

Prepared for:  
**BASF Corporation**



# Use of Aquatic Herbicide Imazamox Clearcast® in the State of New York

## Supplemental Environmental Impact Statement. Final

AECOM, Inc.  
September 2009  
**Document No.: 00760-245-310**

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## 1.0 Introduction

### 1.1 Purpose of the supplemental environmental impact statement

It is the purpose of this Supplemental Environmental Impact Statement (SEIS) to objectively evaluate the scientifically documented evidence regarding all aspects of the use of Clearcast® for the control of nuisance aquatic weeds in waters of the State of New York. This document is intended to present a general description of the potential positive and negative impacts from the use of this product within waters of the State of New York. The SEIS is being submitted to the New York State Department of Environmental Conservation (NYSDEC) by ENSR Corporation (ENSR) on behalf of BASF Corporation (BASF), the manufacturer and distributor of Clearcast®.

The SEIS has been prepared on behalf of BASF specifically for the evaluation of potential use of Clearcast® in New York State and is applicable only to that trademarked product formulation. The information and technical data contained in this SEIS pertaining to the active ingredient, imazamox, is provided to allow full evaluation of Clearcast® products, support selection of appropriate application setback distances and comparisons to other aquatic herbicides or alternative treatment options. The impact evaluation contained herein is not intended nor should it be used as a surrogate SEIS for other imazamox-containing products. While sharing a common active ingredient, these products may differ widely in other formulaic components, resulting in physical and chemical properties that may significantly affect exposure and toxicity factors. Accordingly, NYSDEC should be contacted regarding establishing environmental safe conditions for application of alternative imazamox-containing products in riparian and aquatic settings.

### 1.2 Objective of the SEIS

The development of the SEIS for Clearcast® is intended to provide potential users of this product with a general understanding of the various results that might be associated with the use of Clearcast® in the waters of the State of New York. Clearcast® is an aquatic herbicide containing the active ingredient imazamox. By developing the SEIS, BASF has provided the information necessary for individual potential applicators to easily develop the necessary permit applications. However, the approach taken through the development of the SEIS is not intended to prevent any applicant from preparing a site-specific supplement to the Final Programmatic Environmental Impact Statement on Aquatic Vegetation Control (NYSDEC, 1981a) in the development of a permit for the use of Clearcast® in surface waters of New York State. The preparation of this SEIS is intended to provide potential users and interested parties with information specific for Clearcast® and its positive and negative impacts on surface water resources of New York State.

### 1.3 Regulatory framework

The SEIS was prepared in accordance with 6 NYCRR Part 617, the New York State Environmental Quality Review Act (SEQR). The purpose of SEQR is to incorporate the consideration of environmental factors into the existing planning, review and decision-making processes of State, regional and local government agencies at the earliest possible time. An action is subject to review by the NYSDEC under SEQR if any state or local agency has the authority to issue a permit or other type of approval over that action.

Section 617.15 (a)(4) allows for the development of a SEIS to assess the potential environmental effects of an entire program or plan having wide application. The regulations concerning the use of pesticides in NYS are defined in 6 NYCRR Part 325 through 327. The regulations addressing the use of pesticides in wetlands are defined in 6 NYCRR Part 663 and within the Adirondack Park, 9 NYCRR Part 578.

This registration represents a major change in labeling for the active ingredient imazamox. Initially, the BASF imazamox product Raptor® (USEPA registration number 241-379) was registered for use in New York for post-emergence grass and broadleaf weed control in alfalfa, edible legumes, and soybeans.



Clearcast® received full USEPA Section 3 approval in March 2008 and received New York registration on February 5, 2008. The New York State and USEPA approved labels and Material Safety Data Sheets (MSDS) for Clearcast® are presented in Appendix A.

## 1.4 Identification and jurisdiction of the involved and interested agencies

The following agencies were identified as involved agencies for the development of this SEIS:

- New York State Department of Environmental Conservation (NYSDEC) - Responsible for implementation of the laws and regulations pertaining to the management of environmental resources for the State of New York.
- New York State Department of Health (NYSDOH) - Responsible for potential public health issues associated with the use of the products.
- New York State Office of General Services (NYSOGS) - Responsible for the management of property owned by the State of New York. As pertaining to this project, they are responsible for the management of the lakes and/or lake bottoms owned by the State of New York.
- Adirondack Park Agency (APA) - responsible for implementation of the Adirondack Park Land Use and Development Plan (as described by the Adirondack Park Agency Act).
- New York State Department of State (NYSDOS) - Responsible for the administration of the Coastal Zone Program.

By agreement of the involved agencies, NYSDEC was designated as the lead agency for the SEIS.

## 1.5 Content and organization of the SEIS document

An initial scoping meeting for purposes of identifying the necessary components of the SEIS for Clearcast® was held at the offices of the NYSDEC in Albany, NY on April 29, 2008. Present at the meeting were representatives of NYSDEC (Martin Williams, Jeanine Broughel, Anthony Lamanno, Scott Kishbaugh, Timothy Sinott), BASF (Jeffrey Birk and Judy Fersch), and their consultant ENSR (David Mitchell and Christine Archer).

At this meeting, the registration and SEQR process were reviewed and discussed. A proposed outline of the SEIS was reviewed, discussed, and commented on by the agencies with regard to its content and completeness. This SEIS outline was revised and submitted to NYSDEC in April 2008. This outline was approved by NYSDEC (via e-mail communication from Martin Williams dated May 27, 2008) and other agencies in May 2008.

The SEIS document is organized in the following fashion:

- Section 1.0 Introduction – provides general overview of the product registration and SEQR process and associated regulations;
- Section 2.0 Description of the Proposed Action – Use of Clearcast® - provides information on the aquatic herbicide, the general locale of its proposed application, its use in support of maintaining designated uses, and intended macrophyte target species;
- Section 3.0 Environmental Setting – places the application of Clearcast® in the context of the New York lake environment. The general characteristics of New York lakes are described, along with the macrophyte communities – their ecology and functional roles. The overall objectives of aquatic macrophyte management control by Clearcast® are identified;
- Section 4.0 General Description of Clearcast® and its Active Ingredient imazamox – provides a full description of Clearcast® and its chemical formulations. This description includes proposed use,

mode of action, application factors, solubility, surfactant properties, fate and transport properties and residues;

- Section 5.0 Significant Environmental Impacts Associated with Clearcast® - this section reviews direct and indirect impacts to non-target species, potential bioaccumulation and residence time in water column, and the potential for recolonization of macrophytes following application;
- Section 6.0 Potential Public Health Impacts of Clearcast® - evaluates the potential for concerns or issues associated with human exposure to the product;
- Section 7.0 Alternatives to Clearcast® - describes and briefly reviews the advantages and disadvantages of alternative aquatic macrophyte control methods and technologies including physical, chemical and biological-based alternatives. The use of a combination of these techniques (Integrated Plant Management) or none (no-action alternative) are described. An alternatives analysis is also conducted;
- Section 8.0 Mitigation Measures to Minimize Environmental and Health Impacts of Clearcast® - reviews the approved use instructions and label information to mitigate and/or minimize any potential impacts to humans and the environment and discusses potential permit requirements;
- Section 9.0 Unavoidable Environmental Impacts if Use of Clearcast® is Implemented – considers impacts to habitat, non-target species, and potential for reinfestation; and
- Section 10.0 References – contains the citations and sources of the information presented in the SEIS.

## 2.0 Description of the proposed action – use of Clearcast®

The proposed action is the use of the aquatic herbicide Clearcast® for the control of nuisance aquatic vegetation in waterbodies located in the State of New York.

### 2.1 General description of the aquatic herbicide Imazamox (Clearcast®)

Clearcast® herbicide is currently registered by the USEPA for the control of submerged, emergent, and floating aquatic weed species. Aquatic vegetation management efforts and long-term studies have been conducted in a number of states using the Experimental Use Permit (EUP) label.

Clearcast® is composed of 12.1% active ingredient, ammonium salt of imazamox ((2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid) and 87.9% proprietary ingredients. Imazamox is currently registered in New York as the crop weed herbicide Raptor® for post-emergence control of broadleaf weeds and grass in alfalfa, edible legumes, and soybeans. Clearcast® is currently packaged as a liquid for purpose of aquatic vegetation control, but a granular formulation will be introduced in the future. Based on the discussion at the April 29, 2008 Albany meeting, NYSDEC considers that, due to the identical nature and characteristics of the imazamox product once it is dissociates from the granular form, the SEIS will serve for assessment of both liquid and granular products.

### 2.2 Purpose of the product

Clearcast® is a relatively fast-acting, systemic, selective herbicide proposed for the control of certain submersed, floating, and emergent aquatic plant species found in ponds, lakes, reservoirs, and other slow moving or quiescent bodies of water. Imazamox is a systematic herbicide with selective control of gramineous and broadleaf species.

Imazamox is an imidazolinone herbicide that inhibits the acetohydroxyacid synthase (AHAS) enzyme that is essential for the synthesis of three branched chain amino acids. When applied, imazamox rapidly enters through a plant's leaves and stems, then translocates down into the roots, disrupting the plant's metabolism. Susceptible plants stop growing shortly after application and die within 4-12 weeks. Imazamox is very useful for controlling monocots such as *Hydrilla verticillata*.

#### 2.2.1 Need for the product

The use of Clearcast® can be an important component of a comprehensive and integrated plant management approach to limit the spread of certain aquatic macrophytes. These macrophytes can be undesirable in certain circumstances. They may be introduced non-indigenous (i.e., exotic) species, which because of the lack of natural controlling ecological factors reach a nuisance stage in terms of extreme numbers or biomass. Such exponential growth can significantly reduce the recreational use of a waterbody by interfering with swimming, boating, or fishing. They may also clog intake screens and turbines, impart an unpleasant taste to the water, and reduce the presence of native aquatic species (Madsen et al., 1991a). Vermont Department of Environmental Conservation notes that nuisance vegetation may modify the aquatic habitat for indigenous organisms (VDEC, 1993).

#### 2.2.2 Benefits of the product

Clearcast® provides an alternative means for management and/or control of common non-indigenous and/or invasive species including Eurasian watermilfoil (*Myriophyllum spicatum*), parrotfeather (*Myriophyllum aquaticum*), common reed (*Phragmites*), waterlily (*Nymphaea* spp.), and purple loosestrife (*Lythrum salicaria*). Therefore, Clearcast® can be used selectively for aquatic vegetation control in littoral areas as well as riparian wetlands. Specific target macrophyte species are discussed in Section 2.4 and listed in Tables 2-1 (federal label species) and 3-1 (New York State species).

### 2.2.3 History of the product use

Clearcast® is part of the imidazolinone family of herbicides, which were originally discovered by the American Cyanamid Corporation (“Cyanamid”) in 1969. Imazamox is the last imidazolinone herbicide to be developed by Cyanamid and was first registered for post-emergent weed control in soybeans in 1997, under the tradename of Raptor® herbicide. Imazamox is currently approved for use on 13 crops in the U.S. and 15 crops globally. In the U.S. it is sold under the tradenames of Raptor®, Beyond® and Clearmax® herbicides.

In 2003, imazamox received an exemption from tolerance designation from the USEPA, resulting in the waiving of food residue tolerance requirements for all potential food or feed uses of imazamox, including irrigated crops. Imazamox is the first and only organic pesticide to receive a tolerance exemption.

Experimental work with Clearcast for aquatic vegetation management began in 2004. Aquatic EUP programs were conducted, starting in 2006-2007, and including as many as 16 states (AL, CO, FL, IN, LA, MI, MS, NE, NH, NJ, NC, ND, SC, SD, TX, WI) and the treatment of up to 4,750 acres per year. Clearcast® received full USEPA Section 3 approval on March 20, 2008.

## 2.3 General location of the proposed action

For the purposes of this portion of the SEIS, the general location for the proposed action is in the surface waters of the State of New York. The proposed action is the use of the aquatic herbicide Clearcast® for the control of certain nuisance aquatic macrophytes. Clearcast® is currently seeking registration in New York for use in freshwater ponds, lakes, reservoirs, non-irrigation canals and ditches with little or no continuous outflow, marshes and wetlands. Under Article 24 of the Environmental Conservation Law, some ponded water may be described as wetlands. A specific description of the actual body of water in which Clearcast® is intended for use would be included in the individual permit applications. This would also include any applications in New York State-designated wetland areas. Further descriptions of New York lakes and wetlands and their characteristics are given in Section 3.0.

## 2.4 Support of designated uses

All New York State surface waters are classified under 6 NYCRR Part 701.2 – 701.9, which delineates the protected or so-called designated uses inherent to such classifications. These designated uses for fresh waters include: source of water supply for drinking; culinary or food processing purposes; primary and secondary contact recreation; and fishing. In addition, the waters shall be suitable for fish, shellfish, and wildlife propagation and survival.

To protect these uses, New York has promulgated water quality standards (6 NYCRR Part 703) to support the best uses of the waters. These standards include several types including those pertaining to human health (water source and fish consumption), aquatic life (survival and propagation), wildlife (protection of piscivores) and aesthetic qualities. The latter is defined in a narrative water quality standard (6 NYCRR Part 703.2) that provides a general condition for all taste, color, and toxic and other deleterious substances shall not be in amounts “that will adversely affect the taste, color or odor thereof, or impair the waters for their best usages.”

Presently there are no chemical-specific New York State water quality standards for imazamox or its salts (e.g., Clearcast®) in effect. However, for purposes of the SEIS, information will be provided to show how proper use of the aquatic herbicide Clearcast® for the control of nuisance aquatic vegetation will not adversely affect any of the protected or best uses of the treated waterbody. In addition, there can be secondary economic benefits by control of nuisance aquatic vegetation (Mongin, 2005).

Protection of human health concerns (drinking water, fish consumption, primary and secondary recreation) are considered in Section 6.0; considerations for potential ecological impacts (aquatic life support function, wildlife) are considered in Sections 5.0 and 9.0; and aesthetics in Section 7.0.

## 2.5 Potential aquatic macrophyte and riparian wetland target species

Based on the registered label for Clearcast®, the aquatic macrophyte species listed in Tables 2-1 and 2-2 are considered to be potential target species for this product. Table 2-1 lists the aquatic macrophytes controlled primarily through foliar application while those in Table 2-2 are those controlled by water-injection applications. Not all of the aquatic macrophyte species potentially listed on the product label are typically found in the State of New York (see Table 2-1). The detailed discussions of the primary target species in Section 3.0 refer to representative species that are common throughout much of New York.

**Table 2-1 Aquatic macrophytes controlled by Clearcast® with foliar applications**

Alligatorweed <sup>1,2</sup>	Floating pennywort <sup>1</sup>	Spatterdock
American lotus	Four-leaf clover	Water hyacinth
Arrowhead	Frogbit	Waterlily
Cattail	Mexican lily <sup>2</sup>	Water primose
Chinese tallowtree <sup>2</sup>	Parrotfeather <sup>1</sup>	Watershield
Common reed	Pickerelweed	
Common salvinia <sup>2</sup>	Smartweed	

1 – Retreatment may be needed to achieve desired level of control.

2 – Species not found in the State of New York

**Table 2-2 Aquatic macrophytes controlled by Clearcast® with water-injected applications**

Bladderwort	Curlyleaf pondweed	Spikerush
Hydrilla	Flat stemmed pondweed	Variable pondweed
Eurasian watermilfoil <sup>1</sup>	Illinois pondweed	Water stargrass
Northern watermilfoil	Largeleaf pondweed	Widgeon grass
Variableleaf milfoil	Leafy pondweed	
American pondweed	Sago pondweed	
Clasping pondweed	Small pondweed	

1 – Retreatment may be needed to achieve desired level of control.

### 3.0 Environmental setting

This section describes the environmental setting in which the proposed action, the use of the aquatic herbicide Clearcast®, is projected to occur. While this section presents the available data in as detailed an extent as is required, the information is fairly generic for the State of New York. Further site-specific information may be required for application in particular waterbodies, as well as for wetland areas, which are specifically permitted under Article 24.

#### 3.1 General descriptions of New York State aquatic ecosystems

The aquatic ecosystems of New York State generally fall into four basic categories. These include standing freshwater systems (lakes, ponds, and reservoirs), flowing freshwater systems (rivers and streams), brackish systems (tidal estuaries), and saline coastal systems. Since the use of Clearcast® is aimed principally at macrophyte control in freshwater lentic (standing) systems, the focus will be on this category of aquatic ecosystem, but given the potential for application to macrophytes in littoral or riparian zones, some information is also given regarding wetlands.

It is calculated that New York State has over 3.5 million acres covered by some type of surface water system (NYSDEC, 1967). That includes over 7,500 lakes (NYSDEC, 1987), of which over 1,500 are found in the Adirondack Mountains (NYSDEC, 1967). The Adirondack Mountains also contain over 16,700 miles of significant fishing streams. The state's largest lakes are Lake George, Chautauqua Lake, Oneida Lake, and the major Finger Lakes; Canandaigua, Keuka, Seneca, Cayuga, and Skaneateles (NYSDEC, 1967).

The specific characteristics of each aquatic system are partially determined by its physiographic setting within the state. Changes in the characteristics of each aquatic system will lead to changes in the endemic biota associated with that waterbody. Generally, waterbodies within New York State can be defined geographically by region and drainage basin location. Aquatic ecosystems in the eastern region, which includes the St. Lawrence/Lake Champlain/Black River basin, the Hudson-Mohawk basin, the Delaware basin, and Long Island are defined by either the Adirondack/Catskill mountain areas to the north or the New York Bight tidal estuarine area to the south. Aquatic ecosystems in the central region, which includes the Oswego-Ontario basin and the Susquehanna, are defined by areas of low relief with large areas of marshes to the north and broad, steeply sided valleys with limited natural storage capacity in the south. Aquatic ecosystems in the western region, which includes the Lake Ontario basin, the Erie-Niagara basin, the Genesee basin, and the Allegheny basin, are defined by the glaciated geology of that region (NYSDEC, 1967).

In addition to the watershed drainage basin, it is also possible to classify lakes and ponds according to their respective ecoregions. Ecoregions are geographical map units that depict areas which share common geology, morphology, soils, climate, and other characteristics (Omernick, 1987). Accordingly, due to these similarities in watershed characteristics, water chemistry within an ecoregion tends to be similar and often is distinctive from other ecoregions (unless impacted by human activities). For example, the USEPA has issued Ambient Water Quality Criteria Recommendations (or "reference conditions") for nutrients for lakes in the 14 national ecoregions. For New York, USEPA has established numeric nutrient criteria recommendations for lakes in the following Level III Non-Aggregate Nutrient Ecoregions:

- Ecoregion VII – Mostly Glaciated Dairy Region – this is the ecoregion for the majority of New York including western and central portions, as well as major river and lake plains;
- Ecoregion VIII – Nutrient Poor, Mostly Glaciated Upper Midwest and Northeast – found primary in the Adirondack and Catskill mountain regions;
- Ecoregion XI – Central and Eastern Forested Uplands – a small portion of the lower Hudson Valley is located in this ecoregion;

- Ecoregion XIV – Eastern Coastal Plain – metropolitan New York City region and Long Island are included.

USEPA has also issued waterbody-specific technical guidance, in the form of the Nutrient Criteria Technical Guidance Manual for Lakes and Reservoirs (USEPA, 2000a).

As noted above, water chemistry in each of these basins is influenced by the composition of the geological formations found within the region. For example, waters in the Adirondack Mountains and the Catskill Mountains can be influenced by geologic formations with little buffering capacity. In some lakes, this geological setting, coupled with anthropogenic inputs, has resulted in waters with pH values of less than 5 standard units (S.U.) (NYSDEC, 1981b). Surface water systems in the Erie-Niagara basin in western New York State are characterized by high levels of dissolved solids (140 to 240 ppm) and hard water (108 to 200 ppm, expressed as CaCO<sub>3</sub> equivalents) (NYSDEC, 1968). Surface water in the Delaware River basin is characterized by low total dissolved solid levels (averaging 37 ppm) and an average hardness of approximately 37 ppm. The dominant ions are silica, calcium, bicarbonate and sulfate (Archer and Shaughnessy, 1963). The dissolved solid concentrations in surface waters in the Champlain-Upper Hudson basin rarely exceed 500 ppm (Giese and Hobba, 1970). In surface waters of the Western Oswego River basin, dissolved solid concentrations range from 50 to 300 ppm (Crain, 1975).

Wetlands, both freshwater and coastal, are transitional areas where land and water interact. The State of New York is highly variable in its environment relative to terrain, climate, and other environmental factors, and the state's wetlands are similarly varied. Wetlands in New York are highly diverse and range from Long Island tidal marshes dominated by cordgrasses, emergent and shrub marshes along the clay flats of the Finger Lakes region and the Hudson River valley floodplain, forested wetlands common to the Adirondacks, as well as fringe wetlands along lake shores and riparian wetlands along streams and rivers throughout the state.

The typical wetland environments where application of an aquatic herbicide may be considered vary widely. This variation includes the nature of soil saturation among habitat types such as seasonally flooded freshwater marshes, wetlands located above the mean tide line of estuarine marshes, and marsh and shrub wetlands that exhibit perennially saturated surface soils but may never receive full inundation. Some of these wetlands occur in isolated pockets, characteristic of the "perched" wetlands found upon clay plains, but more often they are found on the periphery of a larger wetland/waterbody complex. Many lakes and ponds, particularly those formed in the glacially-affected landscape of New York, often have shallow aquatic marshes at their boundary with adjacent uplands. Such ecosystems that form in perennial shallow standing water are particularly susceptible to colonization by riparian invasives such as *Phragmites communis*, which exerts a strong competitive advantage due to its ability to colonize disturbed areas and tolerate variable water levels.

### 3.1.1 Lake basin characteristics

The lakes in New York were created in two principal ways. Many lakes resulted from glacial activity approximately 12,000 years ago. Others were created by damming streams or by enhancing a small lake by damming its outflow. Most damming occurred during the early industrial age of the country when water power was a critical resource. Through natural processes, most lakes become shallower and more eutrophic (nutrient-rich) and eventually fill in with sediment until they become wet meadows. The aging process is not identical for all lakes, however, and not all start out in the same condition. Many lakes that were formed by the glaciers no longer exist while others have changed little in 12,000 years. Yet lake aging is reversible. The rate of aging is determined by many factors including the depth of the lake, the nutrient richness of the surrounding watershed, the size of the watershed relative to the size of the lake, erosion rates, and human induced inputs of nutrients and other contaminants.

Existing lakes can be subdivided into four categories. Nutrient-poor lakes are termed oligotrophic, nutrient-rich lakes are eutrophic, and those in between are mesotrophic. A fourth category includes lakes following a different path; these typically result in peat bogs and are termed dystrophic lakes. They are often strongly tea colored. Lakes in one part of the New York State may share many characteristics (depth, hydrology, fertility of

surrounding soils) that cause them to be generally more nutrient-rich while another region may generally have nutrient-poor lakes.

Lakes that are created by man-made impoundments and damming streams often follow a different course of aging than natural lakes. At first, they may be eutrophic as nutrients in the previous stream's floodplain are released to the water column. Over a period of decades, that source of productivity tends to decline until the impoundment takes on conditions governed more by the entire watershed, just as for natural lakes. Impoundments in New York are commonly shallower than natural lakes, have larger watersheds (relative to lake area), and the pre-existing nutrient-rich bottom sediments may provide nutrients for abundant aquatic plant growth early in the life of the lake. However, most impoundments in New York are smaller, shallower systems with high watershed to lake area ratios.

