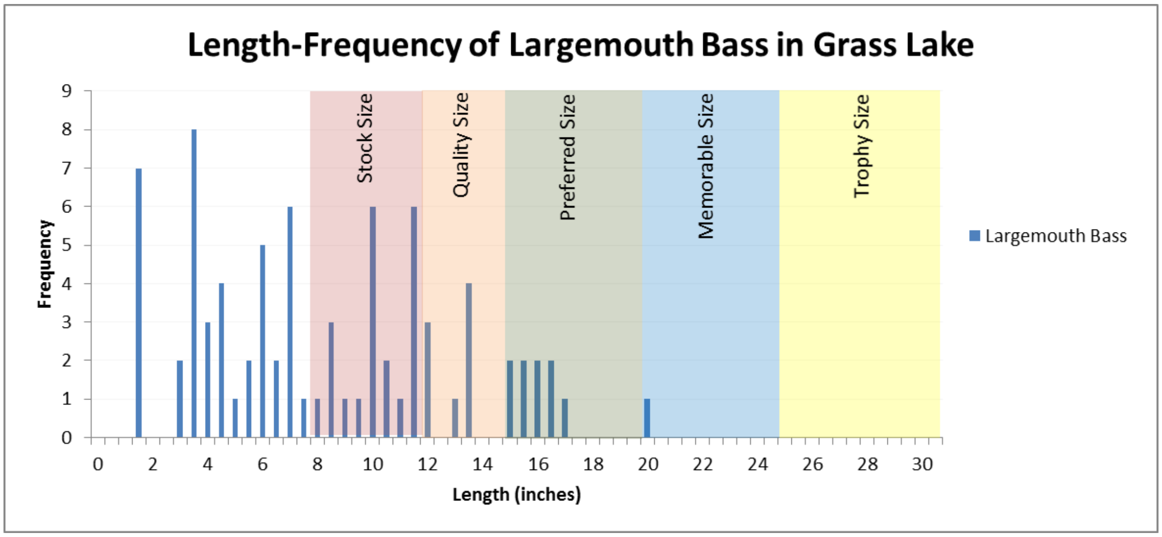


Figure 24. **Size and Abundance of Largemouth Bass in Grass Lake, 2014**

There were too few northern pike caught in the survey to make any confident statement about the northern pike population in Grass Lake. The CPUE for northern pike in Grass Lake was 9.5 (number per hour).

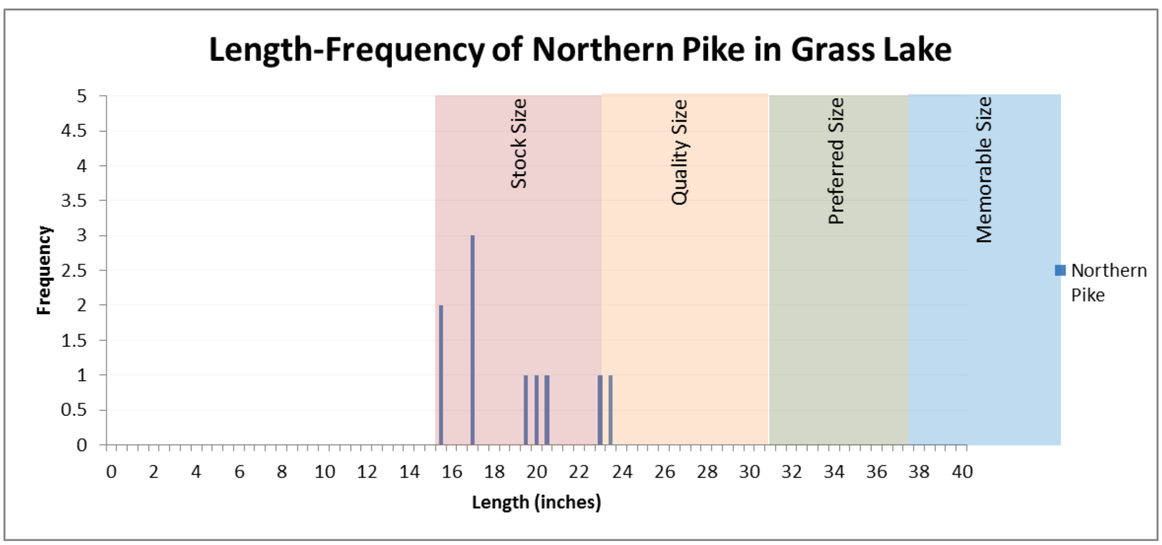


Figure 25. **Size and Abundance of Northern Pike in Grass Lake, 2014**

There were very few walleye (3) caught during the survey. These fish are likely from the 2011 walleye stocking done by the Grass Lake Association.

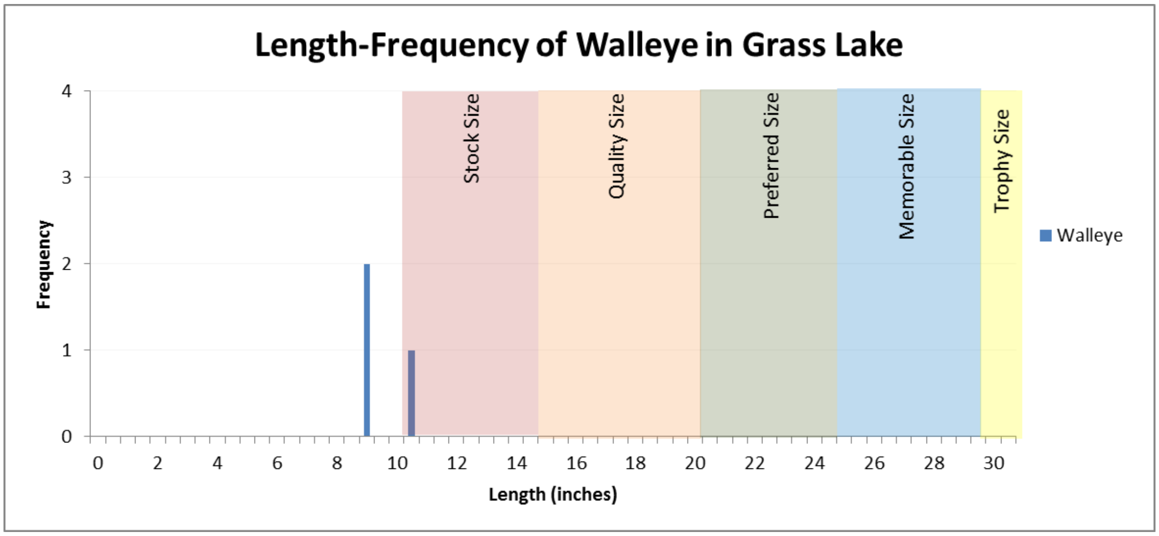


Figure 26. **Size and Abundance of Walleye in Grass Lake, 2014**

Though there were too few yellow perch collected to make any confident statement about their population in Grass Lake; the population seems to be on the stunted side of the spectrum. The CPUE for yellow perch was 68.8 (number per hour).

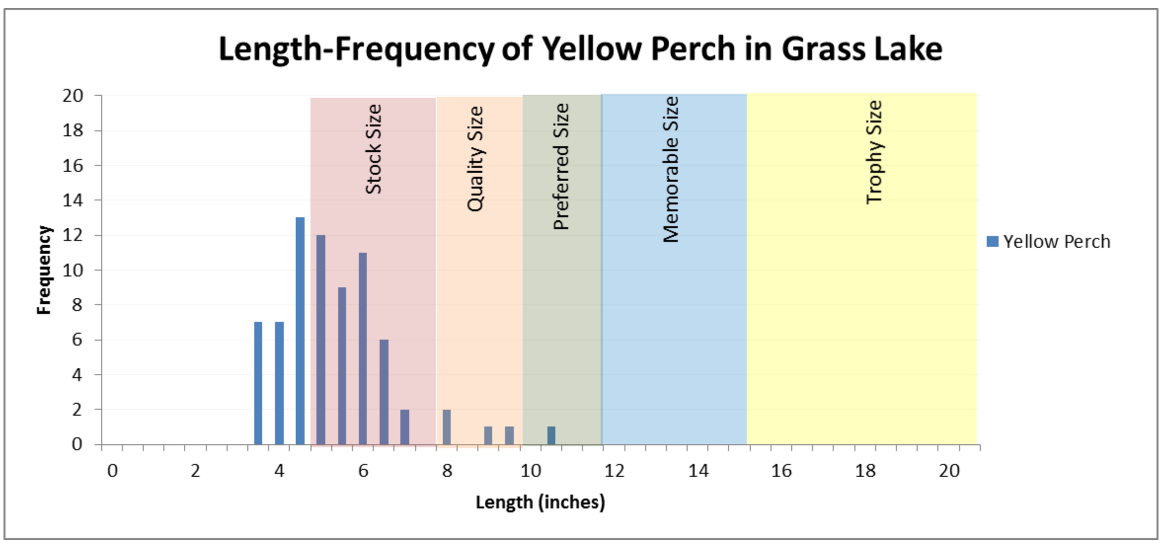


Figure 27. **Size and Abundance of Yellow Perch in Grass Lake, 2014**

The black bullhead population in Grass Lake seems to be satisfactory with a PSD of 48.5 (+/- 21). In the 2006 survey by the NYSDEC there were several brown bullhead collected. During our survey, we collected several black bullhead. It is likely that the species of bullhead may have been misidentified in one of the surveys; not that one species replaced the other within the lake.

