Chemical-Free Lakes

A Resource Guide to New Hampshire's Invasive Aquatic Plants and Non-Toxic Treatment Alternatives

Lake Ossipee, Photo by Alie Sarhanis

TOXICS ACTION CENTER

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At Toxics Action Center, we believe that everyone has the right to breathe clean air, drink clean water and live in a healthy community. For 25 years, Toxics Action Center has assisted residents and community groups across New England to address toxic pollution issues. For more information about Toxics Action Center, please contact our offices at the number below or visit us online at www.toxicsaction.org.

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Executive Summary

Lakes and ponds are complex systems that provide a home for many species of plants and animals. They also provide humans with a place to relax, play, and enjoy nature. When invasive plants are introduced to lakes and ponds, they can drastically change the characteristics of these complex aquatic systems. Invasive aquatic plants are a serious problem and can take over an entire lake and make it unusable, not only by other plants and animals, but also by humans.

In the state of New Hampshire, aquatic invasive species infest 76 water bodies, including lakes, ponds and rivers.[1] As of 2007, there were thirty-four water bodies undergoing treatment to control variable milfoil infestations alone.[2] Management plans are filed with the state Department of Environmental Services and typically outline a 5-year strategy for controlling invasive species infestation. Control strategies currently used to control milfoil include herbicide treatments, weed hand-pull jobs, diver assisted suction harvesting, and benthic barrier implements.[3]

Control of invasive aquatic plants is most common via waterborne pesticides or herbicides. The most common herbicides that were applied to New Hampshire water bodies as an approach to control invasive species, specifically variable-leafed milfoil, are Diquat Dibromide and 2,4-D.[4] All pesticides are designed to kill, and these chemicals often impact more than just their intended target. These and other herbicides threaten plants, animals, and most importantly human health. In particular, exposure to Diquat Dibromide can cause severe long-term impacts on human health such as decreased fertility in males, cataract clouding, and damage to the lungs, liver and kidneys.[5] 2,4-D has been linked to birth defects. In addition, herbicides have not proven a sound long-term approach to controlling invasive weeds.

To protect the fish, plants, and other critters that are critical to a healthy lake ecosystem and preserve the recreational value of the water body, invasive weeds must be attacked. This report offers non-chemical options for managing invasive weeds in New Hampshire's lakes.

More specifically, this resource guide provides a basic explanation of the aquatic invasive plant problem currently facing many lakes and ponds across the United States. Included are profiles of the invasive aquatic plants commonly found in New Hampshire, information on the 8 chemicals that serve as the main active ingredients in aquatic herbicides, and descriptions of 15 alternative, nontoxic treatment techniques. Most pertinent to those looking for safer alternatives, two case studies are reported; one on the tri- town collaborative between Moultonborough, Tuftonboro, and Wolfeboro that has had great results using non-chemical management techniques to control milfoil; and a second study that looks at the success the Squam Lakes Association has had in discontinuing their use of herbicides. Furthermore, this report addresses policy surrounding pesticide regulation on a federal level as well as application, use, and monitoring at the state level. Finally, the manual provides a list of resources available to concerned citizens interested in learning more about managing invasive plants in lakes, rivers and ponds across the region.

Recommendations

Protect your Lake or Pond using Preventative Measures

The best way to control invasive aquatic plants is to stop the invasion before it starts. In order to prevent invasive aquatic plants, the plant must first be identified at the source of infiltration, such as along the bottom of a boat, and then stopped from entering the water body. This strategy involves public education, constant monitoring, and rapid action. If you are a boat owner, be sure to thoroughly clean your boat, trailer, fishing gear and any other items that travel from water body to water body. For a courtesy boat inspection and further training on how to identify invasive aquatic species, get in touch with the New Hampshire Lakes Association and ask about their Lake Host Program, http://www.nhlakes.org/lake-host-program.htm. If you have an aquarium, never dump its contents into lakes, ponds, drainage ditches or down street drains – some aquarium plants are invasive species. Dispose of all invasive or exotic plant species properly – in a dry area, away from water bodies and in an appropriate receptacle such as a compost bin.

Manage Invasive Species by Methods of Control

Once a body of water is infested with an invasive plant, a combination of eradication and suppression techniques can be employed. Communities can implement invasive plant control strategies that consider the area to be managed and then select the correct mix of tools to reduce the population of invasive weed and maintain it at the lowest level possible. Eradication of aquatic invasive plants is difficult, if not impossible. Communities should seek to manage invasive plant growth using methods that minimize adverse impacts on native species, water quality, and public health.

Given the harmful effect of herbicides on human health and on native species, we strongly encourage the use of the alternative techniques outlined in this guide. In addition, alternative techniques can prove more effective at controlling noxious weeds over the long term.

We encourage communities to learn from and engage other towns that have had success using non-toxic methods of invasive aquatic species control. As you'll see in one of our case studies, inter-town coordination and shared resources can provide for mechanical harvesting and other non-chemical techniques.

Phasing Out Persistent Toxic Chemicals

Every year, the United States Environmental Protection Agency (EPA) reviews an average of 2,000 new chemical compounds.[6] The 1976 Toxic Substances Control Act requires that these compounds be tested for any ill effects before approval only if evidence of potential harm exists. Frequently, this evidence is not yet available for new chemicals, which leads to the approval of about 90 percent of new chemicals without restriction. Only a quarter of the approximately more than 82,000 chemicals used in the U.S. have been tested for toxicity.[7]

As for long term effects, the potential impacts that chemicals can have on our health and ecosystems are extensive. When using chemicals in water, the issue gets complicated. Introducing a chemical to treat invasive weeds can largely affect the balance of an ecosystem

through nutrient loading as weeds die and decompose. Along with disrupting a water body's nutrient balance, people have to consider what may happen when using chemically treated lake water in home gardens, as a source of recreation, or even as drinking water. We are seeing chemicals take their toll on our health, as illnesses continue to rise. For example, over the last two decades, autism increased tenfold, male birth defects doubled and childhood brain cancer was up 40 percent.[8] According to the U.S. EPA, more than 70 active pesticide ingredients known to cause cancer in animals are allowed for use. Exposure to tiny amounts of mercury, lead, dioxins, PCBs or other chemicals, which may have little impact on an adult, can greatly harm children whose bodies are still developing.

All chemicals on the market should be tested and approved from a precautionary viewpoint. We must ensure that unnecessary chemical use does not occur and that all chemicals used are the safest options.

Chapter I: Introduction to the Problem of Invasive Aquatic Plants

Invasive species are plants or animals that have been introduced to an area where they were not previously found and/or do not occur naturally and have or are likely to cause environmental or economic harm.[9] Invasive species can reproduce and spread widely, vastly changing the ecosystem. For the sake of this report "invasive species" will refer to non-native or exotic, invasive aquatic plants. As will be discussed below, the adverse impacts of invasive plants can be substantial.

It is important to note that there are many plants introduced to new environments that do not spread rapidly; these plants are not considered invasive species, just *non-native* or *exotic species*. They do not pose the same threat to native animal and plant life as invasive species. What truly makes a species invasive is that it out-competes native plants, and without any natural predator, rapidly expands, covering large areas quickly. As the invasive plant takes over the land or water, it also takes over the available nutrients from that lake or pond, making the area uninhabitable for native plants and animals, and sometimes rendering the area unusable for human recreational or drinking purposes.

History

Many invasive aquatic plants appeared in America very early in our nation's history. For example, Purple Loosestrife was introduced to America in the 1800s, both unintentionally, on ships' ballasts and intentionally as a medicinal herb and decorative plant.[10] Some invasive species, including the Purple Loosestrife, which has attractive purple flowers, were purposely planted in wetlands for aesthetic value. However, once in their new habitats these plants spread quickly crowding out native plant varieties and making the lake habitat unsuitable for many native fish, amphibians and other wildlife. Certain states ban the purchase and sale of invasive species, but some nurseries still sell invasive plants. Be sure to always confirm that the plant you are purchasing is NOT an invasive species. Check with your local government and keep updated on what is legal and illegal in your state. The Invasive Species Committee created a list of 18 species to be banned from sale and transport throughout the state of New Hampshire in 2004 [11]. To check out a full list of prohibited invasive species visit the UNH Cooperative Extension website, http://extension.unh.edu/FHGEC/docs/Invasive.htm. Whether introduced accidentally or

An infestation of Eurasian milfoil in Squam Lake in New Hampshire.
(http://www.des.state.nh.us/wmb/exoticspecies/photos.htm)

deliberately, many invasive plants have had devastating effects on native aquatic plants and animals, and even water quality.

Furthermore, infestation can decrease the property value of the land surrounding the lake by clogging the lake (limiting its uses), creating bad smells and accelerating the natural aging of the lake. Invasive species can block entranceways and decrease the depth of lakes, making swimming, fishing and boating impossible. The overgrowth of invasive species has even resulted in lake and pond closures.

Invasive plants have been known to spread through animal migrations or movements. For example, Canadian Geese have been spotted in flight with Water Chestnut seeds attached to their feathers. Unfortunately, there is little that humans can do to prevent migrating animals from spreading invasive plants. They can however prevent migration through responsible boating and recreation practices.

Today, the most common way invasive species are introduced is by clinging to boats that are moving from lake to lake. Pieces of invasive plants attach to the trailers or the propellers of the boat and are transported between lakes, seeding an entire new colony of invasive plants. For more information about how boaters can keep from the spreading invasive plants, visit the New Hampshire Lakes Association website at http://www.nhlakes.org, or the Stop Aquatic Hitchhikers website at http://www.protectyourwaters.net/nh. For information on state funding, visit the NH Department of Environmental Services website for available grants provided to prevent and manage invasive species infestations, http://des.nh.gov/organization/divisions/water/wmb/exoticspecies/categories/grants.htm.

A Worsening Trend

Lake Ossipee, Photo provided by Alie Sarhanis

Many invasive plants have been around for decades but are increasingly problematic today. Human modification of the environment, the increasing popularity of boating as a recreational activity, and the continual development of rural and wilderness areas has caused the spread of invasive plants to quicken. Since 1800, more than 50,000 foreign plant and animal species have established themselves in the United States, and about 1 in 7 has become invasive.[12] As human activities increases, more animals and plants are endangered or threatened by decreasing habitat. species can cause drinking restrictions if the infested lake or pond is a potable water source.

Chapter II: Models of Successful Management

Case Study: Tri-Town Collaborative

Milfoil is one of the most common and problematic weeds among the collection of several other aquatic invasive species that are claiming an unwelcome dwelling in several of New Hampshire's lakes, ponds, and rivers. Since the 1960's, milfoil has been making its way through the water bodies of New Hampshire, presenting new obstacles for boaters and annoyances for homeowners.[13] Out of the 76 New Hampshire water bodies that are currently infested with some form of invasive species, milfoil inhabits 63 of them.[14] If left, uncontrolled, this weed will invade a water body, becoming a dense, tall lawn. Over time milfoil will leave a lake unfit for boating, swimming, fishing, and overall enjoying. It is therefore necessary that future milfoil infestations are avoided and that sustainable and safe management practices are enacted.

In 2010, Governor Lynch pulled together a summit of interested parties on aquatic exotic weeds. The objective of this summit was to consider funding for management and discuss potential alternatives to chemicals. The summit resulted in the possibility of grant money as well as federal funding to pursue innovative ways to manage milfoil. In response to this summit, members of several milfoil town committees worked with the New Hampshire Department of Environmental Services to identify non-chemical techniques for managing the milfoil in their lakes. The team settled on the DASH Unit, or Diver Assisted Suction Harvester.[15] A DASH Unit is a form of mechanical harvesting that requires professional diving assistance.

http://www.nhlakes.org/LakesideWinter2011.pdf

In an effort to eradicate or lessen the problem of milfoil, the three towns of Moultonborough, Tuftonboro, and Wolfeboro together applied for a multi-town grant to assist with the purchase of a shared DASH unit. The town administrators, town milfoil committees, selectmen and concerned residents all worked together to compose and submit a grant.[16] The tri-town collaborative successfully received a grant from Program the New Hampshire Lakes Association in May 2010 for $26,369 and an additional $15,000 from the three towns.[17] This grant distributed from the NH Lakes Association was funded through federal funding through NOAA and state funding from the NH Recreation Resource Development Committee.