Human activity can accelerate the process of lake aging or, in the case of introduced species or substances, force an unnatural response. Examples of unnatural response include the elimination of most aquatic species as a result of acid deposition, noxious algal blooms resulting from excessive anthropogenic nutrient enrichment, intentional or inadvertent stocking of non-indigenous fish species that leads to the elimination of native species, or the development of a dense monoculture of a non-indigenous aquatic plant and elimination of native aquatic plants. However, it would be unrealistic to assume that managing cultural impacts on lakes can convert them all into oligotrophic basins of clear water and/or clean bottoms, and this would not be an appropriate goal for many lakes. Understanding the causes of individual lake characteristics (i.e., understanding the lake ecosystem) is a fundamental part of determining appropriate management strategies.

### **3.1.2 Hydraulic residence**

Hydraulic residence time is a function of the volume of water entering or leaving the lake relative to the volume of the lake (i.e., the water budget). The larger the lake volume is, and the smaller the inputs or outputs, the longer will be the residence time.

Lake residence time may vary from a few hours or days to many years. Lake Superior, for example, has a residence time of 184 years (Horne and Goldman, 1994). However, New York lakes typically have residence times of days to months. Very short residence times will mean that algae cannot grow fast enough to take advantage of nutrients before the algae and nutrients are washed out of the lake. Long residence times mean that algae can utilize the nutrients and that they will probably settle to the lake bottom rather than be washed out. Those nutrients may become available again to the rooted plants or may be moved by biotic and abiotic internal recycling mechanisms back into the water column for additional algal growth.

Water may flow into a lake directly as rainfall, from streams and from groundwater. Water may leave a lake as evaporation, via an outlet, or as groundwater. Human influences include direct discharges to lakes or withdrawals from them. Lakes that have no inlets or outlets are called seepage lakes while lakes with outlets are called drainage lakes. Seepage lakes are basically a hole in the ground exposed to the groundwater. Precipitation and evaporation may also be influential in such lakes, and will increase the concentration of minerals to some degree. Few particulates will be brought into the lake or leave it. Drainage lakes, on the other hand, may receive significant quantities of particulates and dissolved material from inlet streams. Because lakes slow the flow of water, many particulates will be deposited on the lake bottom. Precipitation, evaporation, and groundwater flow may have some influence, but drainage lakes are normally dominated by storm water flows.

### **3.1.3 Mixing**

The thermal structure of lakes also determines productivity and nutrient cycling (Wetzel, 2001; Kalff, 2002). For many shallow New York lakes, the mixed layer may extend to the lake bottom. Deeper lakes may form a three-layered structure that throughout the summer consists of an upper warm layer (the epilimnion), a middle transition layer (the metalimnion, with the point of greatest thermal change called the thermocline), and a colder bottom layer (the hypolimnion).

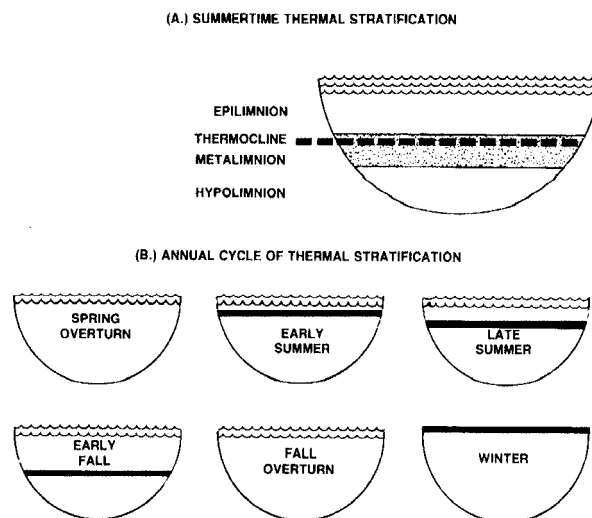


A lake's thermal structure is not constant throughout the year (Figure 3-1). Beginning at ice out in early spring, all the lake's water, top to bottom, is close to the same temperature; the density difference is slight and water is easily mixed by spring winds. With warmer days, the difference between the surface and bottom waters increases until a layer (the metalimnion) is created where the incoming solar heat and wind-mixing effects are balanced. More heat and more wind moves the layer lower in the water column over the summer. Eventually, solar heating declines and the upper layer begins to cool. But the metalimnion does not retreat to the surface; it continues to move downward as wind mixes the remaining heat in the epilimnion ever deeper. Finally, in fall, the metalimnion arrives at the bottom and the lake is completely mixed again (turnover), but the upper layer is much cooler than during summer. In the early months of winter, the whole lake cools until it reaches 4°C. Further cooling which occurs only at the surface causes the surface water to be less dense. Ice forms at the surface and a new, inverse stratification (cold over cool water) is created and normally persists until spring.

This rather curious phenomenon affects many lake processes. During summer stratification, if incoming tributary water is relatively warm, it will float across the top of the cooler hypolimnion. Thus, during stratification, the effective residence time for incoming water and nutrients may be substantially less than when the lake is unstratified. If incoming water is especially cool, it may sink, often running along the thermocline as a sustained layer.

The cooler waters of the hypolimnion provide a refuge for so-called coldwater fish (e.g., salmonids) that are intolerant of warmer waters, as long as oxygen and related water quality is suitable. The metalimnion provides a one-way barrier for many materials. Photosynthetic organisms may grow in the epilimnion, but when they die they will settle by gravity into the hypolimnion. As they settle, they carry nutrients with them to the bottom where they may be incorporated into the sediments or may be recycled by bacteria that will convert the nutrients into an inorganic form. Thermal characteristics of a lake and its tributaries are therefore important to lake ecology and management.

**Figure 3-1 Seasonal patterns in the thermal stratification of north temperature lakes (from Olem and Flock, 1990)**

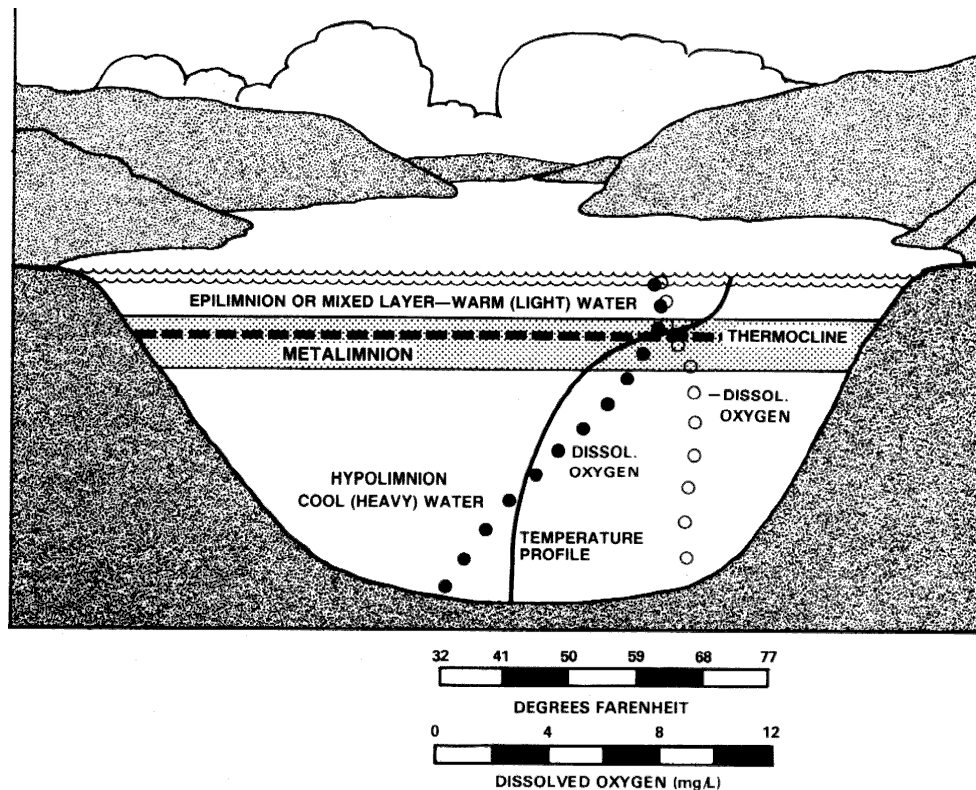


When the metalimnion is established, the hypolimnion no longer has a significant source of oxygen, either from exchange at the surface or as a result of photosynthesis. But animals and bacteria live in these lower waters and consume oxygen. If enough organic matter rains down to the hypolimnion, bacterial decay may consume all the oxygen and kill any fish and other aerobes which may require cooler waters (Figure 3-2).

Lakes can have oxygen problems for other reasons. During winter when the lake is ice-covered, there is little plant photosynthesis and reduced animal and bacterial respiration. When there is heavy snow on the ice cutting off most light, plant photosynthesis is especially low. If the lake has substantial organic material in the water column or surface sediments, bacterial decay can, by late winter, deplete the oxygen and kill oxygen-dependent organisms such as fish. Ice-out may reveal a fishkill.

**Figure 3-2 A cross-sectional view of a thermally stratified lake in mid-summer (from Olem and Flock, 1990)**

Solid circles represent the dissolved oxygen profile in eutrophic lakes; open circles represent oligotrophic lakes.



Similarly, low oxygen levels may occur in areas of dense vegetation within highly enriched lakes as plants respire during darkness, particularly if the days have been very cloudy and photosynthesis has been lower than normal. A fish kill may occur in early morning after a night of heavy respiratory oxygen consumption. These are somewhat rare conditions, but all stratified lakes and some unstratified lakes reveal their trophic state by the degree of loss of oxygen. The greater the amount of primary productivity in the epilimnion, the greater the potential oxygen loss in the hypolimnion. If hypolimnetic oxygen progressively declines from year to year, these simple data provide an excellent record of increasing productivity. Conversely, increasing levels of dissolved hypolimnetic or winter oxygen under the ice is clear evidence of improvement.

### 3.2 General characterization of aquatic plant and wetland communities in New York waterbodies

The characteristics of plant communities in aquatic settings are determined by the type of waterbody in which the community is located. Aquatic plants are often the dominant biotic factors in pond settings and are important ecological features of larger waterbodies such as lakes and reservoirs. New York State, with over

7,500 lakes, contains an extensive array of freshwater systems. This diversity is further increased by the inclusion of streams, rivers, and other bodies of flowing water. Waterbodies vary in terms of color, pH, temperature, silt loading, bottom substrate, depth, rate of flow if it is a moving body, and watershed area. Each of these characteristics will affect, to some extent, the type and distribution of the plant communities in that waterbody.

### **3.2.1 Types of freshwater ecosystems**

Freshwater ecosystems include lentic ecosystems, represented by standing waterbodies such as lakes and ponds; lotic ecosystems, which are represented by running water habitats (rivers and streams); and wetland habitats where water is present at or near the surface and flow may range greatly over the seasons. These habitats are discussed briefly below.

#### **3.2.1.1 Ponds and lakes**

Lentic systems (ponds and lakes) can be further subdivided in littoral, limnetic, profundal, and benthic zones. The littoral zone is that portion of the waterbody in which the sunlight reaches to the bottom. This area is occupied by vascular, rooted plant communities. Beyond the littoral zone is the open water area, or limnetic zone, which extends to the depth of light penetration or compensation depth. This is the depth where approximately 1% of the light incident on the water surface still remains. As a result of this decreased light, photosynthesis does not balance respiration in plants. Therefore, the light is not sufficient to support plant life. The water stratum below the compensation depth is called the profundal zone. The bottom of the waterbody, which is common to both the littoral zone and the profundal zone, is the benthic zone (Wetzel, 2001; Kalff, 2002).

Kishbaugh et al., (1990) note that the bottom morphology (shape) of a lake is a key factor in determining the type and extent of plant communities that are present. The chemical quality of the water is another factor that influences the distribution of plant species. Soft water lakes (total alkalinity of up to 40 ppm and a pH of between 6.8 and 7.4) will often have sparse amounts of vegetation. Hard water lakes (total alkalinity from 40 ppm to 200 ppm and a pH between 8.0 and 8.8) will have dense growths of emergent species that can extend into deeper water (Fairbrothers and Moul, 1965). Sculthorpe (1967) noted that the distribution of species within a waterbody is determined by the bottom substrate, light intensity (function of depth and water clarity), and turbulence (currents or wave action). For additional information on lentic systems typical of New York lakes, see Diet For a Small Lake (Kishbaugh et al., 1990).

#### **3.2.1.2 Lotic systems**

Lotic systems include rivers and streams. In lotic systems the distribution of plant communities is dictated by the velocity of the water flow and the nature of the bottom substrate. In fast moving waters, the system is usually divided into riffle and pool habitats. Riffles, which are areas of fast water, are centers of high biological productivity. However, the speed at which the water flows in these areas usually will not allow for rooted macrophytes to become established. Rooted vascular plants are more characteristic of pool habitats, which are interspersed with the riffle zones. In pool habitats, the softer bottom substrate and the slower current velocities allow for the establishment of rooted plants. This is also the case for slower moving streams and rivers. In larger rivers, as with lakes, ponds, and reservoirs, depth becomes a determining factor for the distribution of plant communities (Wetzel, 2001; Kalff, 2002).

#### **3.2.1.3 Wetlands**

Wetlands constitute a great range of habitat types which demonstrate different floristic, soil, and hydrologic characteristics, but most all share certain important characteristics. These include the ability to attenuate floodwaters, to cleanse surface water and recharge groundwater supplies, and to prevent soil erosion. Within wetlands ecosystems, sediment and associated pollutants from road runoff and other sources are deposited as water velocity slows and moves through the sinuous channels of natural swamps and marshes. Microbes intrinsic to wetland environments are capable of breaking down and using nutrients and contaminants that may

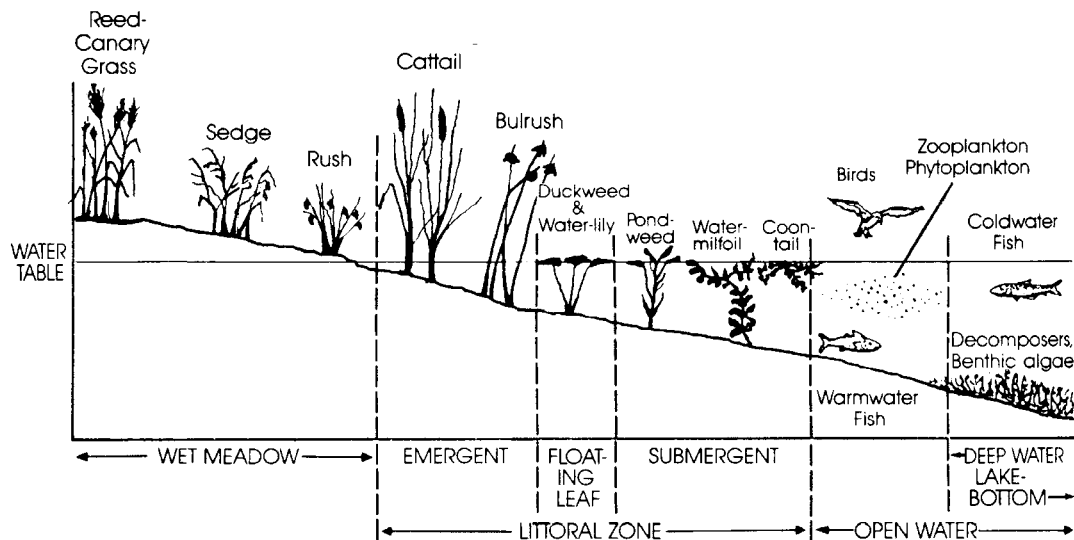
otherwise be harmful to the environment. Similarly, chemical processes in saturated soils characteristic of most wetland types further preserve water quality through the uptake and immobilization of heavy metals, salts, and other contaminants.

In addition to these important biogeochemical attributes, such natural systems are also valued for their recreational and aesthetic characteristics and for provision of valuable habitat for fish and wildlife, particularly those emergent wetlands dominated by cattails, rushes or sedges. Large expanses of wetlands not only serve the purpose of protecting surface and ground water quality, but they are also often used for hiking and other outdoor recreational pursuits, waterfowl hunting, and fishing. Estuarine wetlands, and particularly tidal wetlands, are very important breeding and spawning grounds for a myriad of species of birds, fish, shellfish, and aquatic invertebrates. Not least importantly, wetlands are also valued and protected for their scenic beauty.

### **3.2.2 Growth forms of aquatic macrophytes**

One useful way of classifying aquatic macrophytes conceptually is based on their habitat and location relative to the waterbody surface. There are four growth forms of aquatic plants that are commonly recognized (Figure 3-3): floating unattached, floating attached, submersed and emergent (Rierner, 1984; Kishbaugh et al., 1990). Some plants consist of both submersed and floating leaves, and some have different growth forms under different abiotic conditions (submersed and emergent forms), so the groupings are not quite so distinct.

There are many taxonomic groups but the above categories are often the most useful for understanding the causes of a macrophyte problem and determining an appropriate management strategy. In fact, within each category, many species may look very similar as their growth habit responds to common lake conditions. Although many macrophyte species appear similar, their propensity to cause problems in lakes varies. Effective management of macrophytes usually requires species identification (e.g., Fassett, 1966; Crow and Hellquist, 2000). For example, a drawdown may reduce densities of *Cabomba caroliniana* but may increase densities of *Najas flexilis* based on their overwintering strategies (vegetative vs. seeds).

**Figure 3-3 Typical aquatic plant zones in lakes and ponds (from Kishbaugh et al., 1990)**

Rooted aquatic plants typically grow from a root system embedded in the bottom sediment. Unlike algae, they derive most of their nutrients from the sediments just like terrestrial plants, but they may be able to absorb nutrients from the water column as well. Because they need light to grow, they cannot exist where the lake bottom is not exposed to sufficient light. The part of a lake where light reaches the bottom is called the photic zone. For many such plants, nutrients in the sediments may be in excess and growth is limited by light, particularly during early growth when the plant is small and close to the bottom. Emergent plants solve the light problem by growing out of the water, but that limits them to fairly shallow depths. Free-floating plants also are not limited by light except in cases of self-shading when growths are dense, but cannot use the sediments as a source of nutrients. Finally, floating-leaf plants have attempted to achieve the best of all worlds by having their roots in the sediment and leaves at the surface. Although less limited by water depth, they still have depth limits. Common floating-leaf plants include white water lily (*Nymphaea odorata*), yellow water lily (*Nuphar* spp.), water shield (*Brasenia schreberi*), and waterchestnut (*Trapa natans*).

Submerged plants are generally relegated to the littoral zone and include such genera as *Potamogeton* and *Myriophyllum*. Many of these macrophytes are rooted plants which complete the majority of their life cycle below the water surface, with only the reproductive structures extending above the water surface. Exceptions to this include plants in the genera *Ceratophyllum* and *Utricularia*. These plants do not have true roots, but are considered to be submerged plants found in the littoral zone (Kishbaugh et al., 1990). *Lemna* and other free-floating species are generally found over the littoral zone and deeper water.

Aquatic plant communities are commonly arranged by species along depth contours. These communities are comprised of either heterogeneous mixtures of species, or as is sometimes the case, they are comprised of monotypic stands of a single opportunistic macrophyte. The species diversity or richness of a plant community depends on sediment type, disturbance, and vegetation management efforts. The characteristics of the communities will change with increasing depth as more shade tolerant species become dominant. Mosses, charophytes, several vascular species, and blue-green algae (cyanobacteria) are the common constituents of the near-profundal zone. Open architecture species such as members of the genus *Potamogeton* are found in shallower, better lighted zones. Emergent species will typically dominate the shallowest water, but are usually accompanied by other vascular species.

### 3.2.3 Functional attributes of macrophyte communities

Functionally, aquatic plants play important roles in the aquatic ecosystem. Aquatic macrophytes provide food and shelter for both vertebrate and invertebrate organisms and as spawning habitat for fish (Nichols, 1991; Keast, 1984; Gotceitas and Colgan, 1987; Schramm and Jirka, 1989; Hacker and Steneck, 1990; and Kershner and Lodge, 1995). The ability of the macrophyte community to fill these functions, its value per se, is often a function of the species, density, and distribution of the members of that plant community.

Aquatic vegetation performs four basic functions in waterbodies (Fairbrothers and Moul, 1965). These functions include:

- modification of the dissolved gas content of the surrounding water;
- provision of nutrient material suitable for food and the introduction of inorganic nutrients into the food cycle;
- modification of the physical environment; and
- protection and provision of habitat for other organisms.

However, the extent to which those functions are fulfilled will depend on the location of the plant community (i.e., emergent community versus a deepwater community).

Daubenmire (1968) notes that plants in the genera *Potamogeton* and *Scirpus* are a favored food source for North American waterfowl, whereas muskrats (*Ondatra zibethica*) favor plants in the genera *Carex*, *Sagittaria*, and *Typha*. Brown et al. (1988) reported that vertically heterogeneous stands of aquatic macrophytes tended to contain more invertebrates than a community dominated by a single taxon. Therefore, opportunistic, rapid-growing species such as Eurasian watermilfoil, purple loosestrife, phragmites, and cattails, which develop dense monotypic stands in mature communities, would not be expected to offer the quality or diversity of habitat in such circumstances as more diverse communities would.

Dionne and Folt (1991) note that high plant densities can interfere with the foraging ability and efficiency of piscivorous and insectivorous fish. Dense plant stands can directly or indirectly disrupt the utilization of macrophyte beds by fish and macroinvertebrates by affecting light penetration, temperature regimes, and water chemistry (Lillie and Budd, 1992).

In ponded waters, generally a greater variety of plant genera is available to fulfill the necessary functions provided by the plant communities (Daubenmire, 1968). This occurs because of the small size of the ponds, which results in a reduction in the influence of wave action. Plant communities in large lakes can be influenced by wind driven waves which will restrict the distribution of plants in exposed areas. The functions described by Daubenmire include habitat for fish and invertebrates, food for waterfowl, and nesting or hiding areas for fish and other vertebrates, such as amphibians. Plants in the genera *Ceratophyllum*, *Chara*, *Elodea*, *Najas*, and *Potamogeton* are the most common native species to fulfill these functions. These macrophyte species are generally the first macrophytes to advance over the bottom and will usually dominate the plant community which occupies that portion of the littoral zone at the pond margin to a depth of 7 meters.

Aquatic plants serve as food sources for a variety of organisms, including fish, waterfowl, turtles (snapping, *Chelydra serpentina* and painted, *Chrysemys picta*), and moose (*Alces alces*). Herbivores will consume fruits, tubers, leaves, winter buds and occasionally, the whole plant. Many species in the genera *Potamogeton* and *Najas* are considered to be valuable sources of food items. Plants in the genera *Myriophyllum*, *Nymphaea*, and *Ceratophyllum* are considered to be poor sources of food items (Fairbrothers and Moul, 1965). Nichols and Shaw (1986) note that Eurasian watermilfoil (*M. spicatum*) is a poor source of food for waterfowl.

Submerged plants play an important role in supporting fish populations (Kilgore et al., 1989; Smith et al., 1991). Submerged plants provide food and shelter for fish and their young. Submerged plants serve as the

substrate for the invertebrates that support fish populations. Smith et al. (1991) stated that the production of forage fish and invertebrates generally increases in proportion to the submersed plant biomass. However, they conclude that populations of piscivorous fish tend to peak in water with intermediate levels of plant biomass. This is a function of the ability of the piscivorous fish, such as largemouth bass (*Micropterus salmoides*) to see their prey.

Submerged macrophyte stems and leaves may act as a substrate for a variety of microscopic organisms, called aufwuchs. Aufwuchs include bacteria, fungi, diatoms, protozoans, thread worms, rotifers and small invertebrates. The architecture of a particular plant species will also determine its suitability as a place for egg deposition for fish and amphibians. Additionally, the young of many fish species and some tadpoles will seek shelter in plant structures to evade predators.

