Petition to Vermont Department of Environmental Conversation
for Amended Lake Use Rule for Lake Iroquois

April, 2015

SUPPORTIVE NARRATIVE AND DOCUMENTS

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Information and Support for Amended Lake Iroquois Use Rule

I. Factors Creating Conflicts

The petition for an amended Lake Use Rule for Lake Iroquois is submitted in the context of conflicts that have developed on Lake Iroquois. A survey taken by the Town of Hinesburg in 2014 regarding public uses of Lake Iroquois and Sunset Lake found that over 73% of respondents consider conflicts between uses of the water to be somewhat to very significant challenges facing Lake Iroquois. A copy of this survey is available on the town's website at http://www.hinesburg.org/planning/shoreline-zoning-project/). The survey is also attached. Overall increases in lake usage, boat traffic and congestion on the lake have led to conflicts in three major areas.

Increases in usage, coupled with the limited ability of local and state authorities to provide oversight or a presence on the lake, has compromised public safety. Recent and developing changes in usage have negatively affected water quality and have increased the threats of invasive species.

a. Increase in Traffic

1. *Population Growth*

Lake Iroquois is situated in southern Chittenden County in an area that has witnessed significant population and development growth. Between 2000 and 2010, Vermont's state population increased by 16,914; Chittenden County grew by 9,974, or about 60% of Vermont's growth.

Since 2010, the U.S. Census Bureau estimated that overall state population grew by 405 persons by July 1, 2013 and estimated the growth in Chittenden County to be 2,970 over the same time. Effectively, Vermont's population outside Chittenden County has decreased, while Chittenden County continues steady growth. [Source: U.S. Census Bureau, Vermont Census Counts and Intercensal Population, Vermont Department of Health]

Lake Iroquois lies about half in the town of Williston and half in Hinesburg. These two towns have also seen significant growth and development in recent years and they anticipate further growth. The Town of Williston 2012 Growth Report details comparisons in growth rates: in the 2000-2010 period, overall Vermont growth in population was 2.8%. In Chittenden County it was 6.8%, and in the Town of Williston it was 13.7%.

In its report on Housing Needs Assessment for Hinesburg, a Town of Hinesburg committee (June, 2010) stated on page 5: "Hinesburg is projected to continue growing at twice the rate of Chittenden County and four times the rate of the State of Vermont over the next decade."

Planning for growth in both Williston and Hinesburg has resulted in numerous controversies concerning development and infrastructure issues for the towns.

2. *Development of Lakefront Properties*

Hinesburg was chartered in 1762 and for most of the 253 years since then, Lake Iroquois was known as Hinesburg Pond. The waters of the pond were used in mills that were established as early as the 1790's. A dam was built on the pond's outlet to control the outflow and to store water for the benefit of the downstream mills.

Seasonal camps were first built on Hinesburg Pond as early as 1898 according to some of the camp-owning families. The oldest camps were located on the pond's east shore. Most of the land around the pond was agricultural and undeveloped for residential use throughout the 19th century.

By the 1920's, many seasonal summer camps were located on the shoreline properties. It was not until the mid-20th century that year-round homes were developed, mostly along the west shore. To enhance residential real estate development, Hinesburg Pond was renamed Lake Iroquois. Residents of all the homes on the water have been enthusiastic users of the lake with swimming, boating, and fishing all popular.

Most buildings lots on Lake Iroquois have existing homes. New statewide lakeshore development rules will regulate further development. Current owners of some properties on the lake are seeking permits for new homes and to develop summer homes into year-round residences. Presently, there are 91 residential properties on the lakefront lots on Lake Iroquois.

Prior to 1964, there was no public access to Lake Iroquois. On December 23, 1963, the Vermont Fish and Wildlife Department acquired the land that now includes a driveway, parking area and boat-launching ramp. [Source: Vermont Fish and Wildlife Department].

Later, a tract of land was acquired for public use from the Beebe family. The following statement is included in the Town of Willison website in its section on Lake Iroquois:

> "In 1991-2, with the help of local, state, and federal funds, the land surrounding the beach and fishing access was purchased. After the purchase of the property, a new snack bar and playground were built. More recently, by connecting several of the logging roads and trails, a 1.3 mile hiking trail was cleared, and is open to the public for free, even during Beach Hours. During the off-season, the Beach is a popular fishing spot, especially on spring nights when the Bullheads are biting."

This described public land is at the north end of the lake and now includes the beach area maintained by the Lake Iroquois Recreation District, a public governmental entity.

3. *Boats on the Lake*

There is no official data about boat usage on Lake Iroquois. The Lake Iroquois Association ("LIA"), a tax-exempt water conservation organization, qualified under Section 501(c)(3) of the Internal Revenue Code, has maintained a boat greeter program at the lake's Fish and Wildlife public fishing access since 2009. During the six years of the LIA Greeter Program, an average of 1087 boats was inspected annually. In 2014, the number inspected was 1238. The LIA Greeter Program operates only on weekends (Saturday and Sunday) from Memorial Day to Labor Day, or about 30 days each summer season. On an average weekend day during the summer, as many as 30 or more boats come into Lake Iroquois. The LIA Greeter Program operates for most, but not all, of Saturdays and Sundays. Public use is obviously greater on sunny warm days than on rainy cold days.

Most of the vessels accessing Lake Iroquois are not power boats. In 2014, the LIA Greeter Program data on the 1,238 boats shows that 482 of these were power boats; the rest of the vessels were kayaks (490), canoes (191), paddleboards (53), and other non-powered vessels such as rafts or tubes (22). [Data available from LIA. *See* <u>www.lakeiroquois.org</u> and the Lake Iroquois – State of the Lake 2014 report, pp. 31-33, published by LIA and attached to this petition].

Numerous studies of the effect of power boats on lakes, ponds and rivers have found significant impacts on water clarity, water quality, shoreline erosion, and the introduction and spread of invasive species. Many of these studies and their findings are summarized in a paper published jointly by the Wisconsin Department of Natural Resources and the University of Wisconsin – Madison, Water Chemistry Program, entitled, *The Effects of Motorized Watercraft on Aquatic Ecosystems* by Timothy Asplund, Chief, Water Resources Monitoring Section, Wisconsin Department of Natural Resources (copy attached). These studies document the effects of power boats on lake sediments, water pollution and shoreline erosion that are exacerbated as boat sizes increase.

A primary tool to minimize these negative impacts is to have "no wake" zones and to reduce the frequency of concentrated boating activities. The Vermont "no wake" zone, applied to all vessels operating within 200 feet of a shoreline, dock, mooring, other vessels and swimmers, is helpful in both reducing these negative impacts and in reducing pubic conflicts when multiple vessels, swimmers and other users are in close proximity or are on small bodies of water.

b. <u>Public Safety</u>

1. *2014 Boating Accident*

On June 28, 2014, a power boater was pulling children around the lake on a tube, an activity common on the lake. That same day, a swimmer was swimming along the lakeshore. The power boater ran over the swimmer causing serious, life-threatening injuries. Fortunately for the individuals involved, the swimmer was not killed or permanently disabled.

If the boater in this accident had been following state boating rules, the accident never would have occurred. The accident shocked the lake community and was a significant news item around the community and in the Burlington area in 2014. Several lake residents commented that the accident was inevitable because of the increasing congestion on the lake and the general disregard of state boating rules.

2. *Need for Self-Policing*

There are over 800 lakes and ponds in the State of Vermont. There are 176 public fishing (boat) access areas on Vermont waters maintained by the Department of Fish and Wildlife. Boating on Vermont lakes and ponds is regulated by state law and is under the jurisdiction of the Vermont State Police.

The Marine division of the State Police has 23 total boats at their disposal to police Vermont waters. Many of these boats are kept in Lake Champlain through the entirety of each boating season. With the most significant issues occurring on Vermont's nearby and largest bodies of water (Lake Champlain, 279,067 acres; Lake Menphremagog, 5966 acres; Lake Bomoseen, 2,360 acres; Lake Dunmore, 985 acres; Waterbury Reservoir, 859 acres), the State Police have little time to visit or police Lake Iroquois and other small Vermont lakes and ponds. After the June 2014 accident in the lake, the State Police visited Lake Iroquois to survey the lake for several hours one day. It was the first and only time many residents had ever seen State Police boats in the lake.

Because of the limitations of personnel, equipment and time, the public relies on self-policing by the many lake residents and visitors. In a small lake with virtually no rules or limits to deal with the increasing congestion, self-policing is a difficult ideal when all users want the opportunity to pursue their recreations. For the large boats, this includes the opportunity to open the throttle and enjoy the speed and freedom of their vessels running on a plane over open water.

3. *Boater Misconceptions about Vermont's "No Wake" Rules*

Following the June 2014 boating accident on Lake Iroquois, the State's attorney was prosecuting a criminal case against the power boater who caused the accident. In the course of this prosecution, the State's attorney contacted the victim to inquire about her opinion on possible resolutions to the criminal case. The victim suggested that a set of small safety buoys be placed in Lake Iroquois to provide some marking of the 200 foot distance from the shore which forms part of the "no wake" zone on all Vermont lakes and ponds. In reaction to this discussion between the victim and the State's attorney, one of the power boat owners on Lake Iroquois asserted his opinion in an e-mail to the victim's family, stating:

> "I just wanted to let you know I am not in favor of [installing safety buoys] and would not recommend or support installing buoys. The lake is congested enough and I believe I am correct that a boat pulling a skier could ride the 200' line down the lake with the skier extending 75' into the 200' area. My opinion is all swimmers should have a boat with them at all times if they are in the 200' zone or not...I would rather promote more inspections from the State of Vermont on the lake and I would be in favor of limiting the number of boaters trailering into our lake..."

It is correct that a water skier may approach the shore, another boat or a swimmer up to 100 feet (*see* 23 V.S.A. 3315(c)). The boater's description of the 200 foot no wake rule, however, typifies most boaters' misunderstanding and disregard of the rule.

Long-standing and traditional boating rules and etiquette provide the right-of-way in an order that grants right-of-way to the more vulnerable and less maneuverable person or vessel. Thus, swimmers have the right-of-way over all others. In order, the right-of-way in Vermont lakes and ponds belongs to swimmers, paddle boaters (kayaks, canoes, rowboats, etc.), sailboats, and lastly power boats.

The Vermont "no wake" law requires a power boater to operate his or her vessel *at a speed at which the vessel does not produce a wake*, not to exceed five miles per hour. For many of the heavier fiberglass inboard/outboard boats, this means a speed of <u>less</u> than 5 miles per hour because the boat's displacement causes a wake at 5 miles per hour. Furthermore, the "no wake zone" is not limited to 200 feet from the shore. There is no *fixed* "200 foot area" in any lake or pond unless there is no swimmer or vessel in the water. The "no wake zone" extends 200 feet from every shoreline, swimmer, canoe, rowboat or other vessel, an anchored or moored vessel with a person on board, or an anchorage or dock. If a swimmer is in Lake Iroquois at a distance of 75 feet from shore, the "200 foot line" is 200 feet from that swimmer, and 275 feet from the shore at that point. If there is a 30 foot dock at a lakefront property, the 200 foot zone extends 230 feet from the shore at that point.

Public safety is compromised and conflicts between lake users are exacerbated as a result of (i) the increasing number of swimmers and boats on Lake Iroquois, (ii) the misunderstanding of many power boaters of what "no wake speed" means, (iii) the extent of the ever-changing 200 foot zone, (iv) the lack of public policing, and (v) intentional disregard of rules in pursuit of recreational speed and excitement.

c. <u>Water Quality</u>

1. *State of the Lake*

The Lake Iroquois Association is a conservation organization whose mission is to improve the water quality of Lake Iroquois. In 2014, LIA published *Lake Iroquois – State of the Lake 2014* ("SOTL") containing data on Lake Iroquois' water quality. A copy of the SOTL report is attached.

Lake Iroquois is a eutrophic lake. It is the largest body of water in the LaPlatte River watershed which flows into Lake Champlain at Shelburne Bay. Of the 49 inland lakes in the Vermont Lay Monitoring Program, Lake Iroquois ranks the third highest in levels of phosphorous and chlorophyll concentrations, and it ranks 13th from the lowest in clarity. (*See* SOTL, p. 25). According to the LIA report, "Lake Iroquois is a prime example of a lake that is experiencing anthropogenic eutrophication. The water quality of Lake Iroquois has been statistically highly variable over the last forty five years, but shows accelerated eutrophication due to excessive storm water runoff, shoreland erosion and other human activity." (SOTL, p. 3).

Large power boats are not the sole factor in the eutrophication of Lake Iroquois, but they are a significant contributing factor.

2. *Spread of Eurasian Watermilfoil*

The invasion of Eurasian Watermilfoil (EWM) has distressed many users of Lake Iroquois. In a report commissioned by LIA and published in early 2015 ("Aquatic Plant Survey," copy attached), a professional survey on page 3 stated, "Eurasian milfoil was found to cover approximately 70 acres of Lake Iroquois at high densities."

LIA established a boat greeter program at the public access in 2009 to address the problem of spreading invasive species from lake to lake. It is well-known that EWM, as well as other invasive species, are spread primarily by the movement of boats. Once established in Lake Iroquois, power boats have been the prime factor in spreading EWM all around the lake. The propellers of boat motors fragment the EWM plants, and each fragment will migrate around the lake, develop roots, and re-establish itself. This problem is illustrated by the attached photos taken in 2014 which show the masses of EWM fragments that appear in Lake Iroquois following each day of power boating. The EWM invasion has reached a crisis stage.

3. *Zebra Mussels and Other Invasive Transportation*

There is a heightened awareness of the problem of invasive species in Vermont. Boat greeter programs have been encouraged around the state. DEC officials are concerned about the potential spread of zebra mussels, water chestnut and other species. These are all spread principally by the movement of boats between bodies of water. Notably, in August, 2014, a zebra mussel was identified on a boat trailer exiting Lake Iroquois. It is not known if there is a population of zebra mussels in the lake today.

The risk of spreading invasive species increases with the size of the boats and trailers transported between lakes. Small vessels with smooth hulls and no motors such as paddleboards, kayaks, canoes and windsurfers pose a small risk of transporting unwanted plants and animals. With larger boats and larger trailers, there are increased areas for plants and mussels to attach, and the larger boats are more likely to transport water from one lake to another.

The problem of transporting zebra mussel veligers is especially acute with wake boats. Wake boats were "invented" with the inception of the wake surfing movement in 1995 and the development of the first wake surfing boats. (See attached information sheets from Centurion Boats, reputed to be the first wake boats). A typical wake boat has two water ballast tanks that can take on around 1500 pounds or more of lake water into each ballast tank, thus increasing the displacement of the vessel from around 3000 pounds to 6000 pounds. These boats are powered by 300-500 or more horsepower – enough to move the laden boat at a slow, steady speed while producing an enormous wake that is large enough to surf on. Several wake boats "reside" on Lake Iroquois and are owned by residents with lakefront property. Wake boats can be readily trailered, however, and are brought in Lake Iroquois at the public access.

The risk of spreading zebra mussels by wake boats in particular has been scientifically studied. A scientific paper published in 2013 entitled "*Quagga and zebra mussel risk via veliger transfer by overland boats*" is attached. In this published study, the abstract states:

> "Invasive quagga and zebra mussels pose a great threat to US waters. Recreational boats constitute a significant risk for spreading the organisms. Recreational boats circulate large amounts of raw water when in use, and if not drained and not dried correctly can transport many mussel larvae, called veligers."

Zebra mussel populations are found close to Lake Iroquois in Lake Champlain and Lake Bomoseen. The proposed rule will significantly reduce the risk of introducing zebra mussels into Lake Iroquois because visiting wake boats with their large engines and ballast tanks would be prohibited from launching into the lake.

4. *Shoreline Erosion*

A second major water quality problem exacerbated by the size of boats is shoreline erosion. Natural wave action on a body of water like Lake Iroquois is mild. Before the advent of human development on Hinesburg Pond, the pond's shoreline was relatively unaffected by erosion. Milling interests dammed the lake's outlet in the 19th century and thus periodically raised the water level causing some shoreline erosion. By the time power boat users covertly and illegally disabled the dam in the 1960's by cementing it at its highest position, the mills were no longer in use. With the water level now at an artificially high level, boat traffic and the resulting wave action increased shoreline erosion. (See attached photos)

The importance of maintaining natural shoreline buffers is highlighted by Vermont's Shoreline Protection Act which adopts statewide standards relating to shoreline development. Lake Iroquois should benefit from this legislation over time.

The proposed rule limiting large power boats in the lake will help reduce shoreline erosion by reducing the number of large wave-generating vessels in the lake.

II. Addressing Conflicts in Lake Uses

a. <u>Need for Boating Development Plan</u>

1. *"Open Throttle" Area*

Listed at 243 acres, the actual area of Lake Iroquois that can be considered as surface area where a power boat can open its throttle is much smaller.

As evidenced by the Public Information Chart (*see* SOTL, p. 4) and the milfoil infestation chart (Aquatic Plant Survey, p. 4), there is an area of 64 acres at the north end of the lake which is less than 10 feet in depth, fully and densely filled with weeds and wholly unsuitable for power boating, sailing and swimming. Long before the lake was invaded by milfoil, this shallow flooded northern area was marked as a "weed bed" on the 1972 Public Information Chart. The area of the perimeter of the rest of the lake out 200' from shore and the 200' area around the lake's two islands total approximately 62 acres. This leaves a maximum total of 117 acres of water in which a power boat can open its throttle and make a wake, assuming there are no other boats or swimmers in the water.

A single kayak, other vessel or a swimmer creates its own "no wake" zone of up to 2.9 acres. If the vessel or swimmer is close to shore, the reduction of the overall open throttle area would be less than 2.9 acres. Out in the middle of the lake, however, a vessel reduces the open throttle area by a full, moving, 2.9 acre area. On a hot, sunny summer day, there might easily be one or two dozen boats on the lake and an equal number of swimmers. On those days (*see* attached photos from the lake in 2014), it is possible that the open-throttle area on the lake is very small or even nonexistent.

2. *Effect of Increased Water Usages*

As evidenced in the e-mail from one lake resident, some resident boaters are concerned about the increasing congestion in Lake Iroquois. With the current and projected population growth of Williston, Hinesburg, metro Burlington and Chittenden County, Lake Iroquois will witness increased usage.

The continued growth of the sports of kayaking and stand-up paddle boarding will bring increasing numbers of paddlers to the lake. Bass fishing in Lake Iroquois is excellent and fishermen are seen frequently on the lake. Tubing, waterskiing, and the use of power boats continue as frequent uses. Swimming remains as popular as ever with children and adults.

3. *Balancing of Traditional Uses and Full Access for Public Recreation*

The idea of limiting the number of users coming into Lake Iroquois is not only impractical, it is an anathema to the basic concept of public ownership of Vermont's lakes and ponds. To be sure, the proposed rule will limit access by some boats. At the same time, having a smaller number of large power boats on the lake will open up opportunities for use by the increasing number of paddlers, and it will improve safety for swimmers.

4. *Effect of Rule Change on Lakeshore Owners*

The proposed rule will allow all current lakeshore owners to maintain their current power boats of any size. While plans for the acquisition of newer or larger power boats by lake residents would be altered by the proposed rule, the vast majority of the large power boats will remain on Lake Iroquois for years to come.

5. *Importance of Phase-In for Changes*

The proposed rule change for Lake Iroquois is significant. The lake has had virtually no boating rules, other than statewide rules, since Vermonters first came to Hinesburg Pond. By grandfathering in all the boats currently registered by lakeshore owners, lake residents will be impacted at a minimal level. Over time, the proposed rule will change the nature of boats kept on the lake by residents. Boats in Vermont are only used for about five or six months each year. A recreational boat can be maintained for decades. As a result, the grandfather provision in this proposed rule will allow excepted large power boats to remain on Lake Iroquois for many years to come as the new rule phases in.

b. <u>Focus of Planning on Appropriate Boat Size</u>

1. *Available Venues for Large Power Boats*

With the growth of the nearby population, it is reasonable to project that nearby public users will have more large power boats as well as more kayaks, paddleboards, and other water craft. There will also be more swimmers. A restriction of large power boats on Lake Iroquois imposes a meaningful reduction of recreational opportunities for large power boats.

Recreational opportunities for large power boats are limited by the state-wide rules prohibiting wakes within 200 feet of other boats and swimmers. In a small lake like

Lake Iroquois, the opportunity to open a boat throttle on a warm, sunny day can be limited considerably. To do so safely can be difficult.

Fortunately for large power boaters, there are good nearly boating venues that are far better suited to larger boats than Lake Iroquois. Less than 20 miles from Lake Iroquois, there are 8 boat launches on Lake Champlain and 2 launches on the Waterbury Reservoir. The Waterbury Reservoir, at 859 acres, is better suited to large power boats and has two maintained water ski courses for water skiing enthusiasts. Lake Champlain is well suited for large power boats and has many interesting areas and attractions suited to large power boats.

Trailered boats can be launched at:

LAKE CHAMPLAIN & Watershed	DISTANCE IN MILES FROM LAKE IROQUOIS
Malletts Bay	14.8
Winooski River	14.8
Downtown Burlington	10.4
Shelburne Bay	7.8
Converse Bay	12.0
Lewis Creek	12.4
South Slang Cr.	13.6
Otter Creek	15.8
WATERBURY RESERVOIR	
2 launch areas	15.6; 17.8

2. *Other Venues for Powered Vessels*

Power boats of any size are permitted on Shelburne Pond (452 acres; 4.0 miles from Lake Iroquois), Cedar Lake/Monkton Pond (123 acres; 8.8 miles away), and Winona Lake/Bristol Pond (248 acres; 13.4 miles away). These bodies of water, like Lake Iroquois, are more suited to smaller power boats and paddlers. They provide good boating opportunities to smaller boats that may find the size and conditions on Lake Champlain to be somewhat intimidating. A 14 foot fishing boat with a 15 hp outboard will often find the waters of Lake Champlain inappropriate for the size of the vessel. A boat of this size will normally find the waters of Lake Iroquois or these other inland ponds appropriate and suitable for the safe operation of the boat.

3. *Fishing Access*

Fishing is a popular outdoor sport in Vermont, and Lake Iroquois has excellent bass and other fishing. In the last decade or more, a design of boats has been developed for sport fishermen for use on large lakes. These boats typically have a large outboard engine that can be 200 hp or more along with a small electric engine for use once the boat has arrived at a desired fishing spot. Boats like this are seen on Lake Iroquois and would be restricted under the proposed rule. Boats of this nature are designed to be launched on a large body of water like Lake Champlain where a fishing spot could be miles away from the launch site. Lake Iroquois is about 1.3 miles in length.

Among the approximately 30,000 powered boats registered in Vermont, there are hundreds, if not thousands, of small fishing boats that will have access to Lake Iroquois under the proposed rule. These smaller fishing boats are appropriate on Lake Iroquois.

III. Effects of Proposed Rule Change

a. Grandfather Element

The "grandfather" element of the proposed rule will permit the continuing registration of all residents' large boats and is an important part of the proposal for several reasons:

- It respects the investments in recreational equipment and resources by resident boat owners for as long as they live on the lake.
- It allows increased and safer access by smaller power boats, paddle boats and boards, sail boats and boards, and swimmers.
- It allows a long transitional period within a plan to develop a more appropriate mix of traditional uses on Lake Iroquois.

b. Consistency and Growth for All Appropriate and Traditional Uses

The proposed rule will not eliminate any of the traditional uses on Lake Iroquois.

- The only effect on swimming, kayaks, paddleboards, canoes, rowboats, sculls, sailboats, windsurfers, and small power boats is that all these activities will be a little safer with a lower proportion of large power boats on the lake.
- Some people who enjoy fishing and have only a large trailered fishing boat would no longer have access to the lake in those large boats. Fishing from the shore, from smaller power boats and from kayaks and canoes would not be affected at all.
- Some people who enjoy waterskiing, wake-boarding, and tubing behind large boats would no longer have access to the lake in those large boats. As noted, there are about 28 large power boats that would be excepted from the general rule. These include several wake boats, inboard and stern drive ski boats, and runabouts with larger outboard engines. The Vermont waterskiing community is social and well organized. The Green Mountain Water Skiers organization is dedicated to furthering the sport of waterskiing and everyone's enjoyment of it. Because of these social contacts and the presence of numerous ski boats on the lake, many non-residents of Lake Iroquois will have water skiing access to the lake through their friends in the waterskiing

community. This will continue for upwards of 20 years as these larger boats remain on the lake.