This Tri-Town Collaborative purchased two used 24-foot pontoon boats and hired a contractor for the winter of 2010-2011 who redesigned and outfitted the boats for use as DASH units. Equipment was purchase, plans of action were crafted, and the new units were ready to launch in June of 2011. For the summer and fall months, the tri-town collaborative decided to hire three diving outfits to run the DASH units in partnership with town volunteers.[18]

After the preliminary investment, organizing, and construction of the DASH units, which were all funded by the initial grant, Tuftenboro formed a milfoil committee in conjunction with

Wolfeboro and Moultonborough's preexisting committees. The milfoil committees took on the responsibility of gathering funding for each town's respective diver and services. Each town set up a schedule with 3 different divers for 79 days total of diving services throughout the summer and fall. Diving and harvesting continued until October 2011. The towns all reported success and satisfaction with the outcome of the summer dives and harvesting.[19]

The DASH units are managed between the 3 towns and the NH Lakes Association. When a Weed Watcher spots a new infestation, they notify the town's milfoil committee, who in turn notify the NH Lakes Association to order use of a DASH Unit. The milfoil joint board sets up the daily fees, covers the diver fees and insularly charges, including the cost of fuel.

Photo provided by Ken Marschner

Compared to dives from the previous year, the tri-town collaborative has been able to see a large return rate and a huge increase in efficiency and productivity with the DASH units. It was noted that using three different diving contractors was effective in driving down the price. The competition between the three contractors aided in cutting the price of diving services from an average of $1,800 per day in 2010 to $1,200 per day in 2011. [20]

Moving forward with this collaborative approach, the towns formed an inter-municipal agreement that was signed by three Select Board members from each town. The state attorney general then approved this agreement. The town also created a joint board composed of two members from each town, which functions to develop policies, procedures and scheduling related the DASH units. [21] The NH Lakes Association functions as the contractor for divers while the three towns develop the diving schedules. Through effective planning and use of alternative management tools, the towns of Moultonborough, Tuftonboro, and Wolfeboro have all been able to decrease their use of herbicides.

Back Bay: An Example of a DASH Victory

Successful DASH harvesting activity can be specifically illustrated by efforts and outcomes at Back Bay. About 7 years ago, one could nearly walk across the 35 acres of milfoil-infested waters of Back Bay. The infestation was originally treated with herbicide, 2,4-D, in 2005. The second herbicide treatment, which was scheduled for a year after the first treatment, was canceled due to the Mother's Day floods that occurred in 2006. By 2007, after 2 years without treatment, the milfoil infestation had entirely grown back. In 2008, the bay was treated with DASH spot removal. In 2009 half a treatment of herbicide, 2,4-D, coupled with DASH spot removal was implemented. By 2010, the town was now able to stay ahead of the growth cycle with the DASH unit alone and totally eliminate the use of herbicides. [22]

Case Study: Squam Lakes Association's transition away from herbicides

Within the Lakes Region of New Hampshire are the two beautiful Squam Lakes. The large and small Squam lakes, connected by a channel, are located just 40 miles north of Concord.[23]

The Squam Lakes are gravely infested with variable milfoil. The exact date of when variable milfoil made its way into the Squam Lakes is unknown. In the summer of 2000, the New Hampshire Department of Environmental Services (DES), found variable milfoil in the Squam River in Ashland. Since the DES confirmed this original siting, milfoil has crept throughout various parts of the Squam Lakes. [24]

Photo provided by the Squam Lakes Association

The Squam Lakes Association, a non-profit conservation organization, has since been actively engaged in controlling and eradicating milfoil infestations. In collaboration with DES, the Squam Lakes Association develops long-term management plans for the lakes. Originally the group controlled invasive species infestations with application of herbicides: Diquat Dibromide and 2,4-D.

It was noticed that areas treated with Diquat would only remain milfoil free for a couple of weeks after the herbicide application. [25]In a particular area of the lakes, there was a well established milfoil infestation covering a full acre of surface water. Diquat was applied to the lake's surface in June and by August of that same year, the infestation had entirely grown back. Not only were chemicals not proving to be effective in eradicating the weed, but also the potential health and environmental threats of the chemicals were unknown and intimidating.[26]

The Squam Lakes Association made the decision to stop using herbicides to treat milfoil and began implementing methods such as hand pulling and benthic matting, which have proved to be more effective.. Areas where these alternative management methods were implemented had fewer occurrences of weed re-growth compared to areas that had been treated with Diquat or 2,4-D. [27]

To assist with the hand pulling method, the Squam Lakes Association acquired 2 DASH (Diver Assisted Suction Harvesters) units. One of these boats is designated as a full time DASH unit while the second boat has removable DASH equipment. This allows the second unit to be used half time as a DASH unit and then used for other purposes the remainder of the time. The

equipment purchase was funded by donations and labor was and continues to be provided by interns of the organization. In 2010, interns participated in four 10 hour days throughout the year of intensive milfoil hand pulling. The Squam Lakes Association has been very pleased with the results of implementing these alternative methods and sees no need to return to herbicide use. Chemicals have not been used to treat milfoil infestations in the Squam Lakes in the past 5 years.[28]

Photo provided by the Squam Lakes Association

Chapter III: Commonly Found Invasive Species

The following pages are brief summaries of some of the most problematic invasive aquatic plants found in New Hampshire. For a more in-depth, scientific, or nationwide description of aquatic invasive species, consider looking at some of the national websites suggested in the appendix of this guide. The plant profiles include information on the plant's appearance, growth patterns, reproduction mechanisms, and common methods used to control them. This information can help you identify invasive plants in your water body and distinguish them from some native look-a-likes. Understanding the growth and reproductive patterns of the plant will also help in determining which management tool is most suited for controlling or eradicating the species with which you are dealing.

*Eurasian Watermilfoil (*Myriophyllum spicatum*)*

(http://www.nps.gov/plants/alien/fact/mysp1.htm)

Eurasian Milfoil is a submerged, rooted plant that grows throughout the year. It has long underwater stems that branch out and produce finely divided leaves as it reaches towards the surface. It reproduces primarily through fragmentation of plant tips or root pieces. Eurasian Watermilfoil is the most widespread invasive aquatic plant in North America, found in over 45 states, and commonly referred to as simply "milfoil." The earliest confirmed record is 1942 in the District of Columbia but milfoil is thought to have originally been brought over around 1900.[29]

Even a tiny piece of a milfoil leaf can reseed an entire new colony elsewhere. Milfoil forms extremely dense mats of vegetation on the surface of the water, which limits and eventually prevents swimming, fishing and other recreational activities. Milfoil can interfere with irrigation or power generation by clogging water intake valves. It has less value as a food source for waterfowl than the native plants it replaces. Milfoil can completely infest a lake in as short of a period as two years. [30]

There are at least 20 insects that feed on milfoil, but few have been as thoroughly researched or are as widely available as the weevil. The weevil appears to be the most promising long-term solution to controlling the milfoil population in a lake or pond.

*Variable Milfoil (*Myriophyllum heterophyllum*)*

(http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/frightful_fourteen.pdf)

Variable milfoil threatens the health of water bodies due to its highly regenerative characteristics and growth patterns. It is believed that variable milfoil was introduced to the state of New Hampshire in the late 1960's by motorboat activity. Variable milfoil is now present in over 64 New Hampshire water bodies. This

exotic plant can be identified by its feather-like appearance. Fine, spike-like leaves are compactly arranged along a central stem. This plant is submerged beneath the water and can reach up to 15 feet in height.[31]

Variable milfoil reproduces through fragmentation and seed dispersal. Once the milfoil has fragmented it grows new roots and begins to populate a new area, threatening native plant and animal species. Variable milfoil grows as a monoculture and can mature up to 1 inch per day.[32]

The NH Department of Environmental Services designs an integrated plant management plan for each infestation case. Although the seeds of variable milfoil are resistant to herbicide, the already established plant is commonly managed via the application of herbicide 2,4-D. Harvesting through hand-pulling or diver-assisted suction, as well as use of benthic barriers are viable control options. Use of 2,4-D has often been prescribed for the treatment of variable milfoil, then permitted by the state and performed by professionals. However non-toxic techniques such as hand pulling, harvesting, and benthic barriers work quite well. Aquatic chemical application has the potential to harm other species within the lake ecosystem.[33]

(http://www.mainevolunteerlakemonitors.org/mciap/herbarium/images/NajasMinorSpec4.jpg)

*European Naiad (*Najas minor*)*

European Naiad is an invasive species that first made its way into North America in the 1930's and has since spread through the Eastern United States. The European naiad is a submerged plant and can be identified by its stiff, spiral-shaped leaves. These pointed leaves form clusters along the plant's willowy branch. Branches grow up to 4 feet in height.[34]

August through October is the peak time for European Naiad breeding. The plant becomes frail and populations drop during later summer to early fall.[35]

In an attempt to control European Naiad populations, management techniques such as herbicide application, mechanical harvesting, and benthic barrier construction have been implemented. When using mechanical harvesting and removal as a control action, caution must be taken in order to not leave any remains or fragments in the water. Plant fragments left behind can easily develop into a new, viable invasive plant. As far as chemical management, Endothall, Diquat, and Fluridone are the primary herbicides that have been applied to fight European Naiad infestations.[36]

*Fanwort (*Cabomba Caroliniana*)*

Fanwort is a freshwater, submersed perennial that can be floating or rooted. It is native to the Southeastern United States but is considered invasive in the Northeast and the West. Fanwort is known for forming dense strands of plant growth that make water unusable for recreation, while simultaneously

(http://des.nh.gov/organization/commissioner/pip/factsheets/bb/documents/bb-25.pdf)

crowding out native plants and animals. The plant prefers muddy, shallow and stagnant water that is common in small ponds, slow moving streams and ditches. Because of its attractive leaves it has been a popular aquarium plant.

The Fanwort's leaves are less then 1/2 inch long and are narrow ranging in color from green to reddish-brown. The flowers are white and small, usually less then 1/2 inch in diameter. These flowers float on the water and can be seen from May to September. Grass carp have been used to control Fanwort however it is not their preferred food.

*Brazilian Elodea (*Egeria densa)

Brazilian elodea can be found in many household aquariums as ornamental vegetation as well as in various types of water bodies throughout the northeast United States. The Brazilian elodea is characterized by its bushy appearance. The weed has a bright green stem with short leaves that branch off in a whorled formation in groups of four.[37]

(http://www.ppws.vt.edu/scott/weed_id/belodea12-28.jpg)

The growing population and spread of this weed species can be largely attributed to irresponsible dumping of household aquariums as well as motorboat travel between different water bodies. Once introduced to a new pond, lake or river, Brazilian elodea reproduces solely through fragmentation. Growth of the Brazilian elodea produces thick, impenetrable mat-like colonies.[38] Herbicide applications, such as fluridone, diquat and copper are commonly used to manage Brazilian elodea infestations. None of these herbicides are selective to Brazilian elodea and all have a high potential for damaging other organisms within the ecosystem.[39]


(http://www.adkinvasives.com/aquatic/PlantID/Pondweed.html)

*Curly-Leaf Pondweed (*Potamogeton Crispus*)*

Curly-Leaf Pondweed is a hardy, aggressive plant with hard leaves that have founded tips and a prominent red mid-vein. It emerges in spring and dies back by June or July and can grow in water up to 15 feet deep. It is a native to Africa, Australia and Eurasia.

It is thought that Curly-Leaf Pondweed has infested most of North America.[40] The plant has spread rapidly due in part to fisheries and hatcheries using the plant as source of food and habitat for their animals.

Curly-Leaf Pondweed is characterized by lasagna-like leaves, which are stiff and semitransparent with saw-like edges. The leaves are arranged alternating up the stem with increasing frequency as they approach the tip. Only a flower stalk emerges above the water; the rest of the plant grows beneath the surface of the water. Non-toxic methods of controlling Curly-Leaf Pondweed include encouraging

phytoplankton growth to reduce the sunlight reaching the plant.[41]

*Water Chestnut (*Trapa Natans*)*

(http://tncweeds.ucdavis.edu/esadocs/Trabnata.html)

Water Chestnut is an annual, rooted, floating plant that forms dense (often impenetrable) mats at the water's surface. This plant can grow up to 16 feet long and looks similar to several native plants, however its "nutlets" make the plant distinctive. It is spread primarily by boat traffic, however Canadian geese have been seen migrating with nutlets attached to their feathers. Water Chestnut seeds can lay dormant for up to 12 years.[42]

The Water Chestnut has green, triangular, floating leaves that attach to the main stem by a floating stem, which can reach up to 15 feet in length. The triangular leaves are smooth and waxy on the top, rough to the touch on the bottom, and have toothed edges. Water Chestnut produces thorny nutlets with four points in early summer. Each nutlet contains 100 or more seeds and can cause injury if stepped on.[43]

The Nashua River, the only New Hampshire water body infested by the water chestnut, is covered by acres upon acres of dense, entangled mats of the water chestnut. In 2 years alone, 1,500 tons of water chestnut were collected from the Nashua River by a mechanical harvester.[44] Hand pulling is the most widely used method for removing the plant because the floating tops and thin roots make removal easy. Research on biological controls involving specific moths, weevils and some other insects found naturally in Asia is currently being completed, however no major controlling insect has yet been identified and thoroughly tested.