Pullman (1992) notes that the architectural attributes of a particular plant species are a critical feature in the ability of that plant to function in support of fish populations. Those vertical plants with open architecture (some *Potamogetons*, *Elodea*, *Cabomba*, and a native species of *Myriophyllum*) provide more suitable habitat for fish than those plant species that form dense vertical mats or mats at the surface such as are formed by (*M. spicatum*), and some *Potamogeton* species (including *Potamogeton crispus*). Matted Eurasian watermilfoil plants have few leaves along their stems. The leaves are shaded and replaced by a dense leaf cover at the water's surface. The collection of vertical stems has limited habitat value. Madsen et al. (1991a) supports this by noting that most native species are recumbent or have short stems and do not approach the water surface and therefore tend to support greater fish populations than mat forming macrophyte species. Variable height and leaf architecture will yield more diverse habitats.

### 3.3 Description of nuisance and aquatic invasive species

Nuisance species is a generic term given to organisms (both fauna and flora) that are generally known to interfere with human activities including agriculture, aquaculture, or recreation. Nuisance aquatic plant species can be aesthetically displeasing, may interfere with effective and proper harvest of fishery resources, may interfere with other recreational activities such as swimming or boating, or cause impairment to other designated water uses. Some species may act as nuisance species in some environmental settings but not in others, influenced by, among other factors, their proximity to human activities.

Invasive species are species that display a marked ability, upon being introduced into a new environment, to colonize or exploit that particular environment at the expense of the existing ecological community, resulting in their quantitative or biomass predominance in the resulting community structure. Their replacement of the existing community members is considered to be fundamentally detrimental to the colonized ecosystem in terms of reducing biodiversity, or in more specific ways, such as loss of habitat structure or reduced wildlife function. By virtue of their dominance of the colonized community, an invasive species can become a nuisance species in that they interfere with or are detrimental to human activities.

The ability of an aquatic plant to behave invasively, i.e., spread rapidly and grow to potentially nuisance biomass levels, is dependent on the interactions of many factors, among them reproductive and dispersal mechanisms, growth rate, competitive abilities for light and nutrients, presence of natural biological controls, resistance to and presence of pathogens and favorable abiotic conditions. Favorable abiotic conditions for a particular plant can include nutrient abundance, preferred water depth and sediment type, hardness of water and pH. Occasionally a cycle of expansion and decline is observed in aquatic plants, attributable to the presence of pathogens (Shearer, 1994), the presence of herbivorous insects (Sheldon, 1994), competition between plant species (Titus, 1994, Madsen et al., 1991a; 1991b), or a change in abiotic conditions (Barko et al., 1994; Shearer, 1994).

One of the most striking characteristics of nuisance species is that a large number of them are not native to the geographic area in which they are problematic, i.e., they are invasive. In some cases these invasive, non-indigenous species have expanded their historic range through natural means, but in the large majority of such cases, it is through human activities, either intended or inadvertent (e.g., aquarium and horticulture trades).

Once established in a lake, waterfowl and boats may facilitate their spread to other locations due to the invasive species' growth strategy that emphasizes efficient dispersal of propagules, rapid spread and growth rate, and sometimes high rates of biomass production emphasized by high productivity and rapid growth. In many situations where a non-indigenous invasive species has been introduced, a near monoculture of that species develops, reducing recreational utility and habitat value. These plants are able to occupy a wide diversity of habitats (Wetzel, 2001; Kalff, 2002).

The native plant communities in the ecosystem have evolved under long-term conditions and relationships including inter-specific and intra-specific competition for nutrients, space and sunlight; presence of natural enemies like insects, waterfowl and fish; and a range of environmental conditions such as temperature, pH and mineral content. These relationships tend to keep any one native species from dominating and encourage a diverse plant community. Introduced species are often able to out-compete native vegetation because of the absence of natural enemies and competitive pressures. Suter (1993) maintains that many of the severe anthropogenic effects brought upon natural biotic systems are caused by the introduction of non-indigenous species. Accordingly, there is a great need for control of rooted exotic or non-indigenous plants.

Non-indigenous species, unlike the native biota, may experience few or no predators, parasites or pathogens when introduced into a new habitat. Invasive, non-indigenous species can therefore potentially totally dominate and eliminate native populations. Nichols and Shaw (1986) and Wade (1990) note that an invasive aquatic macrophyte has the potential to infest a waterbody, and then spread to the maximum extent of the available habitat. Following the initial invasion period, the production of the invasive species can attain a degree of stability and habitat equilibrium. Subsequently, the population of the invasive will fluctuate in response to the temporal and spatial dynamics of the aquatic environment (Nichols and Shaw, 1986; Wade, 1990). Usually, the equilibrium condition for the production of invasive species such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curlyleaf pondweed (*Potamogeton crispus*) is considered to be deleterious for most recreational and utilitarian uses as well as a disruptive influence on native plants and animals.

There are many examples of non-indigenous invasive species which have successfully colonized aquatic ecosystems in New York and Northeastern North America. Introductions of Eurasian milfoil (*M. spicatum*) in Lake Champlain (Vermont/New York), Lake George (New York), Okanagan Lake (British Columbia) and many other lakes in New York and Massachusetts and other states threaten otherwise healthy lakes (Mattson et al. 2004). Within just a few years, a small patch of this species can grow to fill the lake, top to bottom, within the photic zone. Another nuisance species, fanwort (*Cabomba caroliniana*), is a popular aquarium plant. Many believe it was introduced from freshwater aquariums (Les, 2002). Purple loosestrife, a non-indigenous wetland plant, completely crowds out native species and creates stands so dense that wildlife habitat is degraded. It was introduced by horticulturists and gardeners desiring the beauty of the plant for their area (Les, 2002). There are many other non-indigenous aquatic species of concern, but not all are as successful as these examples.

It is important to distinguish between nuisance conditions caused by non-indigenous (i.e., non-native) invasive species and those caused by locally dense populations of indigenous plants. In the case of the former, any infestation of non-indigenous invasive species should be considered a *de facto* biological impairment and a threat to the natural aquatic ecosystem which should be dealt with quickly and completely. In the case of the latter, a much greater burden of proof would be required to show a causative impairment due to simple overabundance.

Invasive species are also a concern for wetland habitats. The introduction and spread of non-indigenous invasive plant species represents a potentially significant threat to the structure, function, and associated habitat values provided by New York's freshwater and tidal wetlands. Such species most commonly observed in non-submergent freshwater and coastal wetlands include common reed (*Phragmites australis*), though others such as the woody species buckthorn (*Rhamnus* spp.) and multiflora rose (*Rosa multiflora*) may be locally problematic.



### 3.4 Distribution and ecology of representative aquatic macrophyte target species

Several non-indigenous or native species are potential target species of Clearcast® (see Tables 2-1 and 2-2). Due to its flexibility of use against submersed, floating-leaved, and emergent species, we are providing information on the ecology of three representative target species: Eurasian watermilfoil, white waterlily, and purple loosestrife. While there are other target species which may be applicable for Clearcast®, consideration of these three species provides an opportunity to assess potential impacts across New York riparian and littoral areas and for non-indigenous invasive species and potentially problematic native species. The following sections describe the general distribution and ecology of the representative target macrophytes for Clearcast® with particular focus on Eurasian watermilfoil (Section 3.4.1), white waterlily (Section 3.4.2) and purple loosestrife (Section 3.4.3).

#### 3.4.1 Eurasian watermilfoil

The genus *Myriophyllum*, watermilfoil, is almost cosmopolitan in nature. Approximately 60 species occur world-wide from three main geographic centers. According to Orchard (1981), the three geographic centers are Australia, North America, and India/Indo-China. To date, species in the genus *Myriophyllum* are found on every continent, except Antarctica. For nearly all introduced species, introductions are the result of the aquaria and aquatic gardening industries. Marketing of *Myriophyllum* species is wide-spread in these markets due to their feather-like appearance and hearty nature.

Eurasian watermilfoil, *M. spicatum*, is a submersed perennial herb that attaches to the substrate with fibrous roots. The stems of Eurasian watermilfoil are slender, reddish-brown, and can reach 6 meters in length, typically branching near the surface of the water. The leaves are green, less than 5 centimeters in length, and contain at least 12 segments. When removed from the water, the leaves of Eurasian watermilfoil tend to collapse around the stem. Mature leaves are typically arranged in whorls of 4 around the stem, ranging from 3 to 6 on rare occasions. Flowers of Eurasian watermilfoil are located on a spike protruding from the water. Flowers are reddish to pink in color, each containing four petals, and are most often observed in August and September. The fruit of Eurasian watermilfoil is four-lobed and splits into four separate one-seeded nutlets. Pigment or DNA analysis is sometimes needed for species identification as a consequence of morphological variability and possible hybridization. Other milfoils share some of these characteristics. Reproductive parts are the most definitive character. In the absence of flowers and/or seeds, the most distinctive characteristics are the normally reddish stem tips, the 12 or more filaments on each side of the central axis of each leaf, and the truncated leaf tips. This latter feature gives leaf ends the appearance of having been trimmed with scissors. Eurasian watermilfoil is sometimes confused with other species of milfoils, most notably the native northern watermilfoil (*M. sibiricum*).

##### 3.4.1.1 Geographic range and history of invasion

Eurasian watermilfoil is native to Europe, Asia and northern Africa. First believed to have been introduced to the Chesapeake Bay area in the 1880's (Aiken et al., 1979), the first known sample of Eurasian watermilfoil was collected in a Washington, DC, waterbody in 1942 (Couch and Nelson, 1985). Eurasian watermilfoil has great potential for expansion due to an adaptive life history strategy, rapid vegetative growth, and carbohydrate storage in the root crowns, allowing for overwintering in cold climates (Giesy and Tessier, 1979; Adams and Prentki, 1982; Madsen, 1994, 1998; Madsen and Welling, 2002). Plant fragments are easily transported to new waterbodies by boats, trailers, fishing gear, wind, animals and currents (Aiken et al., 1979). In one study, Minnesota authorities found aquatic plants on 23% of all boats inspected (Bratager et al., 1996). Plant fragments transported to new waterbodies can become rooted and form new shoots.

As of 1992, COLAM (1992) reported that Eurasian watermilfoil had been identified in lakes in 35 of New York State's 62 counties. In its 1993 Annual Report on the Aquatic Plant Identification Program, the Rensselaer Fresh Water Institute noted that 38 counties had documented populations of Eurasian watermilfoil in 1993 (Eichler and Bombard, 1994). By 2006, Eurasian watermilfoil had expanded its geographical extent further,

with verified populations in 50 counties and reports of occurrence in 3 of the remaining 12 counties (Eichler and Boylen, 2006).

By 2002, Eurasian watermilfoil had been reported in 45 of the 50 U.S. States and in the southern portions of Canada from Quebec to British Columbia (Madsen and Welling, 2002). It has since been documented in several additional states, and it is reasonable to believe that it could become established in all U.S. states. Currently, *M. spicatum* is listed as regulated, prohibited, invasive or noxious in at least 15 different states. In addition, Eurasian watermilfoil is on lists of government agencies or pest plant councils in at least 21 different states.

#### 3.4.1.2 Ecology of Eurasian watermilfoil

Eurasian watermilfoil is a tolerant species that has been shown to grow well in a variety of aquatic habitats. Couch and Nelson (1985) note that the plant will thrive in all types of nutrient conditions (oligotrophic to eutrophic), both hard and soft water and under both brackish and freshwater conditions. The plant appears to grow best in fine, nutrient-rich sediments that do not contain more than 20% organic matter and requires a minimum light intensity of 1% to 2% of the available light (Smith and Barko, 1990). Kimbel (1982) reports that the colonization success of Eurasian watermilfoil is highest in late summer months; particularly within shallow water and on rich organic sediments. Eurasian watermilfoil's maximum growth rate occurs at temperatures ranging from 30 to 35°C (Smith and Barko, 1990). The plant utilizes both sediments and the surrounding surface water as sources of nitrogen and phosphorus (Smith and Barko, 1990). Barko and Smart (1980; 1981) indicate that uptake by the roots is the primary means of obtaining phosphorus and most other nutrients.

Eurasian watermilfoil grows in waters at depths of 0 to 10 meters (typically between 1 to 5 meters in depth). Eurasian watermilfoil will commonly grow as an emergent in circumstances where the water level of the lake slowly recedes (Aiken et al., 1979). Smith and Barko (1990) suggest that light intensity determines much of the distribution and morphology of Eurasian watermilfoil. While it grows in waterbodies with wide ranges in water clarity, in turbid waters growth is generally concentrated in the shallow areas (Titus and Adams, 1979). In relatively clear waters, Eurasian watermilfoil grows at much deeper depths and may not reach the water surface.

Pearsall (1920) considers Eurasian watermilfoil to be a deep water plant species, which he defines as a plant growing at a depth where light intensity is less than 15% of full sunlight. The common growth pattern for Eurasian watermilfoil is for the plant to initially colonize deeper waters, where it will generate a large quantity of biomass which extends to the surface (Coffey and McNabb, 1974). As the Eurasian watermilfoil reaches toward the surface, the lower leaves of the plant will be shaded out and will slough off. This creates a dense organic bed beneath dense growths of Eurasian watermilfoil and is part of the process that recycles nutrients back into the water column. The leaves and stems of Eurasian watermilfoil will concentrate at the surface of the waterbody, forming a thick canopy or mat which extends into shallower waters when the plant reaches sufficient densities.

Madsen et al. (1991a), in work done in Lake George, New York, noted that growth characteristics are facilitated by a high photosynthetic rate and a high light compensation point. Because of its high photosynthetic rate and correspondingly increased metabolic activity and productivity, the plant is able to grow at a significantly higher rate than that exhibited by native species such as *Potamogeton* spp. and *Elodea canadensis*. Additionally, with its high light tolerance, Eurasian watermilfoil will tend to grow closer to the waters surface than the native species that occur in low to medium light intensity regions of the littoral zone. This pattern allows for successful replacement or disruption of native vegetative communities. Madsen et al. (1991b) reported that dense growth of Eurasian watermilfoil in a bay in Lake George had significantly reduced the number of native species present.

Eurasian watermilfoil can overwinter with much of its green biomass intact. Because of its adaptation to grow at lower temperatures than many native aquatic species, Eurasian watermilfoil is capable of tremendous growth at the very beginning of the growing season. The early timing of growth, in conjunction with its great

ability to produce large quantities of biomass, further gives Eurasian watermilfoil a competitive advantage over most native aquatic macrophytes (Pullman, 1992). Smith and Barko (1990) report that the characteristic annual pattern of growth is for the spring shoots to begin growing rapidly as soon as the water temperature approaches 15°C. Pullman (1993) notes that this growth generally occurs before most native aquatic macrophytes become active. However, Boylen and Sheldon (1976) state that some native aquatic macrophytes, including *Potamogeton robbinsii* and *P. amplifolius*, will remain metabolically active at temperatures as low as 2°C.

As the shoots grow, the lower leaves slough off as a result of shading. As the shoots approach the surface, they branch extensively and form the characteristic canopy (mat). Biomass peaks at flowering in early July, and then declines. If the population flowers early, a second biomass peak and subsequent flowering may be attained. It is common for Eurasian watermilfoil to adopt a stoloniferous habit in the autumn, growing prostrate over the surface of the lake sediment. This may also assist Eurasian watermilfoil in the displacement of competing native species through the acquisition of space when most native species are dormant. Variations in this growth pattern can occur as a result of differences in climate, water clarity and rooting depth.

Dispersal of Eurasian watermilfoil is primarily through the spread of vegetative fragments. Seed production has been reported, but is considered a minor contributor to the plant spread (Hartleb et al., 1993). Pullman (1993) notes that there is much circumstantial evidence indicating that Eurasian watermilfoil does not form a viable seed bank in infested lakes, but the recovery pattern in some lakes after various treatments is best explained by seed germination. Eurasian watermilfoil has a tremendous capacity for the formation of vegetative fragments. A viable plant can regenerate from a single node carried on a fragment released in the water. Fragmentation can occur from boating or skiing impacts, as well as from mechanical harvesting operations. Additionally, Madsen et al. (1988) and Madsen and Smith (1997) reports that autofragmentation (self-fragmentation) is common after peak seasonal biomass is attained. Often fragments released through autofragmentation bear adventitious roots. Madsen et al. (1988) also noted that fragments are very durable, and resistant to extensive environmental stress.

#### 3.4.1.3 Ecological impacts of Eurasian watermilfoil

Eurasian watermilfoil is an opportunistic species, which is commonly found growing in areas that are not highly disturbed (Pullman, 1992). However, Pullman goes on to report that Eurasian watermilfoil appears to significantly increase in numbers and in biomass in areas of disturbance. This is reflective of the high productivity rate of the species and its resulting ability to outgrow native plant species.

Lillie and Budd (1992) provide a definitive evaluation of the quality of habitat offered by Eurasian watermilfoil. In their study, conducted on a lake in Wisconsin, Lillie and Budd utilized an index of plant habitat quality and quantity to describe the following:

- horizontal visibility within macrophyte beds;
- the amount of shading afforded by the surface canopy;
- the amount of available habitat for macroinvertebrate attachment;
- the relative amount of protection afforded fish by the plants; and
- the degree of crowding or compaction among plants.

The results of their study indicated that the edges of Eurasian watermilfoil beds potentially provide more available habitat for macroinvertebrates and fish than interior portions. This conclusion was based on their observation that habitat space was more optimal at the edges, than in the center of the beds where stem crowding and self-defoliation resulted in a lack of vertical architecture due to the formation of surface mats. They noted that as Eurasian watermilfoil densities increase from sparse to dense, habitat value for prey species increased. However, as the vegetative density increased in Eurasian watermilfoil stands, a reduction in habitat for macroinvertebrates reduced the habitat quality for small fish. Habitat value for predator fish

species initially increased as Eurasian milfoil first colonized areas, but, then decreased as plant crowding impacted the ability of the predators to access their prey.

Pullman (1993) concluded that Eurasian watermilfoil is supportive of fish populations during its initial expansion stages in a waterbody. However, he goes on to note that once Eurasian watermilfoil begins to dominate the plant community and form its characteristic dense mats, the lack of plant species diversity and associated water quality impacts will reduce the quality of the habitat for fish. Nichols and Shaw (1986) and Engel (1995) reported that Eurasian watermilfoil provides beneficial cover for fish, unless the cover is so dense that stunting of fish growth from overcrowding results.

Eurasian watermilfoil significantly modified the habitat available to fish and macroinvertebrates (Keast, 1984; Pardue and Webb, 1985). In work conducted in a lake in Ontario, Canada, Keast (1984) noted that since the advent of Eurasian watermilfoil in his study area, significantly fewer bluegill (*Lepomis macrochirus*) were observed, but greater numbers of black crappie (*Pomoxis nigromaculatus*) and golden shiner (*Notemigonus crysoleucas*) were seen. He reported 3 to 4 times as many fish feeding in native plant beds as in the Eurasian watermilfoil beds. Schneider (2000) found that removal of Eurasian watermilfoil improved fishery conditions in Michigan.

The most critical impact Keast (1984) noted was to prey organisms. Keast reported that significantly fewer macroinvertebrates were seen in the watermilfoil beds than in a native plant community composed of *Potamogeton* and *Vallisneria*. He found 3 to 7 times greater abundance of 5 invertebrate taxa in the native plant communities and noted that foliage of the native plants supported twice as many invertebrates per square meter. Keast observed twice as many insect emergences in the native plant community as in the Eurasian watermilfoil beds.

Other studies have documented the impacts to the aquatic environment by the invasion of Eurasian watermilfoil. Madsen et al. (1991b) noted a sharp decline in the number of native macrophyte species per square meter in a bay in Lake George, New York. The decline was due to the suppression of native macrophyte species by Eurasian watermilfoil. The decline was from 5.5 species per square meter to 2.2 species per square meter over a 2-year period.

Honnell et al. (1992) noted that in ponds containing Eurasian watermilfoil, dissolved oxygen levels were significantly lower than dissolved oxygen levels in ponds dominated by native plants. Additionally, they note that pH levels were higher in Eurasian watermilfoil than in native plant dominated ponds. Nichols and Shaw (1986) noted that Eurasian watermilfoil is poor food for muskrats and moose and fair food for ducks, which will eat its fruit.

Once it has formed dense stands, Eurasian watermilfoil interferes with, or prevents, recreational activities in a lake. Pullman (1993) notes that mats may constitute a safety hazard because they are not penetrable by boats and may hide submerged objects that could be struck by moving boats. He also notes that people can be placed at risk if they swim in dense areas of Eurasian watermilfoil due to the potential for entanglement.

### 3.4.2 American white waterlily

American white waterlily (*N. odorata*) represents an important native aquatic species that may occasionally grow to problematic populations and which Clearcast® is well suited to control. There is considerable information on this species due to its extensive geographic range and common weed status. The following description is adapted and summarized from life history and ecological information obtained from several federal and state agencies and cooperative extension websites (e.g., USDA, NatureServe, and Center for Aquatic and Invasive Plants, University of Florida, 2008). The respective websites are listed in the references.

*Nymphaea* is the type genus of the waterlily family (*Nymphaeaceae*). About 4 genera and 18 species occur throughout North America, and about 40 species of water lily exist in the world, plus numerous hybrids and varieties (Center for Aquatic and Invasive Plants, University of Florida, 2008). The American white waterlily is

also commonly referred to as fragrant waterlily. American white waterlily is a perennial, floating aquatic plant (USDA Plants Database, 2008). The leaves are nearly circular in shape and notched to the center, with pointed leaf lobes. The leaves arise on stalks from long rhizomes in the mud. Fragrant water lily flowers are showy white and aromatic; however, hybrid water lilies may exhibit uncharacteristic or unusual color and shape (Center for Aquatic and Invasive Plants, University of Florida, 2008).

#### **3.4.2.1 Geographic range and history of expansion**

American white waterlily is found throughout North America, from Manitoba and Ontario to the Atlantic Provinces south to Texas and Florida, and is known for its historic occurrences in South Dakota. Although it is native to the eastern United States, it tends to be weedy in the eastern part of its range. It is non-native but naturalized to western parts of the country, and is listed as a noxious weed in California (NatureServe, 2008) and Washington State (USDA Plants Database, 2008). American white waterlily is present throughout all counties in New York State (NatureServe, 2008).

The fragrant water lily was utilized in many ways by Native Americans in the eastern United States. Roots of this and other water lilies were used medicinally as a poultice for sores and tumors, internally for many ailments including digestive problems, and rinse made for sores in the mouth. The leaves and flowers were also used as cooling compresses. In addition, the rhizomes were occasionally used as food and the young leaves and lower buds were eaten as a vegetable. Even the seeds were fried and eaten or ground into flour (WDOE, 2008).

#### **3.4.2.2 Ecology of American white waterlily**

The optimal habitat for American white waterlily includes lakes, lake margins, quiet bays in lakes and rivers, slow-moving streams, and ponds in lowland, steppe and lower montane zones at 0 to 1710 m elevation. River or lake bottoms consisting of soft sediment and neutral pH is optimal. Subspecies *N. odorata odorata* is usually found in more stagnant waters of lakes or ponds, or even in marshes, bogs or fens between 0.5 to 1 m of water. Subspecies *N. odorata tuberosa* prefers slightly alkaline environment (>7.2 pH) (NatureServe, 2008). It is commonly found in wetlands throughout each region of the continental United States, excluding the Northern Plains zones and California (USDA Plants Database, 2008).

Water lilies reproduce by seed and also by new plants sprouting from rhizomes. A planted rhizome will cover about a 15-foot diameter in about five years. Fragrant water lily has an interesting pollination strategy. Each white or pink flower has many petals surrounding both male and female reproductive parts, and is only open during the daytime for three days. On the first morning, the flowers produce a fluid in the cup-like center and are receptive to pollen from other flowers. However, they are not yet releasing pollen themselves. Pollen-covered insects are attracted by the sweet smell, but the flower is designed so that when they enter the flower, they fall into the fluid. This washes the pollen off their bodies and onto the female flower parts (stigmas) causing fertilization. Usually the insects manage to crawl out of the fluid and live to visit other flowers, but occasionally the unfortunate creature will remain trapped and die when the flower closes during the afternoon. On the second and the third days, the flowers are no longer receptive to pollen, and no fluid is produced. Instead, pollen is released from the stamens. Visiting insects pick up the pollen and transport it to flowers in the first day of the flowering cycle. After the three days the flowers are brought under water by coiling their stalks. The seeds mature under water and after several weeks are released into the water. Water currents or ducks, which eat the seeds, distribute them to other areas. This flowering regimen is followed nearly throughout the summer, producing many blooms and a large supply of seeds (WDOE, 2008).