Many adults who have enjoyed waterskiing most of their lives started out skiing on two skis behind a small aluminum boat with 20, 25 and even 18 hp engines. Skiing by young people like this can continue without restriction. Lake Iroquois' water ski course is used primarily by lake residents, and this use will continue. Young water skiers who are not residents on the lake will be able to ski behind smaller boats or with friends on the lake.

Similar to skiing, tubing can be done behind a power boat with a 15 or 25 hp engine. Although tubing is primarily done by or for young people, adults could have fun tubing behind a small power boat with a 25 hp engine.

Wake boarding can only be done behind a large boat. As indicated, this sport began around 1995 and uses boats with engines ranging from 300 to 500 and more horsepower. A number of wake boats will remain on the lake for many years because they will be included in the grandfather exception. Over time, wakeboarding would eventually be an unavailable sport on Lake Iroquois.

c. Effect on Current Users

The proposed rule will limit the number of large boats on Lake Iroquois. Because of the grandfather provision, large boats will remain on Lake Iroquois for many years to come. The mix of boats on the lake, however, will be more appropriate by allowing for the anticipated increase of kayaks, paddleboards, and other non-power boats and swimmers. Eventually, as the transition period of the new rule comes to an end, the future development of Lake Iroquois will include a mix of all the traditional uses with swimming, canoeing, kayaking, sailing, youth waterskiing, tubing and the newer sport of paddle boarding.

The sport of wake boarding started around 1995. The attached promotion from Centurion Boats provides some background of the sport of wake boarding. Wake boarding will not end on Lake Iroquois with the proposed rule because there are several wake boats that have been registered by residents of the lake. At the end of the extended transition period, when the last wake boat leaves Lake Iroquois, there would be no more wake boarding on the lake.

Wake boarding is inappropriate as part of a long-term development plan for Lake Iroquois. With their ballast tanks filled with lake water, wake boats can displace over 6000 lbs and have very powerful engines. These boats can create huge waves that have damaged Lake Iroquois shorelines with increased erosion. The attached scientific article on transportation of zebra and quagga mussels by wake boats illustrates the heightened risk that wake boats pose for movement of invasive species.

Fishing boats with large engines, designed for outings on large lakes, would not be permitted to trailer into Lake Iroquois under the proposed rule. Sport fishermen who own these large boats could still fish Lake Iroquois out of smaller power boats, kayaks, or paddle boats or from shore.

d. Use of Horsepower as a Limiting Factor

The use of horsepower as a limiting factor in the proposed rule is clear and unambiguous in its application. A 10 hp limit is already in use for two Vermont lakes – Beebe Pond and Little Hosmer Pond. 25 hp is proposed because youth waterskiing as well as tubing can be easily pursued behind boats with engines up to 25 hp. This is true of all the other traditional water and boating uses that predate the statewide law changes in 1992.

After an extended transition period because of the grandfather provisions, Lake Iroquois would remain an open and accessible venue for small power boats and all paddle sports, sailing, windsurfing, and swimming. With the anticipated growth in the surrounding communities, the shift in boating on Lake Iroquois will be appropriate for the size of the lake and the anticipated growth in recreational uses among citizens.

e. Effect on Water Quality and Safety

With the third highest phosphorous level among the measured inland lakes in Vermont, the Eurasian watermilfoil problem in Lake Iroquois is at a crisis stage. There is no doubt that trailered power boats and the use of power boats in the lake have brought this problem to Lake Iroquois and accelerated its spread throughout the lake.

A limit in the number of large power boats on the lake will not eliminate the action of boat propellers churning and slicing up milfoil plants and facilitating their propagation around the lake. Huge mats of floating milfoil (see attached photos) may continue to be found on Lake Iroquois, but limiting the number of large power boats will reduce this problem.

Similarly, a limit on large boats will not eliminate the risk of moving invasive species both into and out of the lake. The trailers of small power boats are less complex than those used for large power boats and are less likely to harbor and transport invasive species during launching and retrievals. Paddle boats and boards are usually brought in on car tops. These boards are far less likely to be transporting invasive species.

Fewer large boats will mean less shoreline erosion caused by boat wave action. Studies of small lake water quality and recent legislation have emphasized the importance of maintaining healthy, buffered shoreline areas as critical elements in water quality. If Lake Iroquois is to see improvements in water quality, a reduction in shoreline erosion will be an important part of achieving that objective. A cleaner Lake Iroquois means cleaner water will flow into Lake Champlain.

Finally, a reduction in the proportion of large power boats on Lake Iroquois will make the lake safer for all users. Large power boats are designed to cruise at high speeds. Almost anyone who enjoys boating can attest to the joy and exhilaration of opening up the throttle on a power boat with a big engine. Lake Iroquois is simply too small a body of water to have increasing numbers of large power boats on the lake. If half of the "resident" large boats went out on the lake on a summer's day, those boats alone would create a constantly moving no wake area exceeding 40 acres on the lake that already has a small "open throttle" area of only 117 acres. With the no wake zone surrounding each vessel and swimmer, having only a few moving boats on the lake reduces substantially the area that power boats can operate safely and legally on the lake.

Adoption of the proposed rule will help address increasing congestion on the lake, focus attention of power boat operators on their responsibilities, and will reduce the level of conflict between power boaters and other lake users. The proposed rule will improve water quality and will be an aid in avoiding any future human tragedy on the lake.

PAGE:

1. What do you enjoy most about Lake Iroquois and/or Sunset Lake? Check all that apply.

	Response Percent	Response Count
Scenic view	**70.4%**	**150**
Wildlife viewing/habitat	44.1%	94
Swimming	60.1%	128
Residential/Camp Use	28.2%	60
Fishing	28.6%	61
Water Skiing	11.3%	24
Boating (e.g., sailing, motorboat)	26.8%	57
Paddling (e.g., canoe, kayak, etc.)	60.1%	128
Ice skating	22.1%	47
Other (please specify) Show replies	15.5%	33
	answered question	213
	skipped question	5

2. How often do you encounter/enjoy Lake Iroquois, Sunset Lake, or the shoreline areas around these lakes? Please consider both direct (e.g., residence, boating, etc.) and indirect (e.g., take in the view) experience.

	Response Percent	Response Count
250+ times per year	**28.0%**	**60**
53-250 times per year	23.8%	51
13-52 times per year	22.4%	48
	answered question	214
	skipped question	4

2. How often do you encounter/enjoy Lake Iroquois, Sunset Lake, or the shoreline areas around these lakes? Please consider both direct (e.g., residence, boating, etc.) and indirect (e.g., take in the view) experience.

4-12 times per year	14.0%	30
1-3 times per year	7.9%	17
Less than once per year	2.3%	5
Never	1.4%	3
	answered question	**214**
	skipped question	**4**

3. What do you see as the most significant challenges facing Lake Iroquois, Sunset Lake, and the surrounding area?

	Very Significant	Significant	Somewhat Significant	Not Significant	No Opinion	Rating Average	Rating Count
General water quality	**60.0% (123)**	29.3% (60)	8.3% (17)	1.5% (3)	1.0% (2)	1.00	205
Invasive species (e.g., milfoil, zebra mussels, etc.)	**74.8% (154)**	18.0% (37)	5.3% (11)	0.0% (0)	1.9% (4)	1.00	206
Clearing of shoreline trees and vegetation	20.9% (40)	**30.9% (59)**	23.0% (44)	20.4% (39)	4.7% (9)	1.00	191
Stormwater runoff	**43.5% (87)**	29.5% (59)	18.0% (36)	5.0% (10)	4.0% (8)	1.00	200
Malfunctioning or non-existent septic systems	**51.0% (101)**	26.8% (53)	13.6% (27)	3.0% (6)	5.6% (11)	1.00	198
Conflicts between uses (e.g., fishing, swimming, water skiing, residential, wildlife habitat, etc.)	20.1% (40)	26.1% (52)	**27.1% (54)**	20.6% (41)	6.0% (12)	1.00	199
Development - e.g., new buildings, additions, etc.	25.4% (51)	26.9% (54)	**27.9% (56)**	15.9% (32)	4.0% (8)	1.00	201
Impacts to scenic views	18.6% (36)	**29.9% (58)**	**29.9% (58)**	17.5% (34)	4.1% (8)	1.00	194

18

answered question	**211**
skipped question	**7**

3. What do you see as the most significant challenges facing Lake Iroquois, Sunset Lake, and the surrounding area?

Other (please specify) Show replies	
answered question	211
skipped question	7

PAGE:

4. How far do you think new structures should be set back from the shoreline in order to help protect the lakes? FYI - Hinesburg's current zoning requires that new structures be set back at least 75 feet from the shoreline. Williston's zoning requires a 150' setback.

	Response Percent	Response Count
50 feet (or less)	1.4%	3
75 feet	27.1%	56
100 feet	13.0%	27
150 feet	**30.9%**	**64**
200 feet	9.2%	19
250 feet (or more)	7.7%	16
not sure	10.6%	22
	answered question	**207**
	skipped question	**11**

5. The current shoreline zoning district and its special protections extend 600 feet from the shoreline of Lake Iroquois and Sunset Lake. For example, only half as much of a lot can be covered with buildings, parking, driveways in the shoreline district compared to the surrounding areas/districts in Hinesburg. Do you think the shoreline district should be expanded to include the larger watershed - i.e., all areas that drain to these lakes? See map.

answered question	**205**
skipped question	**13**

5. The current shoreline zoning district and its special protections extend 600 feet from the shoreline of Lake Iroquois and Sunset Lake. For example, only half as much of a lot can be covered with buildings, parking, driveways in the shoreline district compared to the surrounding areas/districts in Hinesburg. Do you think the shoreline district should be expanded to include the larger watershed - i.e., all areas that drain to these lakes? See map.

	Response Percent	Response Count
yes	**45.4%**	**93**
no	23.4%	48
not sure	31.2%	64
	answered question	**205**
	skipped question	**13**

PAGE:

6. Where is your principal place of residence?

	Response Percent	Response Count
Hinesburg	**90.8%**	**187**
Williston	2.4%	5
St. George	1.5%	3
Richmond	0.5%	1
Other (please specify - town, state) Show replies	4.9%	10
	answered question	**206**
	skipped question	**12**

7. Where in Hinesburg do you live or own seasonal-use property? See map for reference. If you have property on/around the lakes, and live elsewhere in in Hinesburg, please answer based on your lake property.

	Response Percent	Response Count
On/around Lake Iroquois	**26.0%**	**53**
On/around Sunset Lake	10.3%	21
Rural Residential Area	22.5%	46
Village Growth Area	10.3%	21
Rural Forest Area	15.2%	31
Rural Agicultural Area	12.3%	25
Industrial Area	1.5%	3
Other (please specify) Show replies	2.0%	4
	answered question	**204**
	skipped question	**14**

PAGE:

8. Do you feel most commercial uses should be prohibited in the shoreline district? Commercial use means non-residential - e.g., retail shop, school, office building, large home occupations (i.e., business occupies more than 1,000 square feet). Note - small home occupations will always be possible per State law.

	Response Percent	Response Count
yes	**81.6%**	**164**
no	10.9%	22
not sure	7.5%	15
	answered question	**201**
	skipped question	**17**

9. What do you think about the amount of development around the lakes?

	Response Percent	Response Count
could accommodate more	7.9%	16
just about right	**59.6%**	**121**
too much	25.6%	52
not sure	6.9%	14
	answered question	**203**
	skipped question	**15**

10. In Hinesburg's village area, zoning requires the preservation of trees and shrubs within stream buffer areas in order to reduce the impact of stormwater runoff, prevent soil erosion, protect wildlife and fish habitat, and maintain water quality. Earlier this year, the Vermont Legislature discussed a bill that would prohibit the removal of trees and shrubs within a certain distance of the shoreline of lakes and ponds. Do you feel trees and shrubs in close proximity to the shoreline should be protected from removal?

	Response Percent	Response Count
yes	**67.0%**	**136**
no	18.2%	37
not sure	14.8%	30
	answered question	**203**
	skipped question	**15**

11. Some homes and camps were built close to the shoreline prior to zoning setback requirements. Over time many of these existing, non-complying properties seek to enlarge the house or camp - e.g., new deck, bigger living space, etc. Should allowances for expansions to non-complying structures in shoreline setback areas be tied to improvements to help lake water quality - e.g., vegetation plantings, stormwater treatment, etc.?

answered question	**202**
skipped question	**16**

11. Some homes and camps were built close to the shoreline prior to zoning setback requirements. Over time many of these existing, non-complying properties seek to enlarge the house or camp - e.g., new deck, bigger living space, etc. Should allowances for expansions to non-complying structures in shoreline setback areas be tied to improvements to help lake water quality - e.g., vegetation plantings, stormwater treatment, etc.?

	Response Percent	Response Count
yes	**74.3%**	**150**
no	17.8%	36
not sure	7.9%	16
	answered question	**202**
	skipped question	**16**

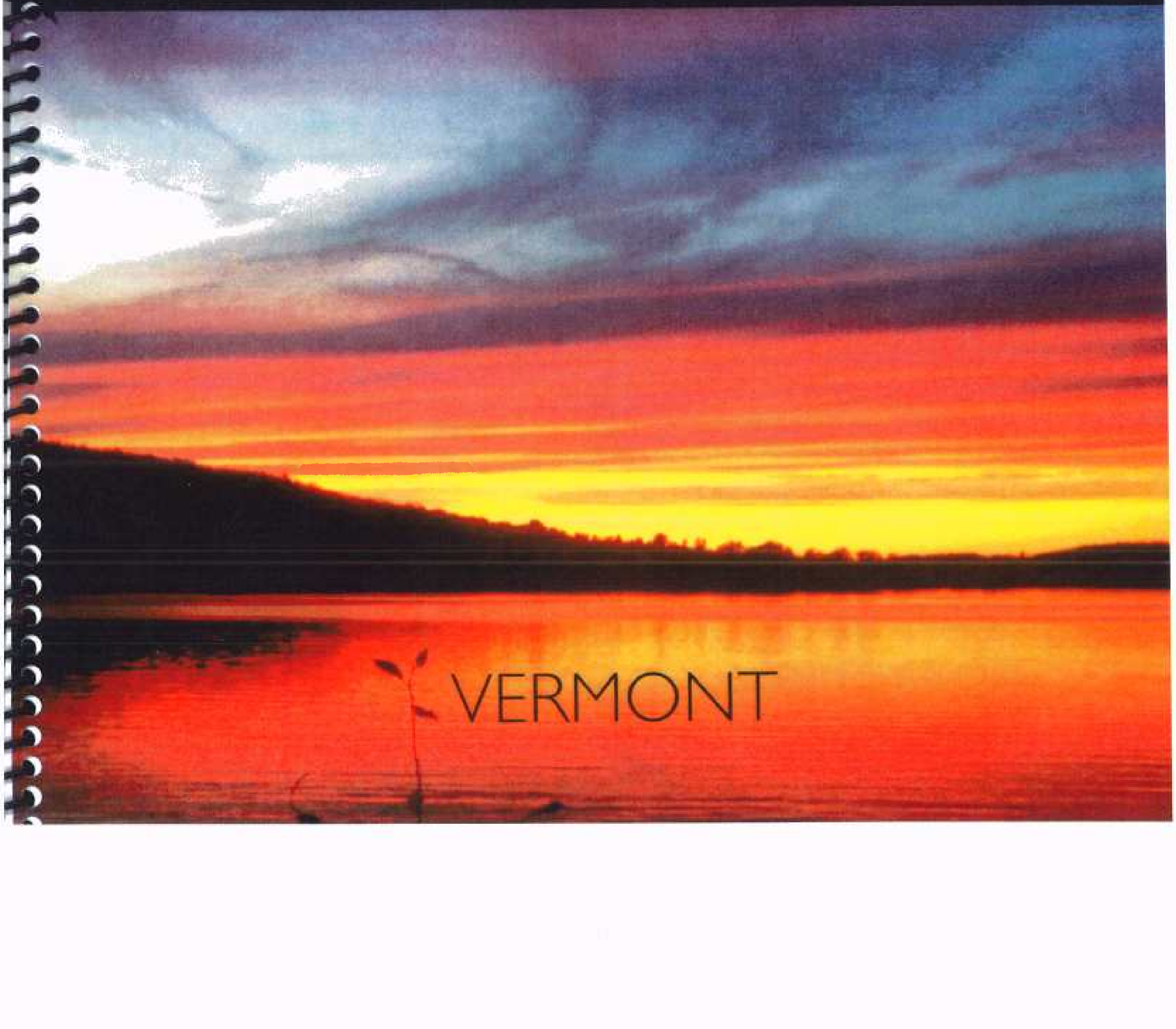
12. Please rate the importance of the following statements as we discuss water quality and the shoreline areas in Hinesburg. Note - we don't see these statements as mutually exclusive, but we are interested in respondents' priorities.

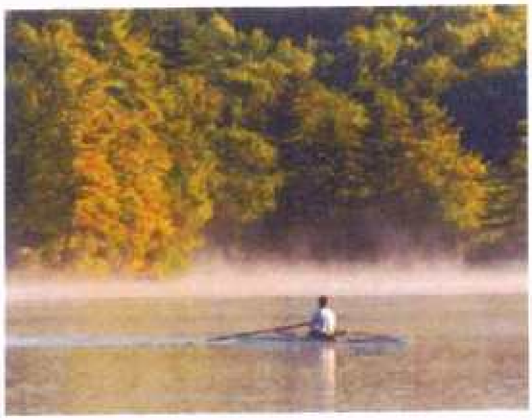
	Not Important	Somewhat Important	Important	Very Important	No Opinion	Rating Average	Rating Count
Preserve water quality via education and outreach.	2.5% (5)	12.4% (25)	37.6% (76)	**46.5% (94)**	1.0% (2)	1.00	202
Preserve individual property owners rights.	3.0% (6)	30.5% (61)	**34.0% (68)**	32.0% (64)	0.5% (1)	1.00	200
Preserve water quality through land use regulations.	4.9% (10)	11.8% (24)	26.6% (54)	**54.7% (111)**	2.0% (4)	1.00	203
Preserve water quality through Town-sponsored projects (using tax dollars, grants, etc.).	7.0% (14)	19.9% (40)	31.8% (64)	**38.3% (77)**	3.0% (6)	1.00	201
						answered question	**203**
						skipped question	**15**

13. Other comments or observations (optional).

	Response Count
Show replies	43
answered question	**43**
skipped question	**175**

LAKE IROQUOIS - STATE OF THE LAKE 2014





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Introduction

Lake Iroquois by the Numbers

Lake Surface Area	243 acres
Drainage Basin Area	2,418 acres
Maximum Depth	37 ft (11.3 m)
Average Depth	19 ft (5.8 m)
Flushing Rate	0.78*
Elevation	685 feet

* The number of times a lake flushes (i.e., a volume of water equal to the lake's volume passes through the lake) in one year, expressed as times/year. In other words, it would take ~1.3 years for the volume of water in Iroquois to pass through the lake.

History and Geology

Lake Iroquois, formerly known as Hinesburg Pond, is geologically a kettle pond located in a valley between Dow and Magee Hills on the east and Mount Prichard on the west. It lies on the borders of the towns of Williston, Hinesburg and Richmond in Chittenden County, Vermont; the town of St. George also lies within the lake's watershed.

The lake was formed about 15,000 years ago after the last ice coverage in Vermont receded. By 1900, settlers had cleared most of the pond's watershed for farming and began to build seasonal camps on its shores. A hundred years later, much of the watershed is reforested but at the same time most of the shoreline has been developed with over 90 summer camps and year-round homes.

In the 19th century, a dam was constructed on the lake's outlet to control the water supply for mills downstream in Hinesburg. Milling declined in the 20th century, and in the 1960s the dam was intentionally cemented in its top position, keeping the pond at an artificially high level throughout the year. The outflow of the lake is over the dam in the south end, into a lower pond, thence into the LaPlatte River and Lake Champlain.

The lake is used extensively throughout the year by residents and visitors accessing the lake via the public beach and fishing access. The fishing access is used by fishermen and recreational boaters. A water ski slalom course is maintained on the lake.

A lake will naturally become more enriched with nutrients over time, typically thousands of years, in a process called eutrophication. This aging process is divided into three trophic states: oligotrophic, mesotrophic, and eutrophic. The rate at which lakes pass through these states depends on the size and shape of the lake, as well as characteristics of the watershed. Oligotrophic lakes are unproductive, with low nutrient levels and cold, clear water. Mesotrophic lakes have moderate amounts of productivity and nutrients. Eutrophic lakes tend to be relatively shallow, with high nutrient levels and warm, turbid (low clarity) water. Eutrophic lakes typically experience excessive algae growth, contain high levels of decomposing organic matter, and low levels of dissolved oxygen. Trophic state is often defined using Secchi water clarity, chlorophyll-a concentration, and total phosphorus concentration. The following ranges for each of these parameters are used to define a lake's trophic state: However, human activity in the watershed can cause cultural or anthropogenic eutrophication, which accelerates this aging process. Lake Iroquois is a prime example of a lake that is experiencing anthropogenic eutrophication. The water quality of Lake Iroquois has been statistically highly

PUBLIC INFORMATION CHART

OF

LAKE IROQUOIS

TOWNS OF

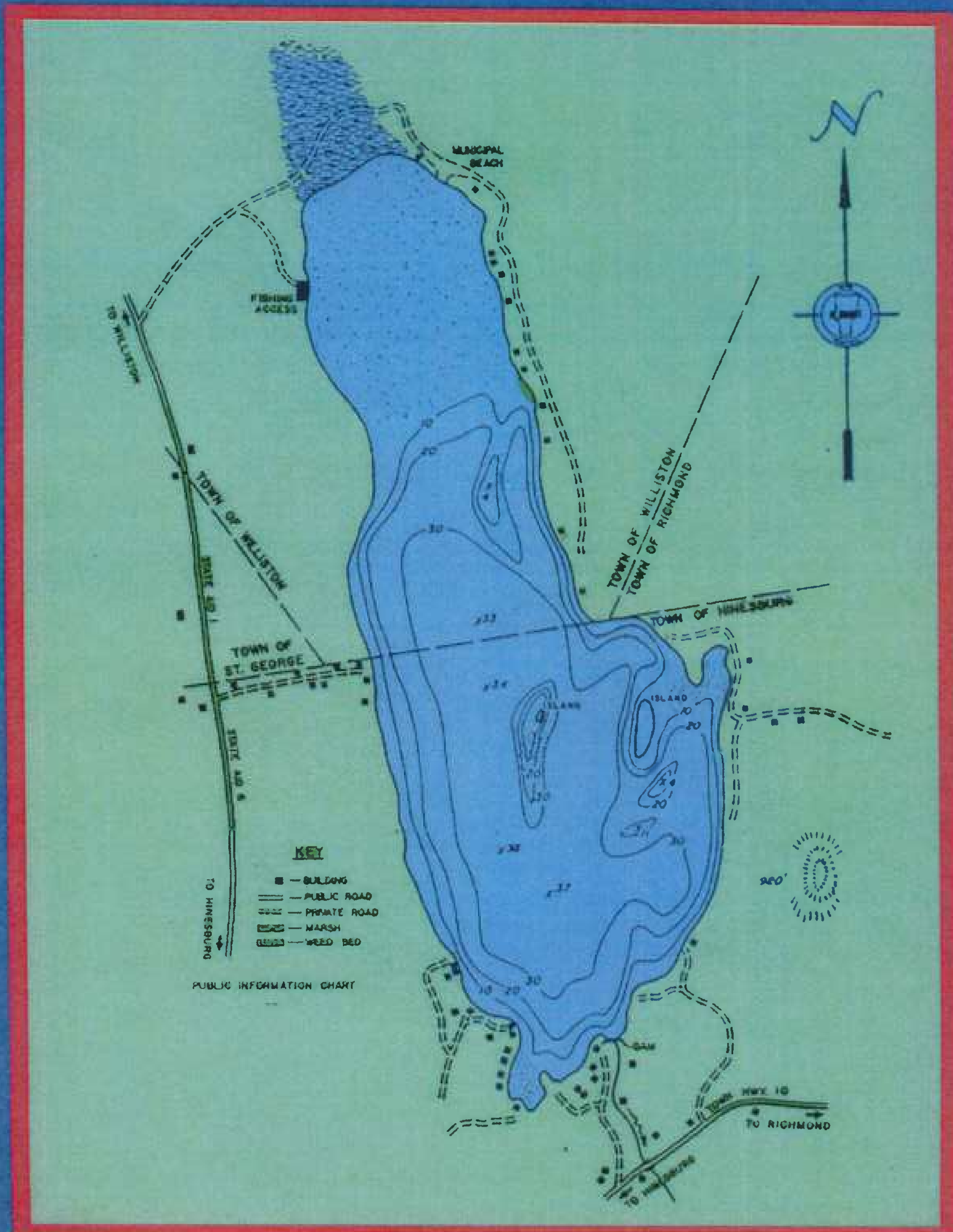
HINESBURG, RICHMOND , and WILLISTON

CHITTENDEN COUNTY

SCALE OF FEET

(DEPTH CONTOURS SHOWN IN FEET)

1972



	Average Secchi Clarity (m)	Average Chl-a (ug/L)	Average TP (ug/L)
Oligotrophic	> 5.5	< 3.5	< 7.0
Mesotrophic	3.0 - 5.5	3.5 - 7.0	7.0 - 14.0
Eutrophic	< 3.0	> 7.0	> 14.0

variable over the last forty years (see LMP In-Lake Measurements below), but shows accelerated eutrophication due to excessive stormwater runoff, shoreland erosion and other human activities in the watershed.