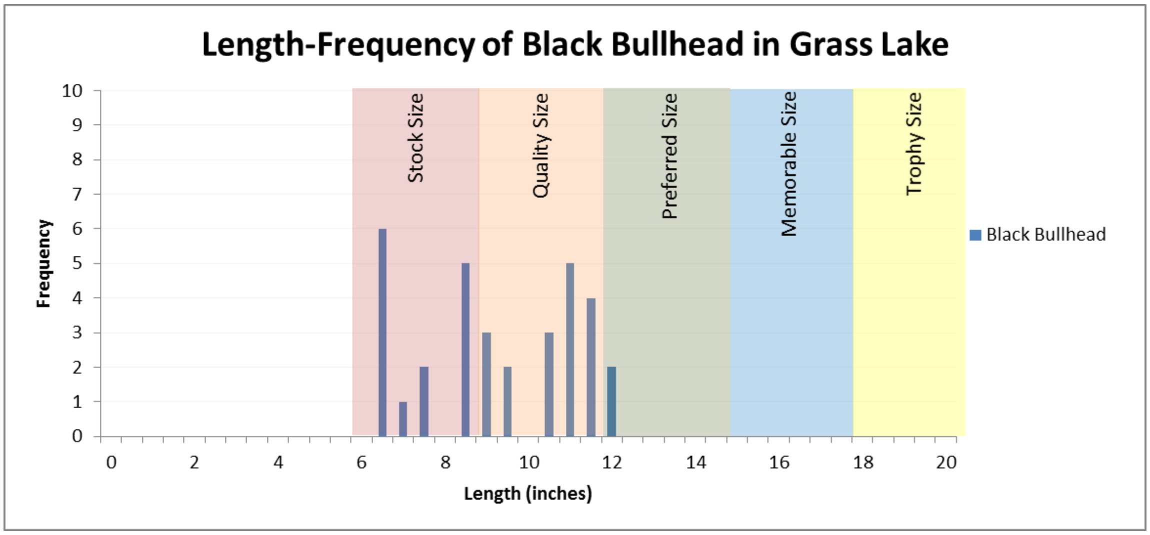


Figure 28. **Size and Abundance of Black Bullhead in Grass Lake, 2014**

There were several other species of fish caught in Grass Lake. These smaller fish are often referred to as forage fish, as they are often the food of the larger sportfish such as largemouth bass, smallmouth bass, walleye, and northern pike. They are an important part of the system. The species caught include the banded killifish, golden shiner, and spot-rail shiner

Other Fauna

Two pairs of common loon (*Gavia immer)* are actively nesting on Grass Lake. The common loon is listed as a species of special concern in New York State (6 NYSCRR §182.5); thus the habitat requirements of the common loon should be taken into account before pursuing a management activity.

The beaver (*Castor Canadensis)* population on Grass Lake has been a topic of discussion at several lake association meetings. A beaver population can have a large impact on an aquatic ecosystem. Beavers can impact the hydrology, geomorphology, water chemistry and ecology of the lake system. Not all of these impacts are negative. For example, presence of beavers can increase the abundance and diversity of forage fish and aquatic invertebrates in near shore areas of the lake (Rosell et al. 2005). While the perceived nuisance of beavers on Grass Lake is high, the extent of the negative impacts attributable to beavers is difficult to discern given that the current state of the beaver population surrounding Grass Lake is unknown. Further monitoring of the beaver population is required to discern if the population is having a negative impact on Grass Lake.

Watershed Landuse and Landcover

Landcover is an ecological characteristic of the watershed that is directly related to how society interacts with the landscape. About 62% of the areal land coverage within the Grass Lake watershed is forested, and approximately 31% are wetlands. Landcover regimes within a watershed can be directly impacted by human development. Planted/Cultivated and developed spaces make up a very small percentage of the areal land coverage within the watershed.

***Table 4.* Landcover in the Grass Lake Watershed. Data from National Landcover Dataset 2006**

Landcover Type	Acres	Percent Covered
Forest	819	61.8%
Wetland	409	30.9%
Water	26	2.0%
Shrubland	36	2.7%
Herbaceous	27	2.0%
Planted/Cultivated	4	0.3%
Developed	4	0.3%
Total	1325	

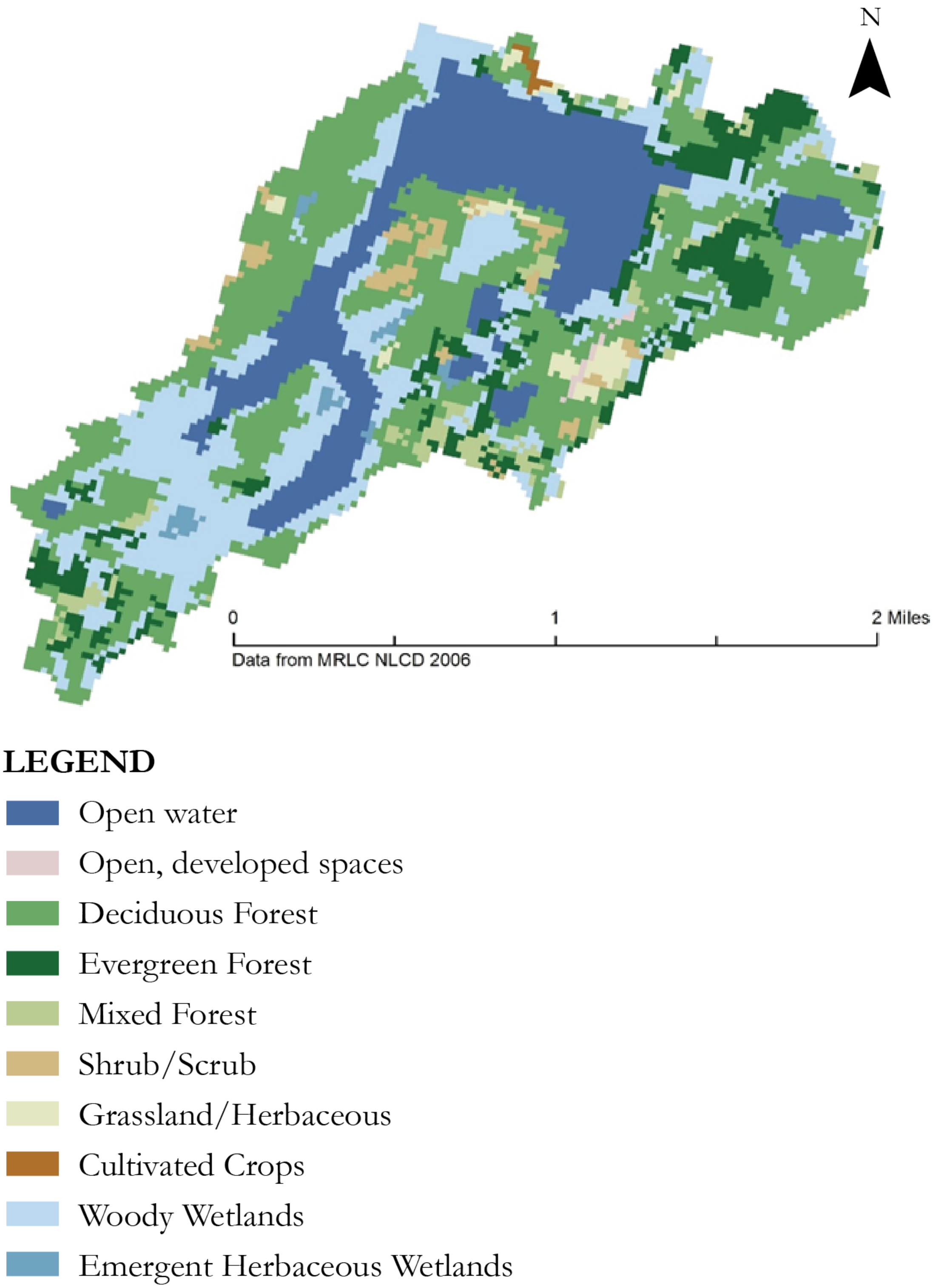


Figure 29. **Landcover in the Grass Lake Watershed**

1.4 Social Geography

Watershed development

According to 2013 tax records there are 110 parcels within the Grass Lake watershed. There are only four one family year round residences within the watershed; the majority of residential parcels within the watershed are seasonal residences – made up entirely of lakeside camps. About ten percent of the areal coverage of the watershed are parcels classified as agriculture; including dairy and other livestock. Half of the parcels within the watershed (55) are classified as vacant; vacant land also has the largest areal coverage within the watershed compared to other major property classifications. This suggests the great potential for further development within the Grass Lake watershed. There are also several parcels within the watershed classified as community services or wild, forested, conservation lands and public parks; but these only amount to 3.4% of the areal watershed coverage.

Table 5. **Property Classifications of tax parcels within Grass Lake watershed according to 2012 Real Property Data**

Property Classification		Number of Parcels	Percentage of watershed area
Agriculture	Agricultural Vacant Land (Productive)	2	1.7%
	Dairy Products: milk, butter, and cheese	4	7.4%
	Other Livestock: donkeys, goats	1	1.0%
	Total Agriculture:	**7**	**10.1%**
Residential	One Family Year-Round Residence	4	1.8%
	Rural Residence with Acreage	2	2.6%
	Seasonal Residences	36	13.7%
	Mobile Home	2	0.2%
	Total Residential	**44**	**18.3%**
Vacant	Residential Vacant Land	18	29.0%
	Residential Land including a Small Improvement	9	4.2%
	Rural Vacant Lots of 10 acres or less	11	2.9%
	Abandoned Agricultural Land	4	7.4%
	Residential Vacant Land over 10 acres	12	15.8%
	Vacant Land located in commercial areas	1	8.8%
	Total Vacant	**55**	**68.1%**
Community Services	Recreational Facilities	1	0.1%
Wild, Forested, Conservation Lands & Public Parks	Private Wild and Forest Lands	2	2.7%
	State Owned Public Parks, Recreation Areas, and Other Multiple Uses.	1	0.6%
	Total Wild, Forested, Conservation Lands & Public Parks	**3**	**3.3%**
	Total Parcels	**110**	

Lake Classification

Grass Lake is classified by the NYSDEC as a class "C" lake; this means the best intended use for Grass Lake is non-contact recreation such as boating or fishing. This classification does not imply that one should not swim in Grass Lake, only that it is best suited for other non-contact activities.

Lake Accessibility

There is a state owned boat launch on Grass Lake. The launch is a beach launch that is suitable for small or lightly trailered boats that can be pushed off a trailer into the water. There is a 10 horsepower motor limit on all boats launched at the state boat launch. The boat launch area has parking for approximately five vehicles. This site allows public access to the lake; though it is difficult to locate.

Use

A survey sent out to all watershed property owners asked lake users to identify how they used Grass Lake. Fishing, boating, swimming and aesthetic uses were the most cited uses. Figure 30 (a-d) identify the spatial density of uses around Grass Lake.