(http://plants.usda.gov/java/profile?symbol=PHAU7)

*Phragmites (*Phragmites Australis*)*

Phragmites are often referred to as the Common Reed and are found in every state of the continental United States. Phragmites can live in fresh or brackish water, however it prefers slow moving and slightly brackish water like that found in small ponds or on roadside ditches. Phragmites is well-known as a hardy and persistent species; it exists on every continent except Antarctica.

It has many commercial uses including being used to create pen tips, papers, mats and can be used to clean sewage or polluted waters. Phragmites can create a potential fire hazard when it dries in fall and winter.[45]

Phragmites are a tall perennial grass that can grow up to 16 feet tall. It has wide stiff leaves and a hollow stem, and flowers start purple and eventually turn white as the plant matures. Phragmites is a colonial plant in that it spreads through its underground root system.

Due to its large size and the denseness of the mats that it forms there are limited mechanical control mechanisms for Phragmites. Cutting or mowing the plant and then applying covers can

be extremely effective as it completely kills the plant including the root system. Additionally, controlled burns and dredging have been used. Changing the ecological balance of the area by adjusting the salinity or water velocity can make the habitat unsuitable for the reed. It should be noted that adjusting water conditions such as salinity is non-selective and may also adversely impact other aquatic plants and animals as well. There are 26 known herbivorous species that attack the Common Reed, however only a few are native. These include the Yuma skipper (*Ochlodes yuma*), a Dolichopodid fly (*Yhrypticus*), a gall midge (*Calamomvia phragmites*), and a native broad-wing skipper (*Poanes viator*).[46]

*Purple Loosestrife (*Lythrum Salicaria*)*

Native to Europe, Purple Loosestrife is thought to have been introduced to the United States in the 1800's. It was introduced accidentally on ships' ballasts and then purposefully as a decorative plant and a medicinal herb. It is estimated that 190,000 acres of land (wet or dry) are invaded each year by Purple Loosestrife. Even though many states consider this plant to be an exotic, invasive species you can still purchase it at some nurseries. It is a hardy species that can establish thick stands in many different types of wetlands.[47]

(http://www.nps.gov/plants/alien/fact/lysa1.htm)

The leaves are heart shaped at their base and arranged in opposite pairs up the stem, which can grow to over 6 feet in height. The stem is distinctive in that it is four sided and woody. Fully grown plants may have 30 to 50 stems rising from one single rootstock. Purple flowers appear from July to September. These flowers have five to seven petals each. Purple Loosestrife reproduces vegetatively, which means it proliferates through non sexual reproduction, through underground stems. Fragments can reseed a new colony elsewhere.[48]

Hand pulling, mowing and burning are common mechanical techniques for control. Covers can be used once the plant has been cut back to increase the level of success. Additionally, five insects have been approved in the United States for use as biological controls, including leaf-eating beetles and stem boring weevils. Biological controls have seen great success in Vermont and Rhode Island.

Potential Future Threats to New Hampshire Water Bodies

There are five other invasive species that are not yet present in the state of New Hampshire yet have been noted by the New Hampshire Department of Environmental Services as potential threats. Community members should be familiar with these species and mindful not to introduce them to water bodies within New Hampshire when boating and traveling across state boundaries.

Parrot Feather's (Myrriophyllum aquaticum)

Parrot feather is an invasive species with feather-like leaves growing from a long rooted stem. The plant grows through the water and even emerges above the surface, giving the weed a shrub like appearance above the water. The leaves visible above the water are bright green, rubbery and are arranged in whorled formations around the stem.[49]

(http://www.plantedtank.net/forums/images/plants/204_Parrots_Feather_Myriophyllum_aquaticum.e.jpg)

This invasive species is indigenous to the Amazon River, so therefore it naturally thrives in warmer climates. However due to its rapid reproduction, since its introduction to the southern United States in 1890 the plant has quickly spread northward. Parrot feather is present throughout the United States as far south as Florida and as far north as Washington in the west and New York in the east.[50] Infestations can quickly crowd the water body's surface making the surface nearly impenetrable to light, which may harm other aquatic species. Other disadvantages to unwanted and uncontrollable populations of parrot feather include: increased mosquito population, drainage and irrigation problems.[51]

A truly effective control method for parrot feather has not yet been identified. Hand pulling and mechanical removal of the plant should be approached cautiously due to the weed's ability to populate through fragmentation. Any bits or fragments of the plant left behind after mechanical weeding or harvesting can very quickly result in a new parrot feather infestation. Herbicide application is not entirely successful at eradicating the weed due to parrot feather's wax-like surface.[52]

Yellow Floating Heart (Nymphoides peltata)

The yellow floating heart is an aquatic invasive species that is very similar to a fragrant water lily. Yellow floating heart grows in large mats on the water's surfaces which may have aesthetic appeal due to its bright colored blossoms but these mats also highly diminish opportunity for boating, swimming or fishing. The dense mats formed on the water's surface also act as a light barrier, threatening the health of the ecosystem below the water.[53]

(http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/frightful_fourteen.pdf)

The name of this invasive species greatly alludes to the plant's appearance. The yellow floating heart is characterized by its yellow flowers and floating heart shaped leaves. The waxy green leaves grow from long stalks and float in dense clusters on the water's surface. The flower blossoms have 5 bright yellow colored petals that hover on long stalks a few inches above the leaves. The yellow floating heart reproduces through seed dispersal and re-growth from broken leaves.[54]

The aquatic herbicide, Rodeo, a glyphosate herbicide, is a commonly used chemical in controlling this nuisance species. Simple but timely methods of controlling yellow floating heart

infestations include cutting and hand harvesting. Utilizing a bottom barrier to cover root growth has also proven effective. Due to species similarities, it's likely that tactics used to control water lily populations may also be effective in managing yellow floating heart.[55] Some methods implemented for controlling water lilies include: covering dense growth with an opaque fabric to limit light exposure, using rotovation techniques, and introducing insects that may potentially serve as a biological control.[56]

(http://dnr.wi.gov/invasives/fact/hydrilla_photos.htm)

*Hydrilla (*Hydrilla Verticillata*)*

Hydrilla is a non-native plant that has a long slender stem that branches profusely as it approaches the surface of the water. Hydrilla can form dense colonies of plants up to 20 feet deep and can reproduce through seeds, fragments of the plant, roots and buds. It creates dense mats preventing the recreational use of the water body. Hydrilla is native to Europe and Asia. It was first brought to the US for the aquarium trade in the 1950s.[57]

Hydrilla leaves are blade like and usually 5-8 inches long with a pointed tip and a mid-vein on each leaf. Female flowers are white while male flowers are greenish in tint. The plant can be identified by the rough feel to the underside of the leaves.

Ducks have been known to eat Hyrdilla, but it is not their first choice of food. There is a leaf-mining fly (*Hydrilla pakistanae*) which is being studied as a control mechanism.[58] It has been shown to provide short-term control. Weevils have also been employed with some success.

Flowering Rush (Butomus umbellatus)

Flowering rush is an eye-catching invasive plant that was originally brought to North America from its native range of Africa, Asia, and Europe for gardening purposes. This invasive plant is a tall perennial that can be found on the shores of various water bodies. Flowering rush typically grows in water about two meters deep and can only grow in sunny conditions. Population growth of this plant is rapid and leads to dense colonies, which can serve as an obstacle for boat traffic and recreational activity as well as a competition for native vegetation.[59]

(http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/frightful_fourteen.pdf)

The flowering rush stems from a fleshy rhizome with basal leaves. The top of the plant has a complex blossom growth that flourishes from July through September. The flower appears as a cluster of 2-3cm wide pink blossoms shaped in an umbrella-like formation. Each individual blossom has 3 petals, 9 stamens, and an extended anther. The entire flower formation is composed of six pistils that are arranged in a whorl with the flower blossoms on one end and all unite with the rhizome at the other end.[60]

The plant spreads through distribution of seed and vegetative fragments which can happen in a variety of ways including: migration through boat transportation, spread from home gardens, dispersal of plant parts by muskrats, and travel through water and ice movements. Once the plant has reached a watershed, the flowering rush continues to regenerate through root pieces and expands through rhizomes.[61]

Cutting and harvesting can be used to control infestation growth. When cutting, pulling, or raking this plant, it is necessary to take extreme caution in removing all parts of the plant as the roots can produce new growths. The harvested flowering rush can be used for culinary and cooking purposes. The tuber of the plant can be peeled and cooked and the roots can be dried, ground, and applied to dishes like soups. It is difficult to control this species through herbicide application because the chemical is not easily contained on the plants narrow leaves. There are also no herbicides specific to managing this species.[62]

European Frogbit (Hydrocharis morsus-ranae)

The European frogbit, another water lily look-alike, was first sited in the United States in 1974 in the Oswegatchie River of New York. European frogbit is a plant native to Europe and northern Asia and was brought to Canada for ornamental purposes. Leathery, heart-shaped leaves, small white flowers, and an un-anchored root system, characterize this invasive species. The flowers have 3 small white petals with a yellow-colored center. [63]

(http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/frightful_fourteen.pdf)

This nuisance plant thrives in stagnant or slow-moving waters and grows in dense mat-like formation across the surface of the water. Reproduction occurs asexually through the growth of underwater runners that form extensive, entangled networks. Persistent reoccurrence and infestation can be attributed to the production turions, the dormant winter buds that fall to the bottom of the water body and only resurface in the spring allowing for a new population of the plant to flourish. Dispersal of the European frogbit commonly occurs through motorboat transport.[64]

The dense mat-like colonies that the European frogbit creates threaten native species by competing for nutrients and light. Very few methods of control have been proven or noted as viable for managing European frog bit infestations. Two methods that have potential in limiting growth and possibility eradicating the plant are hand harvesting and shading.[65]

Chapter IV: Commonly Used Aquatic Herbicides

The problem of invasive plants is real, and these plants must be managed or they will take over an entire water body. Chemical treatment is the oldest method used to control nuisance weeds in lakes. Evidence shows that chemical treatments performed over a number of years become less effective at controlling invasive plants. They may be a quick fix but have not been proven as a long-term solution for controlling invasive species like milfoil.

According to the U.S. EPA, a pesticide is "a substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest." [66] A "pest" is any plant or animal that threatens our immediate environment, our food supply, our comfort or our health.[67] The most common types of pesticides are 1) *fungicides* that control fungi such as athlete's foot, ringworm, and mushrooms, 2) *insecticides* that control insects, 3) *rodenticides* that control rodents like rats and mice, and 4) *herbicides* that control any unwanted land or aquatic plants. There are many other types of pesticides, but in this report we are most interested in the most widely used type of pesticide, *herbicides*.

The improper use and disposal of herbicides into our water bodies can cause nutrient and pH imbalances, kill off beneficial organisms, contaminate drinking water supplies, and severely harm non-target species. Evidence for this is revealed in two studies released by the Vermont Fish and Wildlife Department detailing a history of failure for chemical treatments in two Vermont lakes. The state's studies claim that not only did herbicides fail to control milfoil over a number of years, but they also posed a substantial threat to fish populations and native vegetation.[68] Unfortunately, despite increasing evidence of the dangers of pesticides, it is still the most commonly used aquatic weed-control technique in New Hampshire. The following section provides information on the herbicides approved for use in New Hampshire water bodies.