Use and Water Quality Criteria

The effects of our activity on the landscape since settlement have not been well understood. Land use changes such as deforestation, the building of roads and homes, and over-fertilization of crops, lawns, and gardens have had a great impact on the lake, resulting in the nutrient enrichment of the lake. However, we have learned a lot in recent years. More recently, residents have recognized the impact these activities can have on water quality and have worked to implement better management practices. Prior to the formation of the Lake Iroquois Association (LIA) in 2007, lake residents began to adopt best management practices (BMPs) on their lakeside properties in the effort to improve water quality. There are several possible BMPs that could have meaningful positive impacts on water quality. One such measure is the use of lakeshore, or riparian, buffers. These are strips of vegetation separating streams and lakes from human activity, such as roads, farms, gardens, lawns, and buildings. The buffers intercept sediment and nutrients from surface water runoff as well as reduce nutrients in subsurface water flow. Other BMPs, such as using non-phosphate detergent, "no phosphorus" fertilization programs, and building site restrictions, are all helpful in the overall reduction of nutrient-loading into Lake Iroquois.

This report brings together information about the lake and the quality of its waters. It is intended to further our education about the lake and what we can do to individually and collectively to slow down the eutrophication of the lake we love and improve its water quality for ourselves, our neighbors and visitors, and our children.

Water Data and Trends

LMP In-Lake Measurements

Lake Iroquois has participated in the Vermont Lay Monitoring Program (LMP) since its inception in 1979. This partnership program between volunteers, or Lay Monitors, and the Department of Environmental Conservation was established to track nutrient enrichment in Vermont lakes. Lay Monitors sample for total phosphorus, chlorophyll-a, and determine Secchi water clarity weekly from Memorial Day to Labor Day. From these results, summer annual means for each of these parameters are calculated, which can help define the lake's trophic status. Below is a graph of the summer annual means for Lake Iroquois from 1979 – 2013.

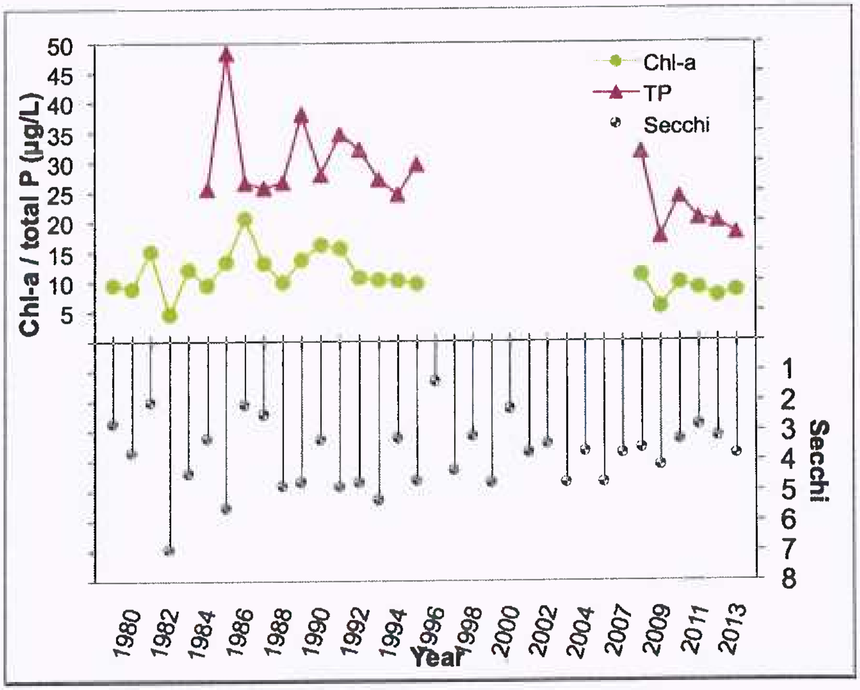


Figure 1: LMP Summer Annual Means for Chlorophyll-a (Chl-a), Total Phosphorus (TP), and Secchi depth measurements (1979-2013)

The data has been statistically highly variable from year to year, which makes the water quality consistently unpredictable from one year to the next. However, even with annual variations, the lake continuously shows high nutrient enrichment levels that categorize it as eutrophic.

Below is a graph of the 2013 LMP data, along with a table that shows the 2013 minimum, maximum, and mean for each parameter, as well as the long-term summer annual mean.

Figure 2: 2013 LMP Chlorophyll-a, Total Phosphorus, & Secchi Depth vs. Time

Parameter	Days	Min	Max	2013 Mean	Long-Term Mean
Secchi (m)	12	3.1	5.2	3.8	3.8
Chl-a (ug/L)	12	5.7	12	8.4	11
Summer TP (ug/L)	12	14.1	25.2	18	28

Figures 4, 5, and 6 below display the LMP data in a different form, including standards used in determining if a lake is eutrophic. While the lake clearly falls into the eutrophic category, the in-lake data is relatively stable.

Clarity

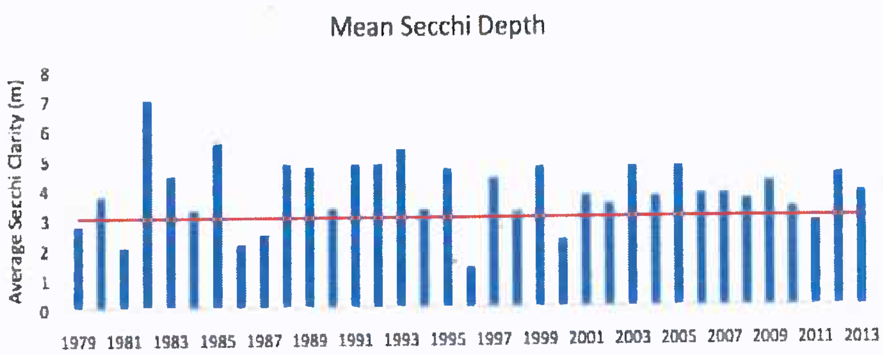


Figure 4: Mean Secchi Depth in Lake Iroquois 1979-2013.

Secchi disk readings measure the clarity of lake water. Clarity is directly related to the amount of algae, pollen, silt and other materials suspended in the water. Secchi depth was recorded in the deepest part of the lake on an approximately weekly schedule during the weeks from Memorial Day to Labor Day. The measurement given for the year is the average on the weekly measurements. The red line indicates a depth of 3.0 meters. A higher bar indicates clearer water. The LMP classifies lakes with average Secchi clarity depths with values <3.0 meters to be eutrophic.

Chlorophyll

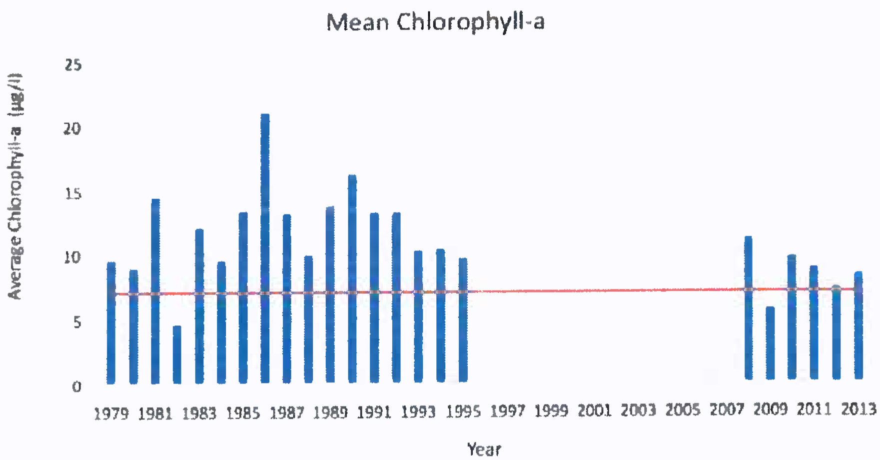


Figure 5: Mean Chlorophyll-a Values in Lake Iroquois 1979-2013 (data not gathered from 1996-2007).

This measurement shows the concentrations of algae present in lake waters. The sampling was done at the same time the secchi depth readings were taken, and the measurements are the average for each year. The red line indicates a concentration of 7.0 ug/l, the level at which the LMP classifies a lake as eutrophic. A higher bar indicates higher concentration of chlorophyll-a.

Phosphorous

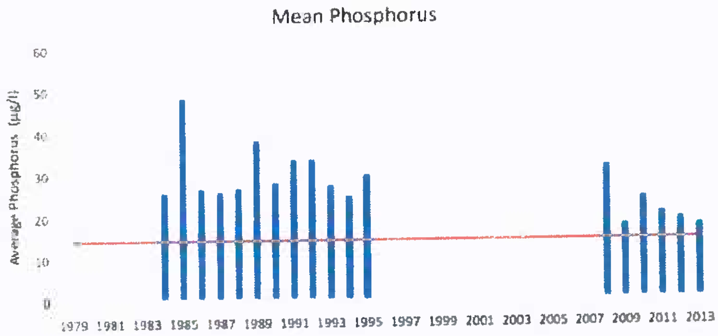


Figure 6: Mean Phosphorus Values in Lake Iroquois 1984-2013 (data not gathered before 1984 or from 1996-2007).

Phosphorus is the primary nutrient found in the lake that stimulates algae growth. Phosphorus enters the lake from tributaries, land runoff, ground water and human activity. The sampling was done at the same time the Secchi depth readings were taken, and the measurements are the average for each year. The red line indicates a concentration of 14.0 ug/l, the level at which the LMP classifies a lake as eutrophic. A higher bar indicates higher levels of phosphorus.

The Tributaries

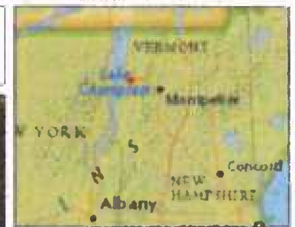
The LaRosa Environmental Partnership Program is a project of the Vermont Department of Environmentqal Conservation (DEC), Water Quality Division. Under this program the state DEC water testing laboratory partners with volunteer organizations to monitor water quality throughout the state. In 2011 the LIA began the Lake Iroquois Tributary Monitoring Program (TMP) under a grant from the LaRosa Environmental Partnership Program. All data and reports for the TMP are shared with the DEC in its statewide efforts to improve the water quality of Vermont's lakes, ponds and streams. The TMP is carried out by volunteers who are trained to gather water samples from lake tributaries and deliver them to the DEC laboratory which analyzes the samples. Five tributaries were monitored in 2011 and ten were monitored in 2012 and 2013. The tributaries chosen are the lake's primary tributaries and the ones most impacted by development on the lake's west side.

The TMP has monitored chloride, nitrogen, phosphorus and turbidity. This monitoring is intended to determine how different pollutants are entering the lake and whether this movement can be miti-

Lake Iroquois North - 2013 Sampling sites

Vermont Agency of Natural Resources

vermont.gov



LEGEND

- Buildings (E911)
- Roads
  - Principal Arterial
  - Minor Arterial
  - Rural Major Collector
  - Rural Minor Collector
  - Urban Collector
  - Local
  - Not part of the Functional Classific
- Stream
- 50 foot Contour

489.0 | 0 | 244.00 | 489.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere

1" = 803 Ft. 1cm = 96 Meters

THIS MAP IS NOT TO BE USED FOR NAVIGATION

DISCLAIMER: This map is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. ANR and the State of Vermont make no representations of any kind, including but not limited to, the warranties of merchantability, or fitness for a particular use, nor are any such warranties to be implied with respect to the data on this map.

NOTES

Map created using ANR's Natural Resources Atlas

Chloride

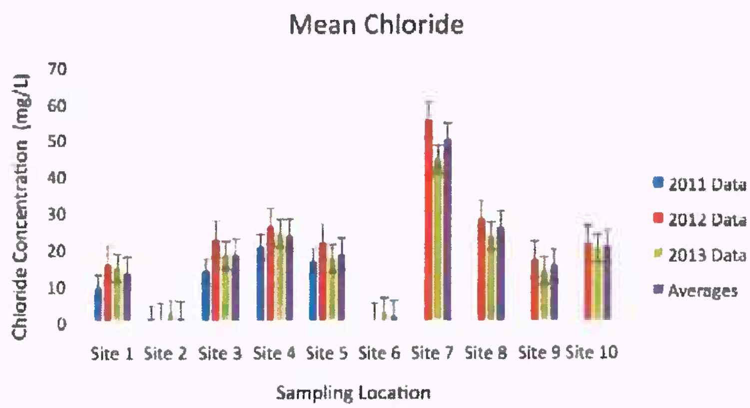


Figure 7: Mean Chloride: Lake Iroquois Tributary Monitoring Program, LaRosa Environmental Partnership Program 2011-2013.

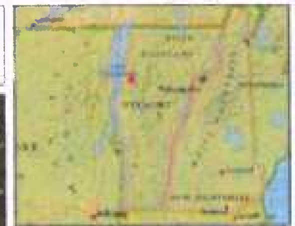
Chloride is a common environmental pollutant, typically entering the environment as a component of road salt. At higher concentrations chloride can be toxic to aquatic organisms and there is no natural mechanism by which chloride is removed from an aquatic environment once it enters it. There is also evidence suggesting that Eurasian watermilfoil, a problematic invasive in Lake Iroquois, is more tolerant of high chloride levels than native aquatic vegetation (Evan and Frick 2001). Chloride levels of Lake Iroquois' tributaries (Figure 7) have remained fairly consistent from 2011 to 2013. The pattern of chloride presence is as expected with the sites with higher levels of chloride being more closely associated with roads and road salt than sites further from roads. The chloride levels currently present in some of these sites is already a sign for concern. A paper by Meador and Carlisle (2007) looked at the chloride tolerance for several common stream fish. Of the fish included, chloride tolerance ranged from 3.1 – 28.7 mg/L. Site 7 consistently has a chloride concentration of above 40 mg/L, and all but two sites have consistent levels well above 3 mg/L. This suggests that chloride could already be impacting aquatic organisms in Lake Iroquois.

VERMONT

Lake Iroquois South - 2013 Sampling sites

Vermont Agency of Natural Resources

vermont.gov



LEGEND

- Buildings (E911)

Roads

- Principal Arterial
- Minor Arterial
- Rural Major Collector
- Rural Minor Collector
- Urban Collector
- Local
- Not part of the Functional Classifica

Stream

50 foot Contour

NOTES

Map created using ANR's Natural Resources Atlas

489.0 0 244.00 489.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere

1" = 803 Ft 1cm = 96 Meters

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Nitrogen

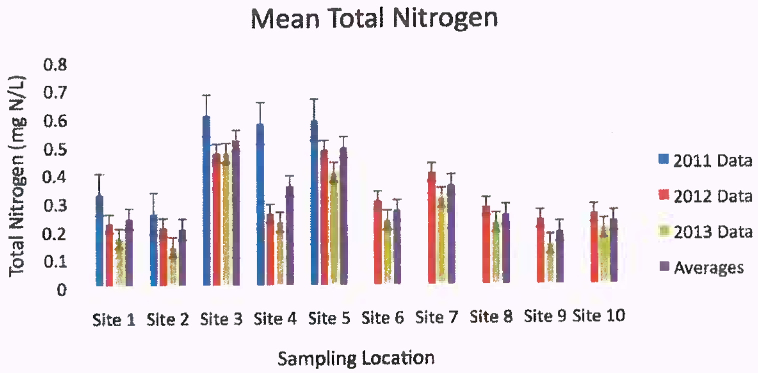


Figure 8: Mean Total Nitrogen: Lake Iroquois Tributary Monitoring Program, LaRosa Environmental Partnership Program, 2011-2013

Nitrogen (N) is an important plant nutrient that in excess can become a pollutant. Higher concentrations can alter the make-up of algal communities and can play a role in the development of blue green algae blooms. While most of the focus of BMPs is to reduce phosphorus levels, a reduction in nitrogen levels is also an objective of BMPs and remedial projects that may be undertaken by LIA to improve water quality.

Turbidity

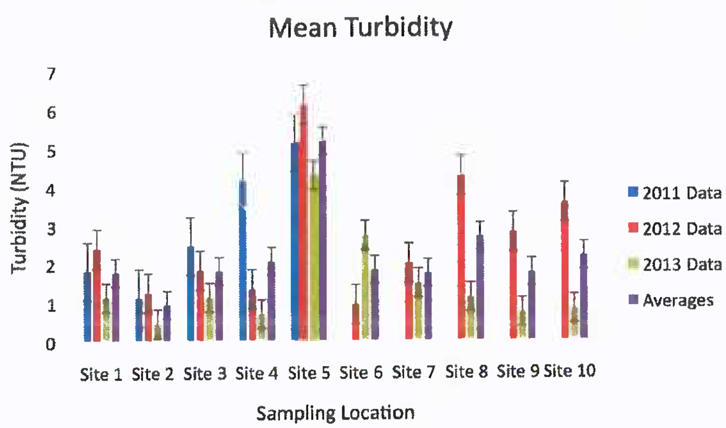


Figure 9: Mean Turbidity: Lake Iroquois Tributary Monitoring Program, LaRosa Environmental Partnership Program 2011-2013.

Turbidity is a measurement of water clarity, similar to secchi disk data in the way that it quantifies the amount of particulates or suspended solids present in the water. With soil erosion along stream beds, levels of turbidity rise. Because phosphorus attaches to soil particles, streams with higher turbidity readings are candidates for remediation projects designed to minimize erosion or to capture erosion in retention ponds so that water entering the lake contains fewer soil particles. A study of turbidity over time will assist LIA in assessing the effectiveness of stream mediation projects.

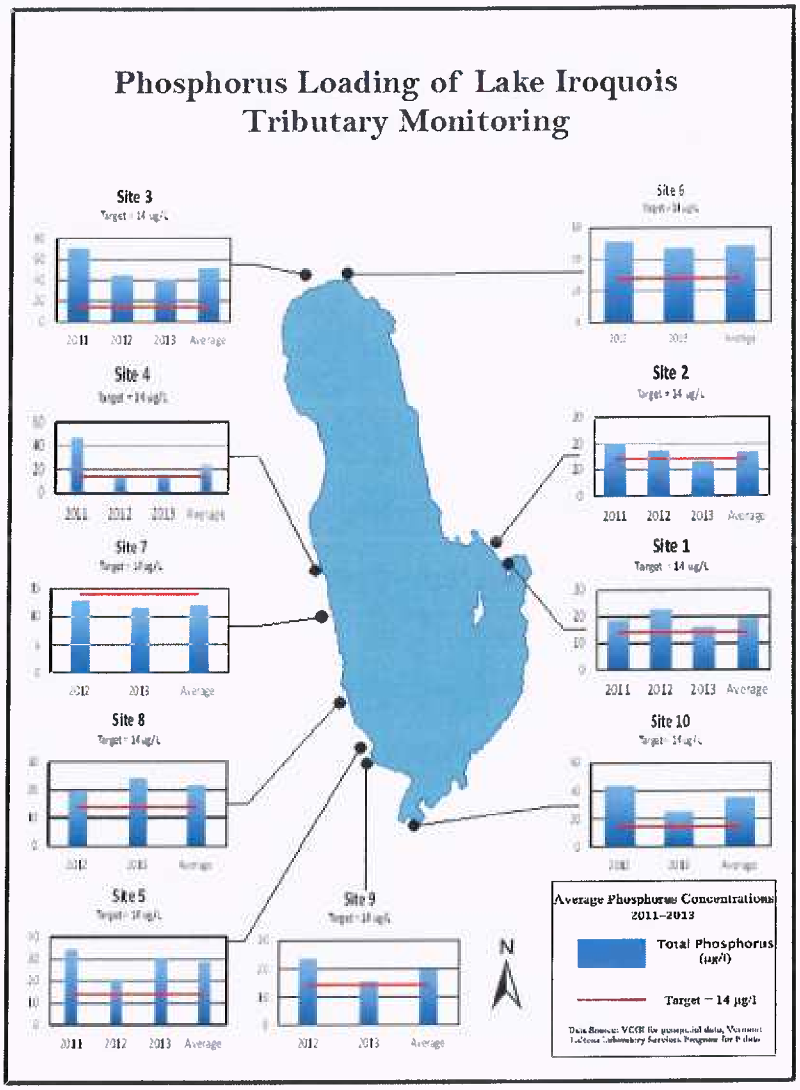


Figure 11: Phosphorus Loading from Lake Iroquois Tributaries 2011-2013.

Phosphorous

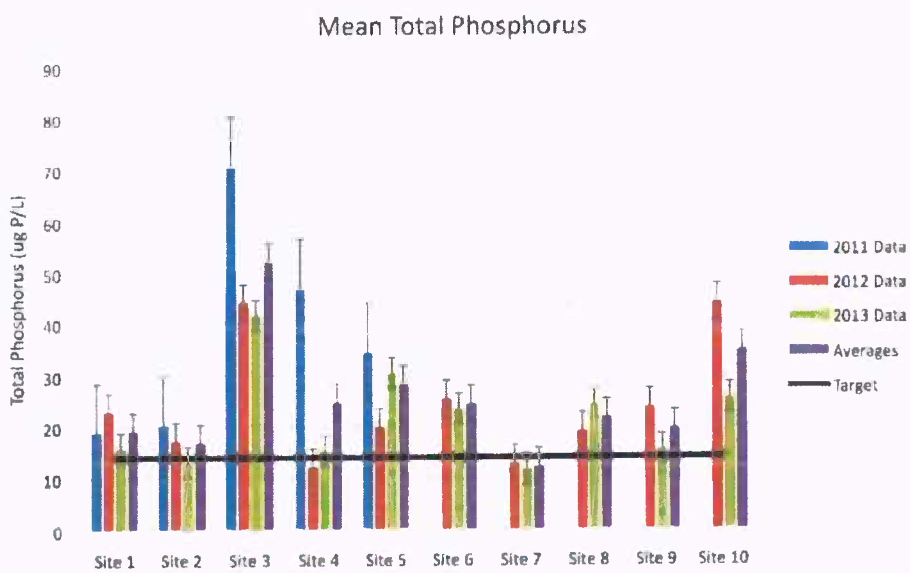


Figure 10: Mean Total Phosphorus: Lake Iroquois Tributary Monitoring Program, LaRosa Environmental Partnership Program, 2011-2013.

Phosphorus levels in Lake Iroquois have consistently been higher than the concentration of 14 ug/l, the threshold level of eutrophic lakes used by the Vermont Agency of Natural Resources. Most of the water entering the lake via its tributaries also exceed this level and contributes to higher levels of in-lake phosphorus. One of the tactics of the LIA in its overall strategy to improve water quality is to work on changes in the watershed that will have the effect of reducing phosphorus levels in the tributaries. If the water coming into the lake is cleaner than the existing lake water, there may be an opportunity to stabilize in-lake phosphorus at a lower level than currently exists.