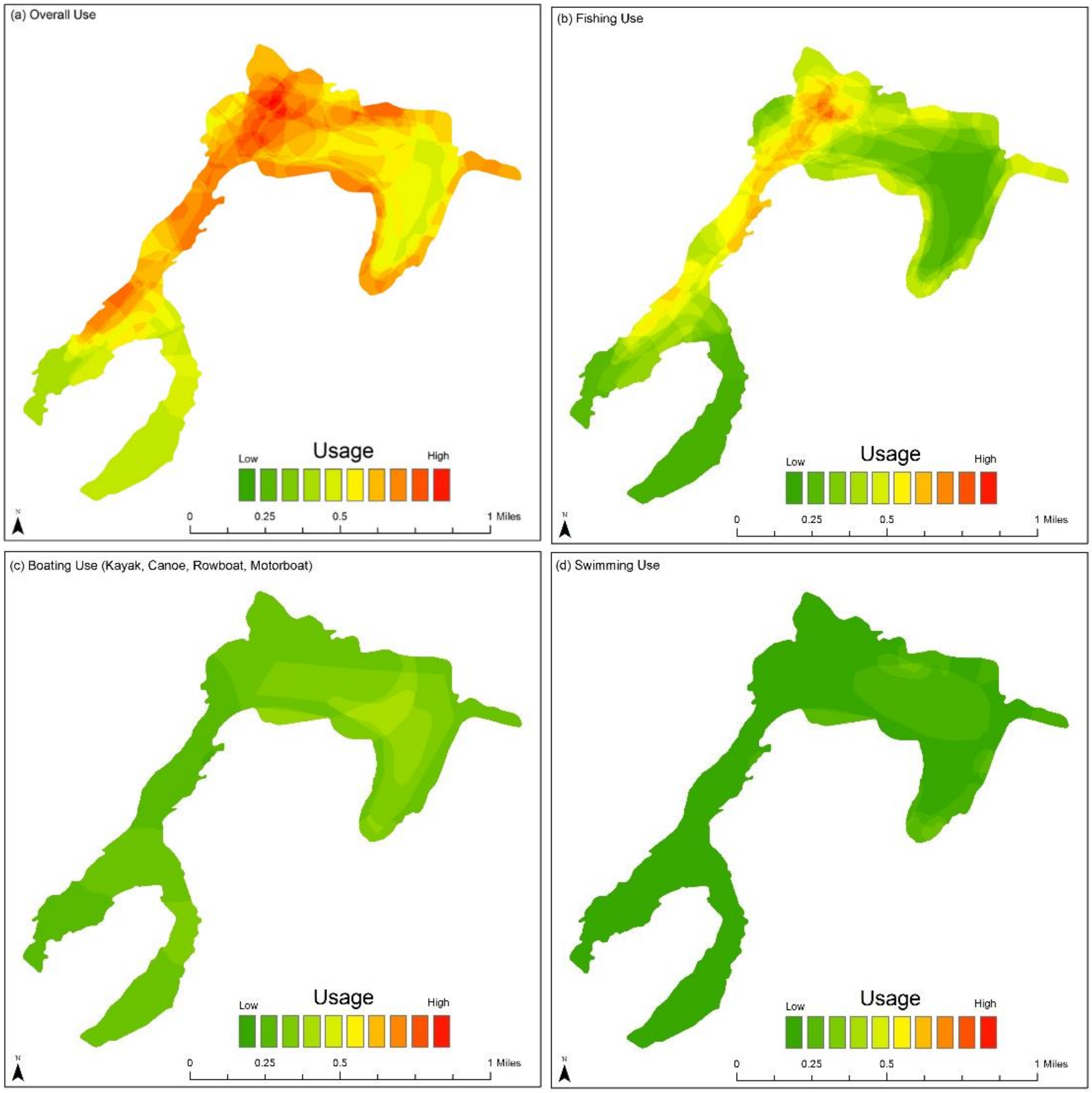


Figure 30. **Lake use within Grass Lake according to 2013 survey**

Legacy of Management

Some of the earliest records regarding Grass Lake date back to the late 19th century. In 1876 citizens from Alexandria and Theresa petitioned for increased fishing regulations on Grass Lake (Watertown Re-union, Nov. 23, 1876). Fish were being stocked in Grass Lake as early as 1881 (Watertown Re-union, Feb. 03, 1881). In 1889, H.H Thompson, a man from Brooklyn, wrote an article in The American Angler detailing a trip he made to Grass Lake. He calls the lake "one of the best lakes for black bass and pickerel in this state" (The Daily Journal Oct. 05, 1889). There are countless other mentions of plentiful and large fish in Grass Lake during this period. In 1914 a local resident John C. Fulmer and other concerned citizens petitioned the New York State Conservation Commission to grant additional protections to the fish of Grass Lake. The cited reason for increased regulations was "risk of extinction"; these increased regulations were granted (The Hammond Advertiser, Nov. 26, 1914). Similar petitions were submitted to the State in 1916, 1921, and 1930; in each case additional regulations were granted.

The formation Grass Lake Association in 2003 continued the legacy of concern for the lake while marking a new era of organized democratic management on Grass Lake. The stated purpose of the Grass Lake Association is:

> ….to provide care, protection, maintenance, purity and conservation of the Grass Lake within Jefferson and St. Lawrence Counties and its adjacent areas, as well as plant life, wildlife and the ecological system of that area. To promote, encourage, sponsor and conduct activities that would educate and inform property owners in the area and general public and governmental agencies on topics and issues relating to the above purpose. To promote, maintain a spirit of cooperation and good fellowship among the residents of the Lake. (Constitution of Grass Lake Association, Inc. 2009)

In order to realize this purpose it is important to first understand what "care, protection, maintenance, purity and conservation" mean to the members of the Grass Lake Association and what they hope to see in the future.

Chapter 2: What you want—scenarios and limitations

To better understand the vision of the stakeholders a survey asked all property owners within the Grass Lake watershed what they saw as the best case scenario and worst case scenario for Grass Lake ten years in the future. The most mentioned characteristics of the best case scenario for Grass Lake were improved fishing, high water quality, fewer weeds, improved swimming, and less development. Characteristics mentioned in the worst case scenario were the inverse of those mentioned in the best case scenario. Sections portraying the current state, best case scenario, and worst case scenario were developed to communicate the idea that Grass Lake is a dynamic system that has the potential to look and function significantly different in future. Figure 32 shows the location of section cut lines used in developing the scenario sections.

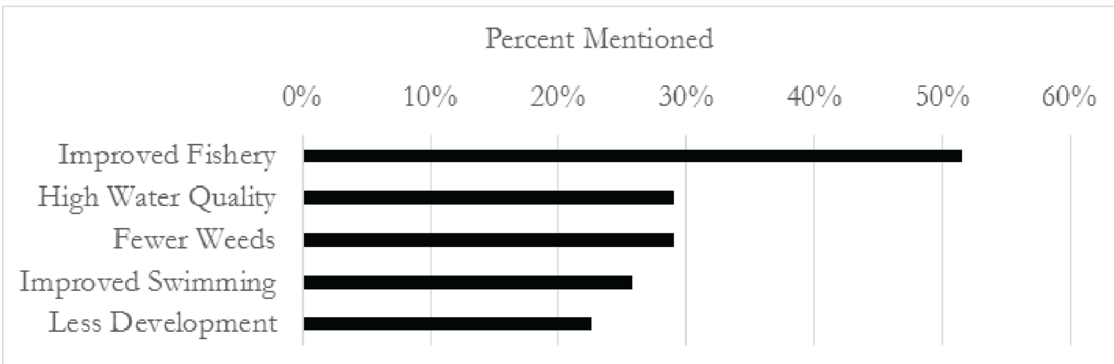


Figure 31. **Most mentioned characteristics of the Best Case Scenario for Grass Lake.**

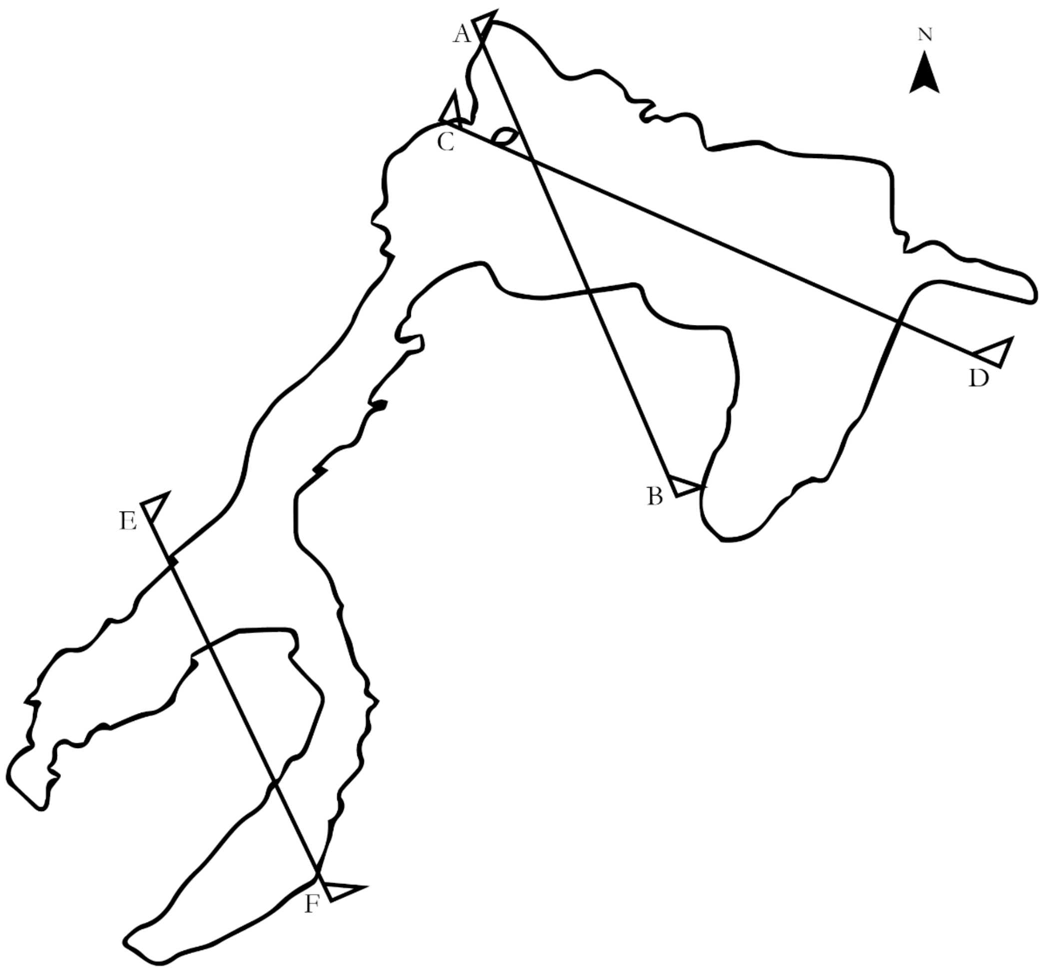


Figure 32. **Cut lines indicating what views of Grass Lake sections AB, CD, and EF depict**