2,4-D (Stands for 2,4 –Dichlorophenoxyacetic Acid)

2,4-D is a systemic herbicide, which means that the chemical is absorbed by roots or foliage and distributed throughout the plant. It inhibits cell division in new tissue and stimulates growth in older tissue resulting in cell disruption. 2,4-D can be applied as a liquid or in granular form, usually during the early growth stages of the plant.[69]

Dioxin and a handful of other products were removed from Agent Orange, a defoliant used in the Vietnam War, to create the pesticide 2,4-D. However, the current chemical is still linked with widespread poisoning, birth defects and health problems. It is the oldest organic (containing carbon) aquatic herbicide approved for use in the United States, dating from the 1940s. Treatment costs are estimated around $300-$800 per acre, depending on degree of infestation and company used. Repeat treatments will be necessary at least once per season.[70]

2,4-D is fast acting and allows for some selectivity depending on application timing and concentration. It is most commonly used to control Water Chestnuts, Eurasian Milfoil, and Curly-Leaf Pondweed.[71] It does not affect seeds, which means that applications must be repeated every season. It restricts the use of water for irrigation or recreation after application. 2,4-D

cannot be used in water for drinking and has the ability to leach into nearby groundwater supplies.[72]

Copper (Also known as Copper Sulfate)

Copper is a contact herbicide, which means that it must come in direct contact with the target species to be effective. Copper is toxic to plant cells, disrupting proper cellular function, inhibiting photosynthesis, and possibly affecting the nitrogen metabolism of the plant. It is usually applied in granular form (it can also come in liquid form) by putting it in bags which are towed behind the application boat.[73]

Different forms of Copper are generally combined with other herbicides or pesticides to make them more effective agents of weed control. The copper ion is persistent in the environment and will either accumulate in soil or move downstream to accumulate there.[74] Treatments typically cost $50-$100 per acre although repeat applications are required and there must be extensive monitoring of the site which will add to the overall cost of application.

(http://www.chss.montclair.edu/~pererat/0000d.jpg)

Copper is often used as an algal control agent.[75] However, copper is highly toxic to zooplankton (*Daphnia* sp.) which eat the algae that Copper Sulfate is used to control. So applying Copper Sulfate to control algae can actually eliminate the natural controlling agent of algae. Additionally, Copper Sulfate is potentially toxic to all aquatic plant species and lacks selectivity. Lastly, if not carefully applied, copper sulfate can create oxygen depletion leading to fish kills and damage to other non-target plants and animals.

Diquat Bromide (Commercial Products: Reward)

Diquat Bromide is a non-selective, contact herbicide, algaecide, disinfectant and defoliant used against broadleaf and grassy weed species in aquatic areas. It is applied in a liquid form, oftentimes mixed with copper. Diquat Bromide is absorbed by foliage, not only by the roots, and only affects the area of the plant with which it comes into contact.[76] Treatment usually costs between $200-$500 per acre with repeat applications required.

The production and use of Diquat bromide poses significant risks. Its manufacturing creates a bi-product named Ethylene Dibromide (EDB), a known carcinogen which is banned from use in the United States. The chemical is listed as toxic to animals and has caused cancer in rats in laboratory studies.[77] Exposure to Diquat Dibromide can cause severe long-term impacts on human health such as decreased fertility in males, cataract clouding, and damage to the lungs, liver and kidneys.[78] Diquat Bromide can be fatal to


(http://www.dep.state.fl.us/lands/invaspec/images/Chem_control_airboat.jpg)

humans if swallowed, inhaled or absorbed through the skin.

Diquat Bromide is fast acting, and is known to control Eurasian Milfoil, Brazilian Elodea, and Curly-Leaf Pondweed. It provides moderate control of immersed plant species and moderate to high control of floating or submersed species.[79] It is non-selective in the target area, meaning that plants and animals that are not necessarily the target can be negatively impacted or harmed.

When Diquat Bromide is used, there must be a 24-hour swimming restriction, a three day domestic water restriction, and a two to five day irrigation restriction on use of water after application. Regrowth of invasive species will occur, so repeat application is necessary. Diquat Bromide forms strong bonds with clay and soil particles, making it ineffective in muddy or murky water and increasing its tendency to have long-term persistency in the soil.

Endothall (Commercial Products: Aquathol, Des-I-Cate, Tri-endothall, Ripenthol and Hyrdothol)

Endothall is a contact herbicide, so only the parts of the plant that come in direct contact with the chemical deteriorate. Endothall limits the plant's use of oxygen by inhibiting photosynthesis and disrupting the cell membrane. It causes structural deterioration of the plant but does not affect the root system of the plant. It is usually applied in liquid or granular form.[80]

It is actually the Dipotassium salt of Endothall which is used in aquatic herbicides. It is not an eradication technique, as it can only be used to control invasive plant numbers. Because it is a contact herbicide, it is generally used for spot treatments, not whole lake treatments. Treatment usually costs $400-$700 per acre with repeat applications and monitoring required.[81]

Endothall is fast acting, and is commonly used to control Hydrilla, Eurasain Milfoil, and Curly-Leaf Pondweed among other species, usually floating or submersed types of aquatic plants.[82] The Endothall label advises a three day fish consumption restriction after application. In addition, there is a 14 day restriction on using treated water for irrigation or for stock watering. There is also a recommended restriction on swimming after application and Endothall cannot be used in drinking water supplies.[83]

Endothall rapidly kills plant matter, creating a buildup of decaying plant matter which can lead to oxygen depletion and fish kills. Endothall is non-selective in target areas and is potentially toxic to all aquatic fauna.

(http://aquat1.ifas.ufl.edu/seagrant/sgherb2.jpg)

Fluridone (Commercial Products: Sonar, Pride, Brake, Rodeo)

Fluridone is a systemic herbicide, which means that the chemical is absorbed by the leaves or roots and then spreads throughout the rest of the plant, killing it. It interferes with the plant's ability to photosynthesize. It is a slow acting chemical that must be in contact

with the plant for 45 to 60 days, which leads to repeat applications and extended exposure time. Fluridone works best when applied as a liquid or in granular form during the early growth phase of the plant.[84]

Highly water soluble, Fluridone remains in the water one to fifty-two weeks. It is restricted from use within 1/4 mile of any drinking water supplies (both surface and well). Costs can range from $500-$1000 per acre for the first treatment and then up to $2000 for the subsequent treatments.

Fluridone has been shown to control Eurasian Milfoil, Fanwort, Hydrilla and Curly-Leaf Pondweed among other invasive plants. It kills plants slowly, limiting the chance that oxygen levels in the lake will be effected therefore reducing the probability of fish kills.[85] Its slow acting nature means that it must remain in the water for long periods of time to be effective. Additionally, it is difficult to perform partial lake treatments because Fluridone is extremely water soluble. Lab tests have shown that Fluridone has chronic adverse effects to the eyes, liver, kidney and can cause testicular atrophy.[86]

Glyphosate (Commercial Products: Roundup, Tumbleweed, Rodeo, Gallup, Touchdown)

Glyphosate is a non-selective systemic herbicide that is absorbed through the leaves. The chemical disrupts enzyme formation, but scientists aren't sure how exactly it kills the plant. It is applied as liquid spray to the targeted area.[87]

The cost for treatment is about $500-$1000 per acre, depending on density of infestation. Glyphosate is not for use within 1/2 mile of drinking water intakes. Glyphosate is fast acting and can be used selectively if applied extremely carefully, and is known to control emergent and floating plant species. Additionally, Glyphosate requires no time delays for use of water when applying per label instructions.[88]

Glyphosate will not work if there are large amounts of suspended particles or if the water is muddy or highly murky. It is easily absorbed by clay and soil particles, which means there is the chance that it will persist in soil after application. Additionally, there are serious concerns over the health effects of Glyphosate, especially when combined with inert ingredients or other herbicides. Though touted by manufacturers as relatively safe and nontoxic, glyphosate can in fact cause serious health repercussions, especially eye and skin irritations that can sometimes be quite severe and can persist for months.[89] Glyphosate has also been linked to non-Hodgkin's lymphoma.[90]

*Triclopyr (*Commercial Products: Renovate, Garlon, Turflon, Pathfinder, Access, Brush-B-Gon, Confront, and Crossbow)

Triclopyr is a commonly used herbicide in managing aquatic invasive weeds within New Hampshire[91]. Triclopyr was registered in 1979 and now exists in several products with toxicity levels ranging from low to high.[92] Triclopyr is the active ingredient in the aquatic herbicide, Renovate OTF. Aquatic weeds that are commonly managed with Renovate OTF include milfoil,

bladderwort, parrot feather, Eurasian water milfoil, water chestnut, and more. Renovate OTF comes in a granule form and can be applied along shorelines, docks, and at any water depths.[93]

The Triclopyr present in Renovate OTF attacks the target plant by disturbing metabolism function. Although Renovate OTF is noted to be a selective herbicide, it may still inflict damage on other aquatic life. The EPA water restriction guidelines suggest that humans should not drink water with a Triclopyr concentration above 0.4ppb. EPA water restrictions also state that after aquatic application of Triclopyr, 120 days should pass before treated water is used for irrigation or ingested by animals. [94]

Within water, Triclopyr has a half-life from 1- 10 days depending on general water conditions and sun exposure. When ingested by humans, Triclopyr has a half-life of 5.1 hours and is excreted through urine. Animal testing showed that Triclopyr exposure results in liver and kidney mutations and elevated levels of breast tumors in female animals.[95] Triclopyr is highly corrosive to eyes and has sensitizing effects on the skin.[96]

Imazapyr (Commercial Products: Habitat, Arsenal, Chopper and Stalker)

Imazapyr is an herbicide most commonly used to manage annual terrestrial weeds and perennial grasses. *Habitat,* the aquatic form of Imazapyr, was registered by the EPA in 2003 and has since been used in New Hampshire to manage phragmites infestations. Imazapyr is a non-selective herbicide and interrupts plant growth by interfering with the production of branched-chain amino acids. Because Imazapyr is non-selective, it is not suggested to apply this herbicide through a broadcast spray technique.[97]

When applied to a water body, Imazapyr has a half-life of two days and is broken down through sunlight exposure. Although Imazapyr is recorded to have a low toxicity among birds, mammals, and aquatic animals, testing results did show mutations and birth defects in some lab animals. Imazapyr does not bioaccumulate in mammals and is readily excreted through urine. When exposed to Imazapyr, humans are at risk for severe skin irritation and irreversible eye damage.[98]

Chapter V: Alternatives to Aquatic Herbicides

The following pages include summaries of some, but not all, of the common types of alternative treatment techniques for lakes and ponds that have been infested by invasive aquatic plants or that have aquatic weed problems. More research on these techniques along with new and innovative approaches are being developed every day, and should be considered when choosing to control an invasive species.

There are benefits and trade-offs for every type of alternative treatment technique. Good management strategies often include combining several different types of treatments to achieve the desired control of the invasive plant based on needs and desires for the lake or pond. Wetlands are extremely complicated and unique systems with many variables that must be considered when choosing a treatment technique or group of techniques.

Hand Harvesting (Also called: Hand Pulling)

Hand harvesting is exactly what it sounds like: people or divers physically pull plants from the lake or shoreline. Hand pulling can include tools like rakes, cutters, nets, etc. Cost of hand harvesting depends on if you are using divers or simply hand pulling in shallow waters or from the deck of a boat. The density of plant infestation will also affect the price. Volunteers or interns can be recruited to do hand pulling cheaply. Permits may be required for hand harvesting. Check with your local and state government for rules and regulations. Hand harvesting is the most accepted method for removal of Water Chestnuts.[99]

(http://www.pbs.org/wgbh/nova/algae/images/abou-program.jpg)

Advantages:

- Highly selective method that allows only the target invasive species to be removed.
- Works well in small patches or where invasive species have not yet become dominant.[100]

Disadvantages:

- This technique is highly labor intensive and will most likely need to be repeated annually. However, it is generally reported that the population of the invasive plants decreases each year after hand pulling efforts.
- Incomplete pulling or breaking of certain species can increase spread of infestation so nets should be utilized to catch any fragmented pieces.
- Hand harvesting can temporarily increase the turbidity of the lake.[101]

Mechanical Harvesting

Mechanical harvesting can encompass a variety of different methods but the most common is simply using a machine to cut the vegetation. There are many commercial harvesters who can be contracted to cut the vegetation. Varying cost depending on company used, plant you are targeting, its density and the area to be covered. Estimates range from $300 to $500 per acre for normal infestation.[102]

Advantages:

- Good for quick removal of thick and dense stands of plant growth without risking oxygen depletion.[103]

(http://www.ecy.wa.gov/programs/wq/plants/management/aqua026.html)

Disadvantages:

- This is a non-selective process and both native and non-native varieties will be removed.
- There is the risk of fragmentation leading to further infestation of the lake.
- Mechanical cutting can actually stimulate re-growth of the plant and more then one cutting per season will most likely be required.
- Risk of fuel spill or leakage from harvesting machine.
- The process is disruptive to aquatic plants and animals in the area of the cutting and some animals might be harmed or killed by the harvesting machine.
- Machine needs to be operated by a professional.[104]

Benthic Barriers (Commercial Names: Aquascreen, Texel)

Benthic barriers are simply bottom covers that limit the amount of light available to aquatic plants. This reduces or prevents photosynthesis and kills the plants. There are a variety of porous and solid materials that have been developed for these barriers, including polyethylene, polypropylene, fiberglass and nylon. Benthic barriers are usually used in localized areas such as around docks.