Lake Iroquois Recreation District (LIRD) and Beach Monitoring

In 2013, the Vermont Department of Health (VDH) made weekly visual assessments of the LIRD Beach on Beebe Lane and took samples for laboratory analysis. The VDH visual assessments were classified into one of three categories; generally safe (category 1), low alert (category 2) and high alert (category 3). Category 1 has sub-categories: little to no blue-green algae present –clear water (1a), little to no blue-green algae present-brown and turbid (1b), and little to no blue-green algae present-other material (1c). The following table illustrates the results from 2013's visual assessments.

Date	Visual Assessment Category
6/26/2013	1a
7/3/2013	1a
7/10/2013	1c
7/17/2013	1c
7/24/2013	1c
7/31/2013	1c
8/7/2013	1c
8/14/2013	1c
8/21/2013	1
8/28/2013	1a

Water surface samples taken from Lake Iroquois were analyzed for algae and for cyanobacteria toxins (i.e., microcystin and anatoxin). The results from the water samples confirmed the presence of potentially toxic cyanobacteria on several dates but in low amounts. LIRD also samples water at the public beach weekly from Memorial Day to Labor Day for e coli bacterial contamination. High levels of the e coli bacteria are harmful to humans. Public health standards require that the public beach be closed to use if levels exceed what is considered healthy. On two occasions in 2013, the LIRD public beach was closed due to high levels of e coli.

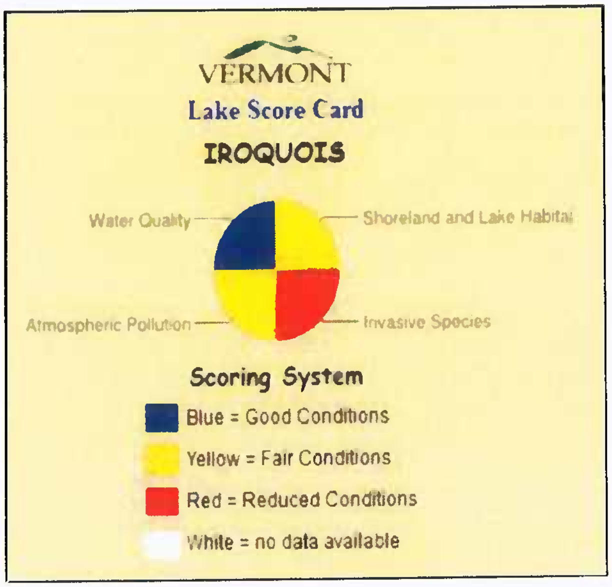
Lake Scorecard

The Vermont Watershed Management Division's Lakes and Ponds Section developed a score card system to standardize the way people view overall quality of lakes and to summarize water quality trends. Each lake is scored by four different categories: water quality, shoreland and lake habitat, invasive species and atmospheric pollution. While Lake Iroquois was given a "good" score on water quality, the low invasive species score and fair score on shoreland and lake habitat are conditions that lead directly to lower water quality. Given the levels of phosphorus concentration is the lake and its tributaries, the current trend of Lake Iroquois is toward deteriorating water quality

Lake Scorecard

While the Lake Score Card shows Lake Iroquois with "good" conditions for water quality, this is based generally on the absence of regular occurrences of algae blooms, e coli or other toxic contamination. Concerns about water quality in Lake Iroquois are centered most around nutrient levels and the growing potential of algae blooms and proliferation of Eurasian watermilfoil growth. Eurasian watermilfoil is presently a significant and pervasive problem in most of the shallow portions of Lake Iroquois.

LMP data covers 49 inland lakes in Vermont. In its Vermont Inland Lakes Lay Monitoring Program Report 1979-2013, the Vermont Agency of Natural Resources provides graphs of the water clarity (Secchi disk measurements), Chlorophyll-a and Total Phosphorus concentration. Out of these 49 inland lakes, Lake Iroquois ranks 13th from the lowest in clarity, and third highest in concentrations of Chlorophyll-a and Total Phosphorus. Without improvement, the levels of nutrient loading in lake Iroquois put the lake at risk for poorer conditions in



Source: http://www.vtwaterquality.org/lakes/html/lp_lakescorecard.htm

Biodiversity & Aquatic Invasive Species

Surveys and Conditions

Lake Iroquois has long supported vibrant wetlands along the shoreline with varied plant and animal life. These areas tend to be less than 6 feet in depth. There are also populations of aquatic plant communities that grow in deeper waters. Because of high nutrient levels in the lake, the native aquatic plants tend to be dominated by a few nutrient-loving species, notably Eurasian watermilfoil (EWM). Fifty-one native species in Lake Iroquois have been identified in several surveys, most recently in 2012. Most prevalent are the 14 species of native pondweeds, including big-leaf, flat stem, and clasping leaf pondweed, along with common elodea (responsive to high phosphorus levels), coontail, water smartweed, and the more obvious species of water lily. A complete list is found on the LIA website, www.lakeiroquois.org. These wetlands and aquatic plant zones offer important habitat for fish and other organisms, and are not always compatible with activities such as swimming and boating.

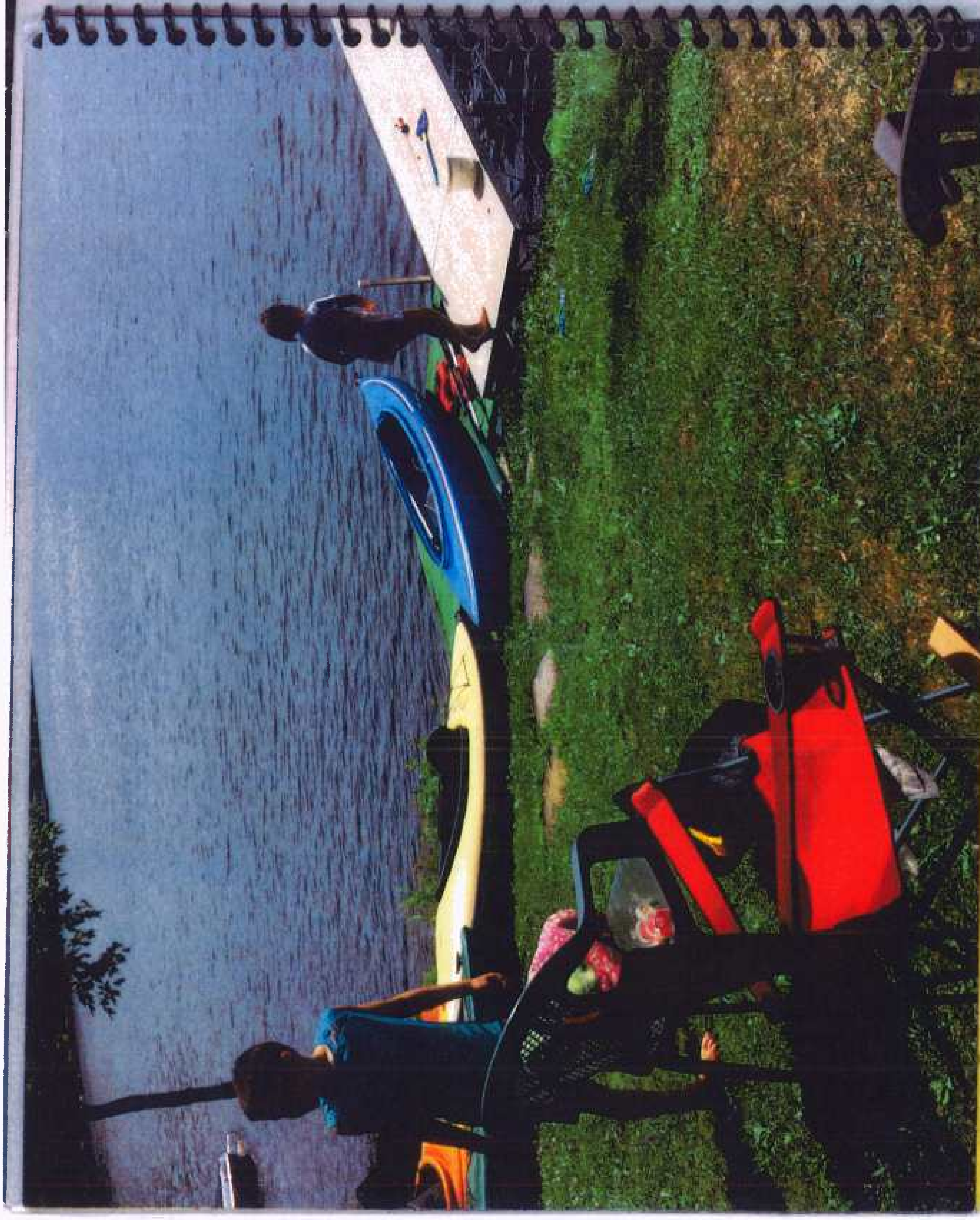
A variety of reptiles, such as painted turtle and snapping turtle, amphibians, such as bullfrog and green frog, and a number of birds, such as the belted kingfisher, great blue heron, spotted sandpiper, and ring-billed gull, call Lake Iroquois home in the summer. Other bird species are found transiently, such as the bald eagle, common loon, and various ducks migrating through. Over 100 species of birds have been identified in the watershed. Insects, including many species of dragonfly and damselfly, are present, as are a variety of mammals in the watershed. Predominant species of fish include yellow perch, smallmouth and largemouth bass, chain pickerel, and others. The lake provides excellent fishing.

While native species of aquatic plants can reach "nuisance" levels in lakes, many non-native species are "invasive". (Not all non-native species are invasive.) Once present, invasive species are costly to manage, cause negative environmental shifts in lakes, interfere with recreational uses and are difficult if not impossible to eradicate. Eurasian watermilfoil (EWM) is the most troublesome invasive species in Lake Iroquois and was first discovered in 1990 near the state fishing access. Early attempts to control it failed, and although growth varies somewhat year to year, it has been a problem since.

Efforts to control EWM have included a number of methods. Hand pulling by residents, volunteers, and paid divers and the use of benthic mats, including an installation at the town beach, have been used over the years to improve recreational uses in localized areas. Since 1999 volunteers have annually installed buoys at the state fishing access to create a channel for boats entering the lake, hoping to lessen spread of the EWM by fragmentation, its chief means of propagation. For many years, a native

weevil known to preferentially damage and kill EWM has been allowed to reproduce in tanks to increase numbers, and then has been introduced to the Lake. To date, there has been no apparent beneficial effect of these weevils.

Other invasive aquatic plant species known to be present are purple loostrife at the north end of the lake and curly-leaf pondweed, which has not yet become a major problem. The snail population of the lake has not been carefully studied. There have been reports of increases in the population of the non-native banded mystery snail (Viviparus georgianus) which is native to the Mississippi and southeast Atlantic drainage, but is non-indigenous to New England. In eutrophic lakes, the snail's populations can reach high densities and grow to become a nuisance. It has been observed to die off in large numbers and create odor issues when the shells wash up on the shoreline. The die offs are probably related to summertime warming and low dissolved oxygen (DO) that could be attributed to algae blooms. It is not known if these can become a greater problem in any way. Both small and largemouth bass are non-native but not considered a nuisance. The rusty crayfish (Orconectes virilis), an aggressive colonizer that can out-compete native crayfish for food and habitat resources, is present. The rusty crayfish is native to the Missouri and Mississippi Rivers and the Great Lakes and probably arrived via bait bucket introductions. It inhabits the shoreline zone of Lake Iroquois in the summer and moves into the deeper waters in the late fall and winter to avoid freezing.



Preventing the Introduction of Additional Invasives

Although Eurasion watermilfoil is currently the only invasive species causing notable problems for Lake Iroquois, the LIA is extremely concerned about the presence of large numbers of other invasive plant and animal species in nearby lakes, states, and provinces, that could easily be transported to Lake Iroquois. Lake Champlain, for example, is host to 49 invasive species. Many boats entering Lake Iroquois have also been in Lake Champlain, and therefore the potential for spread is great. Lake Champlain has confirmed populations of water chestnut and zebra mussel, and more recently the alewife fish and variable-leaved watermilfoil. Additionally, Lake Champlain has waterway connections with the Great Lakes, the Hudson River, and Lake George, where the Asian Clam has recently been found. Once an invasive species enters Lake Champlain, there is considerable risk that the species could move to Lake Iroquois.

In an effort to prevent the spread of invasive species between lakes, Vermont law prohibits the transport of any (not just invasive) plant species or quagga or zebra mussels on a boat or trailer. To lessen the risk of transport of invasive fish species and fish diseases such as hemorrhagic septicemia, Vermont also requires live bait to be purchased only from licensed sources, and prohibits transport of bait into another lake. The VT Department of Environmental Conservation has been educating boaters about the importance of cleaning their boats and trailers when entering and leaving a lake, of draining all water (even small amounts of water, such as found in bait wells, motors, and ballasttanks can transport zebra mussel veligers), and of drying all boating equipment for at least five days (to kill zebra mussels) before moving from one lake to another. Zebra mussel larvae ("veligers") are so small they cannot be easily seen with the naked eye.

Lake Iroquois Association Greeter Program

For the last five years, LIA has participated in the Vermont Boat Access Greeter Program by having a "greeter" at the state fishing access. Paid and trained staff greet entering and exiting boats on weekends. Greeters offer to help clean boats and trailers, educate boaters about the risk of invasive species, and record boater data such as last lakes visited. Since 2009, the year the Greeter Program was implemented at Lake Iroquois, over 5,000 boats have been inspected and nearly 300 of those boats have had an aquatic species that was intercepted and removed (Table 1). When an aquatic species was identified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after it had been removed from a boat during an inspection, the vast majority of those were identified as EWM. Because of cost constraints, there are no greeters at Lake Iroquois during the week, except for hours covered by volunteers. There are, therefore, many windows of time when invasive species may enter the lake.

Year	# of Boats Inspected	# of Intercepts	% Boats Transporting Aquatic Plant Material
2009	943	48	5.09
2010	664	42	6.33
2011	964	28	2.90
2012	1937	33	1.70
2013	773	121	15.65
All Years	5281	272	5.15

VIP Program

The Vermont Invasive Patroller (VIP) program trains volunteers to detect and report new aquatic invasive species, before they become a significant problem. Lake Iroquois has several VIPs and the entire lake is surveyed at least twice each year. Focusing on spread prevention and early detection can provide additional management options, including eradication, if a new invasive species is detected before it is well established.

Blue-Green Algae Observation & Reporting

Cyanobacteria (blue-green algae) are a normal part of Lake Iroquois, and are common in Vermont lakes. Excess nutrients, especially phosphorus, combined with warm calm water can increase cyanobacteria density, resulting in an algae "bloom." Algae blooms can produce harmful toxins causing stomach or skin problems and other symptoms.

If you suspect a bloom: keep children and pets away from water in the area of the bloom. Swimming or boating in an algae bloom should be avoided. If you live on or near the lake, contact any one of the LIA Board members about the suspected bloom or take a sample in a bottle or a photo. If the condition warrants, the state health department is to be contacted and a sample of the bloom can be analyzed. Identifying and documenting toxic blooms is helpful in monitoring the efforts to improve water quality. In the event of illness after exposure to an algae bloom, see your doctor.

While some of the toxin-producing cyanobacteria are present in Vermont, the risk of illness from these toxins is minimal, especially if you are mindful of an algae bloom and keep out of the water affected by a bloom. It is difficult to contain or control a cyanobacteria bloom while it is occurring. In most cases, a bloom only lasts a day or two. The best approach to reducing the number and intensity of blooms is to reduce the phosphorus found in the water.

Lake Iroquois Blue-Green Algae Bloom

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Lake Iroquois Association

Research, education and action for a healthy lake

The Effects of Motorized Watercraft on Aquatic Ecosystems

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Introduction

What do we mean by "motorized watercraft?"

Motorized watercraft include powerboats, fishing boats, pontoon boats, and "jet skis" or personal watercraft (PWC). They are propelled by some sort of motor: outboard, inboard, inboard/outboard, or jet propulsion. Most of these propulsion systems make use of a propeller. In the discussion of impacts presented here, all craft will be lumped together as "boats," unless otherwise stated (for example, see special section on PWCs). "Boat activity" refers to the ways in which these watercraft are used: fishing, cruising, water-skiing, racing. No distinction will be made between the types of activities unless otherwise stated.

Why are motorized watercraft important to aquatic ecosystems?

There are a number of reasons why boats and boat activity are an important issue. Numbers of registered boats in Wisconsin have increased by 87% since the late 1960's (567,000 in 1997-98 compared to 303,000 in 1968-69). Size of boats has also increased: over 40% of the registered boats were between 16 and 39 feet long in 1997-98 compared to just 18% in 1968-69. Along with the bigger boats have come bigger engines. The Duluth News-Tribune reports that horsepower has doubled on new boats registered in MN between 1981 and 1999. There has also been an explosion in recent years in new types of watercraft, especially personal watercraft. PWCs in WI increased from 6500 in 1991 to 28,900 in 1998, representing 5.1% of all registered watercraft. These smaller, more powerful craft have unique issues, due to their maneuverability and accessibility to shallow and remote areas. Finally, increased development of lakes and rivers leads to increased boat activity, especially in areas that have traditionally not been used for recreation.

How might boats affect aquatic ecosystems?

Boats may interact with the aquatic environment by a variety of mechanisms, including emissions and exhaust, propeller contact, turbulence from the propulsion system, waves produced by movement, noise, and movement itself. In turn, each of these impacting mechanisms may have multiple effects on the aquatic ecosystem. Sediment resuspension, water pollution, disturbance of fish and wildlife, destruction of aquatic plants, and shoreline erosion are the major areas of concern and will be addressed in the following pages. Impacts of boats that primarily affect human use of lakes, such as crowding, safety, air quality, and noise will not be addressed specifically.

As we discuss the impacts and effects of boats on the aquatic environment, we need to recognize that:

1) boating is a highly valued recreational activity in Wisconsin ($200 million spent on boating trips per year, $250 million on equipment);
2) most people use boats for fishing (58%);
3) public access is important and actively encouraged by the State of Wisconsin;
4) many of the issues associated with boating are complex, with sociological as well as ecological consequences; and
5) boating activities must be evaluated in the context of the characteristics of each waterbody and other factors that may be more important for the overall health of the aquatic ecosystem.

How is this document organized?

I have organized the material in this document in terms of the aspect of the aquatic ecosystem that may be affected by boat activity. The sections include:

- **A. Water Clarity (Turbidity, nutrients, and algae)**
- **B. Water Quality (Metals, hydrocarbons, and other pollutants)**
- **C. Shoreline Erosion**
- **D. Aquatic Macrophytes (Plant communities)**
- **E. Fish**
- **F. Aquatic Wildlife**
- **G. Personal Watercraft ("Jet skis")**

Each section includes an introduction, a summary of three to five studies relevant to the issue, some conclusions, and a list of additional references for further reading. The introduction attempts to define the issue, explain why it is important to aquatic ecosystems and identify factors that affect it, and summarize some of the particular concerns related to boat activity. The conclusion summarizes the current state of knowledge, identifies uncertainties, and suggests management strategies that may be useful to deal with the issue. At the end of the document, I have included a summary section that incorporates information gleaned from all of the individual sections. A complete list of all studies mentioned in the text is given in the last section, entitled "For Further Reading."

A. Water Clarity (Turbidity, nutrients, and algae)

Introduction:

What do we mean by "water clarity?"
Water clarity is a measure of the amount of particles in the water, or the extent to which light can travel through the water. There are many ways to express water clarity, including Secchi disk depth, turbidity, color, suspended solids, or light extinction. Chlorophyll *a*, a pigment found in all plants, is often used to determine the amount of algal growth in the water and is related to water clarity as well.

Why is water clarity important in aquatic ecosystems?
Water clarity is important for a number of reasons. It affects the ability of fish to find food, the depth to which aquatic plants can grow, dissolved oxygen content, and water temperature. Water clarity is often used as a measure of trophic status, or an indicator of ecosystem health. Water clarity is important aesthetically and can affect property values and recreational use of a waterbody.

What factors affect water clarity?
Algal growth, runoff, shoreline erosion, wind mixing of the lake or river bottom, and tannic and humic acids from wetlands can all affect the clarity of the water. Water clarity often fluctuates seasonally and can be affected by storms, wind, normal cycles in food webs, and rough fish (e.g. carp, suckers, and bullheads).

How might boats affect water clarity?
Propellers may disturb the lake or river bottom directly, or indirectly through the wash or turbulence they produce, especially in shallow water. This may affect water clarity by increasing the amount of sediment particles in the water or may cause nutrients that are stored in the sediments, such as phosphorus, to become available for algal growth. Waves created by watercraft may contribute to shoreline erosion, which can cloud the water.

Studies:

Yousef and others (1980) is the most often cited publication on motor boat impacts. Turbidity, phosphorus, and chlorophyll *a* (chl *a*) were measured on control and intentionally mixed sites on three shallow Florida lakes (all less than 6 m or 18 ft deep), both before and after a set level of motor boat activity. On the two shallowest lakes, significant increases were seen in these parameters on the mixed sites, but not at the control sites. Average increases in phosphorus ranged from 28 to 55%. Maximum increases in turbidity and phosphorus occurred within the first two hours of boating activity. Turbidity declined at a slower rate after boating ceased, taking more than 24 hours to return to initial levels.

Hilton and Phillips (1982) developed an empirical model to predict the amount of turbidity generated by boats passing a stretch of river based upon field measurements of turbidity and timing of boat passes. The model assumes that each boat pass generates the same amount of turbidity and that it decays exponentially with time, such that the amount of turbidity at a given time is dependent upon the timing of the last boat pass. Using the model with maximum expected boat activity, the authors determined that turbidity returned to background levels 5.5 hours after cessation of boat movement, indicating long term build-up of turbidity was unlikely. The model also predicted that on an annual basis, 8 to 44% of the turbidity in the river could be attributed to motorboat activity, depending upon the amount of algal growth that occurred at the test sites.

Johnson (1994) investigated the role of recreational boat traffic in shoreline erosion and turbidity generation in the Mississippi River. Turbidity was monitored at several depths and distances from shore during weekends of heavy boating activity. Turbidity increased the most near the bottom of the river, but did not vary with distance from shore. Peak turbidity corresponded with peak boating activity, but only in sites with high boating activity.

U. S. Army Corps of Engineers (1994) investigated the relationship between boat traffic and sediment resuspension on the Fox River Chain O' Lakes in northeastern Illinois. Samples were collected in channels connecting the lakes so that boats could be counted with some accuracy. There was a direct correlation between the number of boat passes and the amount of suspended solids in the water column. However, the amount of resuspension varied with water depth and sediment type. In silt substrate, the highest amounts were seen in water depths of 3 ft, about half as much at 6 ft, and none at 8 ft. In marl substrate, effects were seen at 3 ft, but not 6 or 8 ft. The authors also determined that sediment resuspension by boats at 3 ft was equivalent to the amount of disturbance generated by a 20 mph wind, but that the frequency of boat passes was much higher than the frequency of winds of that magnitude.

Asplund (1996) investigated the effects of motor boats on sediment resuspension and concurrent effects on nutrient regeneration and algal stimulation in several Wisconsin lakes. Weekend and weekday water quality was measured on 10 lakes during three summer holiday weekends and an additional weekend in August. Motor boat use increased on holiday weekends compared to weekdays (200-350% increase). Water clarity usually decreased, associated with increases in turbidity, particularly in near-shore sites. Chl *a* showed no consistent trends. Phosphorus (TP) often increased in the mid-lake sites, while ammonia generally decreased in both areas. Shallower lakes tended to experience greater changes in turbidity and TP than deeper lakes. Water clarity and boat activity were measured on an additional 20 lakes during every summer weekend. Motor boat use increased consistently on weekends for most of the lakes in the study. Water clarity did not show a consistent increasing or decreasing trend for any individual lake on weekends. However, weekend Secchi disk readings were 10% lower than weekday readings on average for the entire data set. Clear water lakes tended to show slightly larger drops in clarity than turbid lakes, and had more weekends with decreased clarity. The magnitude of change in water clarity was small compared to seasonal changes and differences among lakes.

Conclusions:

What do we know?
Boats have been shown to affect water clarity and can be a source of nutrients and algal growth in aquatic ecosystems. Shallow lakes, shallow parts of lakes and rivers, and channels connecting lakes are the most susceptible to impacts. Depth of impact varies depending upon many factors including boat size, engine size, speed, and substrate type. Few impacts have been noted at depths greater than 10 feet.