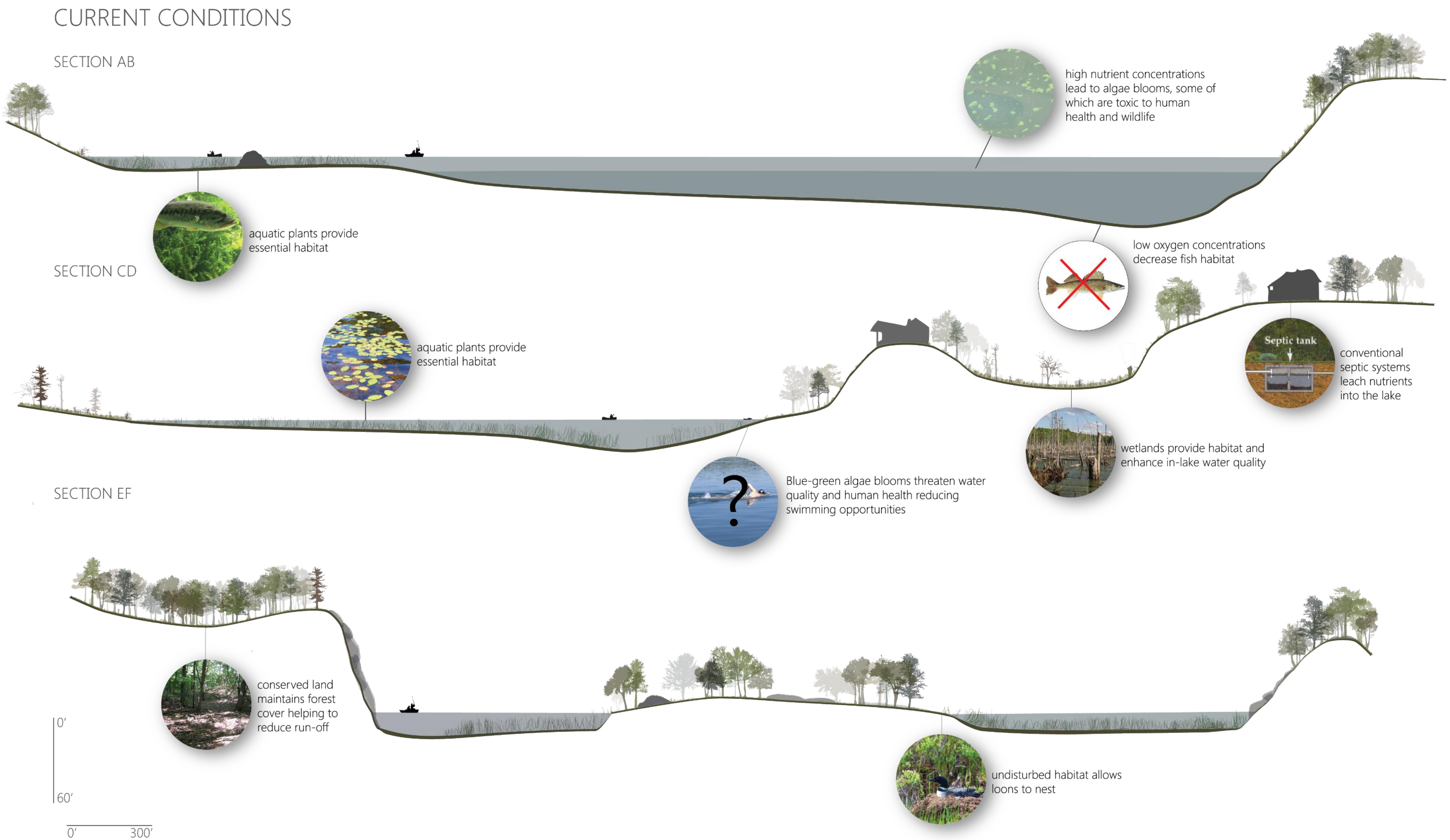


Figure 33. **A visualization of the current conditions on Grass Lake**

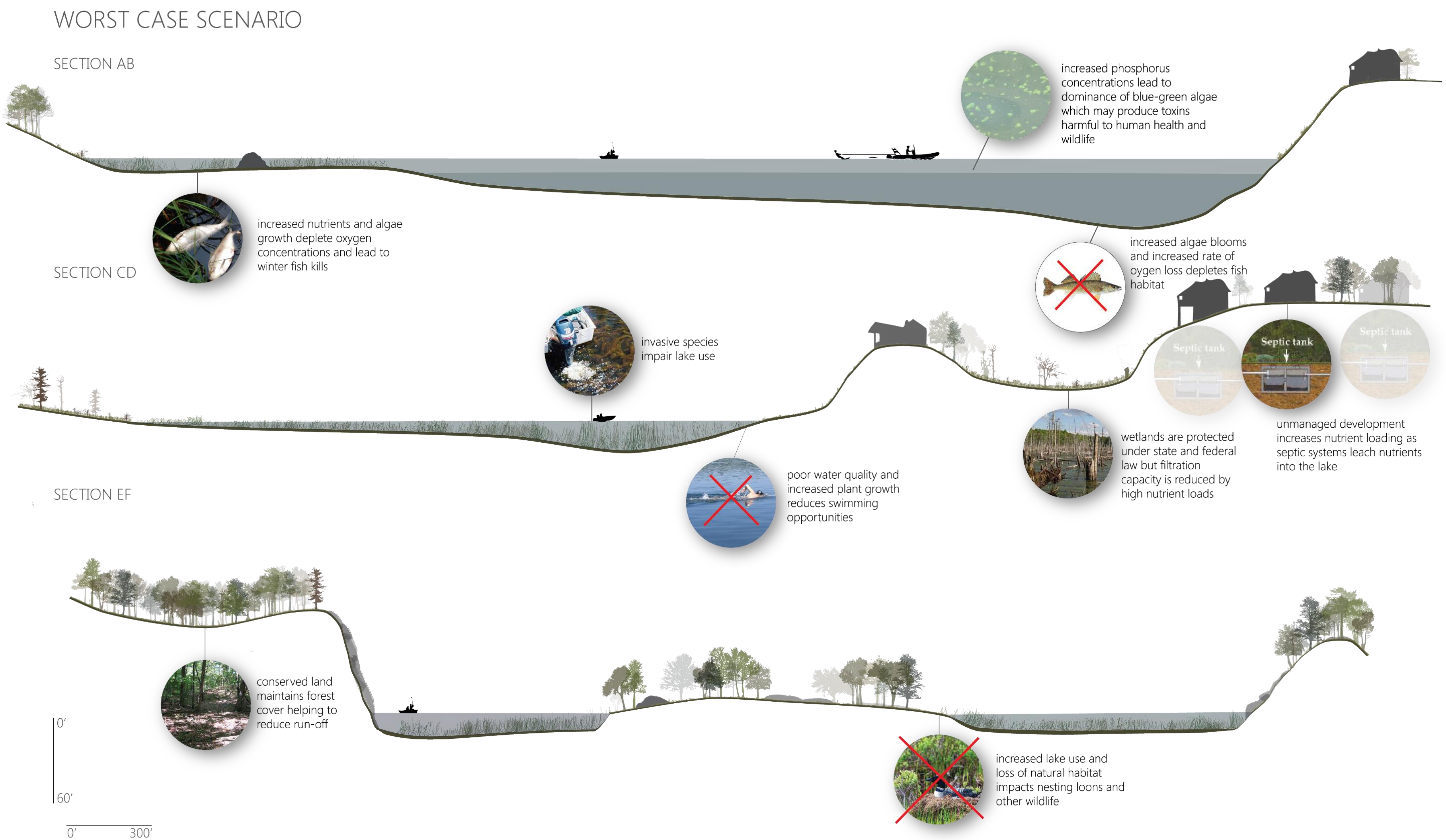


Figure 34. **A visualization of conditions mentioned in the survey as the worst case scenario for the future of Grass Lake**