#### **3.4.2.3 Ecological impacts of American white waterlily**

Water lilies grow in dense patches and can create stagnant areas with low oxygen levels underneath the floating mats. These mats make it difficult to fish, water ski, swim, or even paddle a canoe through. Although relatively slow-spreading, water lilies will eventually colonize shallow water depths to six feet deep and can dominate the shorelines of shallow lakes. Wildlife, including beaver, muskrat, ducks, porcupine, and deer

will eat the leaves, roots, or seeds. In moderate quantities the fragrant water lily can also benefit the lake by providing shelter and habitat for fish and invertebrates and shade to cool the water (WDOE, 2008).

Extensive infestations of waterlily may alter water quality such as creating low oxygen conditions beneath the canopy, changing nutrient dynamics, pH level or light regimes. Dense infestations may accelerate the natural siltation process in shallow bodies of water. White waterlily can clog irrigation ditches or streams, retarding water flow and accelerating water loss through transpiration. Infestations of waterlily may promote other exotic species such as carp, which has the ability to tolerate low oxygen conditions. Extracts from leaf petioles, and rhizomes have allelopathic potential and may suppress the germination and growth of other aquatic species.

Potential control treatments for American white waterlily include physical (handpulling, mowing, hydroraking burning, water level manipulation), and chemical (herbicides such as glyphosate and imazamox). Further information on these methods is provided in Section 7.0.

### 3.4.3 Purple loosestrife

Purple loosestrife (*L. salicaria*) is an important invasive aquatic species of the riparian shoreline area and good representative of the emergent plant community that may be controlled with Clearcast® applications. There is considerable information on this emergent species due to extensive geographic range and nuisance plant status. The following description is adapted and summarized from life history and ecological information obtained from several federal and state agencies and cooperative extension websites (e.g., United States Geological Survey (USGS), Washington State, and Cornell University). The respective websites are listed in the references.

*Lythrum* is the type genus of the loosestrife family (Lythraceae). About 22 genera and 500 species occur worldwide. Although *L. salicaria* has more than 10 common names in America, the most widespread and best established usage is "purple loosestrife." Purple loosestrife is a perennial, emergent aquatic plant (Thompson, et al. 1987; Malecki et al., 1994). As many as 30 - 50 herbaceous, erect, annual stems rise to about 9 feet tall, from a persistent perennial tap root and spreading rootstock. Short, slender branches spread out to form a crown five feet wide on established plants (Thompson, et al. 1987). The somewhat squarish stems are four to six sided, with nodes evenly spaced. Main leaves are 3 to 10 cm long and can be arranged opposite or alternate along the squared stem and are either glabrous or pubescent. Inflorescence is a spike of clusters of reddish-purple petals (10 to 15 mm in length). Flowers are tri-morphic with short, medium, and long petals and stamens (USDA, 2002). Stems submerged under water develop aerenchyma tissue characteristic of aquatic plants. Loosestrife is most easily identified by the characteristic reddish-purple floral masses present during its long season of bloom (late June to early September in most areas).

#### 3.4.3.1 Geographic range and history of invasion

Purple loosestrife was reportedly introduced as a garden perennial from Europe during the 1800's (Cornell University Ecology and Management of Invasive Plants Program, 2006). It is still promoted by some horticulturists for its beauty as a landscape plant, and by beekeepers for its nectar-producing capability. Many of the early records of *L. salicaria*'s spread into the estuaries and canals of northeastern North America indicate it may be traced to incidental transport in ship ballast or in imported wool. It has since extended its range to include most temperate parts of the United States and Canada. The plant's reproductive success across North America can be attributed to its wide tolerance of physical and chemical conditions characteristic of disturbed habitats, and its ability to reproduce prolifically by both seed dispersal and vegetative propagation. The absence of natural predators, like European species of herbivorous beetles that feed on the plant's roots and leaves, also contributes to its proliferation in North America. Currently, about 24 states have laws prohibiting its importation or distribution because of its aggressively invasive characteristics (USDA Plants Database, 2008).

Purple loosestrife has been present in New York State since the 1800's but seemed to achieve problem status during the 1950s. By this time *L. salicaria* was so widely distributed in the uplands of the lower Hudson district

that McKeon (1959) reported "a large percentage of marshes in the district have an almost pure stand of purple loosestrife which provides little food but does give some cover." McKeon chose a 4.9-ha (12-acre) marsh constructed in 1952 as the site of *L. salicaria* control studies. By 1955, the central portion of this marsh had become "almost completely dominated by purple loosestrife with a few sedges interspersed." Water level manipulation, burning (in winter), and cutting at surface and subsurface were attempted in sequence, with no success.

#### 3.4.3.2 Ecology of purple loosestrife

Any sunny or partly shaded wetland is susceptible to purple loosestrife invasion. This plant's optimal habitat includes marshes, stream margins, alluvial flood plains, sedge meadows, and wet prairies. It is tolerant of moist soil and shallow water sites such as pastures and meadows, although established plants can tolerate drier conditions. Purple loosestrife has also been planted in lawns and gardens, which is often how it has been introduced to many of our wetlands, lakes, and rivers.

Vegetative disturbances such as water level drawdown or exposed soil accelerate the process by providing ideal conditions for seed germination. Invasion usually begins with a few pioneering plants that build up a large seed bank in the soil for several years. When the right disturbance occurs, loosestrife can spread rapidly, eventually taking over the entire wetland. The plant can also make morphological adjustments to accommodate changes in the immediate environment; for example, a decrease in light level will trigger a change in leaf morphology. The plant's ability to adjust to a wide range of environmental conditions gives it a competitive advantage; coupled with its reproductive strategy, purple loosestrife tends to create monotypic stands that reduce biotic diversity (WDNR Invasive Species Website, 2008).

The remarkable success of purple loosestrife as a worldwide pioneer is reflected in a combination of attributes that enable it to spread and thrive in disturbed temperate-climate habitats. In addition to an elaborate means of sexual reproduction and prolific seed production, *L. salicaria* has a wide scope of dispersal mechanisms. Some of these modes are adapted to long-range jumps in distribution (i.e., seeds in plumage of migratory birds); others are well suited to vegetative spread during local perturbations (adventitious shoots and roots from clipped, trampled, or buried stems). Moreover, *L. salicaria*'s abundant propagules can establish themselves under a wide range of soil conditions, which enables the weed to colonize new surfaces caused by natural- or human-caused perturbations. Lastly, *L. salicaria*'s ability to make morphological adjustments to changes in its immediate environment (development of aerenchyma on submerged stems; change in leaf morphology with decrease in light level) enables it to adjust to a wide range of seasonal or semi-permanent changes in water levels and gives it a competitive advantage against other plants growing under these conditions (Thompson, et al., 1987).

Purple loosestrife spreads mainly by seed, but it can also spread vegetatively from root or stem segments. A single stalk can produce from 100,000 to 300,000 seeds per year. Seed survival is up to 60-70%, resulting in an extensive seed bank. Mature plants with up to 50 shoots grow over 2 meters high and produce more than two million seeds a year. Germination is restricted to open, wet soils and requires high temperatures, but seeds remain viable in the soil for many years. Even seeds submerged in water can live for approximately 20 months. Most of the seeds fall near the parent plant, but water, animals, boats, and humans can transport the seeds long distances. Vegetative spread through local perturbation is also characteristic of loosestrife; clipped, trampled, or buried stems of established plants may produce shoots and roots. Plants may be quite large and several years old before they begin flowering. It is often very difficult to locate non-flowering plants, so monitoring for new invasions should be done at the beginning of the flowering period in mid-summer (WDNR Invasive Species Website, 2008).

#### 3.4.3.3 Ecological impacts of purple loosestrife

Purple loosestrife displaces native wetland vegetation (e.g., cattail (*Typha latifolia*)) and degrades wildlife habitat. As native vegetation is displaced, rare plants are often the first species to disappear. Eventually, purple loosestrife can overrun wetlands thousands of acres in size, and almost entirely eliminate the open

water habitat, thus reducing fish habitat. It can exclude desirable waterfowl food plants and reduces the effectiveness of the wetland for brooding and nursery waterfowl by reducing availability of secure routes to water and allows greater predator concealment. There is evidence to suggest that replacement of cattails by purple loosestrife will reduce the carrying capacity of the habitat for muskrat. The domination of the sites by tall dense monocultures causes both physical and trophic changes of the habitat and may reduce the quality of bog turtle habitat (Kiviat, 1978). The plant can also be detrimental to recreational water use by choking waterways. Due to its impact to waterfowl and furbearers, there are indirect effects to hunting and trapping.

Potential control treatments for purple loosestrife include physical (handpulling, mowing, burning, water level manipulation), biological (introduction of European herbivorous weevils and beetles), and chemical (herbicides such as glyphosate and imazamox).

### 3.5 Distribution and ecology of other potential aquatic macrophyte target species

In addition to the representative potential aquatic macrophyte target species discussed in Section 3.4, Clearcast® is intended for use to potentially control other aquatic macrophyte species. While not the typical species of concern, under certain conditions, additional species may also reach a nuisance level. These include both introduced and native species. Table 3-1 presents the submerged, floating-leaved and floating macrophyte species that are potential targets for control by Clearcast® and the relatively effectiveness of control. The sources of information for Table 3-1 include Kishbaugh et al (1990), ENSR (2007), and others. These species are found throughout New York State, although the actual presence and distribution in a waterbody are dependent on the physical characteristics of that waterbody.

**Table 3-1 Distribution and ecology of potential submerged, floating-leaved and floating target macrophyte species**

<b>American frogbit (<i>Limnobium spongia</i>)</b> Native floating or rooted aquatic plant; may form dense mats; found from Lake Ontario to the southern United States
<b>American Lotus (<i>Nelumbo lutea</i>)</b> Found in ponds and quiet streams; is at the northern edge of its geographic distribution in NYS
<b>Arrowhead (<i>Sagittaria latifolia</i>)</b> Common shoreline plant widely distributed throughout North America, occasionally can be weedy or invasive
<b>Bladderwort species (<i>Utricularia</i> spp.)</b> Free-floating, common native species found in backwater areas of ponds, lakes and sluggish streams throughout NYS. Loosely rooted and easily displaced to new locations.
<b>Common Reed (<i>Phragmites australis</i>)</b> Non-indigenous highly invasive emergent weed found in riparian zones and in shallow waters. Often targeted for localized eradication due to invasive qualities.
<b>Four Leaf Aquarium Clover (<i>Marselia quadrifolia</i>)</b> Non-indigenous plant from Southeast Asia, increasingly popular in aquaculture and as groundcover for edges of man-made ponds.
<b>Hydrilla (<i>Hydrilla verticillata</i>)</b> Invasive non-native plant long a problem in Southern states and lately established in select northeastern waterbodies. Often targeted for localized eradication due to invasive qualities.
<b>Native pondweeds (<i>Potamogeton</i> spp.)</b> Native pondweed species are found in ponds, lakes and sluggish streams throughout NYS; large variety of species, most of which provide good habitat and shelter for fish and macroinvertebrates
<b>Native watermilfoils (<i>Myriophyllum</i> spp.)</b> Native watermilfoil species are found in ponds, lakes and sluggish streams throughout NYS; is considered a low-grade duck food; is considered to be good habitat and shelter for fish and macroinvertebrates



<b>Non-Native pondweeds (<i>Potamogeton crispus</i>)</b> Non-native, invasive pondweed species that can reach high densities in early to mid-summer; often declining rapidly afterwards.
<b>Non-native watermilfoils (<i>Myriophyllum aquaticum</i>, <i>M. heterophyllum</i>, and <i>M. spicatum</i>)</b> Several non-native watermilfoil species are invasive and can reach problematic concentrations, often lead to degradation of habitat due to large water column biovolumes. <i>M. aquaticum</i> is an introduced species (circa 1900s) that is uncommon and currently limited to Long Island.
<b>Northern cattail (<i>Typha latifolia</i>)</b> Native emergent marsh plant found throughout NYS, keystone species providing important habitat and food source functions for large variety of aquatic and semi-aquatic wildlife
<b>Pennywort (<i>Hydrocotyle ranunculoides</i>)</b> Found in marshes and ponds; endangered in NYS;
<b>Pickeralweed (<i>Pontederia cordata</i>)</b> Native species found along waters edge throughout NYS; leaves and rhizomes eaten by muskrats
<b>Sago Pondweed (<i>Stuckenia pectinatus</i>)</b> Native species found along waters edge throughout NYS; leaves and rhizomes eaten by muskrats
<b>Smartweeds (<i>Polygonum</i> spp.)</b> Very large family of plants, many which prefer wetland or riparian areas
<b>Spatterdock (<i>Nuphar luteum</i>)</b> Found in sluggish streams, ponds, small lakes and swamps throughout NYS; low wildlife food value
<b>Waterhyacinth (<i>Eichornia crassipes</i>)</b> Uncommon and introduced in NYS; found in ponds, lakes and sluggish streams
<b>Waterprimrose (<i>Ludwigia</i> spp., including waterpurslane (<i>Ludwigia palustris</i>))</b> Found in streams and springy areas throughout NYS; serves as a food source for birds and grazing mammals
<b>Watershield (<i>Brasenia schreberi</i>)</b> Found in sluggish streams, ponds, small lakes and swamps throughout NYS; low wildlife food value
<b>Water stargrass (<i>Heteranthera dubia</i>)</b> An aquatic plant either floating in shallow water or creeping along mud flats. Water stargrass also has a terrestrial form that develops when low water levels strand the plant (the origin of its other common name, mud plantain. Little habitat or wildlife food value.
<b>White water lily (<i>Nymphaea odorata</i>)</b> Found in sluggish streams, swamps, and in shallow areas of ponds and small lakes throughout NYS; low wildlife food value
<b>Widgeon grass (<i>Ruppia maritima</i>)</b> Occurs in brackish waters along the U. S. Atlantic coast as well as in alkaline lakes, ponds and streams in the western U.S. Value as habitat, nursery and food source for ecologically and economically important fauna and flora in brackish or estuarine waters.

### 3.6 Role of potential aquatic macrophyte target species in plant communities within New York State waterbodies

As discussed in Section 3.2.2, aquatic macrophytes fulfill valuable functions in the aquatic environment. They assist in oxygenation of the water, recycling of nutrients, and providing nesting and shelter areas for fish, amphibians, birds and mammals. Aquatic macrophytes serve in the stabilization of banks along watercourses and are a food source for a variety of organisms, including both invertebrates and vertebrates. The ability of a particular macrophyte to perform these functions and the quality of that function often depends on the characteristics of the entire aquatic community.

Heterogeneous stands of plant species generally offer more of these functions than a monotypic stand (dominated by a single species). Heterogeneous stands have a greater vertical distribution of niches, which aquatic organisms that are dependent on the vegetation may fill. Additionally, the horizontal distribution of the aquatic plant communities will affect the functions and values that the individual species may offer.

Patchy communities, with a variety of vegetative species spread over the available substrate, tend to offer a greater variety in habitats than a community dominated by a single species that completely covers the substrate. However, if that single species community is localized and is the only available habitat in a large aquatic setting, then at least some of the functions generally offered by aquatic vegetation would be offered. This circumstance may be evaluated in a lake management plan that would determine the goals and objectives of the vegetation management needs for that waterbody. Restoration of a mixed community of desirable plant species is likely to require initial removal of a monotypic plant stand.

### **3.7 General characterization of aquatic vegetation management objectives for the use of Clearcast®**

Aquatic macrophyte management is required when the overabundance of vegetation impairs the use of the waterbody. As mentioned in Section 2.0, the proposed action is the use of the aquatic herbicide Clearcast® for the control of nuisance aquatic vegetation located in the State of New York.

#### **3.7.1 Control of invasive aquatic macrophyte species**

The primary management objective for Clearcast® is the management and control of overabundant submerged and emergent weeds, particularly invasive aquatic species such as Eurasian watermilfoil or purple loosestrife. Secondary objectives that are also relevant are the reduction in impairment of designated water uses, early response eradication of exotic invasives such as watermilfoil during primary infestation period, and being a potential method or technique as part of an Integrated Plant Management (IPM) plan.

Clearcast® can be used either as a foliar or water column treatment; with differential effects seen between floating leaf and submerged plants. For example, when Clearcast® is applied as a foliar treatment for the control of floating-leaved and emergent species, the resulting imazamox concentration in the water is not sufficient to cause significant injury to submersed species. Although in the case of submerged species that have emergent parts (e.g., the inflorescence of parrotfeather (*M. aquaticum*)), foliar applications will impact the aerial shoots. In addition, it is effective against purple loosestrife and common reed (*Phragmites*), two common invasive species of riparian wetlands. Imazamox provides an additional resource to the suite of registered aquatic herbicides commonly used to treat Eurasian watermilfoil (e.g., 2,4-D, fluridone, triclopyr) in New York State (see Section 7.7.4.) For additional information on species selectivity see also Table 4-1.

Imazamox works rapidly so that dosage concentrations do not have to be held in the lake for extended periods. Imazamox rapidly degrades in the environment and is not considered bioaccumulative (e.g., USEPA, has waived of food residue tolerance requirements for all potential food or feed uses of imazamox, including irrigated crops, fish, mollusks, and crustaceans).

Imazamox can be applied to waters used as potable water supply, through use of a setback distance from any functioning intake that is determined by dose and size of the area treated. For smaller sized water supply lakes, this may significantly limit the practical applicability of imazamox due to proximity of intakes. There are no federal label restrictions for recreational use of treated waters, use in livestock watering, or for irrigation area treated with foliar applications (< 2 quarts per acre).

Imazamox has also been proven effective in the control of emergent species such as common reed in wetland areas. Due to the varying nature of freshwater and coastal wetland habitats where invasive species may be found, prescription of one or more specific control techniques is challenging. Unlike the majority of invasive plant species occurring in submergent habitats, the control of emergent species such as common reed generally require multiple treatments over a multi-year period, and a single or incomplete application of an

herbicide to these species may actually worsen their infestation by harming native plant communities and providing the invasive species with a competitive advantage.

Application rates and techniques for herbicides vary among ecosystems, and an herbicide such as Clearcast® would be used differently within a lakeshore emergent wetland dominated by common reed and exhibiting standing water year-round versus a relatively “dry” clay plain shrub wetland with localized patches of common reed. In many instances, as part of an integrated aquatic vegetation management plan, a combination approach of mechanical harvesting or burning in conjunction with herbicide application may be much more effective than herbicide application alone. To this end, invasive species eradication and control plans may need to be individually prescribed for such systems to ensure proper, safe, and effective use of herbicides. These programs may be described in a lake-specific aquatic vegetation management plan or as part of the information and conditions associated with relevant permits (e.g., Article 24 Wetland permits).

### **3.7.2 Reduction in impairment of designated uses**

As part of an Integrated Plant Management plan, Clearcast® can help reduce the level of impairment to designated uses caused by overabundant macrophyte vegetation, particularly by Eurasian watermilfoil. As with any aquatic macrophyte species that produces a high amount of biomass in the water column that is subject to fragmentation and eventual senescence and decay, removal of excess vegetation can lead to improvements in aquatic support (fishery, native macrophytes), recreational uses (contact and non-contact recreation), drinking water (removal of taste and reduction in potential disinfection by-product (DBP) precursors), and aesthetics. Applications of Clearcast® should reduce the level of designated use impairment caused by susceptible macrophytes.

### **3.7.3 Rapid response action**

In most cases, introduced species demand special attention and this is particularly the case for Eurasian watermilfoil. While an overabundance of native species and diminution of desired uses can be managed over time, introduced species generally require quick action if eradication is to be achieved. The environmental cost of delay is potentially higher than the risk of immediate use of most control options. The quicker the response, the smaller the degree of intervention needed to protect the environment. It may be difficult to impossible to actually eradicate an invasive species, but the probability of achieving and maintaining control is maximized through early detection and rapid response. The use of Clearcast® as part of a rapid response action management plan for Eurasian watermilfoil is one of the secondary plant management objectives.

### **3.7.4 Integrated plant management**

The use of herbicides to get a major plant nuisance under control is a valid element of long-term integrated pest or plant management when other means of keeping plant growths under control are then applied (Nichols and Shaw, 1983; Gangstad, 1986; Wade, 1990; Mattson et al., 2004; Wagner, 2004; NYSDEC, 2005). However, failure to apply alternative techniques on a smaller scale, once the nuisance has been abated, places further herbicide treatments in the cosmetic maintenance category; such techniques tend to have poor cost-benefit ratios over the long-term. Therefore, it is critical that an integrated aquatic vegetation management plan (IAVMP) be developed to support selection of an appropriate and cost-effective suite of control treatments to provide immediate and long-term control (i.e., > 5 years) of plants. The elements of an IAVMP are provided in detail in Section 7.2. One of the secondary aquatic plant management objectives of Clearcast® is to provide a useful addition to the methods to be considered when developing such a plan.

## 4.0 General description of Clearcast® and its active ingredient Imazamox

### 4.1 General description of Clearcast® and its formulations

Clearcast® is an aquatic herbicide labeled for control of floating, emerged, or submersed aquatic plants in and around aquatic sites such as ponds, lakes, reservoirs, non-irrigation canals, ditches, marshes and wetlands, and other slow-moving bodies of water. Clearcast® is composed of 12.1% active ingredient, ammonium salt of imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid), and 87.9% proprietary ingredients. Imazamox is an imidazolinone herbicide that inhibits the acetohydroxyacid synthase (AHAS) enzyme which interferes with plant metabolism and allows selective control of gramineous and broadleaf species. In aquatic ecosystems, this differential response gives imazamox the ability to remove *Hydrilla verticillata* and allow non-invasive native dicots and tolerant monocots to proliferate.

#### 4.1.1 Liquid formulation

Clearcast® currently is packaged as an aqueous formation. It may be diluted in water and either applied directly to water for control of submerged species or as a broadcast or spot spray for emergent and floating vegetation. Clearcast® contains 1 lb of active ingredient imazamox per gallon, and imazamox concentration should not exceed 500 ppb per treatment (in non-potable waters) although multiple treatments can be made during the growing season as needed.

#### 4.1.2 Granular formation

BASF is in the process of developing a 2.7G granular formulation of Clearcast herbicide. Many aquatic use herbicides are available in granular form. Granules provide a convenient and effective method of herbicide distribution in quiescent water bodies. Clearcast 2.7G herbicide is designed to be a quick release formulation, with no slow release or extended release capabilities. The specific dissociation constant for the granular formulation is not known, but the technical imazamox active ingredient is expected to be rapidly released from the limestone carrier once it is placed in the water. Field performance with prototype limestone granular formulations of imazamox provided the same levels of submerged vegetation control as the liquid Clearcast herbicide product. Because of the rapid release and the inherent water solubility of imazamox, the 2.7G formulation is not expected to significantly influence the environmental fate characteristics of imazamox in water. Based on the discussion at the April 29, 2008 Albany meeting, NYSDEC considers that, due to the identical nature and characteristics of the imazamox product once it is dissociates from the granular form, the SEIS will serve for assessment of both liquid and granular products.