What don't we know?
Less certain is the overall impact boats have on water clarity compared to other factors such as shoreline development, watershed runoff, storm events, and natural food web cycles. The cumulative impacts of boats on water clarity are also uncertain, as is the link between increased sediment resuspension and algal growth. Translating effects observed under experimental conditions to what happens under actual conditions can be difficult.

What can we do about it?
No-wake zones in shallow areas of lakes and rivers could help to reduce impacts on water clarity, both by reducing the overall amount of boat activity in these areas and by limiting impacts from high-speed boats. In certain cases it may be beneficial to restrict boat activity altogether, such as in extremely shallow waters where boats can disturb the bottom even at no-wake speeds.

Also see:

Garrad, P. N. and R. D. Hey. 1988. River management to reduce turbidity in navigable Broadland rivers. J. Environ. Manage. 27:273-288.

Gucinski, H. 1982. Sediment suspension and resuspension from small-craft induced turbulence. U.S. EPA Chesapeake Bay Program, Annapolis MD. 61 pp. (EPA 600/3-82-084)

Moss, B. 1977. Conservation problems in the Norfolk Broads and rivers of East Anglia, England - phytoplankton, boats, and the causes of turbidity. Biol. Conserv. 12:95-114.

B. Water Quality (Metals, hydrocarbons, and other pollutants)

Introduction:

What do we mean by "water quality?"
By water quality, we are referring to the chemical nature of a water body, particularly as affected by anthropogenic (human) sources. Metals (lead, cadmium, mercury), nutrients (phosphorus, nitrates), and hydrocarbons (methane, gasoline, oil-based products) can all be added directly to the water column through a number of sources, including boat motors. These added chemicals can affect other parameters, such as pH and dissolved oxygen.

Why is water quality important in aquatic ecosystems?
As discussed earlier, nutrients can affect the algal growth in lakes and rivers and have an effect on water clarity. Dissolved oxygen and pH levels influence the type and abundance of fish. In high enough amounts, metals and hydrocarbons can be toxic to fish, wildlife, and microscopic animals. In addition, these substances may have human health effects if a lake or reservoir is also used as a drinking water supply.

What factors affect water quality?
Runoff from watersheds, both urban and agricultural, is a major source of nutrients, pesticides, metals, and hydrocarbons in aquatic ecosystems. Point sources of pollution (from industrial or municipal wastes) are also common, especially in river systems. Even remote lakes can be affected by atmospheric deposition of metals and acid-producing chemicals.

How might boats affect water quality?
Boat engines are designed to deliver a large amount of power in a relatively small package. As a result, a certain amount of the fuel that enters into a motor is discharged unburned, and ends up in the water. Two-stroke engines, which make up a vast majority of the motors in use on all types of watercraft, have been particularly inefficient. Estimates vary as to how much fuel may pass into the water column (25-30% is a reasonable average) and depends upon factors such as engine speed, tuning, oil mix, and horsepower. Other concerns include lowered oxygen levels due to carbon monoxide inputs, and spills or leaks associated with the transfer and storage of gasoline near waterbodies.

Studies:

Schenk and others (1975) used small (0.5 to 4 acres), shallow (4 to 12 feet deep) ponds to investigate impacts of motors on water quality. They ran motors continuously for three years at a rate of 1 gallon of fuel per day per 1 million gallons of water (equivalent to 3 times the maximum likely boat activity on a heavily used lake). No changes were observed in standard water quality parameters (pH, nutrients), except due to scour of sediments, which caused elevations in alkalinity and hardness. Increased lead and hydrocarbon concentrations were detected in the water column and sediments of the test lakes. However, no acute toxicity was observed on any species. Phytoplankton growth, diversity, and species composition were unchanged. Zooplankton and bottom dwelling organisms were not affected. No changes in the fish community composition or mortality rates were exhibited.

Hallock and Falter (1987) measured nitrogen, carbon, and phosphorus levels in small enclosures after operating outboard engines in them for a period of time. Combining this information with estimates of the annual fuel consumption by motor boat users on a heavily used lake, they calculated the proportion of nutrient loading contributed by outboard motors. In this study, motorboat exhaust contributed about 1% of the total nitrogen loading to the lake, while the amount of phosphorus was negligible. On lakes which receive heavy use year-round (in the southern U.S.), motorboats could contribute up to 5% of the nitrogen loading. However, nutrient loading from other sources is much more significant.

Mastran and others (1994) determined the spatial distribution of polyaromatic hydrocarbons (PAH) in a reservoir used for both drinking water and recreation. Engine sizes are limited to a maximum of 10 horsepower in this reservoir. PAHs are a group of organic compounds found in petroleum products that can be released into the environment through combustion processes. Some of these PAHs are known to be carcinogenic, and thus of concern in a drinking water reservoir. The researchers found detectable levels of PAHs (up to 4 parts per billion) in the water column during times of peak boating activity (June), but not during October, when boat activity was minimal. PAHs were found in the sediments during both times, and tended to be higher in the vicinity of three marinas on the reservoir. Other sources of PAHs in the sediments could be from urban runoff and atmospheric deposition.

Reuter and others (1998) investigated the role of motorized watercraft on methyl *tert*-butyl ether (MTBE) levels in a California lake. MTBE is a fuel oxygenate required by many states to be added to gasoline to reduce carbon monoxide emissions in urban areas. MTBE is also a possible human carcinogen and imparts a noticeable taste and odor to drinking water in very low concentrations. The authors found that MTBE was detectable (0.1 μg/L) throughout the lake and throughout the year, but that it rose to 12 μg/L during mid-July in the upper waters of the lake, corresponding to peak boat use and the strongest stratification. This level exceeds drinking water standards under consideration in California. The authors determined that the exhaust from 2-stroke outboard motors was the primary source of MTBE, explaining 86% of the variability in MTBE levels. However, levels declined through the fall due to volatilization at the water surface and did not appear to persist from one year to the next.

Conclusions:

What do we know?
There have been numerous studies on the effects of outboard motor exhaust and related pollution from fuel leakage. (See **Wagner (1991)** for a good review of these studies.) In general, these studies have shown minimal toxic effects on aquatic organisms because 1) the amount of pollution is small compared to the volume of a lake; and 2) most hydrocarbons are volatile and quickly disperse. However, polyaromatic hydrocarbons and fuel additives have been detected in some cases, and could be a concern for drinking water supplies. Build-up of certain compounds in sediments has been documented, especially near marinas or other high concentrations of boats, and may be detrimental to bottom dwelling organisms.

What don't we know?
Most studies have focused on short-term or acute effects of outboard motor fuel and exhaust. Less clear are the long-term or chronic effects on organisms or human health of repeated exposure to low levels of pollutants.

What can we do about it?
Cleaner technology, such as four-stroke engines, and more efficient two-stroke models should help to reduce the inputs of fuel and exhaust into water bodies over time. Education of boaters and stricter controls of places that store and sell fuel near the water would help to reduce sediment contamination from fuel transfer and storage. Keeping engines well-tuned and using manufacturers' recommended mix of oil and gasoline would help engines run more efficiently and reduce the amount of unburned fuel that is discharged.

Also see:

Hilmer, T. and G. C. Bate. 1983. Observations on the effect of outboard motor fuel oil on phytoplankton cultures. Environmental Pollution 32:307-316.

Jackivicz, T. P. and L. N. Kuzminski. 1973. A review of outboard motor effects on the aquatic environment. J. Water Pollut. Control Fed. 45:1759-1770.

Wachs, B, H. Wagner, and P. van Donkelaar. 1992. Two-stroke engine lubricant emissions in a body of water subjected to intensive outboard motor operation. The Science of the Total Environment 116:59-81.

C. Shoreline Erosion

Introduction:

What do we mean by" shoreline erosion?"
Shoreline erosion is a term that refers to the process by which soil particles located along riverbanks or lakeshores become detached and transported by water currents or wave energy.

Why is shoreline erosion important in aquatic ecosystems?
Shoreline erosion may affect water clarity in near shore areas, shading submerged aquatic plants as well as providing nutrients for algal growth. It can interfere with fish use of shallow water habitat, as well as wildlife use of the land-water edge. Excessive shoreline erosion can negatively affect property values and can be expensive for riparian dwellers to prevent and control.

What factors affect shoreline erosion?
Shoreline erosion is affected by two main factors: 1) the intensity or energy of the erosive agent, i.e. water movement; and 2) the characteristics of the bank material itself. Water currents, waves, and water levels are the primary agents that cause shoreline erosion, although overland runoff can also erode shorelines. The erosivity characteristics of shoreline soils can also affect erosion rates – less cohesive materials such as sand erode more quickly than clay. The amount of vegetative cover, slope, and human disturbance also affect shoreline erosion rates at a given site. A certain amount of natural erosion may occur with storm or flood events, but usually erosion is minimal on natural shorelines. Shoreline development can affect erosion rates significantly by removal of vegetative cover or compaction of bank material.

How might boats affect shoreline erosion?
Boats produce a wake, which may in turn create waves that propagate outward until dissipated at the shoreline. Wave height and other wave characteristics vary with speed, type of watercraft, size of engine, hull displacement, and distance from shore. Propeller turbulence from boats operating in near shore areas may also erode shorelines by destabilizing the bottom.

Studies:

Bhowmik and others (1992) developed an equation to predict the maximum wave height of a recreational watercraft based upon the speed, draft, and length of the boat and the distance from a measuring point. Generally, the deeper the draft and longer the craft, the bigger the waves that were produced, while increased speed and distance diminished the size of the waves. During the controlled boat runs that were used to develop the model, wave heights averaged between 1 and 25 cm, with 10 to 20 waves produced per event. Maximum wave heights observed were up to 60 cm. During uncontrolled boating observations on the Mississippi and Illinois rivers, wave activity was observed to be continuous during peak boating times, with wave heights up to 52 cm.

Nanson and others (1994) monitored bank erosion and wave characteristics produced by three ferry boats in a set of staged boat passes to determine if speed limits on boat traffic could reduce river-bank erosion rates. Most of the measurements of the boat waves were positively correlated to rates of bank recession. Maximum wave height within a wave train was the simplest measure and was associated with a threshold in erosive energy at wave heights between 30 and 35 cm (12-14 in.). Above this threshold almost all bank sediments were observed to erode. Further monitoring revealed that reducing wave heights to < 30 cm, through speed limits on boats and reducing the frequency of boat passages, caused a decline in riverbank erosion. This threshold may vary from river to river depending upon the particle size and cohesiveness of the bank material.

Johnson (1994) placed iron stakes along transects in 1989 to monitor shoreline erosion along several stretches of the Mississippi River. Over a 3.5 year period, shoreline recession of up to 14 feet was observed in a channel subjected to intense boating activity (Main Channel) compared to less than 3 feet in a channel with similar river currents and light boating activity (Wisconsin Channel). [Author's update: Transects resurveyed in 1997 indicated 28 ft. of recession in the Main Channel compared to 4 ft. in the Wisconsin Channel. On average, the riverbank is eroding at a rate of 3 feet per year.]

Johnson and others (In preparation) investigated shoreline erosion due to recreational activity along several sites in the Lower St. Croix National Scenic Riverway. Over 4 successive boating seasons (1995-1998), 9 sites had net erosion, 2 sites had net deposition and 3 sites had no net change. When sorted by impact category, those sites with no boat waves and no foot-traffic trampling had sediment deposition or no net change in profile. Little net change was noted at sites with boat waves only. Shoreline erosion was documented at all sites with trampling only, as well as at all sites experiencing both waves and trampling. The surveys suggest that foot-traffic trampling and boat waves are major contributing influences to shoreline erosion in the study area. In the summer of 1998, additional investigations of off-peak and peak boating days included the measurement of maximum wave heights, number and type of boats, and shoreline sediment mobilization (erosion and resuspension). The study results confirmed that wave heights below 0.4 feet did not mobilize sediments, as determined in controlled run studies. However, the more boat waves 0.4 feet and higher in a 30 minute monitoring period, the greater the amount of sediment mobilized. Likewise, the larger the maximum wave height in a 30-minute monitoring period, the greater the amount of sediment mobilized. Of all the boat types recorded, runabouts and cruisers had the highest correlation to the measured maximum wave heights, amount of sediment mobilized, and number of waves greater than the sediment mobilization threshold (0.4 feet). Wind-generated waves above the threshold were not recorded during the study period.

Conclusions:

What do we know?

Waves or wake produced by boats is the primary factor by which boats can influence shoreline erosion. Wave heights depend upon speed, size and draft of boat, but can reach heights of 40-50 cm (15-20 in.) equivalent to storm-induced waves. However, wave heights dissipate rapidly as they move away from the boat, while wind waves increase with larger distances. Therefore, river systems, channels connecting lakes, and small lakes are likely to be most influenced by boat-induced waves, as boats may operate relatively close to shore and wind-induced waves are reduced. Shoreline erosion has been documented in river systems and has been attributed to frequency and proximity of boat traffic. Loosely consolidated, steep, unvegetated banks are more susceptible to shoreline erosion.

What don't we know?

It is unclear what effect boat waves have on shoreline erosion or bank recession in lake or still water environments. All studies to date have been on river systems. Also unknown is the cumulative impacts that boat waves can have on shorelines, especially in combination with wind-induced waves. While equations exist to predict how much of a wake a given boat can produce, very little information is available to suggest how much boat traffic a given shoreline can sustain. Also, individual boat waves may dissipate quickly, but boat traffic often mixes waves from several boats and can create much bigger waves that persist for longer periods of time.

What can we do about it?
No-wake zones are designed to minimize boat wake, so the obvious solution would be to use no-wake zones to limit shoreline erosion, particularly in channels or small sheltered lakes (i.e. areas where effective wind fetch is less than 1000 feet). Currently in WI, boats are restricted from operating at speeds greater than no-wake within 100 feet from fixed structures such as boat docks and swimming platforms. Many lake communities have established no-wake ordinances at 100 feet from shore or more. Seawalls and riprap have been used extensively in lakes and rivers to prevent shoreline erosion; however, these engineering approaches have little wildlife value and are expensive. Maintaining and restoring natural shorelines would help reduce the impacts of all types of waves on shoreline erosion.

Also see:

Bhowmik, N. G. 1976. Development of criteria for shore protection against wind-generated waves for lakes and ponds in Illinois. University of Illinois Water Resources Center Research Report No. 107, Urbana, IL. 44 pp.

Kimber, A., and J. W. Barko. 1994. A literature review of the effects of waves on aquatic plants. Natl. Biol. Surv., Environ. Manage. Tech. Center, Onalaska, WI. LTRMP 94-S002. 25 pp.

D. Aquatic Macrophytes (Plant communities)

Introduction:

What do we mean by "aquatic macrophytes?"
Aquatic macrophytes are large rooted plants that inhabit the littoral (shallow water) zone of most lakes and rivers. They are usually divided into three categories: submerged, emergent, and floating-leafed species. Common species include coontail, milfoil, elodea, pondweeds (submerged species), bulrushes, reeds, sedges, wild rice, and cattails (emergent), and water lilies, spatterdock, and lotus (floating).

Why are aquatic macrophytes important in aquatic ecosystems?
Aquatic plants perform many important ecosystem functions, including habitat for fish, wildlife, and invertebrates; stabilization of lake-bottom sediments and shorelines; cycling of nutrients; and food for many organisms. In some lakes, submerged plants grow in abundance, yet they also may compete with algae for nutrients and help maintain better water clarity. Emergent and floating-leafed species may be valued for their aesthetic qualities and help provide a more "natural" buffer between a developed shoreline and the open water.

What factors affect aquatic macrophytes?
There is considerable variability in plant communities, both within the same lake or river and among similar bodies of water. Macrophyte growth is limited by a number of factors, including light availability, nutrients, wave stress, bottom type, water level fluctuations, and water temperature. The shallow water extent of submerged plant growth is usually limited by bottom conditions and wave stress, while the deep water limit is usually dependent upon light availability. Eutrophication, boat traffic, controlled or raised water levels, shoreline development, invasive species, and rough fish can all have in impact upon aquatic plants, either through changes in abundance or species composition.

How might boats affect aquatic macrophytes?
Boats may impact macrophytes either directly, through contact with the propeller and boat hull, or indirectly through turbidity and wave damage. Propellers can chop off plant shoots and uproot whole plants if operated in shallow water. Increased turbidity from boat activity may limit the light available for plants and limit where plants can grow. Increased waves may limit growth of emergent species. Finally, boats may transport non-native species, such as Eurasian water milfoil, from one body of water to another.

Studies:

Zieman (1976) compared sea grass communities and sediment characteristics in undisturbed and motor boat disturbed areas off the Florida coast. Undisturbed sea grass beds had finer sediments than disturbed areas. In disturbed areas, channels receiving continuous boat traffic had coarser sediments than channels cut into the sea grass by a single boat pass. Sediments had lower pH and redox potential in the channels, indicating that removing aquatic vegetation altered sediment chemistry. As a result, channels cut by motor boats were found to persist for 2-3 years. Recolonization of disturbed areas was slow because of slow rhizome growth. Motor boat impacts are likely to be more pronounced in shallow high use areas with plant species that tend to be slow growing.

Murphy and Eaton (1983) looked at the relationship between boat traffic, turbidity, and macrophytes from several hundred sites in an English canal system. Abundance and biomass of macrophytes were negatively correlated to boat traffic, particularly at high levels (over 2000 boat passes per year). The impact on submerged vegetation was greater than on emergent plants. Total suspended solids were strongly correlated to boat traffic and negatively correlated to submerged macrophyte abundance, suggesting that boat traffic was indirectly suppressing macrophyte growth by generating turbidity. Direct physical damage by boats likely caused the decline in emergent macrophytes.

Vermaat and de Bruyne (1993) investigated factors that limited the distribution of submerged plants along three stretches of a lowland river in the Netherlands. Low light caused by high turbidity and periphyton growth, limited plants to water less than 1m deep. However, plant growth was much higher in the section that received the least amount of boat traffic, even though light conditions were similar to the other sites. In an experiment, plants collected from all three sites grew better in sheltered conditions than plants exposed to waves. The authors speculated that waves from boat traffic limited the shoreward extent of plant growth.

Mumma and others (1996) found a direct correlation between recreational use and drifting plants along stretches of the Rainbow River in Florida. Recreational use included canoeing, inner tubing, and motor boating, but no distinction was made among uses and their effect on the plants. Plants appeared to be damaged either by cutting or uprooting. However, the amount of plant biomass removed by the recreators per hour during peak use times represented a minute percentage of the total plant biomass in the upstream reaches of the river. Also, the researchers found that water depth and substrate type, not the level of use, influenced overall plant biomass among different sites.

Asplund and Cook (1997) studied the effects of motor boats on submerged aquatic macrophytes in Lake Ripley, Jefferson County, WI. Four enclosures, two of solid plastic and two of mesh fencing, were placed in about 1 m of water adjacent to high boat traffic areas. These enclosures were intended to exclude motor boat access and, in the solid-walled enclosures, to block the turbidity generated by boat-induced sediment resuspension. At the end of the study, plant biomass, height and percent cover were measured inside the enclosures and in control plots. Excluding motor boats from the experimental plots significantly increased macrophyte biomass, coverage, and shoot height compared to impacted areas. Results indicated that motor boats affected plant growth through scouring of the sediment and direct cutting; however, turbidity generated by boats did not appear to limit macrophyte growth in this experiment.

Conclusions:

What do we know?

Several researchers have documented a negative relationship between boat traffic and submerged aquatic plant biomass in a variety of situations. The primary mechanism appears to be direct cutting of plants, as many have noted floating plants in the water following heavy boat use. Other researchers have determined that scouring of the sediment, uprooting of plants, and increased wave activity may also be factors. Where frequent boat use has created channels or tracks, it was noted that these scoured areas persist for several years.

What don't we know?
While boats can uproot plants and reduce growth, it is still unclear what the long-term effects of boat traffic are on the macrophyte community, especially in lakes. Most studies that noted decreased plant growth in high boat traffic areas were in rivers where boat traffic is more confined and waves may be more of a factor. Also unknown is the effect on macrophyte species composition and the subsequent effect on other components of the aquatic ecosystem, such as the fish community and water quality. As one study noted, the amount of plant material chopped up by boats was a very small proportion of the whole plant community. It is unclear if such a small amount of plant material lost has larger-scale or longer-term impacts.

What can we do about it?
No-wake zones and restricted motor areas effectively reduce the impact of boats on aquatic plants (see **Asplund and Cook 1999**). Limiting boat traffic in areas with sensitive species or where a large proportion of the plant material is floating or emergent may be a good way to guide boat activity to more appropriate parts of a waterbody. While no-wake zones do not prevent all impacts, they do serve to reduce the overall amount of boat activity in a given area. Basing no-wake zones on water depth or the maximum depth of plant growth may be more useful than those based upon fixed distances from shore.

Also see:

Johnstone, I. M., B. T. Coffey, and C. Howard-Williams. 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: A New Zealand case study. J. Environ. Manage. 20:263-279.

Schloesser, D. A., and B. A. Manny. 1989. Potential effects of shipping on submersed macrophytes in the St. Clair and Detroit Rivers of the Great Lakes. Mich. Academician 21:110-118.

E. Fish

Introduction:

What do we mean by "fish?"
In this discussion of boat impacts on fish or fish communities, we will consider impacts on a variety of levels: 1) individual fish, 2) fish populations, and 3) the community of all fish in a body of water. Aspects such as mortality and behavior affect individual fish, breeding success or recruitment affects fish population dynamics, and species composition and overall abundance of fish affect the fish community.

Why are fish important in aquatic ecosystems?
Fish form an important part of the food web in aquatic ecosystem, and can be either top predators, intermediate herbivores, or plankton eaters. A variety of birds and other animals depend upon fish as their primary food source. The presence or absence of individual species, as well as overall fish numbers can be an indicator of ecosystem health and can affect water clarity and water quality. Fisheries form an important resource for food and recreation for humans as well. In fact, angling is the most popular recreational activity on most Wisconsin waters.

What factors affect fish?
Climate, food availability and quality, suitability of shelter, and the presence of predators (including humans) affect individual fish, as well as fish populations. Water quality, turbidity, and the presence of pollutants can also affect fish reproductive success, which affects fish populations. Species composition is usually determined by a number of factors including water quality, water temperature, and pH. Angling also has a large impact on fish populations and community structure and is usually closely regulated to try to maintain a balanced fishery. In sum, any human activity that affects water quality and habitat has the potential to affect fish populations and overall community structure.

How might boats affect fish?
Direct contact of boats or propellers may be a source of mortality for certain fish species, such as carp. Pollution from exhaust or spills may be toxic to some fish species. Boat movement can affect individual fish directly by disturbing normal activities such as nesting, spawning, or feeding. Increased turbidity from boats may interfere with sight-based feeding or success of eggs or fish spawning. On a population level, boats may affect fish through habitat alteration caused by waves or propeller damage.

Studies:

Lagler and others (1950) addressed several important topics using control and experimental ponds: bluegill and largemouth bass production, location of nests, guarding behavior, mortality of eggs and fry, and habitat alteration. Some differences among motor and non-motor ponds were seen in fish production, but these differences were small and may have been due to other factors. The motor boat followed a defined path around the perimeter of the pond and thus inhibited macrophyte growth, scoured the sediments, and reduced the number of bottom dwelling organisms in its path. Otherwise, the motorboat ponds exhibited no changes in turbidity, water chemistry or phytoplankton production. Motorboat use did cause male sunfish to abandon their nests temporarily, but it did not affect the location of nests. Motorboat use did not significantly affect mortality of eggs or fry. Angling success was monitored on a non-motor lake on which a motor boat was operated every other day during several 3-week periods. No differences in angling success (either catch or strike frequency) were observed on motor vs. non-motor days.

Mueller (1980) used an underwater camera to record guarding behavior by sunfish in response to passes by a canoe, slow motorboat (2 mph), and fast motorboat (11 mph) at varying distances from nests. Boat passage caused fish to leave nests to take cover, leaving eggs vulnerable to predation. In control areas, fish left the nests just as often but for shorter periods of time, primarily to ward off intruders. Absence times were longer if boat passes were close or cover was far away. Fish abandoned nests more frequently in response to slower moving boats, most likely because of increased time for detection.