There are strengths and weaknesses to both solid and porous materials respectively:

- *Solid Materials*—effectively kill plants, but need venting to allow gases to escape and need to be staked down well
- *Porous Materials*—can billow which allows for less securing and weighting of the material but plants can root on top of the material increasing the maintenance requirements

(http://el.erdc.usace.army.mil/aqua/apis/mechanical/image/barrier1.gif)

Benthic barriers can be used in coordination with draw-downs to reduce plant height and density and make installation easier.[105]

Advantages:

- After initial cost for design and purchase of material the annual cost is limited to installation, maintenance and storage during the winter months.

- Material cost can vary from .22 cents to $1.25 per square foot. Commercial installation costs will also vary greatly depending on the retailer and material chosen.
- You do not necessarily need a professional to design, install or maintain the barrier.
- Good for use with invasive plants that reproduce vegetatively because the plants will not be cut or fragmented by the benthic barrier, limiting the chance that the treatment technique will actually exacerbate the problem.[106]

Disadvantages:

- Maintenance can be difficult and/or time consuming.
- Only practical on a small scale; not for whole lake treatments.
- Problems have been reported regarding keeping the covers in place and installing the covers over dense and tall plant growth.[107]

Artificial Aeration/Circulation

Artificial aeration or circulation is the use of air to keep water in motion in order to change oxygen levels in different areas of the body of water. By increasing oxygen circulation, the amount of internal phosphorus recycling is reduced thus limiting the food available for plant growth. Aeration apparatuses come in many different forms, from circulation devices (bubblers, fountains and diffusers) which can been seen on the surface, to devices that function completely underwater (subsurface aerators).

Aeration also can help to reduce the release of nutrients from the sediment, minimize algae blooms, and enhance the breakdown of organic material. Prior to considering the implementation of this management tool one should investigate the source of nutrient loading, the type of algae blooms that persist in the system, and the water quality conditions in the water body. Cost depends greatly on the equipment and company used. Estimates put the maintenance and electricity costs between $200 to $3,000 dollars plus the cost of initial purchase and installation.[108]

Advantages:

- Limited impact on non-target species and no negative health affects for humans.
- Wide variety of devices and companies to choose from when selecting an aeration device.
- New models currently being developed and tested. For example, the Solarbee is an aeration device used to control algae blooms that is being studied to reduce invasive plant growth as well. The Solarbee runs on solar power, thus limiting electricity costs. For more information, see http://www.solarbee.com/.

Disadvantages:

- Costs for installation and maintenance on some models can be high.
- Possibility of vandalism
- Recreation may be restricted within close proximity of circulation/aeration machine depending on the product.
- Potential that the machine may spread localized impact by circulating fragments or seeds.[109]

Rotovation

Rotovation is the removal of plants with an underwater tiller. The tiller disrupts the soil, ripping out root formations. Cost estimates are around $500 to $2,000 per acre depending on the company used, type of plant slated for removal, and the density of the plant infestation. It is a technique that was originally developed by the British Columbia Ministry of Environment to combat noxious weeds in Canada's rivers and lakes. The Minister of Environment was looking for a mechanical method to control weeds because chemical control methods were not yet readily available. Rotovation can reach bottom sediments to the depth of 20 feet.[110]

Advantages:

- Rotovation can provide longer control of invasive plant species as compared to other cutting or harvesting techniques (if rotovation is done correctly).
- Can provide two full seasons of control with one rotovation.[111]

Disadvantages:

- Can cause a certain amount of sediment disruption. If there are contaminates in the soil it can be dangerous to disturb them.
- If not done properly, control of the invasive species will not be achieved. The root system must be completely disrupted and pulled up from the sediment.
- Not effective or realistic in areas with large amounts of underwater disturbances like tree stumps or other large trash items.

(http://el.erdc.usace.army.mil/aqua/apis/mechanical/image/rotovatr.gif)

- If large amounts of plant material are tilled, the plant material might need to be removed from the lake bottom after tilling to remove biomass, prevent possible oxygen depletion, and limit the chance of fish kills.
- Risk of spreading invasive plant through fragmentation.[112]

Hydroraking

(http://www.aquaticanalysts.com/clamrpic1.htm)

Hydroraking is the equivalent of using a backhoe in the water to remove floating islands, stumps, large amounts of debris or thick stands of invasive aquatic plants. The cost of removal of submerged plants will vary greatly depending on the company used and the density/extent of the plant problem; estimates can be between $1,500 and $4,000 per acre. As with submerged plants, the cost to remove surface varieties depends on the company and density/extent of plant problem; estimates can be between $6,000 and $10,000 per acre.[113]

Advantages:

- Hydroraking can additionally be used to physically remove large objects like bulk trash pieces that have been dumped in the lake or pond.
- A relatively quick process that removes large, dense stands of aquatic invasive plants.[114]

Disadvantages:

- It is not a very delicate process and will stir up large amounts of dirt and mud, which could be a problem if there are toxins embedded in the soil and sediment.
- The process is very disruptive to animal life and the area surrounding the lake or pond.
- It is non-selective and will remove both native and non-native plants in the area of treatment.
- Will not completely remove the invasive plant population and may actually spread the problem through fragmentation or debris.[115]

Dredging (Types: Wet, Dry or Hydraulic)

Dredging is the physical removal of sediment and any rooted plants by excavation. Hydraulic or pneumatic dredging is used when removing sediment and plants from within the lake; wet or dry dredging is employed when working along the shoreline.

(http://www.lakesidemc.com/customers/10308 2614393383/images/dredging.001.jpg)

Dredging is usually conducted when attempting to increase lake depth; algal or plant removal is merely a side effect, and is most often performed only on systems that are severely affected due to high costs and implementation difficulties. The costs vary considerably depending on what type of dredging is implemented, the amount of soil

removed, accessibility of the area to be dredged, the disposal cost of soil if contaminated, permitting costs, and other various costs associated with the technique.[116]

Advantages:

- Can restore a severely impacted lake or pond to a usable depth and quality.
- Can remove polluted soil from lake or pond bottom.
- Can completely eradicate an invasive species from the water body if done correctly.[117]

Disadvantages:

- Costs can be extremely high and the time required to complete the project can take years.
- Dredging will restrict access to the area of the lake or pond being dredged.
- There is a large impact on the ecosystem, not only on the animals and plants in the lake but also on the surrounding area due to machinery movement, worker traffic, downstream runoff and the disposal of removed sediment.
- The permitting and planning process can be lengthy. Some states restrict dredging if the soil is contaminated.
- This is a large-scale project with considerable impacts and costs.[118]

Draw-downs

Managers of reservoirs and some lake systems have the ability to lower the water level as a method of controlling aquatic plants; this is called a draw-down. The process is usually done in autumn, when the best results are yielded. A drying and then a freezing period can increase the success of draw-downs. The water should be removed slowly over a period of two to three weeks to prevent erosion, downstream flooding and harm to wildlife.

(http://aquat1.ifas.ufl.edu/guide/physcon10js.jpg)

Though it appears to be a simple technique, there are many variables that must be considered including plant types, seasonal temperatures and surrounding or dependent water bodies. The process can be inexpensive if the infrastructure is already in place for a drawdown (i.e. dam, water pump system or existing outlet facility). If equipment is not in place, the price could be $100,000 or more to build the infrastructure.[119]

Advantages:

- Relatively little impact on wildlife as long as the process is done gradually.
- Reports of great success, eradication of Brazilian Elodea in Black Lake, Louisiana.
- Draw-downs also provide a great opportunity to have a shoreline clean-up removing litter and large items that are normally covered with water.[120]

Disadvantages:

- If infrastructure is not already in place, then cost is probably prohibitive.
- All plants (invasive and non-invasive) are killed in the draw-down area.

- Can temporarily reduce well water levels of those nearby the lake and draw-down area.
- Often requires permits, public notice and a discussion period. Check with local and state governments for rules or regulations.[121]

Selective Plantings (Types: Native or Non-Native)

(http://outdoors.mainetoday.com/trailhead/cat_trail_tales.html)

Selective planting involves planting native or non-native plants that are resistant to undesirable species. The theory is that if native or non-native (non-invasive) plants are taking up the land and nutrients then invasive species will not be able to take root. Usually this approach is used after a drawdown or after the use of a benthic barrier. When used in combination with these methods, selective plantings are more successful.[122]

Advantages:

- Planting native varieties can help restore the aquatic ecosystem to its natural state and can help keep invasive plants from re-infesting the body of water or at least slow their reestablishment.
- Relatively inexpensive. The cost of the native plants and the labor is all that is required.
- Provides food and a habitat for native animal species.[123]

Disadvantages:

- Use of non-native plants might have negative impact on the ecosystem.
- Depending on the situation of the lake or pond the labor required to do the selective planting might be time consuming.
- The selected plants may not take root or establish successfully.
- Must be done in coordination with other treatment techniques to be successful.
- Requires professionals to research native plant species to determine suitable candidates that are resistant to the invasive plants.[124]

Surface Covers

This approach is very similar to benthic barriers, but the cover is put on the surface of the water. There has been limited use of surface covers because of the restrictions they impose on recreational use of the water. Mostly used in limited, small areas like around docks. It takes two to three weeks to work but it effectively limits plant growth under the surface area where it is placed.[125]

Advantages:

- It is an inexpensive method that can be implemented by property owners or other lake users.
- Almost any type of material can be used for the surface cover although opaque covers tend to work more quickly.

- Targets floating invasive plants which benthic barriers do not affect.[126]

Disadvantages:
- Completely limits the use of the area where the surface cover is installed.
- Needs to be repeated at the beginning of every season to prevent growth.
- Is relatively slow acting, taking several weeks to kill plant life under the surface cover.
- Can only be used in limited areas. For example, you couldn't cover the whole lake because it would harm aquatic animals as well.
- It is a non-selective approach that will limit or kill all the plant life under the surface cover, not just the target species.[127]

*Barley Straw (*Hordeum vulgare*)*

The use of barley straw as an algae control agent began in England in the 1900s and has been used there in large reservoirs and canals. Recommended application is 225 pounds of barley straw per acre of the lake being treated. It is best to apply in small sections throughout the pond, and it is important to apply before algae establishes itself in the lake or pond.

(http://www.iecat.net/institucio/societats/ICHistoriaNatural/Bages/planes/Imatges%20grans/07-LESMO.jpg)

Straw should be contained in netting to hold it together in the area where applied. The exact mechanism by which barley straw prevents algae growth is unknown, however it is thought that the rotting barley releases a chemical that prevents the growth of algae.[128]

Advantages:
- Non-chemical method of controlling algae growth and could also provide limited control of other aquatic plants.
- Cost is relatively cheap and labor is minimal.
- Material is readily available at local nurseries, garden shops and on the internet.

Disadvantages:
- Still being researched with mixed results in U.S. although success has been confirmed in Europe.
- Ponds or lakes that are murky and have a high suspended particle count will require additional amounts of barley straw and may be prone to less success.[129]
- Prevents growth of algae but does not kill existing algae.
- Decomposition of barley straw is temperature dependent.

Dyes (Commercial Name: Aquashade)

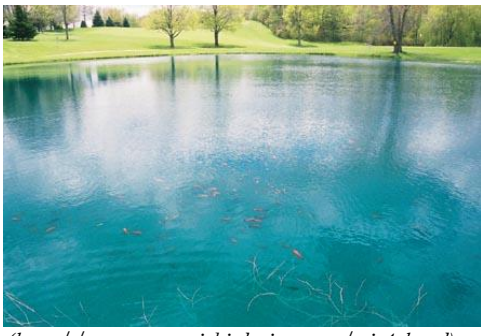
Dyes prevent light from fully transmitting through the water thus limiting an invasive species' ability to photosynthesize, reducing the plant population. Dyes can cost from $100-$500 per acre depending on the amount of dye needed, monitoring, planning, etc. Dyes require repeat treatment

because they eventually wash out.