## 4.2 Description of use

Clearcast® is labeled for herbicidal use in estuarine and marine sites, lakes, ponds, reservoirs, canals or ditches, swamps, marshes, bayous, arroyos, streams, rivers, creeks, wetlands, and noncropland sites for terrestrial and riparian vegetation control. Clearcast® can be applied to aquatic macrophytes through surface applications from a backpack sprayer, boat, helicopter, spray boom or other suitable equipment or through sub-surface applications. Applications to terrestrial sites near wetlands can be accomplished via surface applications from a backpack sprayer or vehicle.

### 4.2.1 Typical application methods

Application of Clearcast® for the control of a submerged weed like Eurasian milfoil in a pond or lake could consist of either a surface or sub-surface application. For treatment of emergent and floating-leaved species, foliar applications are typically conducted.

### 4.2.2 Rapid response

Clearcast® has the potential to kill nuisance weeds with only one or two foliar applications. Yellow or general discoloration is evident almost immediately after application. Delayed symptom development includes growth inhibition and eventual death. Symptoms are evident on new growth first.

### 4.3 Mode of action/efficacy

The mode of action is the overall manner in which an herbicide affects a plant at the tissue or cellular level. Herbicides with the same mode of action will have the same translocation (movement) pattern and produce similar injury symptoms (Purdue, 1996). Plant absorption of imazamox occurs through both the foliage and its roots. As an imidazolinone herbicide, imazamox inhibits acetohydroxyacid synthesis (AHAS), an enzyme involved with the biosynthesis of the amino acids leucine, isoleucine, and valine. The growth of the susceptible plant is slowed and halts once the existing supplies of these three amino acids are utilized. Inability to synthesize new proteins containing the amino acids will ultimately result in stunting and necrosis of leaves and eventually the death of the plant. The time it takes for a treated plant to die is most likely related to the amount of stored aliphatic amino acids available to the plant. AHAS is widespread in plants but the biochemical pathway it catalyzes is not found in animals so that this mode of action will only affect plants.

### 4.4 Application considerations that maximize the selectivity of Imazamox

Several weeds have special application instructions explained on the Experimental Use Permit label, including *Hydrilla*, Eurasian watermilfoil, and Sago pondweed (*Stuckenia pectinatus*). The Clearcast® label has certain concentration restrictions if the product is applied to lakes, reservoirs or ponds that contain a functioning potable water intake for human consumption. Clearcast® concentrations should not exceed 200 ppb if applied outside ¼ of a mile from an active potable water intake, or 50 ppb if within ¼ mile. If no water supply intakes are present then a maximum dose of 500 ppb is permissible. The factors discussed in the following sub-sections should be considered in the application of Clearcast® to ensure maximum selectivity of the product.

#### 4.4.1 Method of application

The method of application of Clearcast® should be chosen based on the target macrophyte to be controlled and the overall management objectives of the control program. As described in Section 4.2, Clearcast® can be applied to aquatic macrophytes through surface applications or sub-surface applications of the liquid formulation. Clearcast® should be applied as evenly as possible over nuisance plant zones. However, certain lake morphometrics may require application non-uniformly over the entire lake. This should be done to enhance the selectivity of the Clearcast® application. The other form of application for Clearcast® is through foliar application through spray treatments.

#### 4.4.2 Time of application

Clearcast® can generally be applied during any time of the growing season. However, it is suggested that Clearcast® should be applied specifically to actively growing *Hydrilla* and Eurasian watermilfoil early in the growing season. Eurasian watermilfoil initiates productivity and metabolic activity at an earlier time than native plants (Smith and Barko, 1990). They report that the characteristic annual pattern of growth is for the spring shoots to begin growing rapidly as soon as the water temperature approaches 15°C. Pullman (1993) notes that this growth generally occurs before most native aquatic macrophytes become active.

Utilizing an early growing season application would allow for the treatment of Eurasian watermilfoil prior to dense biomass establishment and while the remaining plant community is still dormant. Additionally, such applications would occur while the water is sufficiently cold so that contact recreational activities are limited.

#### 4.4.3 Rate of application

The federally registered application rates are described on the Clearcast® label included in Appendix A. Information on in-water and foliar applications are provided below.

##### In-water application

It is expected that this will be the more common application of the two. The target imazamox concentration for in-water application ranges from 50 to 500 ppb, depending on water depth. Specific application rates for each weed can be found on the Clearcast® label included in Appendix A. Not more than 173 fluid oz. of Clearcast® should be used per acre foot or 500 ppb. Repeat applications may be applied during the growing season to maintain the desired vegetation response.

Application rates for individual treatments may be adjusted to reflect site-specific conditions such as the potential for water exchange within the treated area and for the susceptibility of the target macrophytes. Within that range, higher concentrations may be required where applications are made to smaller portions of a waterbody (i.e., shorelines, semi-protected and exposed cove or bay treatments), where a higher level of macrophyte control is desired, and where water movement will cause dilution with untreated water, based on the characteristics of an individual site.

As with any aquatic herbicide treatment, selection of the application rate is subject to the management objectives, site conditions, water movement, applicator knowledge and experience and label language.

##### Foliar application

The other major form of treatment of Clearcast® is through foliar application. The target application rate of Clearcast® for foliar applications to emergent and floating species in aquatic sites and wetlands should not exceed 2 quarts per acre (0.5 lbs. ae). A surfactant should always be used, and for best results should be nonionic with an HLB (hydrophilic to lipophilic balance) ratio between 12 and 17 with at least 70% surfactant in the formulated product. For foliar spot application, treatments should be made with 0.25% up to 5% Clearcast® by volume. It should be noted that control will be reduced if spray is washed off foliage by wave action, and repeat applications may be necessary. Specific application rates for each weed and additional information on foliar application is provided in the labels contained in Appendix A.

#### 4.4.4 Species susceptibility

Clearcast® is a selective aquatic herbicide, in that some plant species are affected while others are not and that the mode of application (foliar or submerged) can also be adjusted to target specific species. Sections 3.4 and 3.5 discuss the potential target macrophytes that are expected to be susceptible to Clearcast®. Susceptibility will be related to the concentration of Clearcast® in the treated water and as such will be a range of sensitivities. Generally, dicots are expected to be less sensitive than monocots, and algae and diatoms are expected to be less sensitive than the diocot *Lemna* (BASF, 2005b). The aquatic macrophyte species identified by the federal label as controlled by Clearcast® are presented in Table 2-1. Table 4-1 provides an updated summary of the susceptibility of aquatic macrophytes, as based on experimental treatments and current lake aquatic vegetation management applications.

Table 4-1 provides the expected level of field control (i.e., following application) to Clearcast® herbicide for common aquatic plants in New York. Given the available data, aquatic plants have been classified as being High (H), Moderate (M), or Low (L) in sensitivity to Clearcast®. If no information is available, then the table is marked with a “?”.

Because Clearcast® can be applied either directly to the foliage of floating and emergent species or indirectly by treating the water that they are growing in, the information on Table 4-1 includes the relative sensitivity for both foliar and submerged applications. The foliar value is given first, followed by the submerged, such as H/L.

This has also been done for submergent species, such as parrotfeather (*M. aquaticum*), which can have emergent foliage late in the season. If only one rating is given, it is for submerged application.

In general, when Clearcast® is applied as a foliar treatment for the control of floating-leaved and emergent species, the resulting imazamox concentration in the water is not sufficient to cause significant injury to submersed species. For example, a 2 quart/acre application of Clearcast® for the control of floating-leaved species in a body of water with an average depth of four feet, results in an imazamox concentration in the water of 46 ppb. Imazamox concentrations of 100 to 200 ppb are commonly needed to achieve submerged plant control. Applications of Clearcast® to the water for the control of submerged species that result in imazamox concentrations >100 ppb can provide control of some sensitive floating or emergent species as indicated in Table 4-1.

Although Clearcast is labeled for water concentrations of up to 500 ppb, the most common use rates are expected to be between 50 and 200 ppb. Higher or lower Clearcast® use rates can be use depending upon the need for selectivity relating to desirable non-target species. It should be noted that due to the requirement for imazamox concentrations not to exceed 50 ppb within ¼ mile of a drinking water intake, that treatment of submergent plants within these areas may not be fully effective.

Regarding recolonization after using Clearcast®, it has been BASF's experience that tolerant species will rapidly recolonize a site after Clearcast® use, because of its relative short half life in both water and soil. In aquatic bodies, tolerant species such as coontail (*Ceratophyllum demersum*) and the macroalga *Chara* will actively colonize or proliferate once the competitive pressure from undesirable submerged vegetation is removed. Because Clearcast® has no long term persistence in water or sediment even sensitive species are capable of recolonizing a site through either natural or artificial means.

A similar situation is true for Clearcast® applications to shoreline species. Clearcast® is primarily active via foliar uptake, with some small contribution from soil uptake, but because the soil half-life of Clearcast® is relatively short (few weeks) non-target plants are able to grow within the treatment site within a few months. Also Clearcast can be used to release suppressed or remnant stands of desirable species through the control of the dominant invasive species. For example, in several locations, Clearcast® has been applied for the control of *Phragmites*, which resulted in the release of remnant cattail stands that had been totally suppressed by the *Phragmites*. This is noteworthy since cattails are more sensitive to Clearcast than *Phragmites*, illustrating the short residual herbicidal activity of Clearcast®.

Table 4-1 Impact of Clearcast® to common aquatic plants in New York

Aquatic Plant	Dicot (D) or Monocot (M)	Expected Level of Field Control (a)
<b>Emergent Species</b>		
<i>Hydrocotyle</i> spp. (pennywort)	D	H/L
<i>Ludwigia</i> spp. (waterprimrose)	D	M/L
<i>Lythrum salicaria</i> (purple loosestrife)	D	H/L
<i>Phragmites</i> spp (common reed)	M	H/L
<i>Pontedaria cordata</i> (pickerelweed)	D	H/M
<i>Sagittaria</i> spp (arrowhead)	M	H/M
<i>Scirpus</i> spp (bulrush)	M	M/M
<i>Typha</i> spp (cattails)	M	H/M
<b>Floating Leaf Species</b>		
<i>Brasenia schreberi</i> (watershield)	D	H/M
<i>Lemna</i> spp (duckweed)	M	L/L
<i>Limnobium spongia</i> (American frogbit)	M	H/M
<i>Nuphar</i> spp (spatterdock)	D	M/L
<i>Nymphaea</i> spp (white water lily)	D	H/L
<i>Trapa natans</i> (water chestnut)	D	H/M
<b>Submersed Species</b>		
<i>Ceratophyllum demersum</i> (coontail)	D	L
<i>Cabomba caroliniana</i> (fanwort)	D	L
<i>Chara</i> spp (muskgrass)	NA	L
<i>Elodea canadensis</i> (common waterweed)	M	?
<i>Egeria densa</i> (Brazilian elodea)	M	M
<i>Heteranthera dubia</i> (water stargrass)	M	H
<i>Hydrilla verticillata</i> (hydrilla)	M	M
<i>Myriophyllum aquaticum</i> (parrotfeather)	D	M/L



<b>Aquatic Plant</b>	<b>Dicot (D) or Monocot (M)</b>	<b>Expected Level of Field Control (a)</b>
<i>Myriophyllum sibiricum</i> (northern watermilfoil)	D	H
<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)	D	M
<i>Myriophyllum heterophyllum</i> (Variable milfoil)	D	M
<i>Megalondonta beckii</i> (water-marigold)	D	?
<i>Najas flexilis</i> (bushy pondweed)	M	?
<i>Najas guadalupensis</i> southern naiad	M	L
<i>Potamogeton amplifolius</i> (largeleaf pondweed)	M	M
<i>Potamogeton diversifolius</i> water-thread pondweed	M	H
<i>Potamogeton crispus</i> (curly-leafed pondweed)	M	M
<i>Potamogeton epihydrus</i> (ribbon-leaf pondweed)	M	?
<i>Potamogeton gramineus</i> (variable-leaf pondweed)	M	?
<i>Potamogeton illinoensis</i> (Illinois pondweed)	M	M
<i>Potamogeton natans</i> (floating leaf pondweed)	M	H
<i>Potamogeton praelongus</i> (white-stem pondweed)	M	?
<i>Potamogeton pusillus</i> (small pondweed)	M	?
<i>Potamogeton robbinsii</i> (Robbins' pondweed)	M	M
<i>Potamogeton zosteriformis</i> (flat-stem pondweed)	M	?
<i>Ranunculus longirostris</i> (white-water crowfoot)	D	?
<i>Stuckenia pectinatus</i> (Sago pondweed)	M	M
<i>Utricularia</i> spp (bladderwort)	D	L
<i>Vallisneria americanum</i> (eelgrass)	M	L

NA – not applicable, since *Chara* is a type of algae

(a) – the first letter given refers to the effect when applied as surface or foliar treatment, the second refers to the effect of water column treatments. Where only one letter is given, it refers to water column treatments.

#### 4.4.5 Dilution effects

Clearcast® can either be applied directly as a concentrate or diluted before application; therefore the product is equally effective if diluted. However, if applied to emergent or floating vegetation within a high wave action area, several treatments may be needed to compensate for being washed off. Proper dosage and application instructions should be followed as directed on the Clearcast® label (Appendix A).

#### 4.5 Imazamox product solubility

Solubility is a physical end point useful for understanding potential environmental impact. High water solubility is frequently associated with mobility and affects distribution in water and soil (WDOE, 2001). The Imazamox Environmental fate general summary (Appendix A) indicates that the product is highly miscible in water. At 25°C, solubility was determined to be 116,000, >626,000, and >628,000 ppm in pH 5, 7, and 9 buffers, respectively. Water solubility is 0.45 g in 100 mL with a pH of 2.5 (Cyanamid, 1995).

#### 4.6 Surfactants

The purpose of a surfactant (i.e., spray adjuvants) is to increase the surface activity of the applied herbicide, thus reducing both the application rate and the cost of the application. Surfactants are not necessary when using imazamox products to control submersed vegetation. The Clearcast® label (Appendix A) indicates that the addition of a nonionic surfactant to the spray mixture is recommended to improve control of floating and emerged weeds (e.g., common reed, water hyacinth, purple loosestrife). The surfactant manufacturer's label should be consulted for the appropriate application rate and any relevant precautions.

Care should be taken to select a surfactant that has been approved for aquatic use to assure that these products will not harm resident fish or aquatic invertebrates. Some common surfactants used with aquatic herbicides are CideKick®, X-77®, PolyControl® and SunWet® (WDOE, 2001). Instead of a surfactant, a methylated seed oil or vegetable-based seed oil concentrate may be used at the rate of 1.5 to 2 pints per acre. When using spray volumes greater than 30 gallons per acre, the oil concentrate should be mixed at the rate of 1% of the total spray volume (see also Section 4.4.3).

#### 4.7 Fate of Imazamox in the aquatic environment

As stated previously, the active ingredient in Clearcast® is imazamox. Imazamox is highly soluble in water and dissociates in less than a minute. Imazamox is moderately persistent, and while mobile it degrades aerobically in the soil to a non-herbicidal metabolite which is either immobile or moderately mobile (USEPA, 1997).

In aquatic conditions imazamox will degrade rapidly if light is present (half-life of 6.8 hours) and proceeds to rapid microbial degradation to carbon dioxide. However, imazamox is stable to degradation under the absence of light and under anaerobic aquatic conditions (half-life > 2 years; Cyanamid, 1995). Because of the rapid microbial degradation under aerobic conditions, it is not expected that volatilization or bioaccumulation in fish will contribute significantly to the dissipation of imazamox. Imazamox is stable at a pH range between 5 and 9, but in the rare event that pH exceeds 9, imazamox would still be stable.

Laboratory tests and field dissipation studies indicate that aquatic photolysis and microbial breakdown are significant degradation pathways for imazamox. Dissipation half-lives of imazamox in water range from 35 days to 50 days due to photolysis, microbial action, and dilution. In sediment, imazamox dissipation rates ranged from 15 to 130 days in field studies. Imazamox is, however, persistent under anaerobic aquatic conditions. It is highly water soluble and is not expected to bind with organic materials (USEPA, 1997). Additional information is provided below for various media.

##### 4.7.1 Water

In an aqueous solution, imazamox has been shown to be hydrolytically stable at pH 5, 7, and 9 over a 30-day period. After 30 days in natural water, it was completely metabolized by photolysis, with CO<sub>2</sub> accounting for

38% of the applied dose. In the presence of light, photodegradation is very rapid in water, having a half life of 6.8 hours, under laboratory conditions. Without light, imazamox is relatively stable (Cyanamid, 1995).

#### 4.7.1.1 Aerobic

Imazamox does not significantly degrade in aerobic aquatic environments without the presence of light. Cyanamid completed a biotransformation study with sediment (classified as sandy loam) and water collected from a farm pond in Ontario, Canada which was incubated in the dark after imazamox application to a nominal concentration of 0.035 ppm. Three different non-sterile and sterile systems were studied, and half-lives for all three systems were >975 days. Biotransformation to other compounds was insignificant after 12 months (Cyanamid, 1995).

#### 4.7.1.2 Anaerobic

Imazamox should not persist in well-lit, oxygenated surface water but is poorly degradable in anaerobic or aphotic conditions. Cyanamid conducted a similar study for anaerobic conditions as their aerobic biotransformation study described in the previous section. In a mixture of water and sandy loam sediment, the half life in a sterile and non-sterile environment at 25°C was 1,439 and 761 days, respectively. Degradation was slower in the sterile system and at lower temperatures. Volatile materials collected during the 12 month testing period was less than 1% of the applied dose, indicating that volatilization of the parent compound had not occurred. There was one major metabolite detected accounting for >10% of the applied dose, CL 336,554, which was also an aqueous photodegrade and not phototoxic to plants (Cyanamid, 1995).

#### 4.7.2 Sediment

Imazamox is steadily degraded in water-sediment systems to produce two extractable degradation products, diacid CL 312622 (main) and hydroxyl acid CL 354825 (minor). In a distribution and degradation study conducted by Cyanamid, two water-sediment systems differing in grain size, microbial biomass, organic carbon, and total nitrogen and phosphorus contents were analyzed after a single application of imazamox to surface water and incubated for period of 103 days. It was found that approximately 40% of imazamox had been degraded, and overall mean recoveries of applied radioactivity ranged from 95% to 99% for both systems (Cyanamid, 1997).

#### 4.7.3 Soil

Imazamox degrades at a slower rate when applied to upland soils. Photodegradation on soil is slow with a half life of 65 days; after 30 days of continuous irradiation in the laboratory, 70% of the applied dose remained. In aerobic soil conditions, imazamox will rapidly degrade during the first 2 months with a calculated half life of 28 days and dissipating to 50% of initial residue level after 14 days. Metabolites produced were found only in soils and were non-phytotoxic and stable (BASF, 2005b). Volatilization is a not significant fate and transport pathway. Field studies have shown that imazamox dissipates with half lives of 130, 50, 35, 15 and 50 days at field sites in North Dakota, Georgia, Arkansas, Iowa, and California, respectively (BASF, 2005b).

#### 4.7.4 Aquatic dissipation

Imazamox has a range of test aquatic dissipation half-lives from 15 to 130 days with the more representative range in natural waters appearing to be 35 to 50 days (USEPA, 1997). The limited persistence will reduce the potential of imazamox from reaching ground water.

#### 4.7.5 Bioaccumulation/biomagnification

For all taxa except plants, the most sensitive species to imazamox testing was the sheepshead minnow (*Cyprinodon variegatus*) with an  $LC_{50}$  > 94.2 ppm and a Risk Quotient (RQ) of less than <0.001. RQs less than 0.05 are below EPA's Level of Concern for acute effects, meaning the toxicity result for the most sensitive species is negligible. This suggests that potential toxicity to non-target animal species is negligible. However,

RQs for aquatic plant species are above EPA's Level of Concern. Therefore a supplemental higher tier assessment was conducted (BASF, 2005c).

Imazamox has a very low potential for bioconcentration due to its low octanol/water partition coefficient ( $K_{ow} < 1$ ). Information contained in supplemental fish studies showed that the maximum BCF was 0.14, where the compound was absorbed, rapidly excreted, and declined to less than quantifiable limits during the first 24 hours of the depuration phase (Cyanamid, 1994a; USEPA, 2008b). Based on this behavior in fish, the potential for bioaccumulation and/or biomagnification in the foodchain is very low.

#### **4.8 Imazamox residue tolerances**

In establishing or reassessing tolerances, the Food Quality Protection Act of 1996 (FQPA) requires the EPA to consider aggregate exposures to pesticide residues, including all anticipated dietary exposures and other exposures for which there is reliable information, as well as the potential for cumulative effects from a pesticide and other compounds with a common mechanism of toxicity. The Act further directs EPA to consider the potential for increased susceptibility of infants and children to the toxic effects of pesticide residues, and to develop a screening program to determine whether pesticides produce endocrine disrupting effects (USEPA, 1999).

A tolerance assessment for soybeans was conducted for the imazamox herbicide Raptor®, indicating a tolerance of 0.10 ppm. The results of this assessment are summarized in Table 4-2.

Imazamox is currently exempt from the requirement of a tolerance on all food commodities when applied as a herbicide in accordance with accepted good agricultural practices (USEPA, 2003). The tolerances listed above are prior to the current exemption from tolerance ruling.

**Table 4-2 Imazamox tolerances from aquatic use exposure at application rate of 500 ug/L.**

<b>Crop</b>	<b>Tolerance (ppm)</b>
Canola, seed	0.05
Legume vegetable, crop group 6 (succulent or dried, includes soybeans, all beans, lentil, and others)	0.05
Wheat, germ	0.6
Wheat, grain	0.3
Wheat, bran	1
Wheat, shorts	0.8
Sunflower, seed	0.05
Rice, grain	0.2
Rice, bran	1

## 5.0 Significant environmental impacts associated with Clearcast®

As a manufactured chemical that is released into the environment, imazamox, the main component of Clearcast®, has been extensively evaluated for non-desired impacts in terrestrial and aquatic ecosystems. The following section discusses the potential impacts from the use of Clearcast® in the waters of New York.

### 5.1 Direct and indirect impacts to non-target species

Clearcast® is formulated as a selective aquatic herbicide for use in the management of unwanted aquatic macrophytes. The main component of Clearcast®, imazamox, has been evaluated during the registration process to determine potential adverse effects to non-target species. Direct impacts evaluated include toxicity, chronic changes in behavior or physiology, genetic defects or changes in breeding success or breeding rates for many test organisms. Indirect effects resulting from aquatic plant management may include changes in population size, changes in community structure or changes in ecosystem function. Both direct and indirect impacts can be evaluated at all stages of the life cycle of the non-target organism; though generally, the most sensitive stage of the organism (the young) is the period during which the organism is at greatest risk.

It should be noted that indirect impacts are often positive. For example, by controlling an exotic weed with Clearcast®, the lake manager can facilitate the restoration of the native plant community. These desired changes in the community structure could be construed as a positive "impact". Additionally, the balance of potential impacts must be considered in relation to the potential impacts from the uncontrolled presence of an exotic nuisance weed in an aquatic environment. The prevention of long-term impacts caused by unwanted aquatic plants may offset a potential short-term impact of the management program.

The direct toxicity of imazamox-based herbicides to fish and wildlife has been assessed using a variety of acute and chronic laboratory toxicity tests. Table 5-1 shows the general categories that have been established to evaluate the relative toxicity of various organisms (USEPA, 1985). As supported by extensive toxicological tests conducted during the product development and registration process, imazamox is reported to be "slightly toxic" to "practically non-toxic" to receptors other than aquatic plants, based on the USEPA's ecotoxicological categories shown below. Table 5-2 summarizes the toxicity data presented for a number of non-target organisms. Many of the mammalian results estimate the NOAEL value at the highest dose tested (HDT), which indicates that adverse effects were not observed over the range of experimental doses.