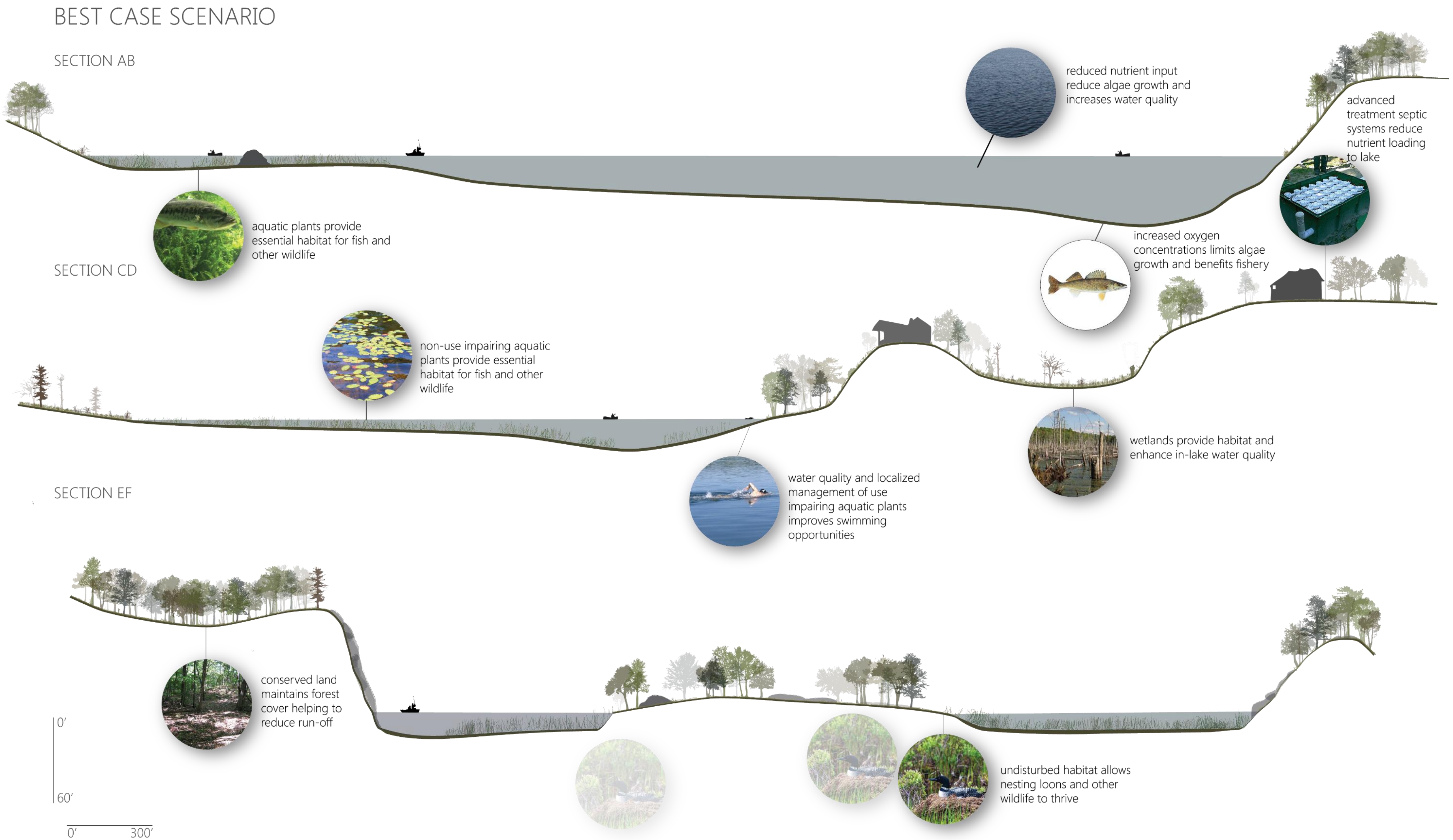


Figure 35. **A visualization of conditions mentioned in the survey as the best case scenario for the future of Grass Lake**

It is important to understand that natural resources, like Grass Lake, are complex, variable, and unique systems and that our understanding of them is limited at best. Thus, when making management decisions it is important to have a vision of where you'd like to end up and to take steps toward achieving that vision, but it is equally as important to understand that the outcome of these activities is often variable and uncertain

Uncertainty comes in two forms – reducible and irreducible (Carpenter 2002). Reducible uncertainties can be dealt with; these uncertainties arise from a lack of, or low quality, data. This uncertainty can be reduced through implementing monitoring programs that contain quality assurance and quality control measures and targeted research projects. Irreducible uncertainty lies outside the realm of ecological prediction; due to the unknown distribution of factors, some of which are outside human control that drive reality (Carpenter 2002). Both of these types of uncertainties should be recognized when managing a natural resource

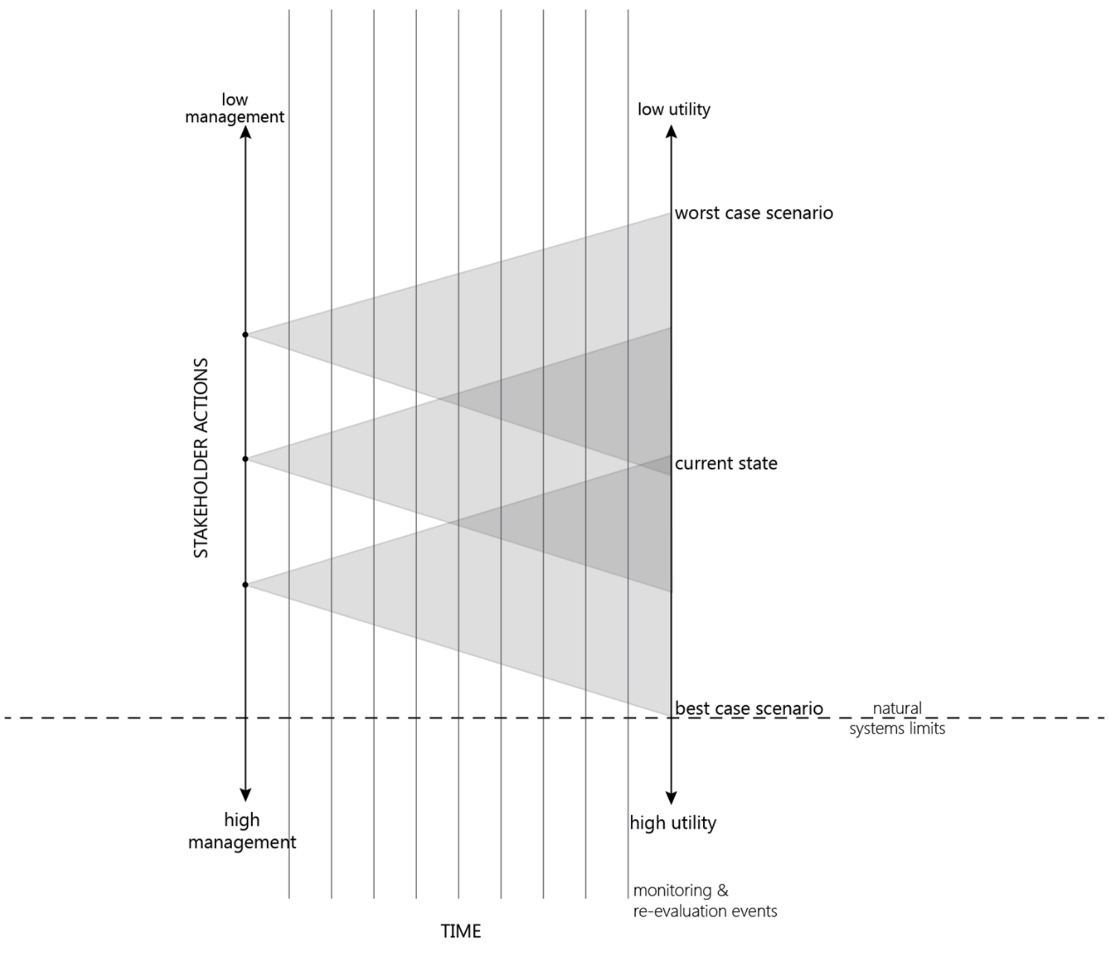


Figure 36. **Theoretical framework for lake management**

Figure 36 represents a theoretical framework for managing natural resources that incorporates scenarios, uncertainty, and aspects of adaptive management. Actions taken at the lower end of the management spectrum (e.g. doing nothing) are more likely to result in the system remaining at its current state or shifting towards the worst case scenario. Actions toward the higher end of the management spectrum (e.g. improving septic systems around the lake) are more likely to result in the system remaining at its current state or shifting towards the best case scenario. However due to system uncertainty the extent and possibly direction of these shifts in the state of the lake is unknown. Though it can be seen that doing something is better than doing nothing. This does not mean that you should do everything; every action taken can have a significant and lasting impact on the lake. As action increases, toward the higher end of the management spectrum, the system reaches its natural limits. The natural limits of the system are defined as the condition of the lake pre-human impact. If management actions are taken past this point the system shifts from a natural – though managed system to a more engineered system. The horizontal axis of this framework represents time. As actions are taken and the system begins to shift monitoring and evaluation of the impacts of actions taken should be done at a regular interval. If the system is not responding well or at all a re-evaluation of the actions should occur. Thought and care should be taken when selecting management strategies. Again, it is important to understand that actions taken can have significant and lasting impacts and the result of these actions is not entirely predictable; and it is also important to make sure that adequate plans for monitoring and evaluation are in place.

Chapter 3: How to get there—management options

This chapter outlines stakeholder actions that can be taken in an attempt to shift the lake towards the best case scenario (BCS) described in the stakeholder surveys.

3.1 BCS Characteristic: Improved Fishery

Management of the fishery on Grass Lake is, for the most part, carried out by New York State. Grass Lake is a public lake, having a state boat launch that is open to the public; thus New York State, through the NYSDEC, has a stake in the lake and will perform fishery monitoring and management activities such as surveys and stocking programs.

The lake association can also impact fishery management activities such as additional stocking programs. The lake associations resources may be better spent dealing with other issues, such as water quality (which directly impacts the fishery), than attempting to directly manage the fishery; as the NYSDEC has the expertise and already established programs to directly manage the fishery on Grass Lake. The lake association can be involved in this management by bringing concerns to the NYSDEC as documented by ongoing monitoring or recognizing the need for changing fishing regulations.

3.2 BCS Characteristic: High Water Quality

Water quality can be improved through a variety of management activities both within the lake itself and within the watershed. Table 6 provides an outline of the current state of several important water quality parameters and how they relate to water quality criteria and guidelines. Grass Lake fails water quality criteria for several water quality parameters; there are many methods for improving water quality to meet these standards. Methods for improving water quality can be separated into watershed management and in-lake management. Many of the current water quality problems within Grass Lake can be attributed to eutrophication – or an over-abundance of nutrients. Phosphorus is the nutrient of main concern within Grass Lake. By directly dealing with phosphorus, both within the watershed and in-lake, many other water quality parameters will be positively impacted.