Aquashade is the only colorant registered with the U.S. EPA for aquatic plant growth control. One gallon of Aquashade can treat one acre of four-foot deep water and costs around $40.[130]

Advantages:

- Dyes can limit algal and rooted plant growth without the use of herbicides and other toxic chemicals.
- Generally non-toxic to all aquatic species.
- Can make water more aesthetically pleasing.
- Aquashade will not cloud the water, it simply adds a tint.
- No restrictions for recreation or to livestock are necessary after application.[131]



(http://www.aquaticbiologists.com/pic4.html)

Disadvantages:

- Not target specific; limits light for all plant species, not just the invasive species.
- Not effective in shallow water that is less than two feet deep.
- Requires repeat treatments.
- Can actually cause anoxic conditions or increase thermal stratification, which can harm aquatic animals. However, careful monitoring and application can prevent this.
- Once applied you simply have to wait for it to wash out, the dye cannot be removed.
- Does not have an effect on surface floating plants since dyes will not interfere with their photosynthesis.[132]

Herbivorous Fish

This method includes purposely adding sterile fish to a lake or pond who specifically feed on the target invasive plant. Triploid Grass Carp (*Ctenopharyngodon idella*), sterile grass carp, are the most commonly used fish in the United States for biological control because of their ability to handle a wide range of temperatures. Although the grass carp has proven effective for minimizing fanwort infestations, the introduction of this fish into New Hampshire water bodies is illegal.[133] Cost estimates for implementing triploid grass carp range from $50-$300 per acre including planning and monitoring. Seven to 15 fish per acre should be stocked; one stocking should last around five years.

(http://www.aquaticmanagement.com/graphics/amur1.jpg)

Another useful type of herbivorous fish is the African Cichlid; however, the African Cichlid can only live in water with temperatures greater then 50 degrees Fahrenheit so they are not a viable option for Northern climates. Plant control effectiveness is site specific, and significant control of vegetation is not apparent until two to four years following introduction. [134]

Advantages:

- Has been used and proven successful in the United States.
- Can provide multiple years of control with a single stocking.
- Faster acting then insect stocking and can reduce biomass in one season.
- People can fish for the herbivorous fish, increasing the recreational use of the lake, although this will then in turn impact the successfulness of the plant control.
- When Triploids are stocked the fish are sterile so there is no chance of the population getting too large. Also, if a fish escapes it will not populate elsewhere.[135]

Disadvantages:

- Fish are bred to be sterile so eventually restocking will be required.
- May impact non-target species of plants or eliminate too much of the plant life; careful monitoring is required.
- Risk of fish escaping upstream or downstream, which would eliminate their effectiveness.
- Results may vary and are hard to predict.
- Illegal in some states. For example, Grass Carp (even the triploid variety) are illegal in the state of Massachusetts.
- Risk of new fish population causing or spreading fish diseases among native fish.
- Difficult to determine correct stocking amount required for plant control but not plant elimination or eradication.[136]

Herbivorous Insects (Common Types: Weevils, Midges, Aquatic Moths, Flies)

Herbivorous insects are insects that are identified as natural predators of certain problem weeds. These insects are then purposely added or "stocked" into a lake or pond to eat the problem weed. The insects are stocked as larvae or adults depending on the insect species and the extent of the plant infestation. Plant control is a rolling cycle: the plant dies back— followed by the insect population dying back– then the plant returns– followed by a surge in the insect population–

The milfoil weevil (*Euhrychiopsis lecontei*) is a known control for Eurasian Milfoil. *(http://www.ecy.wa.gov/programs/*

Midges are also a method of biologically controlling invasive plants. *(http://www.bbc.co.uk/earth/nature/uk/record/1471)*

The Alligator Weed Stem Borer (*Vogtia Malloi*) has been used to control Alligator Weed populations. *(http://aquat1.ifas.ufl.edu/leafm.jpg)*

which then once again reduces the plant population. The plant and insect populations will oscillate. Both native and non-native insects are being studied as control devices; however, it is always better to try and use native species. Treatment costs can range from $300-$200,000 per year depending on the size of the body of water, the type of insect stocked, the amount stocked

and surveying and project management costs.[137]

Advantages:

- Insects facilitate long-term control with limited active management on the part of the lake managers or residents.
- Insects are chosen to control a specific plant so there is little or no effect on non-target species.
- Little or no restricted use of the treated water. Some insects need to be stocked in low recreation zones though so that they are not disturbed.
- No human health risks. Most of the insects are too small to even notice and do not destroy property or harm humans.[138]

Disadvantages:

- Plants die back slowly as insects eat them, therefore the invasive plant problem will not be solved in one season. Herbivorous insects are a multi-year solution often requiring restocking for several years so that the insect population has the opportunity to establish itself.[139]

Management of Nutrient Input

There are two main types of nutrient management: point source and non-point source. Point source pollution comes from a specific, known source, usually a regulated industry like a wastewater treatment plant. Potential tactics for management include increasing discharge requirements, creating a diversion of point source waste, requiring operational adjustments, and implementing pollution prevention plans. Point source pollution management has the potential to create a large reduction of nutrients but can also be very expensive and politically difficult to implement.

Point source pollution dumping excess nutrients into stream. *(http://www.unce.unr.edu/western/SubWebs/NEMO/Images/Examples%20of%20NPS/paint%20pollution%20from%20Snohomish%20County%20Website.jpg)*

Non-point source pollution is when nutrients do not come from a specific source; common examples include septic systems, yard fertilizer run-off, aerial pesticide drift, and street drain run-off. Non-point source pollution management tactics include changing land use bylaws, requiring the use of alternate (non phosphorus or nitrogen) fertilizers, pollution trapping through constructed wetlands, storm-water collection, inlet devices, and installing a septic system on the town sewer. This type of management requires gradual implementation and education of the public, but is a highly flexible approach that can create systemic and lasting change while addressing a wide range of pollutants.[140]

The management of nutrient inputs into a lake or watershed usually focuses on phosphorus since it is a key limiting nutrient that plants need to survive and grow. Nutrient management strategies are most effective when used before infestation or with other in-lake treatment methods. Nutrient

management strategies alone will not remove invasive species from a lake or pond.

Advantages:

- It is treating the cause of the invasive plant problem—not just the symptom; excess nutrients in lakes and ponds are what allow invasive plants to spread rapidly.
- Often reduces amount of pollution entering the lake or watershed.[141]

Disadvantages:

- Most effective prior to plant invasion, or when nutrient recycling in lake is not the main cause of excess plant growth.
- It takes long periods of time for any improvements to be seen.
- If a problem with invasive species already exists in the lake or pond other treatment methods will be needed in addition to nutrient management to control and stop the spread of the species.[142]

Chapter VI: The Problem with Pesticides and the Need for Policy

Many Americans grew up thinking that the prevalence of pesticides in our environment was healthy and normal. We were taught that pesticides keep dangerous mosquitoes off our children and our crops plentiful. When Rachel Carson wrote Silent Spring in 1962, she raised public awareness about the effects of pesticide use on our health and the environment for the first time. However, forty years after Carson drew attention to the health and environmental impacts of DDT, the use of equally hazardous pesticides has only increased.

Today pesticides are found in the air we breathe, on the food we eat, along the roads we travel, in the lakes where we swim, and even the water we drink. Herbicides can leach from lakes and ponds into nearby wells or drinking water supplies. Through testing and monitoring carried out by the U.S. Geological Survey, the herbicide atrazine was found in 80% of the 153 samples taken from public water systems.[143] Atrazine has been found to be linked with a high prevalence of 'small-for-gestational-age' and preterm deliveries.[144] While pesticides are designed to kill *pests, weeds* and other *nuisances*, the target species isn't always the only thing under attack. Pesticide use can result in unintended health and environmental consequences.

The Pesticide Action Network estimates that there are 200,000 deaths worldwide per year from pesticide poisoning. In 1994, 1,332 pesticide-related illnesses were reported to the California Department of Pesticide Regulation.[145] A study of reported pesticide illnesses from 1983-1990 found over 19,000 poisonings, including over 9,000 in non-agricultural settings. It is likely that these numbers vastly underestimate the number of actual poisoning incidents, because many of the symptoms associated with pesticide poisoning are similar to those associated with the flu.

Although challenging to study in humans because delayed health effects are difficult to link to past exposures, chronic health effects may occur years after even minimal exposure to pesticides. Pesticides are linked to many types of cancer in humans. Some of the most prevalent forms include leukemia, brain, bone, breast, ovarian, prostate, testicular, liver cancers and non-Hodgkin's lymphoma. A 1999 study by the American Cancer Society showed an increase in non-Hodgkin's lymphoma for individuals who used pesticides, with the biggest impact from exposure to the pesticide MCPA (4-chloro-2-methylphenoxy acetic acid). Pesticides can also disrupt the endocrine system, playing havoc with the complex regulation of hormones, the reproductive system, and embryonic development.[146]

Children are suffering disproportionately from exposure to pesticides due to the vulnerability of the developing human body. According to a 1990 assessment by the U.S. Congress Office of Technology, "research demonstrates that pesticide poisoning can lead to poor performance on tests involving intellectual functioning, academic skills, abstraction, flexibility of thought, and motor skills; memory disturbance an inability to focus attention; deficits in intelligence, reaction time, and manual dexterity; and reduced perceptual speed. Increased anxiety and emotional problems have also been reported." [147] In 2006, a Denmark study linked pesticide prevalence in breast milk with a high rate of male children with undescended testicles.[148] Studies such as these illustrate the profound impacts of foreign chemicals on the developing body.

In addition to the serious human health concerns that pesticides cause, they also have adverse affects on the environment. Herbicides usually have harmful effects on other, non-target native plants, animals, and the ecosystem as a whole. David Pimentel of Cornell University conservatively estimates that the number of birds lost each year to pesticides is 67 million – on farmland alone. And pesticides account for the majority of wildlife poisonings reported to the United States Environmental Protection Agency (EPA).

Federal Regulation

A set of harmonized test guidelines have been developed by the EPA Office of Chemical Safety and Pollution Prevention (OCSPP), which lays out the exact tests that must be performed on any pesticide before put on the market. These test guidelines include tests that measure a chemical's potential ecological effects, spray drift possibility, health effects, residue chemistry, product performance, fate and transformation, occupational and residential exposure, endocrine disruption, and more. Although testing is performed on all new pesticides, a significant number of health conditions are left ignored and untested.[149] Also, a pesticide containing a known toxin may be used despite its public health hazard if its "economic, social or environmental" benefits are deemed greater than its risk.

Federal law requires active ingredients to be labeled on pesticide products, however active ingredients can be as little as 1% of the product. Although, the EPA has passed policy that requires the labeling of some inert ingredients, there has been push back from groups such the American Crop Protection Association and the Chemical Manufacturers Association to not disclose the comprehensive collection of inert ingredients in pesticides. Federal regulations allow information on inert ingredients to be kept secret when the manufacturers request confidentiality of their pesticide mixture as "trade secrets." Most manufacturers claim this confidentiality, leaving consumers in the dark. Currently some or all of the inert ingredients are disclosed in only approximately 160 of all the pesticide products on the market.[150]

In August 2006, fourteen states, including Connecticut, Maine, Massachusetts and Rhode Island launched a campaign to force the Bush administration to require manufacturers to disclose "inert" ingredients.[151] Petitions resulting from this campaign have forced the EPA to review new policy surrounding the public availability of the identity of inert ingredients in pesticides.This proposed rule, *74 Fed. Reg. 68215*, is still under review. Action regarding this policy can be followed on the EPA's website in the "Regulatory Development and Retrospective Review Tracker".[152]

Poor federal regulations persist in part because powerful special interests have significant influence on pesticide policies in the United States. From 2008-2010, Dupont, one of the leading chemical companies, spent $13.75 million lobbying the Federal Government.[153] A great deal of advice that farmers and urban pest managers receive comes from the chemical industry, whose profits stem directly from the sale of their pesticide products.

As a result of the lack of existing federal leadership to strengthen pesticide laws and regulations, much of the work falls to states and local communities. At the state level, the political climate does not, generally, support a full ban on pesticides. However, environmental organizations and activists have and continue to work to strengthen pesticide laws and phase out specific chemicals at the state level; to limit pesticide practices through the regulatory process; and to target the industry directly.

New Hampshire Regulation

Herbicide application and use within New Hampshire water bodies can be conducted by a town, an organization, or a lakeside property owner, but the proposed management plan needs approval by the state. When a new infestation in a pond, stream, or lake is brought to the attention of the state government, a standard site analysis is performed in order to determine the appropriate management plan. After a concerned individual or government entity recognizes an invasive species infestation as a threat, the state carries out a series of site inspections, mapping, and general assessment of the water body. [154]

Methods of intervention are chosen based primarily on the size and age of infestation. If the infestation is fairly new, small, and contained, the state of New Hampshire will often recommend hand pulling and benthic barriers. If the infestation is expansive and well established, the state commonly turns to chemical treatment. Within New Hampshire, 2.4-D, Triclopyr, Diquat Dibromide and Fluridone seem to be the most common herbicides used in aquatic invasive species management.[155] The local body may follow the state's lead or may pursue other options.