**Table 5-1 USEPA ecotoxicological categories for mammals, birds, and aquatic organisms**

Acute Oral Toxicity in Mammals (mg/kg body wt)	Toxicity in Birds		Acute Toxicity in Fish and Invertebrates (mg/L test solution)	Toxicity Ranking
	Acute Oral (mg/kg body weight)	Dietary (mg/kg feed)		
<10	<10	<50	<0.1	Very Highly Toxic
10-50	10-50	50-500	0.1-1.0	Highly Toxic
>50-100	>50-500	>50-1000	>1-10	Moderately Toxic
>500-2000	>500-2000	>1000-5000	>10-100	Slightly Toxic
>2000	>2000	>5000	>100	Practically Non-Toxic

Source: USEPA, 1985. Hazard Evaluation Division, Standard Evaluation Procedure, and Acute Toxicity Test for Freshwater Fish. PB86-129277. EPA-540/9-85-006.

Table 5-2 Summary of selected Imazamox toxicity

	Study	Organism	Results	Comments
<b>Mammalian Studies</b>				
Acute	Single Oral Dose LD <sub>50</sub>	Rat	2,121 mg a.i./kg-bw <sup>1</sup>	Practically non-toxic
	Inhalation LC <sub>50</sub>	Rat	> 6.3 mg/L <sup>2</sup>	
	Dermal LD <sub>50</sub>	Rabbit	> 4000 mg/kg <sup>2</sup>	
	Dermal Sensitization	Guinea Pig	Non-sensitizer <sup>2</sup>	
	Primary Dermal Irritation	Rabbit	Non-to-Slightly Irritating <sup>2</sup>	
	Primary Eye Irritation	Rabbit	Slightly-to-Moderately Irritating <sup>2</sup>	
Subchronic	90-Day Feeding NOAEL	Dog	40000 ppm [1368 mg/kg-bw/day] <sup>2</sup>	Highest Dose Tested (HDT)
	13-Week Feeding NOAEL	Rat	20000 ppm [1661 mg/kg-bw/day] <sup>2</sup>	HDT
	28-Day Dermal NOAEL	Rat	1000 mg/kg-bw/day <sup>2</sup>	HDT
Chronic	Two-Generation Reproduction NOAEL	Rat	>20,000 ppm [1639 mg/kg-bw/day] <sup>1,2</sup>	HDT Practically non-toxic
	Two Year Dietary NOAEL	Rat	20,000 ppm [1167 mg/kg-bw/day] <sup>2</sup>	HDT
	One Year Dietary NOAEL	Dog	40,000 ppm [1165 mg/kg-bw/day] <sup>2</sup>	HDT
	18-Month Oncogenicity v NOAEL	Mouse	7,000 ppm [1201 mg/kg-bw/day] <sup>2</sup>	HDT
<b>Non-Target Insect Studies</b>				
Acute	Non-target Insect 48 hour	Honey Bee	> 25 ug/bee <sup>1</sup>	Practically non-toxic
<b>Freshwater Organism Studies</b>				
Acute	Fish 96 hour LD <sub>50</sub>	Rainbow Trout	>122 mg a.i./L <sup>1</sup>	Practically non-toxic
		Bluegill Sunfish	>119 mg a.i./L <sup>1</sup>	Practically non-toxic
	Invertebrate 48 hour EC <sub>50</sub>	<i>Daphnia</i>	>122 mg a.i./L <sup>1</sup>	Practically non-toxic
	Algae 120 hour EC <sub>50</sub> and NOEC	<i>Anabaena</i>	>0.038 mg a.i./L <sup>3</sup>	
		<i>Selenastrum</i>	>0.037 mg a.i./L <sup>3</sup>	
	Diatom 120 hour EC <sub>50</sub> and NOEC	<i>Navicula</i>	>0.037 mg a.i./L <sup>3</sup>	
Chronic	Aquatic Plant 14 Day EC <sub>50</sub>	<i>Lemna</i>	0.011 mg a.i./L <sup>3</sup>	Highly Toxic
	Aquatic Plant 14 Day NOEC	<i>Lemna</i>	0.0045 mg a.i./L <sup>1</sup>	Highly Toxic

	Study	Organism	Results	Comments
Avian Studies				
Acute	Single Oral Dose LD <sub>50</sub>	Bobwhite Quail	>1846 mg a.i./kg bw <sup>1</sup>	Slightly toxic to practically non-toxic
		Mallard Duck	>1950 mg a.i./kg bw <sup>1</sup>	Slightly toxic to practically non-toxic
Subacute	Dietary (5 Days) LC <sub>50</sub>	Bobwhite Quail	>5572 ppm a.i. <sup>1</sup>	Practically non-toxic
		Mallard Duck	>5572 ppm a.i. <sup>1</sup>	Practically non-toxic
Chronic	Reproductive Study NOEC	Bobwhite Quail	>2000 ppm a.i. <sup>1</sup>	
		Mallard Duck	2000 ppm a.i. <sup>1</sup>	
Marine Organism Studies				
Acute	Fish 96 hour LC <sub>50</sub>	Sheepshead Minnow	>94.2 mg a.i./L <sup>1</sup>	Practically non-toxic
	Invertebrate 48 hour EC <sub>50</sub>	Mysid Shrimp	>100 mg a.i./L <sup>1</sup>	Practically non-toxic
	Algae 120 hour EC <sub>50</sub> and NOEC	<i>Skeletonoma</i>	>0.039 mg a.i./L <sup>3</sup>	
Plants – Seedling Emergence [results for most sensitive dicot and monocot species presented]				
Monocot	Single Application NOEC	Oat	0.0015 lb a.i./acre <sup>1</sup>	
Dicot		Cabbage	0.00075 lb a.i./acre <sup>1</sup>	
Monocot	Single Application EC <sub>25</sub>	Oat	0.0020 lb a.i./acre <sup>1</sup>	
Dicot		Cabbage	0.0018 lb a.i./acre <sup>1</sup>	
Plants – Vegetative Vigor				
Monocot	Single Application NOEC	Oat	0.0015 lb a.i./acre <sup>1</sup>	
Dicot		Tomato	0.00075 lb a.i./acre <sup>1</sup>	
Monocot	Single Application EC <sub>25</sub>	Oat	0.0016 lb a.i./acre <sup>1</sup>	
Dicot		Tomato	0.0010 lb a.i./acre <sup>1</sup>	
<b>Abbreviations:</b> EC <sub>25</sub> = effective concentration – level resulting in 50% effect response (non-lethal) in test organisms; EC <sub>50</sub> = effective concentration – level resulting in 50% effect response (non-lethal) in test organisms; LD <sub>50</sub> = lethal dose - level resulting in 50% effect response in test organisms; LC <sub>50</sub> = lethal concentration – level resulting in 50% mortality in test organisms; LD <sub>50</sub> = lethal dose - level resulting in 50% mortality in test organisms; NOAEL – no observable adverse effect level; NOEC – no observable effect concentration.				
Studies conducted with imazamox unless otherwise noted. Data obtained from:				
1 - Ecological risk assessment evaluating Imazamox for the proposed new use for the control of vegetation in and around aquatic and non-cropland sites (USEPA, 2008b).				
2 - Pesticide Fact Sheet Imazamox (Raptor Herbicide) (USEPA, 1997)				
3 - BASF Imazamox Higher Tier Assessment (BASF, 2005c)				

The majority of the toxicological information in Table 5-2 was obtained from the USEPA ecological risk assessment evaluating imazamox for the proposed new use for the control of vegetation in and around aquatic and non-cropland sites (USEPA, 2008b) and the Pesticide Fact Sheet Imazamox (Raptor® Herbicide)



(USEPA, 1997). The following sections summarize the potential impacts from the use of Clearcast® in New York waters.

### 5.1.1 Macrophytes and aquatic plant communities

Table 2-1 and Section 2.4 discuss those aquatic plants considered to be sensitive to Clearcast®. Potential impacts to non-target macrophytes will be dependent on the sensitivity of that macrophyte to Clearcast® at the application rate utilized, the time of year of the application, the use rate, and other site-specific environmental factors.

The loss of non-target plants within the aquatic plant community could alter the quality of functions that the vegetative community serves in the aquatic ecosystem. Loss of certain species from the community could alter the available habitat for fish species. The thinning of the macrophyte community could reduce the amount of refuge available to prey species and enhance the success of predators such as smallmouth bass. Such changes could benefit the fishery by altering the size distribution of the fishery (Andrews, 1989).

As part of the product registration process, aquatic plant testing was required because aerial application and outdoor non-residential use may expose non-target aquatic plants to imazamox. Chronic testing was not required for imazamox because the estimated environmental concentration did not exceed 1% of the lowest EC<sub>50</sub> or LC<sub>50</sub> value, making the chronic risk of imazamox to fish and aquatic invertebrates negligible.

#### 5.1.1.1 Potential impacts to riparian wetland community from lake application

Imazamox applied as an in-lake application to control floating leaf and submersed macrophytes could have potential impacts to the riparian wetland community. This is due to the sensitivity of certain riparian wetland plants, particularly common emergents found at the littoral shoreline interface. As indicated by Table 4-1, emergent plants with potential susceptibility to water column treatment include pickerelweed, arrowhead, bulrush, and cattails and, to a lesser extent, pennywort, waterprimrose, purple loosestrife, and common reed. It is possible that a localized excessive concentration of imazamox applied in the waterbody could lead to reduction of these susceptible species. This could occur due to improper dose application or due to environmental factors leading to accumulation of herbicide (e.g., currents or downwind drift).

A direct impact of the imazamox to riparian wetlands could be a reduction in the numbers and biomass of susceptible species and, if severely impacted, in the biodiversity of the wetlands. Secondary impacts of the reduction or removal of vegetation near the shoreline could be the temporary destabilization of the shoreline and increased erosion and/or resuspension of shoreline materials due to wind or wave action. Habitat functions for wildlife for forage, shelter, or breeding habitats could also be adversely impacted. Creation of a disturbed or temporarily sparse shoreline vegetation community could enhance the opportunity for an invasive species to become established.

Although it is possible to have the adverse impacts outlined above, the likelihood of their occurrence is very slight for several reasons. As shown in Table 4-1, all of the emergent riparian species have less to much less sensitivity to a water column treatment. Imazamox degrades quickly so that elevated concentrations would not be expected to persist in the well-lit and aerobic shoreline margin. It is also likely that herbicides impacting shoreline sediments may be rapidly adsorbed by the sediments and rendered inactive. Foliar application could impact the wetland plants, if applied incorrectly or without proper control for wind drift, so use by a licensed and properly-trained applicator is assumed.

If they occur, adverse impacts would likely be confined to a narrow zone at the shoreline margin around the periphery of the lake. This is likely to be of significance only in the circumstance when a state-protected species is located at the shoreline-wetland interface. If herbicide applications are made later in the season, the lake water levels may likely be below full storage levels with reduced impact to shoreline emergents.

Applications of aquatic herbicide are generally made in water 4 feet deep or more since these are the depths where recreational activities are most likely to be impacted; unless application is used for clearing of aquatic

vegetation at a recreational beach or to gain access to a dock. This will likely move the site of the application further from shoreline areas. Finally, there is likely to be an adequate population of wetland plants interior to the shoreline that could repopulate the affected area quickly.

#### 5.1.1.2 Potential impacts to aquatic plant community from riparian application

The potential impact of application to the aquatic plant community from application in the riparian zone was also considered. In this case, exposure of floating leaved or submerged plants could be caused by wind drift of foliar application or by runoff of excess herbicide material into the adjacent waterbody.

A direct impact of the imazamox to affected floating leaved or submerged aquatic macrophyte could be a reduction in the numbers and biomass of susceptible species and, if severely impacted, in the biodiversity of the lake macrophyte community. Habitat functions for wildlife for forage, shelter, or breeding habitats could also be adversely impacted. Creation of a small patch of cleared littoral habitat could allow light-suppressed, understory plants to flourish, however.

There is likely to be low potential risk of a foliar application on a riparian wetland severely impacting floating leaved and submersed species, particularly the latter. As shown in Table 4-1, floating leaved species are more sensitive to foliar application and some could be impacted by wind drift of improperly applied imazamox. Unless the amount of wind drift is substantial, only a limited number of plants would likely be impacted. The potential risk posed by runoff of herbicide is much lower, since the submersed plants are more resistant to imazamox and the dilution occurring in waters of any depth would lower the herbicide concentrations well below effective levels.

#### 5.1.2 Algal and planktonic species

Aquatic plant testing is required for any herbicide which has outdoor non-residential terrestrial uses in which it may move off-site by runoff, by drift, or that is applied directly to aquatic use sites. Tier 1 testing indicated that the aquatic unicellular plant species (i.e., phytoplankton) do not experience adverse effects from exposure to imazamox up to 40 ppb. The maximum exposure level was based on 0.048 lb ai/A applied to a 6 inch water column. The Tier 2 results indicate that the aquatic vascular plant *Lemna gibba* is the most sensitive species floating free in the water. An imazamox concentration of 11 ppb ai is predicted to cause a 50% reduction in growth and reproduction of this species.

#### 5.1.3 Fish, shellfish, and aquatic macroinvertebrates

Imazamox is practically non-toxic to fish and aquatic invertebrates (USEPA, 2008b). At the highest concentration tested, there were no observed adverse effects to fish or aquatic invertebrates. A freshwater fish early life-stage test and an aquatic invertebrate life-cycle test were not required for imazamox registration.

Data from estuarine/marine fish early life-stage and aquatic invertebrate life-cycle toxicity tests are only required if the product is applied directly to the estuarine/marine environment or expected to be transported to this environment from the intended use site, and when any one of the following conditions exist: (1) aquatic acute lowest concentration exhibiting 50% mortality ( $LC_{50}$ ) and lowest concentration exhibiting 50% effect ( $EC_{50}$ ) are less than 1 mg/L, (2) environmental effect concentrations (EECs) in water greater than 0.01 of acute  $LC_{50}$  and  $EC_{50}$  values, and (3) half-life in water greater than 4 days. This potential was initially evaluated for the application of Raptor® for weed control in soybean croplands. Because the initial end-use product of Raptor® is not normally applied directly to water nor is it expected to be transported to water from the intended use site (soybeans) and none of the previous conditions were met, chronic estuarine and marine animal data was not required for imazamox (BASF 2005b).

While ClearCast® is not intended for use in marine waters, it could be transported to these waters from the intended use site (application to freshwater macrophytes). However, the rapid degradation and lack of animal toxicity indicate that none of the ecotoxicity thresholds would be reached; therefore chronic estuarine and

marine biota data should still not be required. Travel time and dilution will be major factors protecting estuarine habitats that may be downstream of treated freshwater areas.

#### 5.1.4 Terrestrial invertebrates

Although not required, a supplemental honey bee acute contact LD<sub>50</sub> study was conducted for assessment of potential effects to terrestrial invertebrates. The LD<sub>50</sub> results were > 25 ug ai/bee, which was the the highest dose tested. The study showed that imazamox is practically non-toxic to the honey bee. The low toxicity of imazamox to honeybees would be expected from its mode of action. For control of submerged aquatic weeds, imazamox is applied as a subsurface treatment. Based on this treatment method, honeybees would not be exposed to significant amounts of imazamox. Exposure during emergent plant treatments is possible, but would not be expected at a high enough level to exceed the impact threshold. It would be possible that aquatic insects could be exposed up to 100 ppb in the water column; however, it is believed that this level would not cause any direct effects on aquatic insects (BASF, 2005c). The EC50 values for other tested aquatic invertebrates, the daphnid and mysid organisms, are >122 ppm and >94.3 ppm, respectively. These values are well in excess of the estimated environmental concentration in water of 0.1 ppm.

#### 5.1.5 Birds

The toxic effects of imazamox on birds have been investigated in a small number of studies conducted by Cyanamid and other investigators (Cyanamid, 1994b; USEPA, 2008b). These results indicate that imazamox is considered “practically non-toxic” to avian species on an acute oral basis.

The results of sub-acute dietary tests with the mallard duck and the bobwhite quail indicate that that imazamox is also “practically non-toxic” to avian species on a sub-acute dietary basis. The LC50s for sub-acute avian dietary assays were >5,572 ppm (USEPA, 2008a).

Chronic avian reproduction studies were required for imazamox registration because birds may be subject to repeated or continuous exposure to the pesticide, especially preceding or during the breeding season, and the pesticide is stable in the environment to the extent that potentially toxic amounts may persist in animal feed.

Water fowl are likely to be the most highly exposed bird species, given that they potentially swim, drink and feed on lakes and ponds proposed for treatment with Clearcast®. However, several factors are likely to mitigate this potential risk since (1) available toxicity values indicate that imazamox is relatively non-toxic to avian species; (2) the nominal maximum exposure concentration in water is 200 ug/L imazamox as per maximum application rates (BASF, 2005a); (3) the non-bioaccumulative properties of imazamox and its metabolites; and (4) the environmental fate characteristics of imazamox demonstrate that they are short-lived in the aquatic environment (see Section 4.7). Overall, it would appear that there are negligible risks to avian species, including those whose diet might consist of aquatic vegetation treated with imazamox.

#### 5.1.6 Mammals

Wild animal testing was not required for Imazamox, and so acute oral LD50 data for laboratory rats submitted to the Health Effects Division (HED) for evaluation of human toxicity were used to assess the mammalian acute toxicity of imazamox. The LD50 for rats was 2313 mg/kg for male and 2121 mg/kg-bw for female. These results classify imazamox as practically non-toxic to mammals on an acute basis. The active ingredient was tested at 90%.

A rat 2-generation reproductive study showed the NOEL to be greater than 20,000 ppm and no effects were observed at the highest dose. The active ingredient was tested at 98.2%.

Using worst-case assumptions in the assessment, the calculated RQs are well below EPA's Levels of Concern for the maximum use pattern and endangered species. The risk of imazamox to small mammals is expected to be low.

### 5.1.7 Reptiles and amphibians

Potential impacts to reptiles and amphibians from herbicides or pesticides are sometimes a concern at relatively low doses (Berrill et al., 1994). However, limited information was identified on the effects of imazamox on reptiles or amphibians. The USEPA's ECOTOXicology on-line database (see list of websites in Section 10 for address) was reviewed for further information (06/17/08), however no data for reptile or amphibian species were found. In light of the mode of action (i.e., AHAS inhibition) and the general non-toxicity to other wildlife, it was assumed that imazamox should not pose an ecological risk for these receptors.

### 5.1.8 Federal and state listed rare, threatened, and endangered species

Of the many rare plant species that are native to New York State (see Appendix B for full list of NYSDEC Protected Plants), only six are listed as threatened or endangered under the Endangered Species Act of 1973. These federally-protected plants are an important piece of New York's natural heritage and biodiversity. They are given legal protection in order to ensure the continued survival of the species. These species are not considered to be aquatic plants and it is unlikely that they would come in contact with Clearcast® applied as directed on the product label.

There are a number of potentially relevant New York State-protected plant species including endangered, threatened and rare categories (Young, 2008). For purposes of the SEIS, a sub-listing of the aquatic macrophytes (i.e., floating-leaved and submerged plants) was developed for consideration of potential impacts and is presented in Table 5-4. This list was adapted from the New York Natural Heritage Program Protected Plant List and identifies protected plants (endangered, threatened, rare, exploitable, vulnerable) belonging primarily to the floating-leaved and submerged plant community.

While the susceptibility of plants to imazamox is largely unknown, indications of potential susceptibility made be derived from comparison to sister species (i.e., same genera) shown in Table 7-3 or on general characteristics (e.g., monocot vs. dicot plants). These protected species would be potential species of interest relevant for applications to treat floating-leaved or submerged plants such as white waterlily or Eurasian watermilfoil.

## 5.2 Potential for impact of treated plant biomass on water quality

Reductions in dissolved oxygen (DO) may be caused by a number of natural events, such as a die-off of the microscopic green plants (phytoplankton) in the pond, or overturns in which oxygen deficient water from the deeper levels of the pond mixes with water in the upper levels and rapid decaying of dead macrophytes. One indirect effect of the use of any "fast acting" and non-selective effective aquatic herbicide is the creation of dead and decaying macrophyte biomass following application. Plants may begin to sink from the lake surface in 1 to 7 days and death of the plant is typically complete in 1 to 3 weeks. This organic material that sinks to the bottom, is subject to bacterial and fungal breakdown, and results in consumption of DO. If the oxygen demand is sufficiently large, a localized DO deficit may occur at the point of treatment that could result in the loss of sensitive fish or invertebrates. Based on the conditions (water temperature, wind/wave conditions, stratified state), these short-term effects may be severe.

If organic biomass is transported internally within the waterbody and enters the hypolimnion of a stratified lake, the severity and duration of hypolimnetic oxygen deficits could be increased. In addition to the lowered DO, water quality may also be affected by the release of nutrients from the dead and decaying macrophytes, with subsequent uptake by phytoplankton. This may lead to an algal bloom and decreased water transparency. Based on the relatively rapid uptake and response to target macrophytes to treatment by Clearcast®, this release of nutrients could be phased over several days to weeks. In the long-term, overall water quality should not be significantly affected since the organic material within the target macrophytes is subject to annual senescence and decay even in the absence of the herbicide.

Petty et al. (1998) reported that dense Eurasian watermilfoil stands in study plots suppressed DO levels in bottom waters by inhibiting circulation and exchange of surface waters, and by contributing greatly to oxygen-consuming respiration processes. Once the Eurasian watermilfoil was removed (using the aquatic pesticide, Renovate®), DO levels rebounded. In both treatment plots, DO levels increased within 1 week post-treatment in the lower half of the water column. When conducting entire littoral zone specific treatments, a significant decline in DO is greatly minimized, since even though the target plant is selectively controlled, the ambient DO is sustained from advective diffusion from untreated deeper waters and through photosynthesis by algae and macrophyte species not affected by imazamox (Eichler and Boylen, 2006).

Mitigation of the potential water quality impacts posed by the generation of large amounts of biodegradable biomass may be achieved by limiting the total amount of area treated to less than one half of the total water area. In addition, phasing the timing of treatments and/or providing adjacent untreated areas to act as temporary refugia for aquatic organisms should be incorporated as part of a site-specific invasive aquatic vegetation management plan. In addition, the diversity and coverage of the plant community within the treatment area and susceptibility of select plant species should also be evaluated, as those species not impacted by a treatment (i.e. naiads, coontail, water celery, *Chara*) in many situations would allow adequate DO levels to be sustained following a Clearcast® treatment.

### 5.3 Impact of residence time of Clearcast® in the water column

Clearcast® is designed to remain in the water column long enough to produce its effects and then degrade and dissipate. There is no need to retain elevated concentrations in the water column for extended periods of time (days to weeks) or periodically reapply to “bump up” concentrations which may be required for other aquatic herbicides (e.g., fluridone). As discussed in the previous sections, Clearcast® is a relatively fast acting (effects observed within days to weeks) systemic herbicide that does not exhibit prolonged residence time relative to impact thresholds. Dissipation half-lives of imazamox in water typically range from 35 days to 50 days due to photolysis, microbial action, and dilution (see Section 4.7.3 for details). Therefore, it is not anticipated that an extended residence time in the water column would be a significant factor or would cause secondary potential impacts.

### 5.4 Recolonization of non-target plants after control of target plants is achieved

Following application of Clearcast®, rapid recolonization and/or increase of pre-application cover of the bottom areas by non-susceptible native plants is expected. By selective removal and decrease of biomass of Eurasian watermilfoil or white waterlily, local native plants will likely experience an increase in light availability (particularly lower in the plant canopy) and available physical habitat, thus facilitating growth. Important floating-leaved target species (e.g., *Nuphar*, *Nymphaea*) are susceptible when treated by direct foliar spray, but they are largely unaffected by sub-surface application of Clearcast®; therefore treatment for Eurasian watermilfoil should not decrease their abundance nor diminish their presence for fishery habitat. Release of nutrients following decay and breakdown of the milfoil could increase concentrations in the local environment, with potential uptake and growth by phytoplankton, periphyton, or benthic macroalgae (*Chara*, *Nitella*).