Kempinger and others (1998) studied the frequent occurrence of fish kills on a stretch of the Fox River in Oshkosh, WI, between Lake Butte des Morts and Lake Winnebago since the 1950's. Throughout the ice-free season in 1988, they monitored cages with fathead minnows and freshwater drum placed at various sites along the river. They discovered that an outboard-motor testing facility located along the river was primarily responsible for the fish kills, due to elevated levels of carbon monoxide in the water. Fish kills were most apparent during warm temperatures and low flow or reversed flow conditions due to incoming seiches from Lake Winnebago. As a result of the study, the testing facility now limits its testing to no more than 1500 horsepower at one time, and ceases operation during low flow and higher temperatures.

Conclusions:

What do we know?
Very few studies have documented direct impacts of boat activity upon individual fish behavior or mortality. The few studies cited here demonstrate that boat activity can disturb fish from their nests, but that overall breeding success is likely not affected. Toxic effects on fish have generally not been observed, except in extreme situations (such as near boat testing facilities). Of much greater concern and effort, however, is the effect of boats on fish habitat (water quality, clarity, and aquatic plants) which subsequently may impact fish populations. These studies have been summarized elsewhere.

What don't we know?
While the effects of boats on fish habitat has been studied extensively, as well as the effects of habitat degradation on fish populations, the link between boat activity and fish populations has not been well defined. How much boat activity can a lake or river handle before fish populations are affected? How much habitat is needed for successful fish recruitment? Is fishing success affected by boat activity? Would restricting boat activity enhance fish populations? These are questions that have not been addressed or answered to date.

What can we do about it?
Keeping boats out of known fish spawning areas may help to improve overall fish success, however, it would be detrimental to anglers. Most boat activity usually occurs after peak fish spawning times, but extending protection of critical areas through early June may help to protect certain species. A more useful approach would be to protect shallow waters and plant beds from boat activity through the use of no-wake zones. No-wake zones in prime fishing areas may also help to reduce user conflicts by creating a separation between anglers and high-speed boaters.

Also see:

Savino, J. F., M. A. Blouin, B. M. Davis, P. L. Hudson, T. N. Todd, and G. W. Fleischer. 1994. Effects of pulsed turbidity on lake herring eggs and larvae. J. Great Lakes Res. 20(2):366-376.

F. Aquatic Wildlife

Introduction:

What do we mean by "aquatic wildlife?"
Aquatic wildlife refers to animals that spend part or all of their life in aquatic environments, or depend upon them for food or reproduction. Examples include waterfowl, shorebirds, herons, eagles, loons, turtles, frogs, and in saltwater systems include manatees, seals, and dolphins. Fish will be addressed in a separate section.

Why are aquatic wildlife important in aquatic ecosystems?
Aside from the aesthetic value of being able to see eagles, loons, deer, and other animals near water, certain species form an essential part of the food chain, especially those that feed on detritus or carrion or those that feed on the top predator fish. The presence of loons and osprey can be an important indicator of ecosystem health.

What factors affect aquatic wildlife?
Wildlife use of aquatic ecosystems depends upon a number of factors. Good water quality and the availability of suitable habitat are important for most species. Other species require a certain amount of wild or natural area in order to find enough food or to be protected from predators. The quantity and quality of food is also essential. For example, loons need an abundant fish population in order to sustain their growth. Species that migrate may need a high quality food source in order to build up enough energy to reach their wintering grounds. Finally, some species are very sensitive to human presence and may not be able to survive on waters that are too "busy" or populated.

How might boats affect aquatic wildlife?
Boats may have direct impacts on wildlife through contact with propellers or disturbance of nests along the shoreline by excessive wave action. Disturbance by the fast movement of watercraft or even the presence of humans near feeding ground or breeding areas may prevent certain species, especially birds from being successful. Noise or harassment may cause some wildlife to vacate nests, leaving eggs or young vulnerable to predators. Indirect effects may include destruction of habitat or food source in littoral areas, or impaired water quality.

Studies:

Kahl (1991) describes detailed observations of the response of canvasbacks to fishing and hunting boats at feeding areas. Disturbances caused the flock to flush and reduced the amount of time the birds spent at feeding areas, possibly increasing energy costs and delaying migration. High frequency of disturbance caused the birds to establish refuge areas in the middle of the lake where they remained for up to 60 min. per disturbance. Boating disturbance accounted for ~50% of daylight hours spent away from feeding areas. Canvasbacks were less likely to flush and flushed at closer distances in response to slower moving boats.

Rodgers and Smith (1995, 1998) directly measured the flushing response of 16 waterbird species exposed to 5 different human activities, including walking, ATV, motorboat, canoe, and automobile. The earlier study focused on nesting birds, while the latter focused on foraging and loafing birds. The authors found considerable variation in flushing distances among different species in response to the same activity (mean distances ranging from 5 to 35 m). In general, birds which were more habituated to human presence (gulls, terns) exhibited the least flushing distance. Walking and canoeing tended to flush birds at greater distances than motorized activity, perhaps due to the slower speeds and more time for birds to become aware of the disturbance. Nesting birds tended to allow closer approaches before flushing, likely because of the greater cost of leaving a nest versus a feeding area. In both studies, the authors recommend buffer zones of 100 m to protect most bird species, or mixed colonies of either nesting or foraging birds. This figure includes a 40 m "buffer" to account for alarm behaviors that do not result in an actual flush.

Madsen (1998) studied the disturbance effects of a variety of recreational activities on coot, widgeon, and mute swan flocks in 2 Danish wetlands. Moving hunting boats caused the most disturbance in terms of flushing frequency (2 times per day on average) and disruption time (up to 75 minutes), compared to stationary boats, fishing, windsurfing, and sailing. However, windsurfing had the highest flushing distance of any activity (450-700 m). Widgeon and mute swan were disturbed much more easily than coots. Repeated disturbances during a day reduced foraging time by 13-33%. In terms of overall effects of recreational activity, birds were disturbed 16% of the daylight hours during the months of September and October.

Stalmaster and Kaiser (1998) observed the effects of recreational activity on wintering bald eagles in a wildlife area in northwest Washington. They observed fewer eagles and less feeding activity during times of highest recreational use (weekends, early morning hours). Foot traffic disturbed individual eagles to a greater extent than motor boats (greater flushing responses and distances), but boat activity disturbed a greater proportion of the eagle population. Eagles resumed feeding relatively quickly after initial disturbances of the day, but were slow to resume after about 20 disturbances. Boat activity was more disturbing on narrow than on wide river channels. The authors estimate that feeding by eagles was reduced by 35% in the wildlife area because of recreational use and suggest limiting boat traffic within 400 m of eagles, especially during early morning hours.

Conclusions:

What do we know?
Boat activity certainly causes many wildlife species to be disturbed from a variety of activities. For some species, this may represent just a temporary disturbance, with little long-term effect. For other species, or in cases where unique habitats are disturbed by high frequency or intensity of boat use, boat activity can have effects on the entire population. Migratory birds may require more protection as their energy needs can easily be disrupted by excessive disturbance. Manatees have been observed with scars and lesions from contact with boat propellers, but few other species likely receive this direct sort of impact.

What don't we know?
Very little research has been done on small animals that use shorelines, such as turtles, frogs, shorebirds, and mammals. Long term effects on wildlife use of an aquatic ecosystem is also difficult to assess, as motor boat activity often goes along with increased development and impaired water quality. Many species may simply move elsewhere if a particular body of water becomes too busy.

What can we do about it?
Buffer zones have been suggested for a variety of bird species, ranging from 100 to 180 m. Protecting littoral zone habitat or known breeding areas with no-wake zones would help to provide this buffer, though it would not eliminate boat activity. Preventing access to undisturbed shorelines or areas may be warranted if it can be shown that these areas provide a unique resource to wildlife populations. Loon

nesting sites, heron rookeries, "turtle beaches," and eagle wintering sites, would all be possible candidates for such a restriction. In some cases, all human activity, not just motor boat use, may need to be restricted in order to protect wildlife populations.

Also see:

Bratton, S. P. 1990. Boat disturbance of ciconiiformes in Georgia estuaries. Colon. Waterbirds; 13(2):124-128.

Mikola, J., M. Miettinen, E. Lehikoinen, and K. Lentilä. 1994. The effects of disturbance caused by boating on survival and behaviour of velvet scoter *Melanitta fusca* ducklings. Biol. Conserv. 67: 119-124.

York, D. 1994. Recreational-boating disturbances of natural communities and wildlife: An annotated bibliography. U.S. Dept. of Interior, National Biological Survey, Biological Report 22. 30 pp.

G. Personal Watercraft ("Jet skis")

Introduction:

What do we mean by "personal watercraft?"
Personal watercraft (PWCs), commonly referred to as "jet skis", include a variety of watercraft that are designed for use by one or two individuals (though newer models are being developed for 3 people). Riders either sit or stand, depending upon the design. Propulsion systems are generally quite different from traditional outboard motors, making use of a water pump rather than propellers to move the craft through the water. Steering is accomplished by ejecting the water at high force through a movable nozzle. PWCs are designed to be powerful and maneuverable and can operate in waters less than 12 inches deep.

Why are PWCs important in aquatic ecosystems?
Since the introduction of the first Jet Ski in 1973, PWC use has skyrocketed throughout the country, especially since the late 1980's. It is estimated that 200,000 PWCs are sold annually in the U.S., representing 30% of all new sales of watercraft. They still represent a small proportion of overall watercraft in use (about 1 million compared to 12 million outboards), but on certain lakes and rivers, they can achieve relatively high numbers. Along with the increase in numbers has come increasing conflicts with other users, as they tend to be more noticeable and create noise and perceptions of reduced safety and increased crowding.

How might PWCs affect aquatic ecosystems?
PWCs can have many of the same effects as described in other sections. However, because of their unique propulsion systems and use characteristics, this special section has been included to summarize studies that have addressed the impacts of PWCs specifically. For example, PWCs are often criticized for the noise that they produce, due to their frequent stops and starts and operation at full throttle. Most PWCs employ two-stroke technology for their engines, thus making them a concern for their air and water emissions of hydrocarbons and other pollutants. Because PWCs can be operated in shallow water, at high speeds, and in remote areas not usually frequented by boats, disturbance to wildlife may be more of a concern than other types of watercraft. Finally, while PWCs do not generally have propellers, the turbulence produced by the jet propulsion may still disturb plant growth and sediments, especially during acceleration or turns when the thrust may be oriented downward.

Studies:

Noise
Wagner (1994) described a study of PWC noise vs. outboard motor noise on a heavily used lake. The study showed that the actual noise level (in terms of decibels) is not much higher than most other types of

watercraft. The loudness decreased with distance from the watercraft, such that the sound level was within background levels at distances of 300 feet or more. However, the PWCs tended to have more variable sound levels and a higher pitch than most other types of watercraft. These frequent changes in pitch tend to make the noise more noticeable to human ears, and were usually the cause of complaints. Responding to these concerns, PWC manufacturers have introduced quieter technology in recent years.

Disturbance to wildlife

Burger (1998) compared the effects of motorboats and personal watercraft on flight behavior over a colony of common terns on an island in Barnegat Bay, New Jersey. The presence of any watercraft caused birds to fly over the colony. However, personal watercraft caused more birds to flush than did motorboats, particularly early in the nesting season (150-200 birds for PWCs compared to 20-30 for boats). Racing and fast-moving watercraft elicited a higher response than slow moving boats, as did boats that operated outside of the established channel. More birds flew in the air the closer the approach by a boat or PWC. The proximity of watercraft and either the fast movement or noise of those operating at high speeds were the most disturbing attributes, and tended to be those associated with PWCs. These disturbances may cause a drop in breeding success for some colonies of terns.

Emissions

The **California Air Resources Board (1998)** has argued that emissions from PWCs on a per machine basis are actually higher than that for a typical outboard motor, due to their larger horsepower, higher speed of operation, and sustained high speeds. Estimates of 2-3 gallons of unburned fuel per hour are typical. However, it has been estimated that all outboard motors discharge 25-30% of their fuel unburned, not just PWCs. The actual amount discharged is a function of speed, tuning, size of engine and other factors.

Physical impacts

The **Personal Watercraft Industry Association (1997),** found that PWCs had no effects on water clarity and seagrass disturbance in a shallow estuary at depths of 21-36 inches when operated on plane (20-30 mph). Some resuspension of fine sediments was documented during tests with frequent stops, starts, and turns in a confined area, however. This study only considered effects of single Jet Ski runs, and did not address cumulative impacts of sustained Jet Ski use in shallow water.

Conclusions:

What we do we know?

Available research into the impacts of PWCs on lakes and other water bodies is relatively limited. In general, the issues that are raised in regard to PWC use apply to all motorized watercraft. There is some evidence that noise and emissions are perhaps a bigger concern than for other types of watercraft, largely due to the way in which the machines are operated (high speed, frequent stops, starts, and turns). One study also showed that PWCs present a larger threat nesting waterbirds. PWCs may be more disturbing due to their ability to access areas typically avoided or restricted to other types of watercraft.

What don't we know?

Very few studies have been done which have documented physical impacts of PWCs on aquatic vegetation or sediment resuspension. No studies have compared the effects of PWCs to those of outboard motors. While PWCs may not have as much impact as a propeller-driven craft at a given depth, their operation in shallower water may have more overall effect. This area of concern remains to be addressed.

What can we do about it?

Manufacturers have voluntarily been introducing quieter, cleaner burning machines in response to citizen complaints and EPA rules requiring 75% reductions in air emissions from all marine engines by 2025. Wisconsin currently has a no-wake rule for PWCs within 200 feet of shore, which effectively minimizes the effect of PWCs on shallow water habitat. This no-wake restriction also reduces the noise level experienced by people on shore. Enforcement of this no-wake rule would go a long way toward minimizing the effects of PWCs. Restricting PWC use in natural areas or critical bird breeding areas may be justified in some cases; however restricting all motorized watercraft may be necessary to truly protect species of concern. Some states and the National Park Service have considered or enacted bans on PWCs within their jurisdiction, largely based upon disturbance to wildlife and the noise issue.

Also see:

San Juan Planning Department. 1998. Personal Watercraft Use in the San Juan Islands. A Report Prepared for the Board of County Commissioners, San Juan County, Washington.

Summary Section

Potential mechanisms by which boats impact aquatic ecosystems and the effects that they can have on the aquatic environment. Shaded areas indicate where a "Mechanism" has an "Effect."

Mechanism: *Effect:*	**Emissions and exhaust**	**Propeller or hull contact**	**Turbulence**	**Waves and wake**	**Noise**	**Movement**
Water Clarity (turbidity, nutrients, algae)		■	■	■		
Water Quality (metals, hydrocarbons, other pollutants)	■					
Shoreline Erosion				■		
Macrophytes (plant communities)		■	■	■		
Fish	■	■	■			■
Wildlife (Birds, mammals, frogs, turtles)		■		■	■	■
Human enjoyment (air quality, peace and quiet, safety, crowding)	■			■	■	■

What do we know?

While the effects of boats on aquatic systems are complex and depend on a number of factors, a few general observations can be made. First, the physical effects of propeller, waves, and turbulence appear to be more of an issue than engine fuel discharge. Water clarity, aquatic plant disturbance, and shoreline erosion all are serious issues that can be exacerbated by boat traffic. Second, most of the impacts of boats are felt most directly in shallow waters (less than 10 feet deep) and along the shoreline of lakes and rivers not exposed to high winds (less than 1000 feet of open water). Third, these effects can have repercussions for other features of the aquatic ecosystem, including the fish community, wildlife use, and nutrient status. These observations all emphasize that the most important area of a lake or river to protect is the shallow-water, near-shore habitat known as the littoral zone. Boats that operate in deep waters with large surface areas are not likely to be impacting the aquatic ecosystem.

What don't we know?

Given these observations, there are still a number of unknowns regarding motor boat impacts. Most of the studies that are summarized here have focused on the short term or acute impacts of boat activity, pollution, disturbance, sediment resuspension, etc. It is not very clear what role boats can play in the long term changes of a water body, i.e. changes in macrophyte community, overall water quality, or fish and wildlife use. Many other factors influence these same features and many have changed along with boat activity. For example, increased shoreline development often causes increased boat activity, yet it is difficult to separate out which factor is more important for plant community changes. As another example, it has been demonstrated that boats and PWCs can disturb breeding bird activity, but it is difficult to determine what effect this may have on overall bird populations, due to the increasing amount of all human activities in historic breeding areas of many bird species.

What can we do about it?

While specifics of boat use management will be covered extensively in other chapters, we will make a few comments here regarding ways in which environmental impacts of boats can be reduced.

No-wake zones

Given that most impacts of boats are exhibited in shallow-water near-shore areas, protecting these areas with no-wake zones would be the most effective way of reducing impacts. No-wake zones have a dual benefit by both slowing boats down and directing traffic elsewhere. Currently in Wisconsin, boats are required to operate at no-wake speeds within 100 feet of piers, docks, and moored boats, while PWCs are required to operate at no-wake speeds within 200 feet of the shoreline. Lakes less than 50 acres in size are entirely no-wake. While established primarily for safety and navigation reasons, these restrictions appear to be adequate for protecting against shoreline erosion, at least in developed lakes. In many cases, however, these restrictions do not adequately protect shallow-water sediments or beds of aquatic macrophytes. Some communities have extended no-wake restrictions to 200 or even 300 feet through local ordinances. These extended no-wake areas have the potential to protect a much more significant proportion of the littoral zone and may help to reduce shoreline erosion.

A much more useful way of establishing a no-wake area would be to determine the depth at which plants grow in a given waterbody, and then establish a no-wake zone based upon water depth and vegetation parameters. At minimum, a no-wake zone based upon a 6-foot depth would reduce disturbance to sediments. A deeper depth threshold could be justified if the tops of plants come within 5 feet of the surface, or if the sediments were particularly fine. These guidelines could then be coupled with the minimum 100-foot no-wake zone to protect shorelines.

Restricted areas

In some cases, protection of aquatic resources may require restricting all boat activity, not just speed. Boats can still disturb plants, sediments, and wildlife at no-wake speeds. These types of restrictions need to be based upon unique features of a resource and are often used to provide a certain type of experience on remote or "wild" lakes. For example, to adequately protect waterbird breeding areas, a "buffer zone" of at least 100 m (300 feet) has been suggested, in which all human activity would be banned. Similar areas could be established for emergent or floating-leafed plant beds, which may be impacted by boats operating at any speed. Research on Long Lake in the Kettle Moraine State Forest – Northern Unit showed that no-motor zones did a better job of preventing disturbance of submerged plants than simple no-wake zones (Asplund and Cook 1999). Some lakes currently have electric-motor only or no-boat restrictions, which may help to protect particularly unique or sensitive natural areas. These types of restrictions need to balance protection of the resource with the right of public access.

Enforcement and Education

Many of the environmental problems associated with boat activity could be resolved with better enforcement of existing ordinances or regulations and promoting awareness among boaters. Slow-no-wake rules are often ignored or misunderstood by boaters, such that impacts to sediments, aquatic plants, and shorelines occur even in no-wake zones. Another important avenue is informing recreators about the value of plants, littoral zones, and natural shorelines and how their activities may affect the aquatic ecosystem. If people understand that their activities may be hurting the ecosystem, they may be willing to confine their activities to more appropriate places.

Technology

Recent technology spurred by Federal air quality standards has the potential to reduce water pollution impacts from outboard motors as well. All 2-stroke engine manufacturers, including traditional outboard motors and PWCs, must reduce air emissions by 75% by the year 2025. Most manufacturers have already introduced cleaner burning 2-stroke engines and PWCs. Four-stroke engines, which use fuel more efficiently, produce cleaner exhaust, and run more quietly than traditional 2-stroke engines, are becoming much more common. However, technology may have the opposite effect on physical impacts, as engine sizes continue to increase and PWC manufacturers continue to emphasize speed and power. The consequences of operating bigger and faster machines in our inland waterways must continually be addressed in the future.

For further reading:

Asplund, T. R. 1996. Impacts of motorized watercraft on water quality in Wisconsin lakes. Wis. Dep. Nat. Res. Bur. Research, Madison, WI. PUBL-RS-920-96. 46 pp.

Asplund, T. R., and C. M. Cook. 1997. Effects of motor boats on submerged aquatic macrophytes. Lake and Reserv. Manage. 13(1): 1-12.

Asplund, T. R., and C. M. Cook. 1999. Can no-wake zones effectively protect littoral zone habitat from boating disturbance? Lakeline, 19(1): 16-18+.

Bhowmik, N. G., T. W. Soong, W. F. Reichelt, and N. M. L. Seddik. 1992. Waves generated by recreational traffic on the Upper Mississippi River System. Report by the Illinois State Water Survey, Champaign, Illinois, for the U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, WI. EMTC 92-S003. 68 pp.

Burger, J. 1998. Effects of motorboats and personal watercraft on flight behavior over a colony of common terns. The Condor, 100 (3): 528-534.

California Air Resources Board. 1998. Draft proposal summary, proposed regulations for gasoline spark-ignition marine engines 2 (June 11, 1998). Mobile Source Control Division, California Air Resources Board.

Hallock, D. and C. M. Falter. 1987. Powerboat engine discharges as a nutrient source in high-use lakes. USGS Res. Tech. Comp. Rep. 14-08-000-G1222-06. Washington, D.C. 45 pp.

Hilton, J. and G. L. Phillips. 1982. The effect of boat activity on turbidity in a shallow broadland river. J. Appl. Ecol. 19:143-150.

Johnson, S. 1994. Recreational boating impact investigations - Upper Mississippi River System, Pool 4, Red Wing, Minnesota. Report by the Minnesota Department of Natural Resources, Lake City, Minnesota, for the National Biological Survey, Environmental Management Technical Center, Onalaska, WI. EMTC 94-S004. 48 pp. + appendices.

Johnson, S., and others. In prep. St. Croix River shoreline studies, 1995 – 1998: Executive summary. Minnesota Department of Natural Resources.

Kahl, R. 1991. Boating disturbance of canvasbacks during migration at Lake Poygan, WI. Wildlife Society Bull. 19(3):242-248.

Kempinger, J. J., K. J. Otis, and J. R. Ball. 1998. Fish kills in the Fox River, Wisconsin, attributable to carbon monoxide from marine engines. Trans. Amer. Fish. Soc. 127:669-672.

Lagler, K. F., A. S. Hazzard, W. E. Hazen, and W. A. Tompkins. 1950. Outboard motors in relation to fish behavior, fish production, and angling success. Trans. N. Am. Wildl. Conf. 15:280-303.

Madsen, J. 1998. Experimental refuges for migratory waterfowl in Danish wetlands. I. Baseline assessment of the disturbance effects of recreational activities. J. Applied Ecology 35(3): 386-397.

Mastran, T. A., A. M. Dietrich, D. L. Gallagher and T. J. Grizzard. 1994. Distribution of polyaromatic hydrocarbons in the water column and sediments of a drinking water reservoir with respect to boating activity. Wat. Res. 28(11): 2353-2366.

Mueller, G. 1980. Effects of recreational river traffic on nest defense by longear sunfish. Trans. Amer. Fish. Soc. 109(2):248-251.

Mumma, M. T., C. E. Cichra, and J. T. Sowards. 1996. Effects of recreation on the submersed aquatic plant community of Rainbow River, Florida. J. Aquat. Plant Manage. 34:53-56.

Murphy, K. J. and J. W. Eaton. 1983. Effects of pleasure-boat traffic on macrophyte growth in canals. J. Appl. Ecol. 20: 713-729.

Nanson, G. C., A. von Krusenstierna, E. A. Bryant and M. R. Renilson. 1994. Experimental measurements of river-bank erosion caused by boat-generated waves on the Gordon River, Tasmania. Regulated Rivers: Res. and Manage. 9(1):1-15.

Personal Watercraft Industry Association. 1997. Effects of personal watercraft operation on shallow-water seagrass communities in the Florida Keys: Executive Summary. Prepared by Continental Shelf Associates, Inc. Jupiter, FL.

Reuter, J. E., and many others. 1998. Concentrations, sources, and fate of the gasoline oxygenate methyl *tert*-butyl ether (MTBE) in a multiple-use lake. Environ. Sci. Technol. 32:3666-3672.

Rodgers, J. A., and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology, 9(1): 89-99.

Rodgers, J. A., and H. T. Smith. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildl. Soc. Bull. 25(1):139-145.