If the local body chooses a chemical intervention as the method of management, a pesticide permit application must be submitted and then a process of approval is carried out by various state agencies. The entity seeking permission to use an aquatic pesticide, be it an organization, landowner, or town resident, must submit an application in conjunction with a licensed applicator to the NH Division of Pesticide Control. The Division of Pesticide Control then circulates this application through other related state departments, such as Department of Environmental Resources, Wildlife Recreation, and Health and Human Resources. In the case of aquatic herbicides, the NH Water Division is also involved in reviewing the specific chemical properties of the herbicide at hand, such as affinity with soil, as well as proximity to public and private drinking water.[156] Each department independently reviews the permit request and analyzes the nature of the proposed chemical and its potential health and environmental effects. The Division of Pesticide Control is then responsible for reviewing all of the comments and recommendations submitted from various departments along with the proposed lake management plans. Ultimately, the Division of Pesticide Control makes the final decision to grant or deny the pesticide permit.[157]

As part of the permit process, the local body must create follow-up monitoring plans and provisions based upon the chemical proposed. Provisions include follow up testing, including water sampling and a survey of treatment effectiveness. The required sampling and site monitoring will be defined and discussed in the permit very specifically to the features of each site. Site characteristics such as proximity to drinking water, recreation areas, and residencies are

taken into consideration when developing these follow-up plans.[158] Before a pesticide is applied to a water body all landowners around the lake are required to be notified through a mailing or other mode of communication about the intended chemical application. Concerned landowners who oppose the pesticide application can attend a public hearing to contest the application.[159]

Responsibility for managing the invasive species infestation, whether this is chemical or alternative management, is shared in a partnership between state and local entities. The state actively coordinates management activities in lakes, ponds and streams, however does not tend to get involved in the treatment and management of small private ponds and water bodies. For water bodies not managed by a private homeowner, DES prepares a long-term management plan. To view a comprehensive list of water bodies that currently have a management plan, visit this page on the Exotic Species Program website, http://des.nh.gov/organization/divisions/water/wmb/exoticspecies/waterbodies_draft.htm.

When a management plan is fully developed between the state, town and other interested parties, funding comes partly through grants from DES and partly from local municipalities. DES provides matching grants; the local match often comes from The NH Lakes Association or from private donors. The state will only entirely fund control measures if the invasive species infestation is new.[160]

Appendices

Appendix A: Further Resources for Management of Aquatic Invasive Species

The American Chemical Society
http://acswebcontent.acs.org/home.html

Beyond Pesticides
http://www.beyondpesticides.org/

Extoxnet
http://extoxnet.orst.edu/

Center for Aquatic and invasive Plants: Institute of Food and Agriculture Services - University of Florida
http://plants.ifas.ufl.edu/

Invasive and Exotic Species Website
http://www.invasives.org

Invasive Species Information Center
http://www.invasivespeciesinfo.gov

LakeNet
http://www.worldlakes.org

NH Department of Environmental Services: Exotic Species Program
http://des.nh.gov/organization/divisions/water/wmb/exoticspecies/

NH Department of Environmental Services: Weed Watchers Program
http://des.nh.gov/organization/divisions/water/wmb/exoticspecies/weed_watcher.htm

Pesticide Action Network
http://www.panna.org/

Protect Your Water
http://protectyourwaters.net/

The New Hampshire Lakes Association
http://www.nhlakes.org/

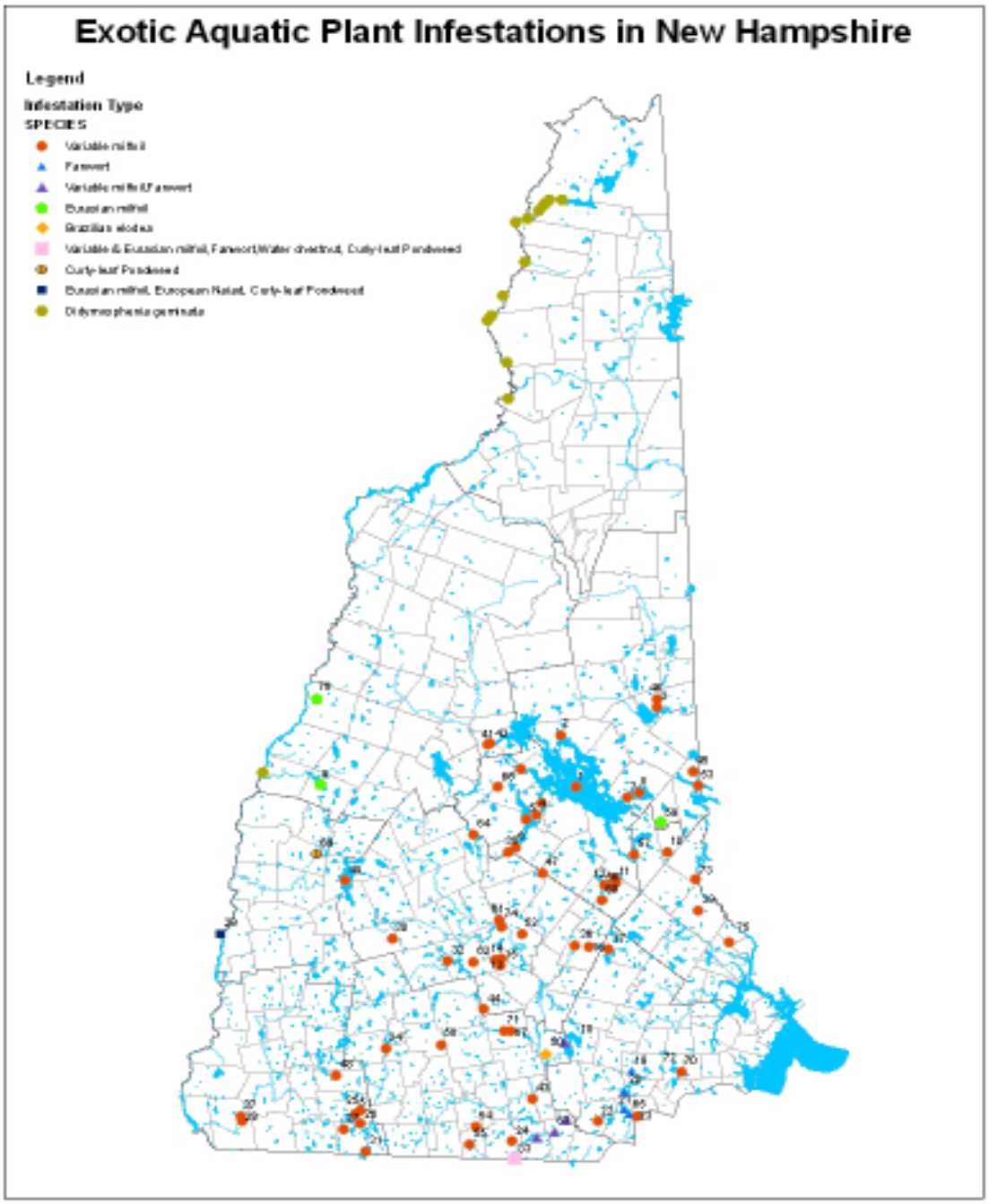
The Western Aquatic Plant Management Society
http://www.wapms.org

United States Department of Agriculture Natural Resource Conservation Service
http://www.fs.fed.us/invasivespecies/index.shtml

USGS Nonindigenous Aquatic Species Website
http://nas.er.usgs.gov

Winnepesaukee Gateway
http://winnipesaukeegateway.org/the-watershed/watershed-issues/

Appendix B: New Hampshire Department of Environmental Services, Exotic Aquatic Plant Infestations



Appendix C: Certified Weed Control Divers (NH Department of Environmental Services)

Below is a list of individuals who have taken the Weed Control Diver Certification Program. They have each passed this course and earned their specialty certification to dive for and remove exotic aquatic plants. They are familiar with the methods, notification protocols, and existing regulations that pertain to this activity. They are available for hire for removing exotic aquatic plants (only) like variable milfoil, fanwort, and others.

Certified Date	Last Name	First Name	Address	City	State	Zip	Phone	E-mail
2007								
2-Jun-07	Wachmuth	Tom	POB 1282	Wolfboro	NH	O3894	603-569-8080	divewinn@worldpath.net
16-Sep-07	Tencati	Allen	339 Woodbound Rd	Jaffrey	NH	O3452	603-313-2071	tryst2@comcast.net
29-Sep-07	Cabral	Cliff	391 Center Rd	Brownfield	ME	O4010	207-935-3779	zoo@fairpoint.net
29-Sep-07	Spaulding	Mark	POB 1372	Kennybunkport	ME	O4043	207-229-6180	
29-Sep-07	Lovering	Jeffrey	364 Hampshire Rd	Brownfield	ME	O4010	207-935-1014	coachlove@fairpoint.net
29-Sep-07	Bolton	Greg	59 Grandview Dr	Dover	NH	O3820	603-740-9850	gregbolton@aol.com
16-Sep-07	Dowland	David	209 Ingalls Rd	Jaffrey	NH	O3452	603-532-7404	dowland@localnet.com
20-Mar-07	Aldrich	Ted	POB 82	Marlow	NH	O3456	603-446-3375	weedcontroldiver@gmail.com
2008								
11-Jul-08	Beals	Joe	306 Merrymeeting Rd	New Durham	NH	O3855	603-859-2369	beals.fam@mindspring.com
9-Jun-08	Bedard	Roger	10 Taylor Circle	Washington	NH	O3280	603-495-1408	rb10@gsinet.net
9-Jun-08	Bevilacqua	Jim	15 Liberty Drive	Winchendon	MA	O1475	978-297-3482	jbev10@yahoo.com
11-Jul-08	Brady	Keith	60 Bellingham St	Mendon	MA	O1756	508-478-5028	bradyz@sprynet.com
16-Jun-08	Burrows	David	18 Old Bye Rd	Raymond	NH	O3077	603-244-1083	d_burrow@plymouth.edu
9-Jun-08	Burt	Tom	POB 1009	Washington	NH	O3280	603-495-0449	grampaburt@gsi.net
9-Jun-08	Chesley	Bruce	3 Bellic St	Claremont	NH	O3743	603-477-8469	brucechesley@verizon.net
2-Jun-08	Devine	Chris	59 Range Rd	Holderness	NH	O3245	603-968-7336	chrisdevine@squamlakes.org
2-Jun-08	Durham	Brett	7 Wentworth St	Plymouth	NH	O3264	603-536-7663	brettdurham@squam lakes.org
9-Jun-08	Folsom	Philip	128 Kimball Rd	Rindge	NH	O3461	603-899-6754	folsomfamily@pctnh.net
8-Jun-08	Makin	Karl	24 Lamphrey St	Manchester	NH	O3102	603-641-6543	kasb24@msn.com
9-Jun-08	O'Neil	Rod	603 Redwater Brk Rd	Claremont	NH	O3743	603-588-0998	weekendwar2002@yahoo.com
2-Jun-08	Tabor	Mick	3 Homestead Rd	Amherst	NH	O3031	603-672-7084	mick.tabor@sun.com
2-Jun-08	Worcester	Christina	15 Augustus Cir	Merrimack	NH	O3054	603-262-5059	kczconsulting2@aol.com
8-Jun-08	French	Will	1092 Great Pond Rd	N Andover	MA	O1845	603-571-8408	frenchw@hartwick.edu
8-Jun-08	Patterson	Bob	17 Chase Island Rd	Atkinson	NH	O3811	603-475-1503	rfp357@aol.com
8-Jun-08	Witley	Steve	413 1/2 Chases Grove	Derry	NH	O3038	978-836-6521	switley@yahoo.com
2-Jun-08	Heise	Joe	127 Merrill Rd	Campton	NH	O3223	603-726-4563	josephheise@aol.com
16-Jun-08	Trethaway	Billy	11 WB Hill Rd	Northfield	NH	O3276	603-286-8714	billyhockeyguy@aol.com
8-Jun-08	Pilotte	Larry	431 Foxboro Rd	Lovell	ME	O4051	603-398-0833	divecon@juno.com
16-Aug-08	Houde	Ron	175 Kent Farm Rd	Hampstead	NH	O3841	603-329-8109	houdefam@comcast.net
16-Aug-08	Anderson	Eric	POB 701	Hampstead	NH	O3841	603-329-5277	baldunitx@yahoo.com
16-Aug-08	Henriquez	Joela	17 Chase Island Rd	Atkinson	NH	O3811	603-475-5005	arubajoela@aol.com
16-Aug-08	Orlando	Brian	9 Geary Lane	Atkinson	NH	O3811	603-362-5471	borlando@yahoo.com
25-Aug-08	Fernald	Kevin	POB 4	Plymouth	NH	O3264	207-432-1469	kevinf@rock.com
25-Aug-08	Harvey	Rebecca	57 Depot St Apt 6	Ashland	NH	O3217	207-432-4121	rebeccaharvey@squamlakes.org
25-Aug-08	Howe	Mike	65 Ann Ave	Manchester	NH	O3102	603-624-8235	
25-Aug-08	Jones	Ben	POB 156	Salisbury	NH	O3268	603-648-6068	mrbenjaminjones@yahoo.com
12-Sep-08	Accornero	Frank	169 Portsmouth St #6	Concord	NH	O3301	603-228-9550	frank_accornero@comcast.net
12-Sep-08	Reid	Scott	31 Mallard Point	Merrimack	NH	O3054	603-540-5779	reids77@hotmail.com
12-Sep-08	Sandstrom	Gary	13 Whitney Ave	Manchester	NH	O3104	603-627-4230	
14-Sep-08	Patterson	Bobby	17 Chase Island Rd	Atkinson	NH	O3811	603-475-1503	sparkbob4@aol.com
2009								
11-Jun-09	Hickey	Robert	44 Varney Pt Rd Left	Gilford	NH	O3249	603-293-1192	bobhickey11@hotmail.com
11-Jun-09	Thompson	Grant	POB 282	Laconia	NH	O3247	603-455-6560	gtom@metrocast.net
23-Jun-09	Foudriat	Bob	77 Patten Rd	Bedford	NH	O3110	603-624-1211	j.foudriat@comcast.net
23-Jun-09	Foudriat	Rob	77 Patten Rd	Bedford	NH	O3110	603-624-1211	j.foudriat@comcast.net
23-Jun-09	Higgins	Scott	POB 619	Milford	NH	O3055	603-566-4587	sshiggins@myfairpoint.net
23-Jun-09	Ouhrabka	Tom	242 Cedar St	Warwick	RI	O2818	401-885-2852	tomouhrabka@yahoo.com
23-Jun-09	Rines	Ricky	POB 17	New Durham	NH	O3855	603-859-5631	rineselc@worldpath.net
8-Jul-09	Cassidy	Esther	380 Stoddard Rd	Hancock	NH	O3449	603-525-9307	skbar@surfglobal.net
8-Jul-09	Cassidy	Mark	380 Stoddard Rd	Hancock	NH	O3449	603-525-9307	skbar@surfglobal.net
25-Jul-09	Deblois	Mike	908 Mammoth Rd	Manchester	NH	O3104	603-361-8658	senormike275@aim.com
25-Jul-09	Deblois	Wayne	65 Granite St	Allenstown	NH	O3275	603-340-1995	
25-Jul-09	Dionne	Shane	4 Country Club Dr #8	Manchester	NH	O3102	603-674-0632	
25-Jul-09	Huss	Steven	30 Heritage Hill Rd	Holderness	NH	O3245	603-236-1830	slhuss@gmail.com
25-Jul-09	Knoetig	Christopher	12 Timberwood Dr #302	Goffstown	NH	O3045	603-361-2128	tchn77@yahoo.com
25-Jul-09	Patterson	Lindsey	25 Amberwood Dr	Atkinson	NH	O3811	603-362-6599	sportiegurl90@aol.com
25-Jul-09	Snell	Leonard	29 Escumbuit Rd	Derry	NH	O3038	603-660-2070	lensnell@aol.com