Table 6. **Standards, Guidelines, and Current Condidtions of water quality parameters within Grass Lake.**

Parameter	Standard/Guideline	Current Condition in Grass Lake
Phosphorus	**Standard**: None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages. **Guideline:** 20 ug/L.	At several times during 2012-2013 sampling Grass Lake failed to meet both the narrative standard and numerical guideline for phosphorus concentrations.
pH	**Standard:** Shall not be less than 6.0 nor more than 9.5 (NYS ECL Sec. 703.3)	The pH standard was exceeded at both the high and low end of the standard range in individual samples. At no time was the entire water column average in violation of the standard.
Dissolved Oxygen	**Standard:** The minimum daily average shall not be less than 5.0 mg/L, and at no time shall the DO concentration be less than 4.0 mg/L (NYS ECL Sec. 703.3)	The dissolved oxygen standard was violated in the hypolimnion of Grass Lake for an extended period of time in late summer 2013.
Nitrogen	**Standard:** None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages.	This standard may have been violated due to presence of algae blooms in late summer 2013- though phosphorus limits growth of algae in Grass Lake

Watershed Management

Watershed management practices for improved water quality typically focus on reducing nutrient inputs into waterbodies. These activities are long term management strategies that attempt to solve the root of the problem; ecological response to these management activities is often slow. Watershed management can include alteration of behaviors to prevent degradation as well as improving or adding infrastructure that can improve water quality.

Option 1: Best Management Practices (BMPs): Agriculture, Forestry, and Construction

What are they?

Best Management Practices attempt to increase or maintain water quality through implementation of specific practices that reduce runoff, and other pollution. There are BMPs for each major activity/land-use that occur within a watershed – namely in the Agricultural, Forestry, and construction fields. The focus of many of these practices is to reduce the movement of soils and sediments (and thus nutrients and other pollutants) into a waterbody. Although, the agricultural best management practices touch on nutrient, herbicide, and pesticide management strategies. These strategies could reduce water column phosphorous and nitrogen concentrations which in turn could improve oxygen and pH within the lake.

Vegetated buffers are a common BMP used in agricultural and forestry operations. The concept is to plant or conserve a vegetated area between streams or other waterbodies and areas of high erosion/ nutrient loading risk such as crop fields, pasture, logging roads and landings. A vegetated buffer can intercept sediment and nutrients before it enters the stream/waterbody and thus serves to help maintain water quality.

Silt fences are often used in logging and construction operations to reduce sediment transport into a waterbody. This is done by the forester or contractor by identifying areas that are at risk for erosion and installing a silt fence to prevent the movement of sediment into the waterbody.

Some other examples of agricultural best management practices include crop rotation, conservation tilling, fertilizer management, manure management and pesticide management. Forestry best management practices can include proper siting and construction of logging roads and landings and winter harvesting. Construction best management practices can include mulching, straw bale barriers, and waste management. These are just a few examples of how steps can be taken to maintain water quality during these ongoing operations.

Is this applicable to Grass Lake?

Yes. BMPs can be implemented throughout any activities that take place within the watershed. Forestry and construction BMPs may be of greater relevance due to the small proportion of agriculture within the watershed. The Grass Lake Association can educate themselves and the public about these best management practices; and ask that association members use contractors that adhere to these practices.

Option 2: Constructed Ponds/Wetlands

What are they?

Detention basins are engineered management strategies that attempt to reduce sediment and nutrients from entering the lake. Detention basins are often connected to streams. The water from the stream enters the basin, where the sediment can drop out of suspension before entering the lake. Water could also be treated with a chemicals, such as alum, while in a detention basin to remove phosphorus. This strategy could reduce water column phosphorous and nitrogen concentrations which in turn could improve oxygen and pH within the lake.

Are these activities applicable to Grass Lake and the Grass Lake Association?

Not easily. The landscape restricts sites where construction of detention basins might be effective. Generally speaking, the low/seasonal flow of the streams in the Grass Lake watershed make these strategies ineffective.

Cost?

Variable. It is difficult to estimate cost for constructed pond/wetlands since they are very site specific.

Option 3: Lakescaping

What is it?

Lakescaping can be defined as landscaping/aquascaping of water front properties with the purpose of improving water quality. A major component of lakescaping is to have a vegetative buffer on the lake shore; lakescaping can also include allowing some growth of aquatic vegetation around your dock. Maintaining natural cover and reducing the amount of impervious surfaces within the watershed could also fall under the lakescaping category. Lakescaping attempts to reduce nutrient loads to the lake through the settling of sediments, and biological uptake of nutrients. This strategy could reduce water column phosphorous and nitrogen concentrations which in turn could improve oxygen and pH within the lake.

Is this applicable to Grass Lake?

Yes. There are many opportunities for lakeside residents to apply lakescaping practices to their properties. Some areas are more suited to lakescaping more than others.

Cost?

Variable. The cost of lakescaping is dependent on the property and on the approach. Some aspects of lakescaping can be done at no monetary cost to the property owner.

Option 4: Improving/Maintaining Septic Systems

What is it?

Septic systems can be a major source of nutrients to a lake. Installation of advanced treatment systems, such as those that remove phosphorous from the effluent, can greatly reduce the phosphorous load to a system. Proper maintenance of existing septic systems can also reduce nutrient loads to the lake. This strategy could reduce water column phosphorous and nitrogen concentrations which in turn could improve oxygen and pH within the lake.

Is this applicable to Grass Lake?

Yes. The soils within the Grass Lake watershed are unsuitable for septic tank absorption fields; thus in order to improve water quality existing septic systems must at least be properly maintained if not replaced with above ground advanced treatment systems.

A septic system inspection program may be organized by the Grass Lake Association to assess the current state of septic systems within the watershed. Most companies that service septic systems can be contracted to inspect septic systems. A dye test can be used by property owners to assess septic system failure. Property owners must enter into inspection programs voluntarily.

Cost?

The cost of properly maintaining a septic system is typically between $100-$300 per household per year; while the cost of replacing a failing or installing an advanced treatment septic system can range from $3,000 - $10,000 per household. If camps are close together some lakeside residents may consider sharing a clustered system with other property owners around them; this can reduce individual costs.

Financial assistance is available for those with failing septic systems who wish to replace their septic systems in the form of low/no interest loans from the Clean Water State Revolving Fund. (EPA 2015).

In Lake

The majority of in-lake management activities are short term in nature – dealing with symptoms of water quality degradation rather than the cause. These activities can allow a lake to meet water quality criteria on a shorter time scale, but they come at a cost and are typically not long term solutions. However, if external factors negatively impacting lake use have already been remediated in lake management strategies can be useful in achieving longterm water quality. The following options could be pursued in an attempt to improve water quality through management actions that take place within the lake itself.

Option 5: Aeration/oxygenation

What is it?

Aeration/oxygenation involves the direct addition of air or pure oxygen to the lake in an attempt to increase oxygen concentrations. This strategy may also improve several other water quality parameters; it may reduce internal phosphorous loading, and subsequently reduce the extent of local pH fluctuations.

Is this applicable to Grass Lake?

Somewhat. Aeration and Oxygenation would likely be successful in increasing oxygen concentrations within Grass Lake. This strategy requires significant upfront costs for the oxygenation/aeration system, as well as long term costs for operation and maintenance of the system. This management strategy works only as long as the system is in operation; when the system goes out of operation the oxygen problem will return, perhaps worse than before. There are also aesthetic costs associated with this strategy. Though this management strategy may improve oxygen concentrations in the short-term it may not currently be feasible for the Grass Lake Association. A permit from the NYSDEC is required to conduct this management strategy.

Cost?

The typical cost for an oxidation/aeration system for $500-$3000 per acre of treated area (Holdren et al. 2001). The treated area on Grass Lake would be the area covered by the hypolimnion (~85 acres); the cost for treating Grass Lake could cost $42,500-$255,000. Much of this cost is for the installation of these systems; though once installed there are operating costs. The operating costs are higher when using pure oxygen as opposed to using air.

Option 6: Artificial Circulation

What is it?

Artificial circulation attempts to increase water column oxygen concentrations through breaking thermodynamic stratification through physical movement of water.

Is this applicable to Grass Lake?

No. This approach has challenges that are similar to that of aeration/oxygenation. Though oxygen concentrations could be improved it would only be while the destratification system is in operation. The system come as a lesser cost than aeration/oxygenation systems; but results are more varied. The cool-water fishery in Grass Lake may be jeopardized if the thermodynamics of the lake were significantly altered. Lakes with high nutrient loads may not respond to this approach; this could be a concern with Grass Lake. There are also aesthetic costs to this approach; it may detract from the natural aesthetic surrounding grass lake. A permit from the NYSDEC is required to conduct this management strategy.

Cost?

The typical cost for an oxidation/aeration system for $300-$7000 per acre of treated area (Holdren et al. 2001). The treated area on Grass Lake would be the area covered by the hypolimnion (~85 acres); the cost for treating Grass Lake could cost $25,000-$595,000. Much of this cost is for the installation of these systems; though once installed there are operating costs. The operating costs for artificial circulation are less than those associated with aeration/oxygenation.

Option 7: Chemical Sediment Treatment

What is it?

Chemical Sediment Treatment attempts to reduce internal loading of phosphorus and other sediment-water reactions that negatively impact water quality. Most sediment chemical treatments aim to oxidize the sediments. Therefore the treated area would be those sediments exposed to prolonged anoxic conditions.

Is this applicable to Grass Lake?

Somewhat. If internal loading were shown to be a major source of water column phosphorus; this strategy would be effective at reducing the rate of loading. However, this method is ineffective if external phosphorus loading has not been dealt with. The cost of chemical sediment treatment also is a significant barrier to its implementation. The longevity of effectiveness of this treatment option is unknown. A permit from the NYSDEC is required to conduct this management strategy.

Cost?

The cost of a typical sediment treatment is around \$1,500-\$12,000 per acre of treated area. If the entire sediment area covered by the hypolimnion on Grass Lake (~85 acres) was treated it could cost \$127,000-\$1,020,000.

Option 8: Nutrient Inactivation

What is it?

Nutrient inactivation attempts to reduce the amount of phosphorous in the water column and reduce the rate of internal loading. It is typically accomplished by addition of an aluminum salt which strips phosphorus from the water column and collects it into a floc that settles on the bottom of the lake. The treated area would be those sediments exposed to prolonged anoxic conditions; in the case of Grass Lake the area underlying the hypolimnion.