Overall, the colonization by native species expected after control of target nuisance plants is achieved could be rapid and effective. The relative success of the short-term expansion of the native plant community will be dependent on the percent reduction of the nuisance species, which is a function of the application dosage, contact period, size of application, and seasonal timing of application, along with the presence of native plant propagules (especially seeds, but also nearby vegetative forms). The longevity of the increased native plant success will depend on the long-term suppression of the nuisance species through application of a successful IAVMP. Substantial removal of standing Eurasian watermilfoil shoots and reduced frequency of the plant can be obtained in the same season as the treatment, but complete kill of rootcrowns may not occur due to dosage or exposure limitations. Without further treatment, recovery of milfoil to nuisance levels could occur within one to several growing seasons. It would be very unusual to eradicate an established population of an invasive species with a single action of any kind, and follow up management is to be expected for maximum control.

**Table 5-3 Federally listed threatened or endangered plant species found in New York State <sup>1</sup>**

<b>Name and Federal Status</b>	<b>Description</b>
Northern wild monk's-hood ( <i>Aconitum noveboracense</i> ) Threatened	An herbaceous perennial with distinctive blue, hood-shaped flowers. The plants range from one to four feet in height, with wide, toothed leaves. They prefer to occupy cool sites such as stream sides or shaded cliff sides.
Sandplain gerardia ( <i>Agalinis acuta</i> ) Endangered	A small annual plant with delicate pink blossoms. Six of the twelve known natural populations in the world can be found in coastal grassland areas on Long Island.
Seabeach amaranth ( <i>Amaranthus pumilus</i> ) Threatened	An annual plant with reddish stems and small, rounded leaves. For years it was thought to be extirpated from New York State, until it was found again in 1990. It is found along sandy beaches of the Atlantic coast, where it grows on the shifting sands between dunes and the high tide mark.
Hart's-tongue fern ( <i>Asplenium scolopendrium</i> var <i>americanum</i> ) Threatened	A member of the spleenwort genus with large lanceolate to strap-shaped fronds. Over 90% of the U.S. population of this fern is found in Central New York, where it requires moist, sheltered locations and lime-rich soils.
Leedy's roseroot ( <i>Sedum integrifolium</i> ssp. <i>leedyi</i> ) Threatened	A perennial with waxy, succulent leaves. The flowers are small and densely arranged, with four or five petals, and vary in color from dark red to orange or yellow. It grows on a few cliffs only in New York and Minnesota. This sub-species has probably always been rare, because of its very specific habitat requirements.
Houghton's goldenrod ( <i>Solidago houghtonii</i> ) Threatened	Grows only in the wetlands along the Great Lakes shoreline. It is a perennial with an upright stem and many yellow flower heads, which are arranged in somewhat flat-topped clusters. The leaves are narrow and grouped toward the base of the plant. There are many other goldenrods found in New York, some of which are similar-looking. One way to differentiate Houghton's goldenrod is by confirming the presence of tiny hairs on the flower stalks within the flower cluster.

<sup>1</sup> Information obtained from NYSDEC website: <http://www.dec.ny.gov/animals/7133.html>.

**Table 5-4 New York State protected aquatic macrophytes <sup>1</sup>**

<b>Endangered Status</b>	
<i>Callitriche hermaphrodita</i> (D)	Autumn Water-Starwort
<i>Elatine americana</i> (D)	American Waterwort
<i>Hydrocotyle ranunculoides</i> (D)	Floating Pennywort
<i>Hydrocoyle verticillata</i> (D)	Water-Pennywort
<i>Lemna perpusilla</i> (M)	Minute Duckweed
<i>Lemna valdiviana</i> (M)	Pale Duckweed
<i>Myriophyllum pinnatum</i> (D)	Green Parrot's-Feather
<i>Najas guadalupensis</i> var. <i>muenscheri</i> (M)	Muenscher's Naiad
<i>Najas guadalupensis</i> var. <i>olivacea</i> (M)	Southern Naiad
<i>Najas marina</i> (M)	Holly-Leaved Naiad
<i>Potamogeton diversifolius</i>	Water-Thread Pondweed
<i>Potamogeton filiformis</i> var. <i>alpinus</i> (M)	Slender Pondweed
<i>Potamogeton filiformis</i> var. <i>occidentalis</i> (M)	Sheathed Pondweed
<i>Potamogeton ogdenii</i> (M)	Ogden's Pondweed
<i>Potamogeton strictifolius</i> (M)	Straight-Leaf Pondweed
<i>Sagittaria teres</i> (M)	Quill-Leaf Arrowhead
<i>Utricularia inflata</i> (D)	Large Floating Bladderwort
<b>Threatened Status</b>	
<i>Ceratophyllum echinatum</i> (D)	Prickly Hornwort
<i>Megalodonta (Bidens) beckii</i> var. <i>beckii</i> (D)	Water-Marigold
<i>Myriophyllum alterniflorum</i> (D)	Water Milfoil
<i>Myriophyllum farwellii</i> (D)	Farwell's Water Milfoil
<i>Podostemum ceratophyllum</i> (D)	Riverweed
<i>Potamogeton alpinus</i> (M)	Northern Pondweed
<i>Potamogeton confervoides</i> (M)	Algae-Like Pondweed
<i>Potamogeton hillii</i> (M)	Hill's Pondweed
<i>Potamogeton pulcher</i> (M)	Spotted Pondweed
<i>Proserpinaca pectinata</i> (D)	Combed-Leaved Mermaid Weed
<i>Rorippa aquatica</i> (D)	Lake-Cress
<i>Sagittaria calycina</i> var. <i>spongiosa</i> (M)	Spongy Arrowhead
<i>Utricularia juncea</i> (D)	Rush Bladderwort
<i>Utricularia minor</i> (D)	Lesser Bladderwort
<i>Utricularia radiata</i> (D)	Small Floating Bladderwort
<i>Utricularia striata</i> (D)	Bladderwort
<b>Rare Status</b>	
<i>Isoetes lacustris</i> (Q)	Large-Spored Quillwort
<b>Exploitably Vulnerable Status</b>	
<i>None listed</i>	

<sup>1</sup> - This list was adapted from the New York Natural Heritage Program Protected Plant List and identifies protected plants belonging primarily to the floating-leaved and submerged plant community. For verification of the status of the much more numerous emergent and semi-aquatic plant species refer to the source document (Young, 2008). Abbreviations: D = dicot plant, M = monocot plant; Q = quillwort.

## 5.5 Impacts on coastal resources

At the present time, application of Clearcast® is expected to be limited to largely freshwater settings and is not currently intended for use in the marine environment (label indicates not to apply to saltwater bays or estuaries). However, potential downstream migration of the product from application areas into estuarine or marine environments is possible. As noted in Section 5.1.3, the use of Clearcast® at the recommended application rates is considered to pose little risk of potential adverse impacts to marine or coastal resources. The likelihood of any effect is small due to the short half-life of the product, lack of bioaccumulation, and the potential for significant dilution in estuarine and marine environments due to waves, tidal action, etc.

If the use of Clearcast® is proposed to be located within the NYS Coastal Zone and is determined to require federal licensing, permitting, or approval, or involves federal funding, then the action would be subject to the NYS Coastal Zone Management Program (19 NYCRR Section 600). This determination would be required during the preparation of an individual permit application.



## 6.0 Potential public health impacts of Clearcast®

### 6.1 Brief overview of Imazamox toxicity

An overview of the toxicology information indicates that imazamox is not considered to be a carcinogen, a mutagen or to cause adverse reproductive effects or birth defects. Imazamox is considered to have a low degree of systemic toxicity based on findings from acute and subchronic toxicology studies (USEPA, 1997). USEPA determined that the toxicological profile of imazamox supports an exemption from the requirement of tolerance because no adverse effects were observed in the submitted toxicological studies regardless of route of exposure (USEPA, 2003). The lack of toxicity is due to the unique mode of action for imazamox. Imazamox belongs to the imidazolinone class of compounds. The herbicidal activity of the imidazolinones is due to the inhibition of acetohydroxy acid synthase (AHAS), an enzyme only found in plants. AHAS is part of the biosynthetic pathway leading to the formation of branched chain amino acids. Animals lack AHAS and this biosynthetic pathway. This lack of AHAS contributes to the low toxicity of imazamox in mammals (USEPA, 2000b).

#### 6.1.1 Acute toxicity

For pesticides, there are typically six acute toxicity studies performed with the product formulation (USEPA, 2007). The acute oral, acute dermal and acute inhalation studies evaluate systemic toxicity via the designated routes of exposure. The primary eye irritation and primary skin irritation studies measure irritation or corrosion, while the dermal sensitization study evaluates the potential for allergic contact dermatitis. With the exception of dermal sensitization, each acute study is assigned to a toxicity category based on the study results. There are four acute toxicity categories, designated Category I through IV. Category I designates the most toxic or irritating effects, while Category IV represents the least toxic or irritating effects. Effects in Categories II and III fall in between the two extremes. The acute oral, acute dermal, and acute inhalation toxicity of imazamox are in Categories IV, III and IV, respectively. The skin irritation study in rabbits placed imazamox in Category IV, indicating that it is non-to-slightly irritating to the skin. The primary eye irritation study in rabbits placed imazamox in Category III, indicating that it is slightly-to-moderately irritating to the eye. The acute dermal sensitization study in guinea pigs indicates that imazamox is not a dermal sensitizer (USEPA, 1997).

The results of a rat acute oral toxicity study determined that the LD<sub>50</sub> (dose causing lethality in 50% of the test animals) was greater than approximately 5,000 mg/kg. The acute dermal LD<sub>50</sub> was greater than 4,000 mg/kg based on a study in rabbits. A rat acute inhalation toxicity study resulted in a 4-hour LC<sub>50</sub> (concentration causing lethality in 50% of the test animals) of greater than 6.3 mg/L (USEPA, 1997).

Neither dermal nor systemic toxicity was seen at the highest dose tested of 1,000 mg/kg/day in a 28-day dermal toxicity study in rats (USEPA, 1999).

The USEPA has determined that there is no appropriate endpoint attributable to a single exposure for imazamox based on the toxicity database including oral developmental toxicity studies with rats and rabbits. Therefore, USEPA concluded that an acute dietary risk assessment was not needed.

#### 6.1.2 Subchronic and chronic toxicity

A 90-day oral toxicity in rodents showed no effects at the highest dose tested, which was 1661 mg/kg-day. No developmental or reproductive effects were noted at the highest dose tested which was 1,000 mg/kg/day in rats and 900 mg/kg/day in rabbits (USEPA, 1999).

2-year carcinogenicity studies in rats and mice showed no treatment-related effects (USEPA, 2003). Imazamox has been classified as a "Not Likely" carcinogen (USEPA, 1999).

USEPA (1999) discusses a chronic Reference Dose (RfD) of 3 mg/kg-day based on a developmental toxicity study in rabbits that identified a NOAEL of 300 mg/kg-day. However, a more recent USEPA document (USEPA, 2003 - Imazamox; Exemption from the Requirement of a Tolerance) concluded that a chronic dietary risk assessment is not needed for imazamox since no toxicity was observed at doses exceeding the maximum limit-dose (1000 mg/kg bw/day) in chronic or subchronic studies with mice, rats, or dogs. A dose of 1000 mg/kg bw/day is equivalent to a human diet in which the pesticide comprises 7% of the total dietary consumption. However, to evaluate the chronic risk from imazamox, the lowest NOAEL from the short-, intermediate-, and chronic toxicity studies in dog, mouse, and rat was used. The lowest NOAEL is 1000 mg/kg bw/day (highest dose tested) from the mouse oncogenicity study. Applying the 10x safety factor for variations in the human population, 10x safety factor to account for potential differences between humans and animals, and a 1x FQPA safety factor, the chronic population adjusted dose (cPAD) is 10 mg/kg bw/day.

### 6.1.3 Metabolism

Metabolism and distribution tests have shown that imazamox is readily absorbed by male and female rats following intravenous or oral dosing. Imazamox was rapidly excreted as the unchanged parent compound, primarily in the urine following intravenous administration and in the urine and feces following oral administration (USEPA, 2003).

## 6.2 New York State drinking water standard

There are no specific drinking water standards available for imazamox. Section 702.15 of 6 NYCRR (Derivation of Guidance Values) states that a "general organic guidance value" of 50 ug/L may be used for an individual organic substance. NYSDEC's registration of the pesticide product, Raptor®, which contains imazamox states "Based on its chemical structure, imazamox falls under the 50 microgram per liter New York State drinking water standard for "unspecified organic contaminants" (10 NYCRR Part 5, Public Water Systems)" (NYSDEC, 2003).

To determine whether this standard is protective for imazamox, a drinking water calculation was done using the calculated cPAD for imazamox of 10 mg/kg-day. Using the cPAD of 10 mg/kg-day and assuming that a 60-kg adult female drinks 2 L of water per day results in an acceptable concentration of imazamox in drinking water of 300,000 ug/L.

$$Concentration(ug / L) = \frac{10mg / kg - day \times 60kg \times 1000ug / mg}{2L / day} = 300,000ug / L$$

Even assuming a 20% source contribution factor (which is often used by USEPA in setting drinking water standards), the resultant concentration is 60,000 ug/L, which should be extremely protective for drinking water.

While it is very unlikely that imazamox would impact a drinking water source, potential risk to humans via drinking water due to application of imazamox is *de minimis* because:

- Imazamox use in waters of New York used for drinking water purposes would be highly regulated and expected to result in intermittent exposures to those using such waters;
- Imazamox labeling requires a minimum setback distance of ¼ mile for applications of greater than 50 ppb in proximity to active potable water intakes; and
- Imazamox can be used within ¼ mile of an active potable water intakes at low levels (<50 ppb), but if concentrations exceed this the intake must be turned off until the imazamox level in the intake water is determined to be 50 ppb or less by laboratory analysis or immunoassay.

### 6.3 Risk from recreational exposure

A more likely exposure scenario would be someone swimming in a pond or lake that has been treated with imazamox. This exposure was evaluated using the Swimmer Exposure Assessment Model (SWIMODEL). The water concentration used in the chronic exposure evaluation was 500 ug/L, which is a worst case assumption. Some of the other assumptions used with the SWIMODEL were:

- The skin surface area of adults is assumed to be 21,000 cm<sup>2</sup> as cited in the Residential Standard Operating Procedures (SOPs).
- The skin surface area for children is assumed to be 9,000 cm<sup>2</sup> as cited in the Residential SOPs.
- The body weight for the adult male is assumed to be 70 kg.
- The body weight for the adult female is assumed to be 60 kg.
- The body weight for children is assumed to be 30 kg.
- The mean water ingestion rate is 0.05 liters per hour for both adults and children as cited in the Residential SOPs.
- The exposure time is assumed to be 5 hours per day.
- The maximum application rate of 0.50 mg/liter (500 ppb) was used to assess acute and short/intermediate term imazamox exposures.

The swimmer safety was evaluated using a Margin of Exposure (MOE) approach. The MOE is calculated by dividing the appropriate NOAEL by the exposure estimate. The acute NOAEL is 900 mg/kg bw/day and the chronic NOAEL is 1000 mg/kg bw/day (USEPA, 2003). The acute NOAEL is a lower value than the chronic NOAEL because these were the highest doses tested in the studies and no effects were observed at any of the tested doses. Therefore, the actual acute and chronic NOAELs could be higher. A MOE of greater than 100 indicates there that there is not a safety concern. Table 4-5 shows the swimmer exposure and the calculated MOE values. The MOE values are extremely high, ranging from  $4.76 \cdot 10^{+3}$  to  $4.76 \cdot 10^{+5}$ , which indicates that the concern of recreational swimming in water bodies treated with imazamox is very low.

**Table 6-1. Summary of recreational swimmer exposure and risk for Imazamox treated water bodies**

	<b>Total Exposure</b>	<b>Acute</b>	<b>Chronic</b>
<b>Population subgroup</b>	<b>mg/kg bw/day</b>	<b>MOE</b>	<b>MOE</b>
US Population	0.00021	4,285,714	4,761,905
Children	0.00189	476,190	529,101
Females	0.00025	3,600,000	4,000,000

The risks from exposure to imazamox via recreational uses should be negligible based on the following:

- That imazamox is only slightly toxic via acute oral and dermal route of exposure and is not a dermal sensitizer; and
- That imazamox use in waters of New York used for recreational purposes is highly regulated and expected to result in intermittent exposures to those using such waters.

Finally, there are no restrictions on fishing or domestic use of water treated with imazamox.

#### **6.4 Summary of human health risk concerns**

The available information on imazamox indicates that it is not acutely toxic or irritating to the skin and eyes. Imazamox also did not cause any significant toxicity in subchronic, chronic, developmental or reproductive toxicity studies. The US EPA has determined that future risk assessments for imazamox are not needed because imazamox is non-toxic from acute or chronic exposure.

## 7.0 Alternatives to Clearcast ®

This section details various alternatives to the proposed action. Specifically, this evaluation considers the advantages and disadvantages of potential macrophyte control treatment alternatives other than use of Clearcast®. These other potential alternatives to the use of Clearcast® include those based on physical control (manipulations of light, water depth, substrate, etc.), chemical control (other aquatic herbicides), and biological controls (herbivorous fish, insects, etc.), as well as the no-action alternative (which entails the lack of any aquatic macrophyte control measure). The no-action alternative does not preclude the ability of an applicant to apply for a permit for the use of those products described in the Final Programmatic Environmental Impact Statement on Aquatic Vegetation Control (NYSDEC, 1981a). Each of the possible macrophyte control treatment alternatives should be evaluated from the standpoint of efficacy, positive and negative environmental impacts, and relative costs. The choice of a particular alternative over the proposed use of Clearcast® should be based on the management objectives for the waterbody and the specific characteristics of the problem.

### 7.1 Identification of relevant macrophyte control treatment alternatives

There are a large number of control treatments potentially available for use to control non-desirable macrophyte populations. The various methods typically used to control aquatic plants are summarized in Table 7-1 (adapted from Wagner (2001), categorized by the principal mode of action (i.e., either physical, chemical or biological)). Table 7-1 provides a quick summary of the mode of action, advantages and disadvantages for these alternatives. The three classes of macrophyte treatment control alternatives are introduced briefly below, with additional detailed information on the specific alternatives provided later in this section.

Physical treatment alternatives refer to macrophyte control treatment alternatives that work primarily by altering the light regime, the depth or nature of the benthic substrate, or the elevation of overlying surface water. These macrophyte control treatment alternatives include:

- Benthic Barriers - Placement of materials on the bottom of a lake to cover and impede the growth of macrophytes;
- Dredging – removal of underlying sediment through various methods (dry, wet, pneumatic) to either remove suitable or nutrient-rich substrate or to decrease available light (attenuation);
- Dyes and surface covers – Addition of coloring agents or sheet material to inhibit light penetration and reduce vascular plant growths;
- Harvesting - Multiple methods of mechanical plant cutting, with or without removal, and algal collection; and
- Drawdown - Lowering of the water level to dry and freeze susceptible vegetation.

**Table 7-1 Management options for control of aquatic plants (adapted from Wagner, 2001)**

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
<b>PHYSICAL CONTROLS</b>			
1) Benthic barriers	<ul style="list-style-type: none"> <li>• Mat of variable composition laid on bottom of target area, preventing growth</li> <li>• Can cover area for as little as several months or permanently</li> <li>• Maintenance improves effectiveness</li> <li>• Usually applied around docks, in boating lanes, and in swimming areas</li> </ul>	<ul style="list-style-type: none"> <li>• Highly flexible control</li> <li>• Reduces turbidity from soft bottoms</li> <li>• Can cover undesirable substrate</li> <li>• Can improve fish habitat by creating edge effects</li> </ul>	<ul style="list-style-type: none"> <li>• May cause anoxia at sediment-water interface</li> <li>• May limit benthic invertebrates</li> <li>• Non-selective interference with plants in target area</li> <li>• May inhibit spawning/feeding by some fish species</li> </ul>
1.a) Porous or loose-weave synthetic materials	<ul style="list-style-type: none"> <li>• Laid on bottom and usually anchored by weights or stakes</li> <li>• Removed and cleaned or flipped and repositioned at least once per year for maximum effect</li> </ul>	<ul style="list-style-type: none"> <li>• Allows some escape of gases which may build up underneath</li> <li>• Panels may be flipped in place or removed for relatively easy cleaning or repositioning</li> </ul>	<ul style="list-style-type: none"> <li>• Allows some growth through pores</li> <li>• Gas may still build up underneath in some cases, lifting barrier from bottom</li> </ul>
1.b) Non-porous or sheet synthetic materials	<ul style="list-style-type: none"> <li>• Laid on bottom and anchored by many stakes, anchors or weights, or by layer of sand</li> <li>• Not typically removed, but may be swept or "blown" clean periodically</li> </ul>	<ul style="list-style-type: none"> <li>• Prevents all plant growth until buried by sediment</li> <li>• Minimizes interaction of sediment and water column</li> </ul>	<ul style="list-style-type: none"> <li>• Gas build up may cause barrier to float upwards</li> <li>• Strong anchoring makes removal difficult and can hinder maintenance</li> </ul>
1.c) Sediments of a desirable composition	<ul style="list-style-type: none"> <li>• Sediments may be added on top of existing sediments or plants.</li> <li>• Use of sand or clay can limit plant growth and alter sediment-water interactions.</li> <li>• Sediments can be applied from the surface or suction dredged from below muck layer (reverse layering technique)</li> </ul>	<ul style="list-style-type: none"> <li>• Plant biomass can be buried</li> <li>• Seed banks can be buried deeper</li> <li>• Sediment can be made less hospitable to plant growths</li> <li>• Nutrient release from sediments may be reduced</li> <li>• Surface sediment can be made more appealing to human users</li> <li>• Reverse layering requires no addition or removal of sediment</li> </ul>	<ul style="list-style-type: none"> <li>• Lake depth may decline</li> <li>• Sediments may sink into or mix with underlying muck</li> <li>• Permitting for added sediment difficult</li> <li>• Addition of sediment may cause initial turbidity increase</li> <li>• New sediment may contain nutrients or other contaminants</li> <li>• Generally too expensive for large scale application</li> </ul>

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
2) Dredging	<ul style="list-style-type: none"> <li>Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering/disposal</li> <li>Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system</li> <li>Plants and seed beds are removed and re-growth can be limited by light and/or substrate limitation</li> </ul>	<ul style="list-style-type: none"> <li>Plant removal with some flexibility</li> <li>Increases water depth</li> <li>Can reduce pollutant reserves</li> <li>Can reduce sediment oxygen demand</li> <li>Can improve spawning habitat for many fish species</li> <li>Allows complete renovation of aquatic ecosystem</li> </ul>	<ul style="list-style-type: none"> <li>Temporarily removes benthic invertebrates</li> <li>May create turbidity</li> <li>May eliminate fish community (complete dry dredging only)</li> <li>Possible impacts from containment area discharge</li> <li>Possible impacts from dredged material disposal</li> <li>Interference with recreation or other uses during dredging</li> <li>Usually very expensive</li> </ul>
2.a) "Dry" excavation	<ul style="list-style-type: none"> <li>Lake drained or lowered to maximum extent practical</li> <li>Target material dried to maximum extent possible</li> <li>Conventional excavation equipment used to remove sediments</li> </ul>	<ul style="list-style-type: none"> <li>Tends to facilitate a very thorough effort</li> <li>May allow drying of sediments prior to removal</li> <li>Allows use of less specialized equipment</li> </ul>	<ul style="list-style-type: none"> <li>Eliminates most aquatic biota unless a portion left undrained</li> <li>Eliminates lake use during dredging</li> </ul>
2.b) "Wet" excavation	<ul style="list-style-type: none"> <li>Lake level may be lowered, but sediments not substantially dewatered</li> <li>Draglines, bucket dredges, or long-reach backhoes used to remove sediment</li> </ul>	<ul style="list-style-type: none"> <li>Requires least preparation time or effort, tends to be least cost dredging approach</li> <li>May allow use of easily acquired equipment</li> <li>May preserve most aquatic biota</li> </ul>	<ul style="list-style-type: none"> <li>Usually creates extreme turbidity</li> <li>Tends to result in sediment deposition in surrounding area</li> <li>Normally requires intermediate containment area to dry sediments prior to hauling</li> <li>May cause severe disruption of ecological function</li> <li>Impairs most lake uses during dredging</li> </ul>
2.c) Hydraulic (or pneumatic) removal	<ul style="list-style-type: none"> <li>Lake level not reduced</li> <li>Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area</li> <li>Slurry is dewatered; sediment retained, water discharged</li> </ul>	<ul style="list-style-type: none"> <li>Creates minimal turbidity and limits impact on biota</li> <li>Can allow some lake uses during dredging</li> <li>Allows removal with limited access or shoreline disturbance</li> </ul>	<ul style="list-style-type: none"> <li>Often leaves some sediment behind</li> <li>Cannot handle extremely coarse or debris-laden materials</li> <li>Requires advanced and more expensive containment area</li> <li>Requires overflow discharge from containment area</li> </ul>