Appendix D: Worksheet for NH Lake Management Planning (NH Department of Environmental Services)

Data/Input Needs for Exotic Species Long-Term Management Plans

Waterbody Name/Town: **Contact Name:** **Contact Phone:** **Contact E-mail:**	
Question	**Answer**
How many houses are considered 'shorefront dwellings' on your lake or pond (i.e., those that sit immediately adjacent to the lake/pond?	
How many 'back lots' have waterfront access or rights of way?	
Roughly how many power boats use the waterbody on a daily basis in the open water months during *weekdays*?	
Roughly how many power boats use the waterbody on a daily basis in the open water months during *weekends*?	
Are there many canoes or kayakers on the lake? If yes, are they local or transient? Please estimate number per day.	
Specifically, what are the impairments you see to using the lake for swimming, boating, or fishing that result from exotic plant infestations? Please specify what location for each impairment on the attached map.	
Are there any access problems and how serious are they?	
Roughly how many swim rafts/platforms are there on the lake/pond?	
Does your town support the efforts to control exotic plants in your waterbody?	
Has the town made a financial commitment to managing exotic plants in your lake/pond?	
Do you have a group of people that can be committed to Weed Watching and possibly hand-pulling the exotic plant over time once a larger-scale management plan is done? If yes, please describe, using additional paper as may be needed.	
Please obtain a copy of the tax map(s) for the waterbody's shoreline, and mark the locations of the following (Note that if you cannot obtain tax maps, please use the separately attached maps to approximate locations of these):	

Appendix E: Rutland Herald news article regarding aquatic herbicides.

RUTLAND HERALD
WINNER 2001 PULITZER PRIZE
RUTLAND, VERMONT, U.S.A.
RUTLANDHERALD.COM

June 11, 2006

Chemical use in two lakes is under fire

DENNIS JENSEN Staff Writer

Further chemical treatment of milfoil on the waters of Lake St. Catherine and Lake Hortonia cannot be justified since the chemicals have failed to stop the return of the exotic plant and because the use of the chemicals results in the loss of fish habitat and aquatic vegetation cover, says two studies released by the Vermont Fish & Wildlife Department.

The two studies, written by Fish & Wildlife fisheries biologist Shawn Good and dated April 5 and April 7, are reviews of the applications made by the Lake St. Catherine Association and the Town of Sudbury to treat areas of the two lakes and Burr Pond. In the studies, Good spells out why further chemical treatments are both harmful and have a track record of failure.

Good wrote that both applications for further chemical treatments should be denied. "The significant loss of fish habitat and cover in the form of submerged aquatic vegetation in treated lakes also raises many concerns regarding the potential impact to fish populations," he said.

The Lake St. Catherine Association and Lake Hortonia Association have both financed the chemical treatments of their respective lakes.

"While aquatic vegetation control may be considered a 'benefit' to lake association members, the threats and negative impacts vegetation control programs pose to recreation angling quality and opportunities in state waters cannot be considered a public benefit or in the public good," he wrote.

Good said that his research and personal observations show that chemical treatment of milfoil is a waste of money and a threat to game fish populations, particularly largemouth bass, in the lakes. "… It is generally accepted that control and eradication (of Eurasian milfoil) in most every situation is difficult, if not impossible," he said.

Lake Hortonia and Burr Pond were both treated with chemicals in 2000.

"The earliest treatments in Vermont (Lake Hortonia and Burr Pond) were considered failures in controlling" milfoil, Good said. Meanwhile, a spokesman for the Lake Hortonia Association said that Good's analysis could not be further from the truth.

Carole Silvera, who lives in Round Lake, N.Y., and who owns a summer camp on the lake, said in an interview that chemical treatment on Lake Hortonia has been an unqualified success. She also said that fishing on the Rutland County lake is far better since the lake has been treated with chemicals.

"There is absolutely no truth to what he is talking about," Silvera said of Good's report. "We have no other choice but to clean up the milfoil so the fish have place to swim and breed, and people have a place to swim again and to water ski in the lake."

Silvera said that the fishing, and particularly the bass fishing, has improved immensely since the association began to apply chemicals into the lake.

"Over the years, since the milfoil has come in, it's actually made the fishing a lot worse," she said. "Since we treated the lake, we're seeing largemouth bass right off the dock. We're seeing more bass in the lake than we've seen in 10 years."

The association last week received its permit for further chemical treatment of the lake and for Burr Pond, set for sometime in July, Silvera said, but she added, "We need to work out the details to make sure that we can fill all of the requirements in time to do the treatment."

Silvera said that the association, with financial assistance from the State of Vermont, has spent more than $150,000 for chemicals to treat the lake. "The property owners around the lake are so thankful that we've done the work. Taxes are going up because it's more desirable summer property," she said. "We consider it (chemical treatment) highly successful." Further treatment is still needed, Silvera said, in several areas of Lake Hortonia and Burr Pond.

"We are halting the growth of it (milfoil) in a huge way but there have been a couple of areas on the lake that need to be treated with spot treatment because the milfoil wasn't eradicated there as much as in the rest of the lake," she said.

Silvera said she believes that chemical treatment of Lake Hortonia and Burr Pond have improved the quality of fishing, boating and swimming and that further treatments will make both bodies of water even better.

"I can't tell you how thankful people are that they can fish on the lake again," she said. "We wouldn't be doing this if we didn't want the lake to stay alive. There will be no bass in there if they let the lake die."

Bass and milfoil

In his report, Good said that largemouth bass and milfoil appear to have a healthy relationship. Largemouth bass are a particularly popular gamefish in waters throughout Vermont.

"Eurasian milfoil is not considered to be problematic for bass or other species of fish in these lakes," he said. "Largemouth bass populations are extremely healthy and the removal of Eurasian watermilfoil will not improve their population dynamics." Good went on to say that, conversely, the loss of milfoil will have a detrimental effect on largemouth bass populations.

"All stages of largemouth bass rely on aquatic plants for protection from predation and as foraging areas to hunt and consume invertebrates and prey fish," he said. "Juvenile largemouth bass are particularly dependent on areas of submerged aquatic vegetation and alteration or loss of this may reduce bass growth, overwinter survival and recruitment." Good also said that the 2004 chemical treatment on Lake St. Catherine "did not effectively control" milfoil.

Attempts to reach a spokesman for the Lake St. Catherine Association were unsuccessful. Rather than turning to chemicals, Good said that there are other, less-drastic ways to treat milfoil infestation.

"Usually, the most feasible options are to manage around the problems brought about by invasive species." He said.

One way to deal with the fast-growing, thick weed, which hampers boating and grows around docks and along lakefronts. is through biological control, Good said. "One non-chemical control technique that does not seem to have been seriously considered in Vermont is that of biological control," he said.

Good said that, according to a number of studies, declines in milfoil abundance in North America have been attributed to feeding damage by three insects - a midge, a weevil and an aquatic moth.

"The most promising of the three are the pyralid moth and the native weevil," he said. Cayuga Lake, in New York, has experienced "long-term declines" in milfoil abundance and the recovery of native plant species, thanks to these insects that feed on milfoil, Good said.

Good said that biological remedies to milfoil take longer than chemical methods. But some people don't want to wait for long-term results, he said.

"Pressure by lake associations for quick and immediate control and reductions of Eurasian watermilfoil likely have played a role in preventing a longer-lasting, ecologically-sound and less-expensive biological control program from being fully investigated," he wrote.

Appendix F: Notable Moments in Pesticide History

1800s: American farmers use **copper and sulfur based chemicals** to control pests in their fields. This resulted in dangerous health effects and almost no selectivity in which plants were being targeted.

1930s: The true era of chemical use begins with **development of synthetic** (man-made), **organic** (containing carbon) **compounds** for use as pesticides. Referred to as "2nd generation" pesticides.

1939: **DDT is introduced** and widely used (the creator, Paul Miller, won the Nobel Prize for his invention). The devastating effects of DDT were not realized until after widespread public and private use.

1940s: The **use and creation** of synthetic chemicals in the form of pesticides **rises dramatically** with new and more dangerous chemicals entering the market including chlorinated hydrocarbons and organophosphates.

1950s: Appearance of **pesticide resistant insects** and effects on non-target organisms become apparent. DDT is detected in woman's breast milk.

1960s: Rachel Carson writes *Silent Spring* which brings public awareness to the **unknown long-term effects of the use of pesticides** and helps launch the modern day environmental movement. **IPM** (Integrated Pest Management) begins to be considered as a feasible alternative to blanket chemical use.

1972: **Federal ban on DDT is enacted** because of dangerous effects on human health and the environment.

1980s: Development of synthetic chemicals that are "low-dose" or "selective" meaning they are **more concentrated, acutely toxic** and **more water soluble**.

1990s: Coalition of environmental groups wins a precedent setting campaign that successfully forced the Environmental Protection Agency to disclose most of the "inert" ingredients in six common pesticide products.

2000: Treaty to phase out **Persistent Organic Pollutants** (POPs) signed by the US and 121 other nations.

2009: Herbicide **2,4-D**, one of the two Dow chemicals used in Agent Orange, is banned in Ontario.

2011: The Permanent People's Tribunal names 6 of the largest pesticide companies- **Monsanto, Syngenta, Bayer, BASF, Dow and Dupont**- guilty of human rights violations. Every year over 355,000 people die of pesticide poisoning.

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