Is this applicable to Grass Lake?

No. If internal loading were shown to be a major source of water column phosphorus; this strategy would be effective at reducing the rate of loading. However, this method is ineffective if external phosphorus loading has not been dealt with. The cost of nutrient inactivation may be a significant barrier to implementing this strategy. Results for this management strategy, last between 4-21 years (Cooke et al. 2005); and would need to be reapplied for continued results. A permit from the NYSDEC is required to conduct this management strategy.

Cost?

The cost for a typical nutrient inactivation treatment costs \$800-\$1300 per acre of treated area. If the area underlying the hypolimnion were treated on Grass Lake (~85 acres) one treatment could cost \$68,000-\$110,000.

Option 9: Dilution

What is it?

Dilution attempts to reduce phosphorous in the water column through addition of low nutrient water.

Is this applicable to Grass Lake?

No**.** Water of low nutrient content is not readily available. Import of such water to Grass Lake may bring with it invasive species, unless it is pre-treated. The outlet of Grass Lake is not equipped to handle increased discharge, without the possibility of flood damage downstream. Little is known about the movement of water within Grass Lake; this needs to be determined before this method is applied. This management strategy must be often repeated to maintain results.

Cost?

The cost for a typical dilution treatment is dependent on the availability and locality of water low in nutrients but can cost \$500-\$25,000 per acre. .

3.3 BCS Characteristic: Fewer Weeds

Though often referred to as weeds – aquatic plants are a natural and essential part of the lake ecosystem. They provide habitat for aquatic organisms, seasonally sequester nutrients, and stabilize the substrate. However, they are often viewed as nuisances because they can impede lake uses such as boating and swimming. Actions taken to reduce aquatic plants, if taken too far, may be at odds with actions taken to improve the fishery. Therefore localized management of use impairing aquatic plant assemblages is recommended in order to balance fish habitat with boating and swimming uses.

It should also be noted that decreasing the amount of aquatic vegetation can impact algal dynamics within Grass Lake. It is often found that a large decrease in aquatic vegetation (macrophytes) can lead to an increase in algae within the lake. This is primarily due to the increased availability of nutrients that would have been used by the aquatic vegetation (macrophytes). In some cases a lake can shift from a macrophyte dominated system to a system dominated by algae; the reversal of this shift can be difficult.

Option 10: Sediment Covers

What is it?

Sediment covers, also called benthic barriers, are typically a fabric or similar material that is laid atop the lake bottom to locally deter plant growth.. While sediment covers can locally reduce plant growth they may also locally limit benthic invertebrates, locally decrease oxygen concentration at sediment water interface, and locally limit some fish spawning.

Is this applicable to Grass Lake?

Yes. Sediment covers offer an effective way to control use impairing plant assemblages while maintaining habitat for fish and other wildlife in other parts of the lake. Permits from the NYSDEC may be required before installing sediment covers.

Cost?

Sediment Covers can be constructed by the homeowner at a cost of about $0.41 per square foot; or purchased commercially for around $1.00-$1.25 per square foot (or $30,000-$40,000 per acre). Commercially available sediment covers are usually around 150-250 square feet in size.

Option 11: Hand pulling

What is it?

Handpulling is a method of plant management that involves removal of aquatic vegetation by hand. Handpulling can be selective meaning only certain species are pulled, or that only a certain area is pulled. Hand pulling is only effective in the short term and regular maintenance of hand pulled areas is required to maintain it. To increase the effectiveness and reduce the possibility of spread of nuisance plants all plant fragments should be removed from the waterbody and disposed of in an appropriate location.

Is this applicable to Grass Lake?

Yes. Though hand pulling is inefficient on a large scale it can be effective at locally reducing use impairing plant assembages. A permit from the NYSDEC is not required to perform this management strategy.

Cost?

There is no monetary cost to hand pulling; however it can be very time consuming.

Option 12: Herbicides

What is it?

Herbicides attempt to reduce amount of aquatic vegetation through the application specifically formulated chemicals. There are many different types and formulations of herbicides; table 7 addresses the similarities and differences of several herbicides. Though herbicide applications are effective in dealing with use-impairing plant assemblages, they can impact other systems and uses. Some herbicides can be harmful to non-target plants/animals, temporarily restrict lake use, and may cause a release of nutrients allowing for new growth. Herbicide applications typically need to be done periodically, every 1-5 years, to maintain results.

Table 7. **Overview of common herbicides used in aquatic plant management**

Herbicide	Systemic/ Contact	Effective on…	Selective?	Spot treatment?	Response Time (days)	Exposure Time (days)	Temporary Use Restrictions?	Toxicity to Aquatic Life
2,4-D	Systemic	floating, submersed, emergent	Yes	Yes	5-7	1.5-3	Yes	Variable
Fluridone	Systemic	floating, submersed	Yes	—	30-90	30-60	—	Low
Triclopyr	Systemic	floating ,submersed	Yes	Yes	5-7	0.5-3.5	Yes	Low
Endothall	Contact	floating, submersed, emergent	—	Yes	7-14	0.5-1.5	Yes	Moderate
Glyphosate	Contact	Floating ,emergent only	—	Yes	7-10	NA	—	Low

Is this applicable to Grass Lake?

Somewhat. Localized herbicide treatments can be used to selectively target a species of concern in a designated area. An herbicide treatment requires a permit from the NYSDEC and may require a survey of the existing aquatic plant community.

Cost?

Depending on the herbicide selected a typical application can cost $200-$1500 per acre of treated area.

Option 13: Biomanipulation

What is it?

Biomanipulation attempts to reduce nuisance aquatic vegetation through manipulating the biological community within the lake. Typically through introduction of a species that will eat the nuisance vegetation. Some of these introduced species will target only specific plants, while others are generalists. Table 8 details several species that can be used to control aquatic plants.

Table 8. **Overview of species used in bio-manipulation strategies for aquatic plant management**

Species	Effective on…	Cost	Effective density
Milfoil Weevil (Eurchyopsis lecontei)	Very selective toward Eurasian water-milfoil	~$1200 per 1000 adult weevils	200-300 per square meter
Triploid Grass Carp *(Ctenopharyngodon idella)*	Generalists, have distinct feeding preferences but do not favor Eurasian Water-milfoil.	$13-15 per fish	10-15 fish per acre for medium-high plant density
Watermilfoil Moth (Acentria ephemerella)	High preference for milfoil, but will eat other plants.	Not commercially available	---

Is this applicable to Grass Lake?

No**.** Biomanipulation has not been proven to be effective in managing nuisance aquatic plant assemblages. Many biomanipulation strategies involve the stocking of invertebrates; these types of additions would be ineffective in Grass Lake due to the high abundance of pan fish. Stocking of triploid Grass Carp may be effective in reducing the overall plant population in Grass Lake but it would most likely result in a major decline in native species and an increase in dominance of Eurasian water-milfoil. The required infrastructure is currently not in place for a Triploid Grass Carp stocking program. A permit from the NYSDEC would be needed implement any biomanipulation strategy were to be implemented.

Cost?

See table 8 for costs associated with several different species used in biomanipulation strategies.

Option 14: Dredging

What is it?

Dredging involves the removal of soft sediments and associated rootstock and seedbank from the bottom of the lake. This method is intensive though it has the potential to reduce aquatic plants and improve some water quality parameters. Dredging can be done in a wet or dry environment; to achieve dry dredging conditions the lake must be drained. Wet dredging can be done with water still in the lake, but it can cause extreme turbidity. Dredging does not need to be done lake wide and can be done in localized areas. There is an extensive permitting process associated with dredging; this can be a major obstacle to implementing this strategy.

Is this applicable to Grass Lake?

No. Dry dredging would be impractical, although there is no physical reason why this wet dredging would be ineffective in reducing aquatic vegetation in the shallower areas of the lake. However, regrowth of plants would likely occur soon after the dredging operation is completed – and it would likely be dominated by aggressive nuisance aquatic plants such as Eurasian water-milfoil. The permitting process and the high cost of this management strategy make this inhibitive for the Grass Lake Association to pursue.

Cost?

The cost for a dredging operation is approximately $15,000-$80,000 per acre depending on depth of the dredging and distance to disposal site.

Option 15: Water Level Control

What is it?

Water level control involves intentional manipulations to the water level in attempts to reduce aquatic plant growth. Increasing lake levels in the spring may inhibit growth of some aquatic plants, and increased flow may remove seeds or plant fragments from the lake. Lowering the lake level over winter can expose plants to freezing, drying, or physical damage to some plants.

Is this applicable to Grass Lake?

No. There is not adequate physical infrastructure to properly control water level on Grass Lake. Raising the lake level would likely cause flooding to several lakeside properties, and sufficient water may not be available to raise the lake level enough to make this strategy effective. Lowering the lake level may be unfeasible because there may not be sufficient water to refill the basin in the spring. For these reasons, and the current attitudes regarding lake levels on Grass Lake, make water level control an unrealistic strategy to implement on Grass Lake.

Cost?

If the infrastructure is readily available this management strategy can be implemented with little cost. If infrastructure is not available this strategy can have an initial cost upwards of $25,000, but if the infrastructure is maintained this cost can be a good investment.

Option 16: Dyes and Surface Covers

What is it?

Addition of a dye or installation of a physical surface covers attempt to reduce the amount of aquatic vegetation through reduction of light availability for plant photosynthesis. These methods are not selective and reduce all plant growth in treated areas. Dyes are typically a lake wide application while surface covers can be installed locally. There are aesthetic costs to these strategies as they detract from the "naturalness" of the lakes viewshed. These strategies are not effective at controlling emergent plants. Surface covers can be effective at locally reducing nuisance plant assemblages; though they restrict use of the treated area. Surface covers can also impact thermal dynamics and minimize atmospheric gas exchange in treated areas.

Is this applicable to Grass Lake?

Somewhat. These strategies have been proven effective in reducing nuisance plant assemblages in much smaller systems. Dyes are typically used in systems which do not have an outlet; the presence of an outlet on Grass Lake makes it an unsuitable system for a dye treatment. Surface covers could be installed locally around docks and swimming areas during early spring and removed prior to the beginning of the summer season to locally reduce plant growth. However, the treated areas would be unable to be used while the surface covers are installed.