Schenk, J. E., P. F. Atkins Jr., R. L. Weitzel, P. B. Simon, J. C. Posner, and W. J. Weber Jr. 1975. Effects of outboard marine engine exhaust on the aquatic environment. Prog. Wat. Tech. 7(3/4):733-741.

Stalmaster, M. V., and J. L. Kaiser. 1998. Effects of recreational activity on wintering bald eagles. Wildlife Monographs; No. 137, 46p.

U. S. Army Corps of Engineers (USACE). 1994. Cumulative impacts of recreational boating on the Fox River - Chain O' Lakes area in Lake and McHenry Counties, Illinois: Final Environmental Impact Statement. Environ. and Social Anal. Branch, U.S. Army Corps of Eng., Chicago, IL. 194 pp. + App.

Vermaat, J.E., and R. J. de Bruyne. 1993. Factors limiting the distribution of submerged waterplants in the lowland river Vecht (The Netherlands). Freshwater Biology 30:147-157.

Wagner, K. J. 1991. Assessing the impacts of motorized watercraft on lakes: Issues and perceptions. pp. 77-93. In: Proceedings of a National Conference on Enhancing States' Lake Management Programs, May 1990. Northeastern Illinois Planning Commission, Chicago IL.

Wagner, K. J. 1994. Of hammocks and horsepower: The noise issue at lakes. Lakeline, 14(2): 24-28.

Yousef, Y. A., W. M. McLellon, and H. H. Zebuth. 1980. Changes in phosphorus concentrations due to mixing by motor boats in shallow lakes. Water Research 14:841-852.

Zieman, J. C. 1976. The ecological effects of physical damage from motor boats on turtle grass beds in southern Florida. Aquatic Bot. 2:127-139.

Lake Iroquois

Aquatic Plant Survey

Prepared For:

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Mansfield, CT

February 13, 2015

Background

Lake Iroquois is situated in northwestern Vermont and is bordered by the towns of Hinesberg, Williston, and Richmond. The lake has a surface area of approximately 244 acres with maximum and average depths of 37 feet and 19 feet, respectively (LIA SOTL Report). Lake Iroquois is considered to be a eutrophic lake by LIA due to phosphorus concentrations that exceed the threshold of 14 ppb, and chlorophyll-*a* concentrations that exceed the threshold of 7 ppb.

2014 Project Goal

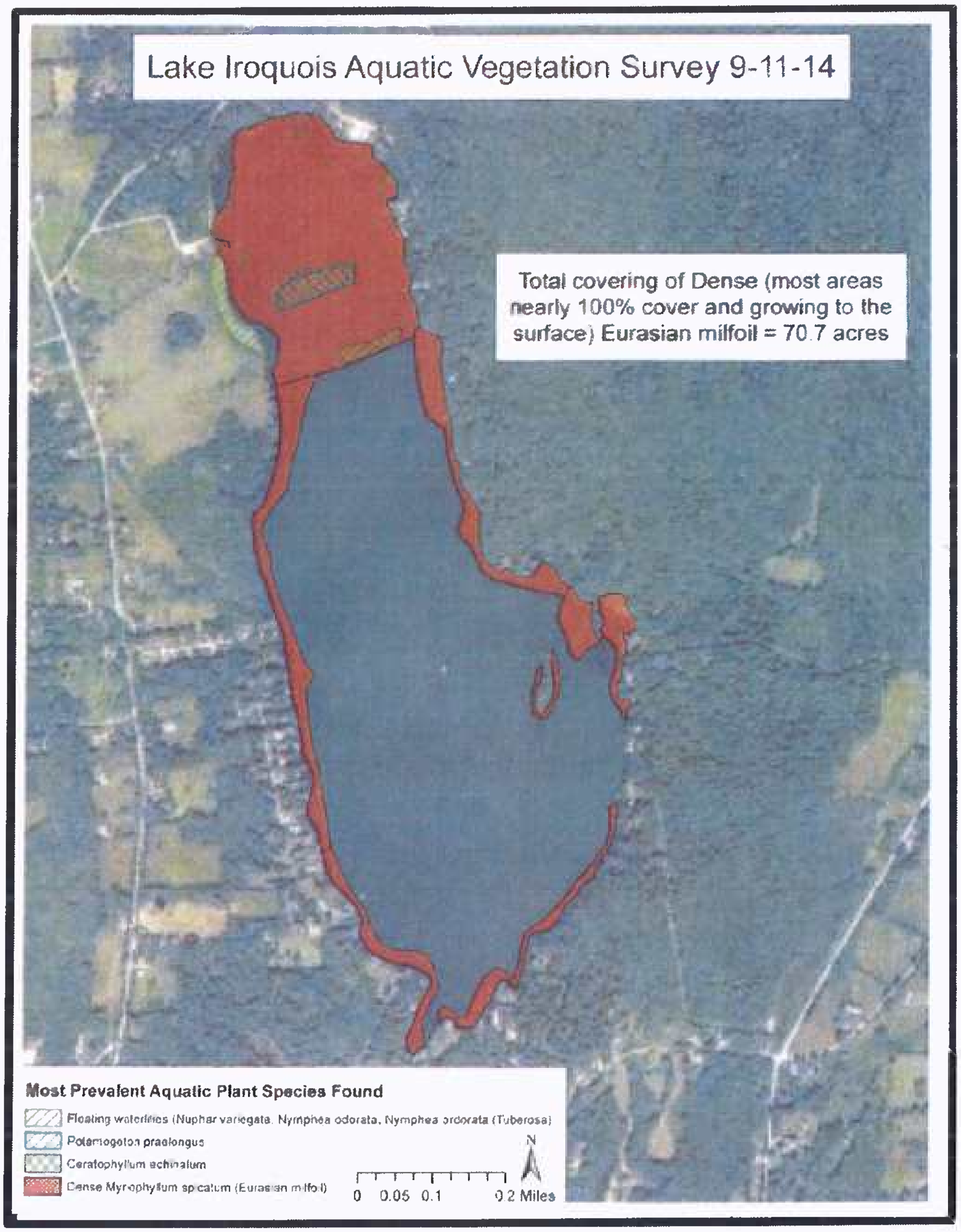
Northeast Aquatic Research (NEAR) was hired to conduct an aquatic plant survey of Lake Iroquois in order to provide an accurate, up-to-date estimate of the coverage of invasive Eurasian milfoil. This invasive non-native aquatic plant was reported (LIA SOTL Report) to be first discovered in Lake Iroquois in 1990 near the state fishing access. Our survey was conducted on September 11, 2014 and consisted of observing aquatic plant species presence and growth form at 136 locations (waypoints) around the shoreline of the lake, **Map 1**. Waypoints were typically made at regular 200 feet intervals. Plant cover between points was observed for similarity to last made point. Significant differences in species presence prompted making a new waypoint. The weather on the date of the survey was not entirely conducive for conducting detailed aquatic plant investigation due to strong Northerly winds, overcast skies, and intermittent rain showers. Due to these factors, venturing out to the center of the lake to investigate plant growth around the center island was omitted due to rough water, however shoreline surveying was completed without problem.

Map 1 – Locations of waypoints made during NEAR 2014 survey

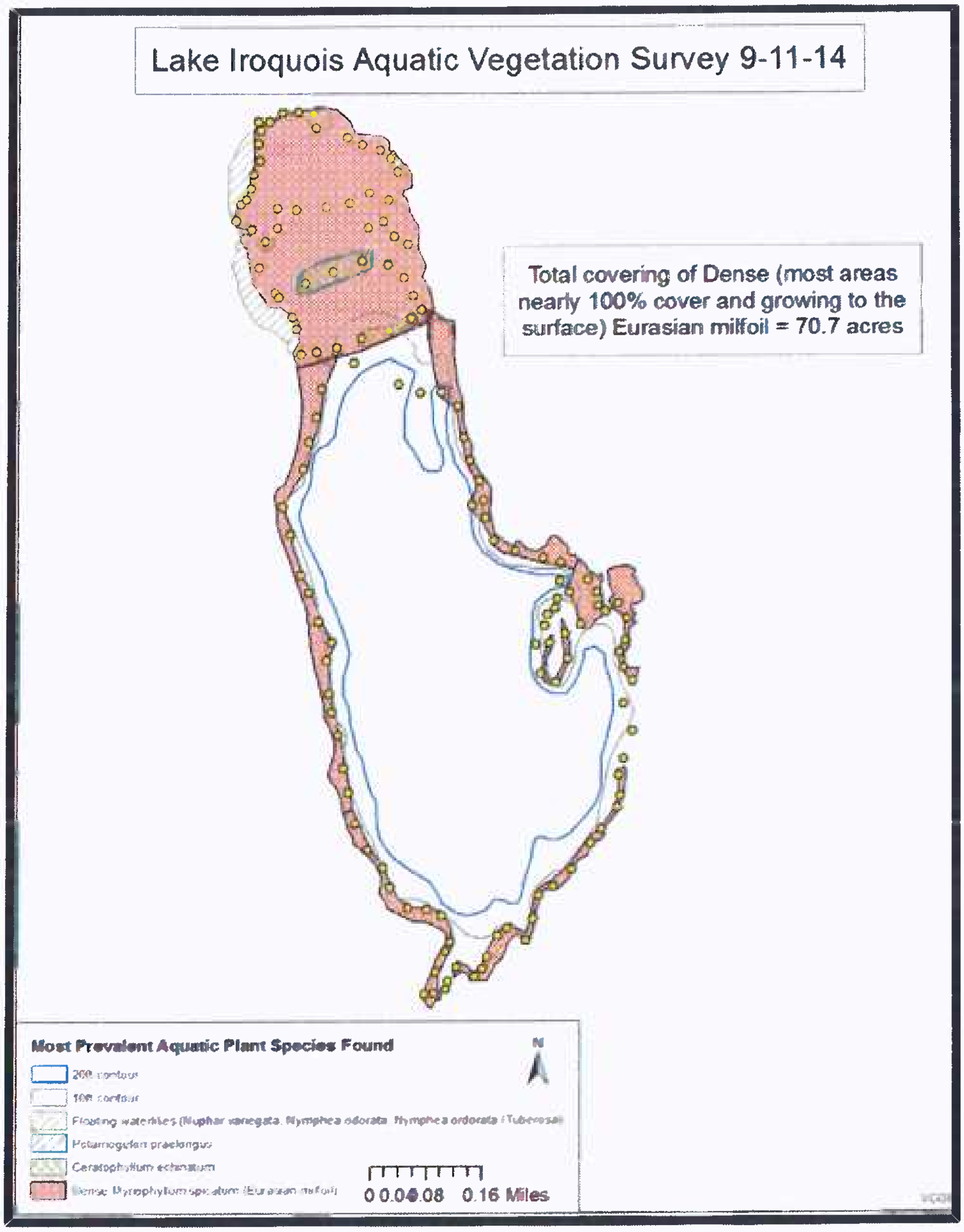
Survey Results

Eurasian milfoil was found to cover approximately 70 acres of Lake Iroquois at high densities (**Map 2**). The plant was usually growing to the surface in thick, matted, continuous beds in depths up to 14.2 feet (4.3 meters), however, in most areas Eurasian milfoil was found growing out to only 10 or 11 feet of water depth (**Map 3**).

Map 2 – Distribution of Eurasian milfoil in Lake Iroquois September 2014



Map 3 – Distribution of Eurasian milfoil in relation to the 10 and 20 foot water depth contours



The lake has a large littoral zone of 105 acres, or about 43% of the total lake surface area. On the date of our survey 70.7 acres of the lake was infested or about 67% of the littoral zone. This suggests that an additional 33 acres of milfoil colonization is possible in Lake Iroquois. The outer boundary of the littoral zone was estimated using 14 feet of water depth. This decision was based on our finding Eurasian milfoil growing to a maximum depth of 14 feet. The outer edge of the littoral zone is based on the depth of light penetration which will vary from month to month and year to year as the water clarity changes. Typically, summer clarity is what dictates the growth of plants so Secchi disk depth readings taken during the summer can estimate changes in size of the littoral zone. Average summer Secchi disk depths at Lake Iroquois have been between 2.8 and 4.6 meters for several years. Secchi disk depth on the day of our survey September 11, 2014 was 4.2 meters (13.8 feet). However, 5 and 6 meter Secchi disk depths have been recorded at the lake in the past. This suggests that should the LIA become successful at reducing phosphorus loading to the lake which leads to a subsequent decrease in lake phosphorus concentrations and water clarity improves, milfoil will colonize deeper water. NEAR has found milfoil growing in 22 feet of water depth in clear lakes but the plant has a theoretical depth maximum of 33 feet. If milfoil was to expand to the 20 foot contour the coverage would increase to about120 acres, about 70% more than found during our survey.

Aside from the extremely shallow areas dominated by water lilies, there were only two small areas--combined less than seven acres--of the shallower littoral area that were colonized by primarily native plants (*Ceratophyllum echinatum* and *Potamogeton praelongus)*.

Below is a list of all species identified during the September 2014 survey listed from most to least percent occurrence in the lake. Bold species are protected species in Vermont.

Lake Iroquois Aquatic Plant Species List			**Survey Date = September 11, 2014**	
#	**Common Species**		**#**	**Less Common to Scarce Species**
1	Myriophyllum spicatum		6	Potamogeton amplifolius
2	Vallisneria americana		7	Nymphaea odorata (subspecies tuberosa)
3	Nymphaea odorata		8	Ceratophyllum demersum
4	Elodea canadensis		9	Zosterella dubia
5	**Ceratophyllum echinatum**		10	Potamogeton hybrid (crispus x richardsonii)
			11	Chara sp.
			12	Potamogeton perfoliatus
			13	Potamogeton zosteriformis
			14	Polygonum amphibium
			15	**Eleocharis robbinsii**
			16	Potamogeton berchtoldii
			17	Utricularia macrorhiza
			18	Lemna trisulca
			19	Nuphar variegata
			20	Spirodela polyrhiza
			21	Eleocharis acicularis
			22	Nitella sp.
			23	Potamogeton nodosus

Bold = VT protected species

In Lake Iroquois, milfoil has become the dominant aquatic plant in the lake. The plant has so overrun the littoral zone that native aquatic plant species are disappearing. NEAR found 23 species during the September 2014 survey compared with 34 species that were present in the lake in 2012 according to the LIA species roster.

Since 1984, 45 species have been found at one time or another in Lake Iroquois. By 2012, 10 of those species had been lost including two species of special concern, Vasey's pondweed (*Potamogeton vaseyi*) and straight-leaf pondweed (*Potamogeton strictifolius*). By 2014, a further 12 species were no longer found in the lake (4 of these species are shoreline plants which may still be present in the lake as NEAR didn't pay special attention to the shoreline during our survey). There were two species of special concern that were found in 2012 but not by NEAR in 2014: lesser bladderwort (*Utricularia minor*) and Nuttall's waterweed (*Elodea nuttallii*).

Excluding shoreline plants, species that were present in 2012 and not found during the 2014 NEAR survey include: *Lemna minor, Najas flexilis, Elodea nuttallii* (Uncommon in VT), *Potamogeton gramineus, Potamogeton spirillus, Potamogeton alpinus*, *Ranunculus* sp. and *Utricularia minor* (Rare in VT). Interestingly NEAR found *Eleocharis robbinsii* in 2014, which is the first occurrence of this state listed plant in the lake. NEAR also found a hybrid *Potamogeton* species identified by Barre Helquist as *P. richardsonii X crispus*. It is possible that some, or all, of these species are still present in the lake but have become so scarce as to make them virtually impossible or very difficult to find, essentially requiring each square meter of the littoral zone to be thoroughly investigated. These searches require specific detailed surveys designed to locate and map scarce plants.

If Eurasian milfoil continues to dominate the littoral zone, expanding its dominance from 74% surface coverage noted during this survey, expect to keep losing species diversity in this once vibrant plant community.

Milfoil control options

There are only a few ways that aquatic plant infestations can be effectively controlled. Essentially, it comes down to using herbicides which give the best scale of control for the money spent. Other methods–other than drawdown—are considerably more expensive, and have smaller scale of control. The only other large scale control method that is inexpensive is triploid grass-carp which is currently illegal in Vermont. The non-chemical methods are; hand-pulling, mechanical harvesters, drawdown, or milfoil weevils. Table below lists the approximate costs of different options including the two herbicides allowed in Vermont. Each management option has pros and cons so choosing a method correctly suited to the specific situation is necessary. Lake management also involves a significant degree of trial and error with deliberate analysis of success during and after each management attempt. Robust lake management requires considering the lake as a whole so that all management is consistent with all aspects of the water body. Individually attempting management in localized areas without knowing connections to the rest of the lake typically are not successful long-term, or can cause impacts to other sections or areas of the lake—essentially transferring the problem to somewhere else. Once whole lake goals are set and visions established, incorporate before and after survey analysis to assess success or failure based pre-described goals. Annually provide feedback to goal setting and visioning to determine if different strategies are needed for the next year.

Table 1 – Comparisons of different Eurasian milfoil control options:

Control Option	Estimated Cost	Benefits	Drawbacks	Bottom line
Winter Water-level drawdown	None--provided release by gravity is possible	Essentially a free control option	Plant control dependent on a number of environmental variables include winter air temperature and snow cover Winter water level drawdown impacts a number of lake factors including invertebrate populations, fisheries, dissolved oxygen of deep water.	Only controls plant beds that are exposed during winter freeze. Plants below drawdown level survive and possible move out further into the lake Requires outlet structure that allows water release and elevation difference between lake level and downstream
Mechanical harvesting/ cutting	Purchase cost ~ $250,000 per machine + ongoing labor and mechanical upkeep costs Contracting harvesters $5,000/ acre	No chemical herbicides	Heavy plant fragmentation and nearly immediate regrowth Generally increased density of harvested plants and causes rapid spreading, and density of plants	A staging area, disposal grounds, and qualified operational personnel are required Compared to 'mowing one's lawn,' regrowth is inevitable
Diver Assisted Suction Harvesting	$6,000-12,000/acre	No chemical herbicides	Very expensive for large areas of dense beds Slow work progress, re-growth possible	Not usually recommended for whole lakes, better option for small ponds or around personal docks Not likely for long-term control or dense beds
Milfoil Weevils	Based on stocking rate of	No chemical herbicides, biological	Very few stocked lakes report success over time.	Labor intensive stocking, typically two to three years before plants

Euhrychiopsis lecontei	about $1/weevil with many 1000s required	control		are affected, may impact *M. sibiricum*-reported to be in Lake Iroquois a State of VT listed plant
Herbicides				
Fluridone (Sonar) *Systemic*	$300-600/acre	Relatively nontoxic	Chemical treatment dispersed through whole lake, liquid application requires 60-90 days of contract	Typically whole lake treatments Longer irrigation restriction
Triclopyr (Renovate) *Systemic*	$900-1300/acre	Low toxicity to aquatic organisms Can be applied only to infested areas	Requires higher dose than Fluridone for effective milfoil control	Less effective chemical treatment, requiring a higher dose

At this time, the infestation is seriously out of control and calls of a significant method to reclaim the lake and the native aquatic plant community it once had. Although it appears that milfoil has spread to its maximum extent this is not the case. Existing beds of milfoil will continue to increase in density, that is plant material per square meter will increase, and spread to areas that did not have milfoil—there were in fact a few areas along the east and south sides where we did not find dense milfoil stands. The plant will also slowly creep out further into deeper water as root runners of the deep water plant extend outward, and more quickly if water clarity improves. Increased density of existing milfoil will further limit native plant survival. Weed control strategy ideas are offered here for review.

Option 1: Conduct a whole lake Fluridone treatment (probably about $150,000). Since this herbicide is applied as liquid and the whole lake is dosed, it affects all the Eurasian milfoil in the lake, such that the following year there will be virtually no Eurasian milfoil in the lake. The principal drawbacks to this approach are that many other aquatic plant species in the lake will also be affected, and the chemical needs to remain in the lake for 60-90 days. However, with such a dramatic loss of native species over the last several years, the remaining species in the lake now are all in jeopardy of loss. It is possible for milfoil to overwhelm most of the remaining submersed aquatic plants in the lake. It is likely that some of the common submersed plants will continue to exist but to what extent this will occur is very uncertain and will remain to be seen. However, with fluridone, Eurasian milfoil will also return in the following years but at a much reduced degree of cover and a much lower density such that most of the littoral zone of the lake will remain open for 2-4 years. During this time the seed bank and dormant root stocks of natives will begin to grow. In subsequent years the re-occurring milfoil can be effectively controlled with spot treatments or non-chemical means, leaving native beds to colonize. Over time native species will return.

Option 2: Conduct a deep water drawdown during the winter. Provided the lake has capability to lower the lake level during the winter, and there are no shallow wells along the shoreline, a deep water drawdown can be very effective at reducing milfoil density in the exposed area. The deeper the drawdown the more acres of milfoil will be affected. Exposed shore needs at least a week of sub-freezing temperatures for affective control of milfoil. However, drawdown will also affect all other plants in the exposed zone, as well as contiguous wetlands that rely on the lake level for inundation. Drawdown will also affect all the invertebrates in the drawdown zone and may have impacts on fish populations and long-term water quality. Also, prior to any drawdown, simple hydraulic analysis of potential refill volumes should be made to insure that there will be enough runoff in the spring to refill the lake.

Option 3: Treat small areas (10-20 acres) of the milfoil with Triclopyr herbicide sequentially each year. Pick areas where plants are causing severe impairment for first treatments. Such areas would include the channel from the boat ramp to deeper water, along shorelines where the most active use occurs, or where milfoil is interfering with other lake functions. Like Fluridone Milfoil will regrow the following season but a much reduced density and cover, allowing for at least one summer season to be milfoil free in the treated areas.

Option 4: Conduct mechanical harvesting of dense milfoil beds along shorelines were active use is currently impaired. Mechanical harvesters typically cut plants between 4-6 feet below the surface so provides relief from topped-out plant beds. Plants will regrow reaching the surface in a number of weeks so this type of control is very short lived, having the poorest control to dollars spent ratio. Harvested milfoil will need to be off-loaded to shore and removed. Harvesting using mechanical means produces fragments which eventually root and regrow causing spreading. Although there may be significant fragmentation by motor boats occurring now this boats produce considerable less fragmentation than harvesters because boats tend not to drive through milfoil beds all day. This option is not recommended because it will cause fragmentation causing further spread, stimulate lateral shoot formation leading to bushier plants, and cause increased transport of plant material to bottom waters where it will accelerate deep water oxygen loss.

Option 5: Remove Eurasian milfoil using diver assisted suction harvesting. This method is very expensive and efficient only over small areas, typically less than an acre. Areas to be suction harvested have to be chosen carefully because of the limitation on how much can be removed in any given season. Suction harvesting typically shows control for longer periods due to most operators being able to get root material out as well. But, it is not a given that suction harvesters will be attempting to get as much root material out as they can, as in the interest of clearing as much area as possible end up just ripping the plants out and leaving most root material intact. Suction harvesting is suited to small beds and isolated re-growth. This option is not recommended because of the large costs, poor area of control, and relative lack of control over the process.

Option 6: Do nothing. For whatever reason doing nothing always results in nothing getting done. There is a myth that nature will take care of things and if left alone the lake will fix itself. This is not true. Doing nothing allows milfoil to maintain dominance over the lake which includes, the water quality, the aquatic invertebrate community, the fisheries populations, the shoreline animal populations, the recreational use of the lake, and the visual aesthetics. Dense stands of milfoil will cause phosphorus to increase in a lake by at least four ways, 1) bottom sediments in a dense stand of milfoil will become effectively isolated from the atmosphere as vertical mixing in the bed is reduced to near zero. Once isolated, water will become anoxic and internal release of phosphorus will occur. 2) Milfoil is a generally leaky plant in that phosphorus translocated from the sediments into the stems and leaves can leak out of the plant into the water column. 3) Continual build-up of organic matter from annual growth and senescence of huge amounts of plant material causes increased decomposition on the lake bottom both in the beds and in deeper water where accelerated oxygen loss will occur furthering internal phosphorus release from bottom sediments. 4) Dense stands of milfoil will foster growth of periphyton and associated planktonic phytoplankton which increases recycling of phosphorus in the water column where it can be used by, and cause, succession to bluegreen (cyanobacteria) forms. This option is not recommended because over health of the lake is compromised.