Cost?

A dye treatment costs $100-$500 per acre of treated area. There are few commercially available surface covers specifically designed for use in lakes; black polyethylene sheeting has been used in the past and can be readily purchased for around $0.50 per square foot ($22,000 per acre)

Option 17: Mechanical Removal

What is it?

Use impairing plant assemblages can be managed through direct mechanical removal of the plants. There are many methods for the mechanical removal of plants they include harvesting, rototilling, hydroraking. Harvesting aquatic plants involves a mechanical harvester which cuts plants at a pre-determined depth, collects them, and deposits the cut fragments on shore. Rototilling and Hydroraking involve a piece of equipment which uses blades/rakes to disturb the plants, roots, and sediments in the treated areas; plant fragments and other debris can be collected and removed from the system. Each of these approaches can be applied locally to use impairing assemblages; though they are not selective within the treated area. All of these methods have the potential to negatively impact aquatic fauna and spread nuisance vegetation through uncollected fragments. Rototilling and Hydroraking may stir up the sediments and create high turbidity, as well as resuspend phosphorous into the water column. A location for the deposition of plant fragments and other debris is a concern related to these strategies; plants classified as invasive species may not to be transported outside the watershed.

Is this applicable to Grass Lake?

Yes. To balance habitat with other lake uses these strategies could be implemented to manage use impairing plant assemblages. However, careful collection of milfoil fragments would be essential to prevent the spread of this nuisance species. A permit from the NYSDEC may be required to carry out any of these mechanical removal strategies in Grass Lake.

Cost?

The cost of leasing a harvester is approximately $150-300 per hour; and a harvester can harvest an acre of plants in 4-8 hours for a total cost of approximately $900-$2700 per acre. A partnership with other lake associations in the region could reduce costs for mechanical removal of aquatic plants.

Invasive Species Management

Management of aquatic invasive species is relevant to maintaining acceptable amounts of aquatic vegetation within the lake. The following are several management activities that can be used in an attempt to prevent the spread of aquatic invasive species

Option 18: Aquatic invasive species education

What is it?

Increasing the knowledge and awareness pertaining to the identification of and threats associated with aquatic invasive species to those who live around and use Grass Lake may help prevent the spread of new invasive species to Grass Lake. Aquatic species education could take the form of putting on AIS identification workshops, distributing pamphlets, or increased signage.

Is this applicable to Grass Lake?

Yes.

Cost?

Cost of implementing educational programs is variable.

Option 19: Aquatic invasive species disposal bins

What is it?

In an addition to increased invasive species signage at the boat launch a bin/container could be constructed/installed to remind lake users to check their boats and trailers for invasive species and give them a space to dispose of them before entering the lake.

Is this applicable to Grass Lake?

Yes. This strategy may be used in addition to the invasive species signage. The effectiveness of this strategy is dependent on lake users.

Cost?

The cost of installing a disposal bin for invasive species at the Grass Lake boat launch would be minimal. The NYSDEC should be contacted before implementing this strategy – as the boat launch is owned and operated by the state of New York.

Option 20: Boat wash

What is it?

Boat washes can be used to physically remove AIS from boats and trailers in an attempt to prevent the spread of AIS.

Is this applicable to Grass Lake?

Somewhat. This approach has been implemented on many larger lakes throughout New York State. It may be cost prohibitive to install, operate, and maintain a boat launch on Grass Lake; though a shared boat launch that was centrally located to many of the lakes in the Indian Lake Region could provide a shared opportunity for AIS management.

Cost?

The cost of installation, operation, and maintenance of a boat launch is variable and dependent on size and availability of infrastructure. A portable boat wash unit costs approximately $20,000. This does not include the cost of operation.

3.4 BCS Characteristic: Improved Swimming

Improved swimming can be achieved through many of the same management activities as those for obtaining high water quality and reducing nuisance aquatic vegetation.

3.5 BCS Characteristic: Less Development

Though development is difficult to control, there are several tools available which can help manage development within the Grass Lake watershed.

Option 21: Landuse/Zoning Regulations

What is it?

Landuse/Zoning regulations attempt to reduce the negative impacts associated with development; and in some instances can reduce development or restrict the types of development that can occur in an area.

Is this applicable to Grass Lake?

Yes. Additional land-use regulations can be advocated for at the town and county levels. There are differences in the landuse regulations between Jefferson and St. Lawrence counties. For example, the town of Theresa, in Jefferson County, has a 'water frontage funneling' regulation (article 6, section 670) that requires a minimum amount of water frontage in order to allow access to any waterbody; this regulation does not exist in the Town of Rossie, St. Lawrence County. The following landuse regulations that could be advocated for in Jefferson/St. Lawrence county are just a few examples, out of many, which could reduce the negative impacts associated with un-managed development.

- Implementation of the site plan review process applied to **all development** within the Grass Lake watershed or within a specified distance from any waterbody.
- Restrictions regarding type, location, and maintenance of residential on-site waste disposal systems.
- Requirement for minimum widths of vegetative buffer strips along lakeshores.
- Restrictions on minimum lot size, maximum house size, percentage of land cleared, and impervious surface coverage
- Implementation of a 'water frontage funneling' regulation in the town of Rossie.

Cost?

There is no monetary cost for an individual or the Grass Lake Association to advocate for increased land use/zoning regulations.

Option 22: Conservation easements

What is it?

Conservation easement can be placed on parcels to inhibit certain types of development.

Is this applicable to Grass Lake?

Yes. All conservation easements differ but many prohibit further development, but still allow property owners to use land for recreational purposes. The Indian River Lakes Conservancy (IRLC) already owns several large tracts of land within the Grass Lake watershed; and is active in the conservation and protection of area lakes. Opportunities exist, in cooperation with the IRLC, to conserve land and lessen the extent of development within the watershed.

Cost?

There is no cost for placing a conservation easement on your property. In fact, property owners can place conservation easements on their land for tax credits

3.6 BCS Characteristic: Reduced algae blooms

Although algae blooms were not highly mentioned among stakeholders concern for the future blue-green algae blooms within recent years require a mention here. Control of algae blooms can only be done proactively through many of the same methods as those to attain higher water quality; especially those aimed at reducing water column phosphorus concentrations. Once a bloom presents itself it is unwise to attempt any management activities. This is especially true in Grass Lake as blooms in 2013 and 2014 were found to contain the algal toxin microcystin. Any management activity that attempts to kill the a toxin containing algae bloom while it is ongoing can increase the concentration of the toxin within the water column; this is because the toxins are contained within the algal cells; if these cells are ruptured by an algaecide these toxins are then released directly into the water column. This increases the risk of contact with these toxins. However there are several pre-emptive management techniques that can be used in an attempt to reduce harmful algae blooms that have not been previously mentioned.

Option 23: Selective Nutrient Addition

What is it?

Manipulation of nutrient ratios may shift algal populations away from toxic bloom forming species to non-toxic species. For example addition of silica and nitrogen may favor an algae community dominated by non-toxic diatoms, rather than having a community dominated by toxin forming blue-green algae.

Is this applicable to Grass Lake?

Somewhat. Theoretically this method can reduce the occurrence of harmful algae blooms. Use as a management practice has been limited and examples of success are limited to non-existent. This method only shifts the species composition of the algal community; it often increases algal biomass, adding additional oxidative stress to the hypolimnion.

Cost?

Since examples of lakes implementing this management practice are limited; there is no cost data available associated with this management practice. This method would need to be applied annually, and thus there would be a recurring costs to maintaining results.

Chapter 4: From scenarios to goals—a plan for action

The next step for the Grass Lake Association is to review the characteristics of the best case scenarios and choose which characteristics to adopt as the Association's goals. In order for goals to be effective they must be specific, measurable, attainable, realistic, and time bound (Doran 1981). The resources of the Grass Lake Association such as budget, manpower, and time are factors that should be taken into consideration when determining which characteristics to pursue as goals. It should also be noted that some goals can be at odds with one another; in cases like these it one should prioritize goals or reassess the goals in order to maintain the desired characteristics of the lake. As suggested in the theory of adaptive management, monitoring the effectiveness of management activities and adjusting strategies based on the results of these monitoring efforts are essential for goals to be met.

4.1 Action Process

The following lays out specific steps that can be taken.

1. Identify specific goals to pursue.
2. Adopt a monitoring program to monitor success of these goals.
3. Select management options to pursue as an organization.
4. Identify possible funding sources for management activities and pursue those funding sources.
5. Develop a plan for implementing the management activity.
6. Implement management activity.
7. Assess success of management activity.
8. Repeat process

4.2 Hypothetical Timeline

The following is a hypothetical timeline meant to illustrate how the process mentioned above might flow.

MAY 2015

1. Grass Lake Association identifies specific goals to pursue.
   - Improve Fishery
     - Increase the abundance of walleye.
   - Improve Water Quality
     - Reduce extent of hypolimnetic oxygen depletion.
     - Reduce average water column phosphorus concentrations to 20 $\mu g\ L^{-1}$.
   - Fewer Weeds
     - Prevent introduction of new invasive species to Grass Lake
     - Reduce dock-side vegetation through hand-pulling
2. Grass Lake Association adopts a monitoring program to track the state of the lake
   - Re-enrolling in CSLAP
   - Starting a monitoring program that utilizes the Lake Association's oxygen meter
3. Grass Lake Association discusses possible management options.

AUGUST 2015

1. Grass Lake Association identifies management options they would like to pursue.
   - Improve Septic Systems around lake
   - Utilize contractors/forestry managers that follow Best Management Practices
   - Lakescaping
   - Walleye stocking program
   - Boat washing station
   - Aquatic Invasive Species education
   - Hand-pulling
   - Benthic Barriers
2. Grass Lake Association forms project oriented committees.
   - For example, a committee whose objective is to research, find funding for, and implement a program to improve septic systems around the lake.
3. Members of Grass Lake association take initiative and use lakescaping practices on their property, implement dockside removal of use-impairing vegetation.

MAY 2016

1. Project oriented committees present the outcome of their work.
2. Grass Lake Association reassesses goals and discuss results of prior years' monitoring.

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