Dense stands of any aquatic plant, but most specifically invasive aquatic plants, retard diversity of aquatic insects within the beds. Loss of aquatic invertebrates affects the entire food chain. However, often dense beds of milfoil will pose problems for fisheries in that spawning beds are lost and linkages between young fish and aquatic insects are lost. Sometimes an illusion that milfoil improves fishing occurs because the edge of the milfoil stands are typically well defined making bass fishing off the edge of the beds very productive. However, this is not actually the case because the fish have become concentrated on this edge as there is nowhere else to go and the sources of prey fish has dwindled. When the entire littoral zone becomes a monoculture stand of milfoil, most functional aspects of this highly productive part of the lake are lost.

Increased lake monitoring is required in any event. The temperature and dissolved oxygen, in profile from surface to deepest water, should be measured monthly—beginning after ice-out to October--to track both the location of the thermocline and dissolved oxygen loss in deeper water. The maximum depth of Lake Iroquois is stated as 37 feet (11 meters) with recent water clarity of between 3 and 5 meters typical. These data imply a thermocline depth of about 6 meters, leaving about 5 meters of the lake depth from the thermocline to the bottom that is vulnerable to oxygen loss and subsequent internal loading of phosphorus, ammonium, sulfide, and methane. Water quality collections from different depths in the water are required to determine if phosphorus is being generated from an anoxic bottom layer.

Example of a 5 year plan

2015

Submit application to VT DEC for permit to apply herbicides in 2016

$2,500

Annual aquatic plant survey to document extent of Eurasian milfoil and extent of native species—specifically VT protected species

$5,000

2016

Treat Eurasian milfoil with a whole lake Fluridone herbicide, including notifications

$ 150,000

2017

Two aquatic plant surveys, first in spring, second in late summer

$ 10,000

2018

Two aquatic plant surveys, first in spring, second in late summer

Submission for permit to apply herbicides in 2019

$ 25,000

2019

Spot treat Eurasian Milfoil with Triclopyr -or-

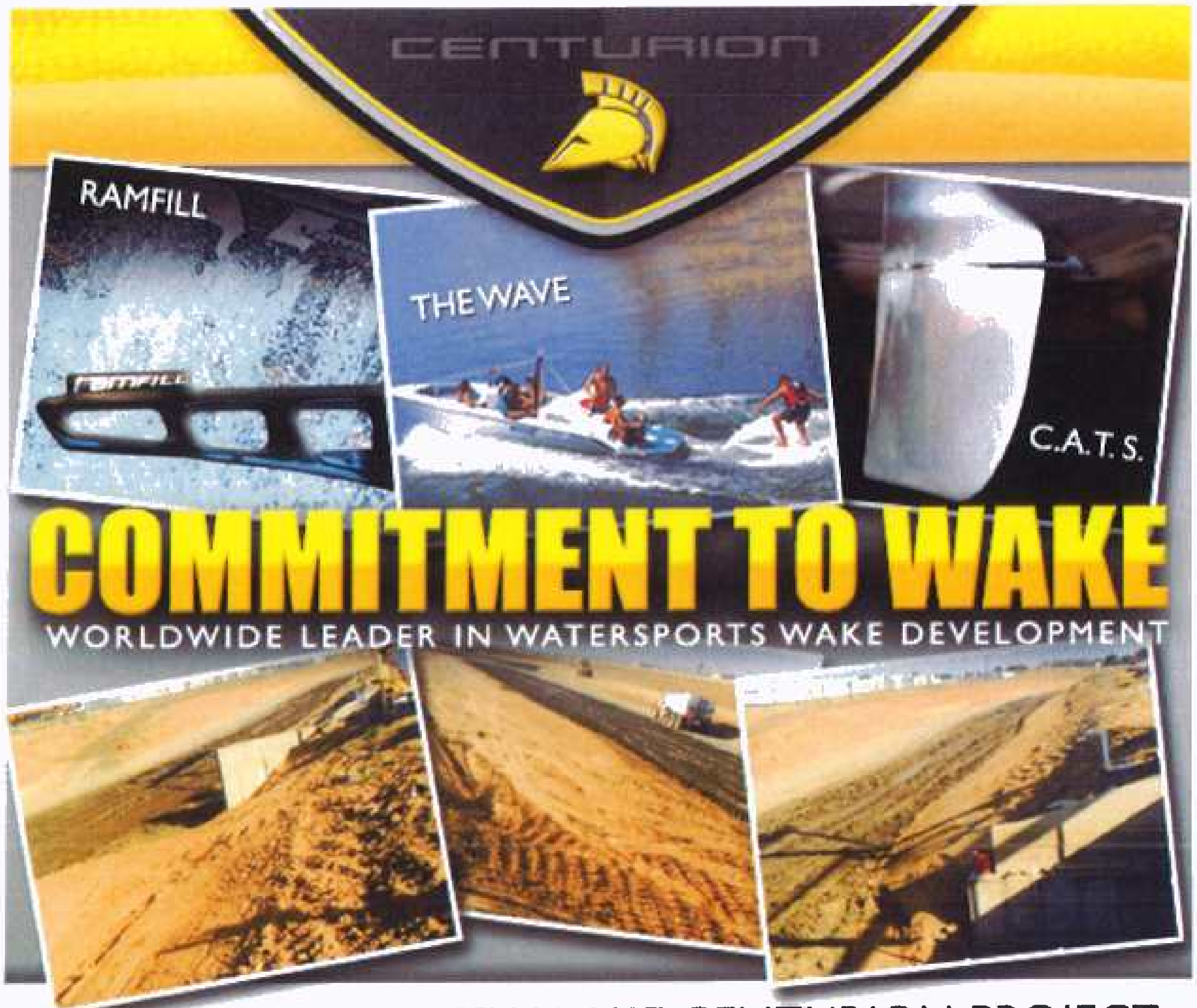
Alternatively: use suction harvesting or bottom barriers on localized beds

$12,500

One aquatic plant survey in late summer

$ 5,000

Note: Cost figures are only estimates and bids should be obtained from actual contractors once LIA decides on their approach and the actual scope of the work.



THE ALL NEW LAKE CENTURION PROJECT

CENTURION DIGS NEW WAKE SURFING LAKE ADJACENT TO THE FACTORY

Merced, CA JUNE 20, 2014; Centurion Boats recently dug a new wider and deeper test lake adjacent to their Merced, California factory. The Lake Centurion project is a half-million dollar investment in the company's wake surfing future. Centurion, the worldwide leader in watersports wake development, invested in the test lake to maintain its leadership in the development of wake enhancing technology for wake surfing and wake boarding.

Centurion created the wake surfing movement in 1995 when it introduced the first wake surfing towboat called The Wave. Now, due to slower speeds and less demand on the body, the pastime is hugely popular and is the number one activity among new watersports towboat buyers. To maintain its leadership in the development of wake enhancing technology, Centurion ordered the lake improvement, including deepening it by eight feet, to give researchers the opportunity to immediately test new technologies such as the all new CATS system. The deeper lake better simulates real-world conditions where towboats are commonly used.

Les Clark Vice President of Manufacturing said, "Wake surfing has been at the epicenter of our culture for more nearly 20 years. We are into wake surfing so much that we built a lake specifically for testing the new technologies that we have coming soon! Now our R&D team will be able to go from design to concept and test it immediately. Coupled with the recent industry leading sales news, it's an exciting time to be in the marine industry and especially at Centurion."

According to the NMMA, growth in sales of inboard powered watersports towboats are currently leading the boating industry ahead of all other propulsion and use categories. In the first quarter of 2014, Centurion recorded the highest percent increase in year-over-year sales among all towboat manufacturers. Lake Centurion is the latest tool in the arsenal that Centurion engineers use to produce more innovative and build better boats.

For more information on Centurion Boats, please visit www.CenturionBoats.com.

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Short Communication CORRECTED PROOF

Quagga and zebra mussel risk via veliger transfer by overland hauled boats

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Abstract

Invasive quagga and zebra mussels (*Dreissena rostriformis bugensis* and *Dreissena polymorpha*, respectively) pose a great threat to US waters. Recreational boats constitute a significant risk for spreading the organisms. Recreational boats circulate large amounts of raw water when in use, and if not drained and dried correctly can transport many mussel larvae, called veligers. Veligers experience very high mortality rates; however, the number of potentially transported veligers can be a serious risk to non-infested bodies of water, especially if multiple boats are involved. The risk of veliger transport was calculated for Lake Mead and Lake Michigan using boat capacities for water circulation and specific veliger density data. Results illustrate the importance of draining, drying, and/or decontaminating recreational boats after use.

Key words: veliger; *Dreissena rostriformis bugensis; Dreissena polymorpha*; transport; decontamination

Introduction

The risk for transporting microscopic larvae (called veligers) from the quagga mussel *Dreissena rostriformis bugensis* (Andrusov, 1897) or the zebra mussel *Dreissena polymorpha* (Pallas, 1771) between water bodies via retained raw water in a boat being hauled overland threatens spreading the invasive species to uninfected waters. It is unknown whether historical inoculations have involved breeding-sized mussels, larvae, or both. To determine the level of threat from veligers, the following example assesses the risk of overland mussel transportation based on veliger density data from Lake Mead on the Colorado River and Lake Michigan in the Midwestern United States. These lakes were selected for this assessment due to their large dreissenid mussel populations and because that boats from either lake have been intercepted throughout the Western United States, frequently with retained lake water and sometimes encrusted with live or dead dreissenid mussels.

The potential rate of reproduction and survival for this aquatic invasive species is alarming. Quagga and zebra mussels are known to be prolific breeders: a single adult female can produce 40,000 eggs or more per breeding cycle (Kachanova 1961; Karpevich 1955) and can breed multiple times per year when water temperatures are favorable (Borcherding 1991). Although the mussels have a high reproduction rate, they also have a high mortality rate. More than 90% of veligers spawned in laboratory conditions perish before reaching maturation and breeding (Nichols 1993). Furthermore, mussels must settle close enough to each other to achieve successful breeding, since reproduction is achieved via open water broadcast spawning between a male and female. Some contend that individuals existing just feet apart cannot successfully breed (McMahon, personal communication, 5 October 2011).

Breeding-sized quagga or zebra mussels and their veligers are known to survive an extended amount of time during transit on or within a boat. Adult mussels are known to live as long as 30 days out of water when humidity and temperature conditions are ideal; that is, temperatures are low but not freezing and humidity is high, near 100% (McMahon et al. 1993). Veligers can live in a static bath simulating contained water in a hauled boat for less than a day at 35 °C and as long as 24 days at 10 °C (Craft, Myrick 2011). Field tests demonstrate that veligers can survive 5 days in summer and about 27 days in autumn in contained water in the southwest United States (Choi et al. 2013). The goal of this paper is to assess the risk posed by these prolific and hardy veligers via overland hauled boats and how to minimize the risk.

Methods and results

Determination of the risk of mussel transport requires consideration of the density of veligers present in the water body and the total volume a boat can hold. Veligers are photophobic (Kobak 2001) and have a slight ability for locomotion (Sprung 1993).While they are consequently not as likely naturally found near the water surface in the daylight, they can be stirred upward by wave action from weather or surrounding boat use. It is thought that overland transport of small-craft boats is responsible for the spread of veligers (Rothlisberger et al. 2010; Schneider et al. 1998; Stokstad 2007). The threat is real: live veligers have been recovered from the engine cooling system of a boat traveling from Lake Mead to Lake Powell in March, 2011, where 19 confirmed veligers were found in the 0.47 L of water recovered (Lake Powell Invasive Mussel Prevention Coordinators Meeting Notes April 7, 2011, personal communication, 5 March 2013). It would therefore not be surprising for normal boat operations to inadvertently move some veligers via raw water circulation into boat motors, wells (bait, transom, and live), ballasts, or even sinks and showers (Colorado Division of Wildlife [CDOW] 2011). Splashed water or drippings from swimmers flowing into the bilge is another potential source for veligers to enter a boat. Given that larvae have been found evenly distributed throughout the water column in sites with disturbed waters (Lewandowski and Ejsmont-Karabin 1983), the number of veligers moved into a boat could be proportional to the estimated veliger density existing in the water column as determined by a vertical plankton tow sample.

Several types of boats frequent at-risk and infected waters and take up some amount of water, including wake boats, fishing boats, and multi-use boats. Boat capacities for water uptake vary greatly, and in our effort to assess risk, we will describe our assumptions on boat capacities as we see most likely to represent the type of boats in question. Wake boats are used for recreational purposes (wake boarding, water skiing, tubing, etc.), and wake boaters regularly circulate raw lake water into their ballasts (a tank used to provide stability and adjust the boat's center of gravity), achieving extra weight to create an ample wake for these recreational purposes. The most aggressive wake-boaters desire between 450 and 1360 kilograms of extra weight, which equates to approximately 470 to 1420 liters of ballast water. For the scenario to follow, we will assume a ballast of 950 L. Fishing boats take up water in a different way: they have live wells and bait wells to keep their catches and bait alive and active. The capacities of these wells varies greatly according to boat and fishing needs, but the combined volume of these wells range from 38 to upwards of 200 liters (CDOW 2011; Petersen Marine Draper UT, personal communication, 11 April 2013). For the risk scenarios presented below, we will assume the capacity of a fishing boat that has 130 liters of on-board life or bait wells. Multi-use boats are those that take on significant ballast and also have live or bait wells onboard. It is also common for the bilge of many of these boats to collect up to 75 liters of water before the bilge pump kicks in to remove it. This water can be collected from leaks, water splash from wave action, or drippings from swimmers. Therefore, boaters failing to drain the ballast, wells, and bilge between various locations could transport significant volumes of water, which could, in turn, contain veligers. Boaters, inadvertently, would then pump the retained raw water and veligers into the next water body upon resumption of routine boat operations.

Two risk scenarios follow which incorporate veligers into these water estimates. The density of dreissenid veligers in lakes is also important to consider in these scenarios. Lake Mead at times has high veliger densities, particularly during the fall season. Researchers have counted Lake Mead veligers via vertical plankton tow samples in all months of the year, with a peak in September 2008 showing 28 veligers per liter. The numbers during other months of the year

Table 1. Risk Scenario – Initial count of veligers aboard a vessel obtained from raw water.

	Lake Mead#		Lake Michigan^	
	Low estimate	High estimate	Low estimate	High estimate
Wake-boat[a]	5,700	26,600	11,400	29,450
Fishing boat[b]	780	3,640	1,560	4,030
Multi-use boat[c]	6,930	32,340	13,860	35,805

Table 2. Risk Scenario – Count of veligers aboard a vessel after veliger mortality, with 10% survival.

	Lake Mead#		Lake Michigan^	
	Low estimate	High estimate	Low estimate	High estimate
Wake-boat[a]	570	2,660	1,140	2,945
Fishing boat[b]	78	364	156	403
Multi-use boat[c]	693	3,234	1,386	3,580*

Water volume estimates: *[a]950 L in ballast, [b] 130 L in live/bait wells, [c]1155 L sum of ballast, live/bait wells, and 75 L bilge*
Veliger populations: *#Lake Mead low-month average: 6 veligers/L; high (Sep 2008) value: 28 veligers/L; ^Lake Michigan low month average: 12 veligers/L; high (Oct 2008) value: 31 veligers/L*
*Value rounded down to the nearest whole number

vary, but average at about 6 veligers per liter (Gerstenberger et al. 2010; Holdren et al. 2010). Likewise, Lake Michigan also has high veliger densities in the fall. The highest veliger density for 2008 was in October, with approximately 31 veligers per liter, and the average of the low months in Lake Michigan was 12 per liter (Nalepa et al. 2010). These numbers constitute our high and low estimates for veliger density.

The following tables represent the risk scenarios for Lake Mead and Lake Michigan, based on the veliger density data and the potential raw water circulation from boats discussed above. Table 1 reflects a scenario based on the number of individual veligers that could be taken aboard a water vessel at each use. Table 2 shows the resulting scenario, assuming the 90% mortality rate found by Nichols (1993). It presents the number of veligers taken aboard each vessel that, theoretically, could likely survive to reproductive maturity, and could survive transport between bodies of water by recreational boaters.

As a worst case scenario, a single multi-use boat containing 1155 L of raw water, when not drained, could haul between 6,930–32,340 veligers from Lake Mead to another water body, re-depositing the veligers upon resumption of normal boat operations. From Lake Michigan, such a boat could haul between 13,860–35,805 veligers. Based on the assumption that 90% of the veligers would fail to survive to maturity, the single inoculation is reduced to between 693–3,234 veligers from Lake Mead and from 1,386-3,580 veligers from Lake Michigan. Risk increases if veliger transfer occurs at a point in time when the veligers have matured to the pre-settler pediveliger stage (e.g., November to January for Lake Mead) because much of the natural mortality has already occurred (Gerstenberger et al. 2010).

On the other hand, if the worst-case scenario multi-use boat were to be drained, but not dried, approximately 4 liters of water are estimated to be retained (likely a few liters always remain in an un-dried boat, no matter the efficiency of draining) (CDOW 2011; Petersen Marine Draper UT, personal communication, 11 April 2013). Regarding Lake Mead or Lake Michigan, respectively, this equates to 2–11 and 4–12 surviving veligers that could be transported, after accounting for a 10% survival rate. Thus, the risk for dreissenid veliger transfer is reduced when a boat is drained. However, if the boat were air dried over a period of time following its draining, as defined by the 100th Meridian Initiative (2011), the risk would be minimized, since all retained veligers would likely perish.

Discussion

The above Lake Mead and Lake Michigan examples only assess inoculation risk from veligers in retained water within a boat and do not assess risk from other life forms of dreissenid mussels when attached to boats.

Considering a 90% mortality rate from the initial (trochophore) larval stage of a veliger to a breeding-sized dreissenid, the risk of veliger transfer in retained water is between 693–3,234 veligers from Lake Mead and 1,386–3,580 from Lake Michigan if transferred by a single multi-use boat containing as much as 1,155 L of raw lake water. The risk of veliger transfer is even lower (2–11 veligers from Lake Mead and 4–12 from Lake Michigan) if that boat is drained. However, if the boat is drained and allowed to dry for a suitable period of time, the risk from veligers is likely negligible.

Transport in onboard raw water is a source for inadvertent movement of *Dreissena* mussels. The risk of successful inoculation increases with multiple boats transporting veligers. However, advanced life stages of a live dreissenid mussel (settlers, juveniles and breeding sized or larger adults) attached to a hauled boat or other wetted equipment as compared to veligers in retained water may present the greatest risk. Attached mussels may already be a breeding colony or will soon become one if the boat is not decontaminated prior to launch. Nonetheless, the above examples demonstrate the need for boats departing *Dreissena* mussel-affected waters to be drained and preferably fully decontaminated prior to entering another water source. This is a core recommendation of the national "Stop Aquatic Hitchhikers!" campaign (ANS Task Force 2013). Nearly all state wildlife agencies in the Western United States advise that boats departing any water body be decontaminated after each use, since the presence of aquatic invasive species, including dreissenid mussels, is never fully predictable (100th Meridian Initiative 2011; Zook and Philips 2012). Successful decontamination by boat owners may be an effective deterrent to introducing aquatic invasive species to new water bodies.

Various states and water body managers should develop and enforce sufficient laws coupled with useful outreach programs to encourage boaters and other water body users to participate in the appropriate management and minimized spread of aquatic invasive species (Zook and Phillips 2012). It is critically important that boat operators, no matter where they originate, be required to decontaminate their vessels prior to use on another water body. Success in controlling the spread of aquatic invasive species, including quagga and zebra mussels, can only be achieved if the public understands the problem and risks to water delivery infrastructure, outdoor recreation areas, and aquatic resources. Unless the public understands, we cannot expect that they will become willing participants in best management practices, that is, boat and wetted equipment inspection and decontamination.

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References

100th Meridian Initiative (2011) Drying Time Estimator for Zebra/Quagga-Mussel Contaminated Boats. http://www.100thmeridian.org/emersion.asp (Accessed December, 2011)

ANS Task Force (2013) Protect your waters and stop aquatic hitchhikers! http://www.protectyourwaters.net (Accessed 11 April 2013)

Borcherding J (1991) The annual reproductive cycle of the freshwater mussel *Dreissena polymorpha* Pallas in lakes. *Oecologia* 87(2): 208–218, http://dx.doi.org/10.1007/BF00325258

Choi WJ, Gerstenberger S, McMahon RF, Wong WH (2013) Estimating survival rates of quagga mussel (*Dreissena rostriformis bugensis*) veliger larvae under summer and autumn temperature regimes in residual water of trailered watercraft at Lake Mead, USA. *Management of Biological Invasions* 4: 61–69, http://dx.doi.org/10.3391/mbi.2013.4.1.08

Colorado Division of Wildlife [CDOW] (2011) Boat compendium for aquatic nuisance species (ANS) inspectors, 41 pp http://wildlife.state.co.us (Accessed December, 2011)

Craft CD, Myrick CA (2011) Evaluation of Quagga Mussel Veliger Thermal Tolerance. Colorado Division of Wildlife (CDOW). CDOW Contract Report CSU #53-0555, 21 pp

Gerstenberger SL, Mueting SA, Wong WH (2010) Veligers of invasive quagga mussels (*Dreissena bugensis*) in Lake Mead, Nevada-Arizona. Department of Environmental and Occupational Health, University of Nevada Las Vegas, 19 pp

Holdren C, Wong D, Hosler D (2010) Spread and abundance of quagga mussel veligers in Lake Mead, Nevada-Arizona from 2007 to 2009. In: Conference Presentations Aquaculture (American Fisheries Society/ National Shellfishereis Association/ World Aquaculture Society Triennial Conference) San Diego, CA, March 1–5, 2010

Kachanova AA (1961) Some data on the reproduction of *Dreissena polymorpha* Pallas in Uchinsk reservoir. *Trudy Vses. Gidrobiol. Obsc.* 11: 117–121

Karpevich AF (1955) Some data on Morphogenesis in Bivalves. *Zool. Zh. Mosk.* 34: 46–67

Kobak J (2001) Light, gravity and conspecifics as cues to site selection and attachment behaviour of juvenile and adult *Dreissena polymorpha* Pallas, 1771. *Journal of Molluscan Studies* 67:183–189, http://dx.doi.org/10.1093/mollus/67.2.183

Lewandowski K, Ejsmont-Karabin J (1983) Ecology of planktonic larvae of *Dreissena polymorpha* (Pall.) in lakes of different degrees of heating. *Polskie Archiwum Hydrobiologii* 30(2): 89–101

McMahon RF, Ussery TA, Clarke M (1993) Use of Emersion as a Zebra Mussel Control Method. U.S. Army Corps of Engineers Contract Report EL-93-1, 31 pp

Nalepa TF, Fanslow DL, Pothoven SA (2010) Recent Changes in Density, Biomass, Recruitment, Size Structure, and Nutritional State of *Dreissena* Populations in Southern Lake Michigan. *Journal of Great Lakes Research* 36: 5–19, http://dx.doi.org/10.1016/j.jglr.2010.03.013

Nichols SJ (1993) Spawning fo zebra mussels (*Dreissena polymorpha*) and rearing of veligers under laboratory conditions. In: Nalepa TF, Schloesser DW (eds), Zebra mussels: Biology, impacts, and control. Lewis Publishers, Boca Raton, Florida, pp 315–329

Rothlisberger JD, Chadderton WL, McNulty J, Lodge DM (2010) Aquatic invasive species transport via trailered boats: What is being moved, who is moving it, and what can be done. *Fisheries* 35: 121–132, http://dx.doi.org/10.1577/1548-8446-35.3.121

Schneider DW, Ellis CD, Cummings KS (1998) A transportation model assessment of the risk to native mussel communities from zebra mussel spread. *Conservation Biology* 12: 788–800, http://dx.doi.org/10.1046/j.1523-1739.1998.97042.x

Sprung M (1993) The other life: An account of present knowledge fo the larval phase of *Dreissena polymorpha*. In: Nalepa TF, Schloesser DW (eds), Zebra mussels: Biology, impacts, and control. Lewis Publishers, Boca Raton, Florida, pp 39–53

Stokstad E (2007) Feared Quagga Mussel Turns Up in Western United States. *Science* 315: 453, http://dx.doi.org/10.1126/science.315.5811.453

Zook B, Phillips S (2012) Uniform Minimum Protocols and Standards for Watercraft Interception Programs for Dreissenid Mussles in the Western United States (UMPS II). Aquatic Nuisance Species Project, http://www.aquaticnuisance.org/wit/reports