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
3) Dyes and surface covers	<ul style="list-style-type: none"> <li>Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting plant growth</li> <li>Dyes remain in solution until washed out of system.</li> <li>Opaque sheet material applied to water surface</li> </ul>	<ul style="list-style-type: none"> <li>Light limit on plant growth without high turbidity or great depth</li> <li>May achieve some control of algae as well</li> <li>May achieve some selectivity for species tolerant of low light</li> </ul>	<ul style="list-style-type: none"> <li>May not control peripheral or shallow water rooted plants</li> <li>May cause thermal stratification in shallow ponds</li> <li>May facilitate anoxia at sediment interface with water</li> <li>Covers inhibit gas exchange with atmosphere</li> </ul>
4) Mechanical removal ("harvesting")	<ul style="list-style-type: none"> <li>Plants reduced by mechanical means, possibly with disturbance of soils</li> <li>Collected plants may be placed on shore for composting or other disposal</li> <li>Wide range of techniques employed, from manual to highly mechanized</li> <li>Application once or twice per year usually needed</li> </ul>	<ul style="list-style-type: none"> <li>Highly flexible control</li> <li>May remove other debris</li> <li>Can balance habitat and recreational needs</li> </ul>	<ul style="list-style-type: none"> <li>Possible impacts on aquatic fauna</li> <li>Non-selective removal of plants in treated area</li> <li>Possible spread of undesirable species by fragmentation</li> <li>Possible generation of turbidity</li> </ul>
4.a) Hand pulling	<ul style="list-style-type: none"> <li>Plants uprooted by hand ("weeding") and preferably removed</li> </ul>	<ul style="list-style-type: none"> <li>Highly selective technique</li> </ul>	<ul style="list-style-type: none"> <li>Labor intensive</li> <li>Difficult to perform in dense stands</li> </ul>
4.b) Cutting (without collection)	<ul style="list-style-type: none"> <li>Plants cut in place above roots without being harvested</li> </ul>	<ul style="list-style-type: none"> <li>Generally efficient and less expensive than complete harvesting</li> </ul>	<ul style="list-style-type: none"> <li>Leaves root systems and part of plant for re-growth</li> <li>Leaves cut vegetation to decay or to re-root</li> <li>Not selective within applied area</li> </ul>
4.c) Harvesting (with collection)	<ul style="list-style-type: none"> <li>Plants cut at depth of 2-10 ft and collected for removal from lake</li> </ul>	<ul style="list-style-type: none"> <li>Allows plant removal on greater scale</li> </ul>	<ul style="list-style-type: none"> <li>Limited depth of operation</li> <li>Usually leaves fragments which may re-root and spread infestation</li> <li>May impact lake fauna</li> <li>Not selective within applied area</li> <li>More expensive than cutting</li> </ul>



OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
4.d) Rototilling	<ul style="list-style-type: none"> <li>Plants, root systems, and surrounding sediment disturbed with mechanical blades</li> </ul>	<ul style="list-style-type: none"> <li>Can thoroughly disrupt entire plant</li> </ul>	<ul style="list-style-type: none"> <li>Usually leaves fragments which may re-root and spread infestation</li> <li>May impact lake fauna</li> <li>Not selective within applied area</li> <li>Creates substantial turbidity</li> <li>More expensive than harvesting</li> </ul>
4.e) Hydroraking	<ul style="list-style-type: none"> <li>Plants, root systems and surrounding sediment and debris disturbed with mechanical rake, part of material usually collected and removed from lake</li> </ul>	<ul style="list-style-type: none"> <li>Can thoroughly disrupt entire plant</li> <li>Also allows removal of stumps or other obstructions</li> </ul>	<ul style="list-style-type: none"> <li>Usually leaves fragments which may re-root and spread infestation</li> <li>May impact lake fauna</li> <li>Not selective within applied area</li> <li>Creates substantial turbidity</li> <li>More expensive than harvesting</li> </ul>
5) Water level control	<ul style="list-style-type: none"> <li>Lowering or raising the water level to create an inhospitable environment for some or all aquatic plants</li> <li>Disrupts plant life cycle by dessication, freezing, or light limitation</li> </ul>	<ul style="list-style-type: none"> <li>Requires only outlet control to affect large area</li> <li>Provides widespread control in increments of water depth</li> <li>Complements certain other techniques (dredging, flushing)</li> </ul>	<ul style="list-style-type: none"> <li>Potential issues with water supply</li> <li>Potential issues with flooding</li> <li>Potential impacts to non-target flora and fauna</li> </ul>
5.a) Drawdown	<ul style="list-style-type: none"> <li>Lowering of water over winter period allows desiccation, freezing, and physical disruption of plants, roots and seed beds</li> <li>Timing and duration of exposure and degree of dewatering are critical aspects</li> <li>Variable species tolerance to drawdown; emergent species and seed-bearers are less affected</li> <li>Most effective on annual to once/3 yr. basis</li> </ul>	<ul style="list-style-type: none"> <li>Control with some flexibility</li> <li>Opportunity for shoreline clean-up/structure repair</li> <li>Flood control utility</li> <li>Impacts vegetative propagation species with limited impact to seed producing populations</li> </ul>	<ul style="list-style-type: none"> <li>Possible impacts on contiguous emergent wetlands</li> <li>Possible effects on overwintering reptiles and amphibians</li> <li>Possible impairment of well production</li> <li>Reduction in potential water supply and fire fighting capacity</li> <li>Alteration of downstream flows</li> <li>Possible overwinter water level variation</li> <li>Possible shoreline erosion and slumping</li> <li>May result in greater nutrient availability for algae</li> </ul>

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
5.b) Flooding	<ul style="list-style-type: none"> <li>Higher water level in the spring can inhibit seed germination and plant growth</li> <li>Higher flows which are normally associated with elevated water levels can flush seed and plant fragments from system</li> </ul>	<ul style="list-style-type: none"> <li>Where water is available, this can be an inexpensive technique</li> <li>Plant growth need not be eliminated, merely retarded or delayed</li> <li>Timing of water level control can selectively favor certain desirable species</li> </ul>	<ul style="list-style-type: none"> <li>Water for raising the level may not be available</li> <li>Potential peripheral flooding</li> <li>Possible downstream impacts</li> <li>Many species may not be affected, and some may be benefitted</li> <li>Algal nuisances may increase where nutrients are available</li> </ul>
<b>CHEMICAL CONTROLS</b>			
6) Herbicides	<ul style="list-style-type: none"> <li>Liquid or pelletized herbicides applied to target area or to plants directly</li> <li>Contact or systemic poisons kill plants or limit growth</li> <li>Typically requires application every 1-5 yrs</li> </ul>	<ul style="list-style-type: none"> <li>Wide range of control is possible</li> <li>May be able to selectively eliminate species</li> <li>May achieve some algae control as well</li> </ul>	<ul style="list-style-type: none"> <li>Possible toxicity to non-target species</li> <li>Possible downstream impacts</li> <li>Restrictions of water use for varying time after treatment</li> <li>Increased oxygen demand from decaying vegetation</li> <li>Possible recycling of nutrients to allow other growths</li> </ul>
6.a) Forms of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid)	<ul style="list-style-type: none"> <li>Contact herbicide with limited translocation potential</li> <li>Membrane-active chemical which inhibits protein synthesis</li> <li>Causes structural deterioration</li> <li>Applied as liquid or granules</li> </ul>	<ul style="list-style-type: none"> <li>Moderate control of some emerged plant species, moderately to highly effective control of floating and submersed species</li> <li>Limited toxicity to fish at recommended dosages</li> <li>Rapid action</li> </ul>	<ul style="list-style-type: none"> <li>Non-selective in treated area</li> <li>Toxic to aquatic fauna (varying degrees by formulation)</li> <li>Time delays on use for water supply, agriculture and recreation</li> <li>Safety hazards for applicators</li> </ul>
6.b) Forms of diquat (6,7-dihydropyrido [1,2-2',1'-c] pyrazinedium dibromide)	<ul style="list-style-type: none"> <li>Contact herbicide</li> <li>Absorbed by foliage but not roots</li> <li>Strong oxidant; disrupts most cellular functions</li> <li>Applied as a liquid, sometimes in conjunction with copper</li> </ul>	<ul style="list-style-type: none"> <li>Moderate control of some emerged plant species, moderately to highly effective control of floating or submersed species</li> <li>Limited toxicity to fish at recommended dosages</li> <li>Rapid action</li> </ul>	<ul style="list-style-type: none"> <li>Non-selective in treated area</li> <li>Toxic to zooplankton at recommended dosage</li> <li>Inactivated by suspended particles; ineffective in muddy waters</li> <li>Time delays on use for water supply, agriculture and recreation</li> </ul>

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
6.c) Forms of glyphosate (N-[phosphonomethyl glycine])	<ul style="list-style-type: none"> <li>• Contact herbicide</li> <li>• Absorbed through foliage, disrupts enzyme formation and function in uncertain manner</li> <li>• Applied as liquid spray</li> </ul>	<ul style="list-style-type: none"> <li>• Moderately to highly effective control of emerged and floating plant species</li> <li>• Can be used selectively, based on application to individual plants</li> <li>• Rapid action</li> <li>• Low toxicity to aquatic fauna at recommended dosages</li> <li>• No time delays for use of treated water</li> </ul>	<ul style="list-style-type: none"> <li>• Non-selective in treated area</li> <li>• Inactivation by suspended particles; ineffective in muddy waters</li> <li>• Not for use within 0.5 miles of potable water intakes</li> <li>• Highly corrosive; storage precautions necessary</li> </ul>
6.d) Forms of 2,4-D (2,4-dichlorophenoxy acetic acid)	<ul style="list-style-type: none"> <li>• Systemic herbicide</li> <li>• Readily absorbed and translocated throughout plant</li> <li>• Inhibits cell division in new tissue, stimulates growth in older tissue, resulting in gradual cell disruption</li> <li>• Applied as liquid or granules, frequently as part of more complex formulations, preferably during early growth phase of plants</li> </ul>	<ul style="list-style-type: none"> <li>• Moderately to highly effective control of a variety of emerged, floating and submersed plants</li> <li>• Can achieve some selectivity through application timing and concentration</li> <li>• Fairly fast action</li> </ul>	<ul style="list-style-type: none"> <li>• Variable toxicity to aquatic fauna, depending upon formulation and ambient water chemistry</li> <li>• Time delays for use of treated water for agriculture and recreation</li> <li>• Not for use in water supplies</li> </ul>
6.e) Forms of fluridone (1-methyl-3-phenyl-5- [-3-{trifluoromethyl} phenyl]-4[1H]- pyridinone)	<ul style="list-style-type: none"> <li>• Systemic herbicide</li> <li>• Inhibits carotenoid pigment synthesis and impacts photosynthesis</li> <li>• Best applied as liquid or granules during early growth phase of plants</li> </ul>	<ul style="list-style-type: none"> <li>• Can be used selectively, based on concentration</li> <li>• Gradual deterioration of affected plants limits impact on oxygen level (BOD)</li> <li>• Effective against several difficult-to-control species</li> <li>• Low toxicity to aquatic fauna</li> </ul>	<ul style="list-style-type: none"> <li>• Impacts on non-target plant species possible at higher doses</li> <li>• Extremely soluble and mixable; difficult to perform partial lake treatments</li> <li>• Requires extended contact time</li> </ul>
6.f) Forms of triclopyr (3,5,6-trichloro-2- pyridinyloxyacetic acid triethylamine salt)	<ul style="list-style-type: none"> <li>• Systemic herbicide</li> <li>• Synthetic plant growth hormone (auxin) that interferes with plant metabolism</li> <li>• Best applied as liquid or granules during early growth phase of plants</li> </ul>	<ul style="list-style-type: none"> <li>• Can be used selectively, based on concentration</li> <li>• Gradual deterioration of affected plants limits impact on oxygen level (BOD)</li> <li>• Effective against several difficult-to-control species</li> <li>• Low toxicity to aquatic fauna</li> </ul>	<ul style="list-style-type: none"> <li>• Impacts on non-target dicot plant species possible at higher doses</li> <li>• Little impact on monocots</li> <li>• Extremely soluble and mixable; amenable for conducting partial lake treatments</li> <li>• Requires minimal contact time</li> </ul>

Chemical treatment alternatives refer to macrophyte control treatment alternatives that work primarily by application of chemical agents (aquatic herbicides) to directly kill the aquatic macrophytes. These include registered aquatic herbicides which differ in both application and mode of chemical action (general, systemic). For purposes of this analysis we will consider six of the major pesticides registered for use in New York State: Diquat, Endothall, Glyphosphate, 2,4-D, Fluridone and Triclopyr.

Biological treatment alternatives refer to macrophyte control treatment alternatives that work primarily by interaction of other species with the target macrophytes. These may include the stocking or manipulation of phytophagous (i.e., plant-eating) fish and invertebrates to control macrophytes through biological interactions.

## 7.2 Integrated plant management

As described briefly above and discussed in greater detail in the following sections, there is a potentially large selection of possible macrophyte control treatments or technologies that exist. However, not all techniques are appropriate for a given lake and/or to effectively address nuisance macrophyte concerns. Furthermore, techniques may either be non-compatible or may exacerbate the problem (e.g., harvesting of limited pioneer watermilfoil stand leading to fragmentation and widespread colonization of the lake). Given the potentially high costs necessary for extensive whole lake treatments, it is important that the appropriate techniques be used to maximize the benefits that such treatments can provide. In addition, there are potential societal conflicts that can occur between groups of lake users, who may have very different ideas regarding the best use of the lake. Therefore, it is important that the selection of any macrophyte control treatment, including herbicides, be conducted as a result of a well thought-out long-term Integrated Aquatic Vegetation Management Plan (IAVMP). This approach is also consistent with NYSDEC guidance, which endorses the development of an Aquatic Plant Management Plan as an important component of any strategy to deal with nuisance macrophytes (Appendix A in NYSDEC, 2005).

There are many guidance documents that describe the steps and necessary data to be collected in developing an IAVMP (e.g., Hoyer and Canfield, 1997; WDOE, 1994; NYSDEC, 2005). These methodologies are roughly equivalent and are likely to include the following components (adapted from WDOE, 1994):

- **Develop a problem statement** – the problem statement summarizes the types, locations, and density of problem aquatic vegetation, and identifies the nature and the extent to which beneficial water uses are being impaired;
- **Describe past management efforts** – summarizes the previous efforts at chemical and non-chemical plant control methods (for last 5 years or longer) and identifies the organizations (e.g., county, lake association, beach association, etc) that sponsored them (this last step is important in identifying possible stakeholders);
- **Define management goals** – based on the problem statement and previous experiences in plant control, and the characteristics of the lake, the management goals define what is to be achieved in response to the aquatic plant problems. Defining goals helps in selection of appropriate control treatments. The scope of the management efforts should cover at least 5 years;
- **Determine waterbody and watershed characteristics** – identify geographic limits, land use, potential point and non-point sources, and tributary systems within the waterbody watershed. Provide basic information on the lake size, depth, water quality, residence time, sediment types, water uses, riparian uses (including wetlands), biotic communities (aquatic plants, fish, amphibians, waterfowl), and identify any listed threatened or endangered (T&E) species within or adjacent to the lake;
- **List the beneficial uses of the waterbody** – list the beneficial uses of the waterbody; map their location (this will allow for matching control treatments to within lake habitats and/or recreational focal points);
- **Map aquatic plants** – map the approximate location and species of aquatic plants, the sediment depth and type, water depths (bathymetry), locations of wetlands, and location of any T&E species.

Correct identification is essential in order to prevent the eradication of rare and endangered species and to document the plant population so that it can be monitored over time (Hellquist, 1993; Crow and Hellquist, 2000). A listing of plants considered rare, threatened or endangered in New York is available in Appendix B. Based on the beneficial uses identified in the step above, indicate whether a high or low level of aquatic plant control is desired. In some cases, no control may be appropriate (i.e., leaving intact aquatic vegetation in selected locations to support fish populations);

- **Identify the aquatic plant control treatment alternatives** – identify and screen potential control treatment alternatives, their effectiveness, environmental impacts, human health risks, and costs. For some lakes, several treatment techniques may be immediately eliminated from further consideration, based on the waterbody and watershed characteristics;
- **Select the aquatic plant control treatment method(s)** – an IAVMP plan needs to be waterbody-specific and is likely to involve a combination of methods. This step involves choosing the best control treatment (or set of methods) that best achieves the long-term management goals, with least impacts to the environment and is cost-effective;
- **Public involvement** - the IAVMP should be a consensus document, with support or acceptance by major stakeholders and permitting agencies. The draft IAVMP should be presented in public meeting and public and regulatory comments sought. The final IAVMP will be revised according to this feedback;
- **Develop an action strategy** – Based on the final IAVMP, take initial steps or immediate actions (e.g., install BMPs, purchase harvester, etc), provide foundations for later actions, and institute monitoring; and
- **Monitoring and evaluation of plan** – monitoring plans should include sampling for concentrations of an applied herbicide, at various time and locations (a pre-treatment sample is recommended). Other field monitoring may be required for other techniques (e.g., turbidity for dredging project). A pre- and post-treatment measurement of plant density and biomass is recommended to evaluate the effectiveness of various treatment alternatives.

The IAVMP should be considered an evolving document. The IAVMP, its supporting information, and management goals should be periodically re-evaluated. The results of the post-treatment monitoring should be evaluated to see how well a particular treatment is controlling nuisance plants or whether unexpected side effects are noted. Quantitative criteria for target plant species reduction are useful benchmarks, but a more important measure of success will be the amount of increase or improvement in the beneficial uses of a waterbody.

## 7.3 Physical controls

Physical controls involve the direct alteration of the plant itself, the substrate, water column or general environment in which it depends on for survival. Physical controls include benthic barriers, dredging, dyes, surface covers, harvesting, water level controls and controlled burns. Each of these techniques is described below. Much of this information is adapted from Mattson et al. (2004) and Wagner (2004).

### 7.3.1 Benthic barriers

#### 7.3.1.1 Description

The use of benthic barriers, or bottom covers, is predicated upon the principles that rooted plants require light and cannot grow through physical barriers. Applications of clay, silt, sand, and gravel have been used for many years, although plants often root in these covers eventually, and current environmental regulations make it difficult to gain approval for such deposition of fill. Artificial sediment covering materials, including polyethylene, polypropylene, fiberglass, and nylon, have been developed over the last three decades. A variety of solid and porous forms have been used. Manufactured benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth,

and allow unfavorable chemical reactions to interfere with further development of plants. Various plastics and burlap have also been used, but are not nearly as durable or effective in most cases.

In theory, benthic barriers should be a highly effective plant control technique, at least on a localized, area-selective scale. In practice, however, there have been difficulties with the deployment and maintenance of benthic barriers, limiting their utility over the broad range of field conditions. Benthic barriers can be effectively used in small areas such as dock spaces and swimming beaches to completely terminate plant growth. The creation of access lanes and structural habitat diversity is also practical. Large areas are not often treated, however, because the cost of materials, application and maintenance is high.

Benthic barrier problems of prime concern include long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. Successful use is related to selection of materials and the quality of the installation and subsequent maintenance.

Bottom barriers will eventually accumulate sediment deposits in most cases, which allow plant fragments to root. Barriers must then be cleaned, necessitating either removal or laborious in-place maintenance (Eichler et al., 1995). Despite application and maintenance issues, a benthic barrier can be a very effective tool. Benthic barriers are capable of providing control of rooted plants on at least a localized basis, and have such desirable side benefits as creating more edge habitat within dense plant assemblages and minimizing turbidity generation from fine bottom sediments.

#### **7.3.1.2 Applicability to representative target species**

Benthic barriers have been effectively used for the control of Eurasian water milfoil (Boylen et al., 1996; Eichler et al., 1995; Lyman and Eichler, 2005), although recolonization has been documented after removal of the barriers (Eichler et al., 1995; Boylen et al., 1996). Barriers are most useful when plant biomass is low, and where Eurasian milfoil is not intermixed with desirable native species. Control of purple loosestrife through benthic barriers or other types of physical shading systems has not been demonstrated. It has been suggested generally that benthic barriers are largely ineffective on emergent species (Whetstone, 2005). KCNWP (2005) suggests that shading barriers may be used as an interim option for dense seedling infestations to slow down growth and seed production, but that such barriers will not kill the root systems. Control of waterlilies has been documented, though it can be difficult to secure barriers over the fleshy rhizomes of the waterlily (WDOE, 2009).

### **7.3.2 Dredging**

#### **7.3.2.1 Description**

Dredging is perhaps best known for maintaining navigation channels in rivers, harbors and ports or for underwater mining of sand and gravel, but dredging can also be an effective lake management technique for the control invasive growth of macrophytes (Holdren et al., 2001). The management objectives of a sediment removal project are usually to deepen a shallow lake for boating and fishing, or to remove nutrient rich sediments that can cause algal blooms or support dense growths of rooted macrophytes.

Dredging can be accomplished by multiple methods that can be conveniently grouped into four categories:

- Dry excavation, in which the lake is drained to the extent possible, the sediments are dewatered by gravity and/or pumping, and sediments are removed with conventional excavation equipment such as backhoes, bulldozers, or draglines.
- Wet excavation, in which the lake is not drained or only partially drawn down (to minimize downstream flows), with excavation of wet sediments by various bucket dredges mounted on cranes or amphibious excavators.

- Hydraulic dredging, requiring a substantial amount of water in the lake to float the dredge and provide a transport medium for sediment. Hydraulic dredges are typically equipped with a cutterhead that loosens sediments that are then mixed with water and transported as pumped slurry of 80 to 90% water and 10 to 20% solids through a pipeline that traverses the lake from the dredging site to a disposal area.
- Pneumatic dredging, in which air pressure is used to pump sediments out of the lake at a higher solids content (reported as 50 to 70%). This would seem to be a highly desirable approach, given containment area limitation in many cases and more rapid drying with higher solids content. However, few of these dredges are operating within North America, and there is little freshwater experience upon which to base a review. Considerations are much like those for hydraulic dredging, and pneumatic dredging will not be considered separately from hydraulic dredging for further discussion.

Dry, wet and hydraulic methods are illustrated in Figure 7-1. Cooke et al. (1993) provides a discussion of dredging considerations that will be helpful to some readers. Recent developments, methods, impact assessment and methods for handling dredged material can be found in McNair (1994). No technique requires more up front information about the lake and its watershed, and there are many engineering principles involved in planning a successful dredging project. No technique is more suitable for true lake restoration, but there are many potential impacts that must be considered and mitigated in the dredging process. Failed dredging projects are common, and failure can almost always be traced to insufficient consideration of the many factors that govern dredging success.

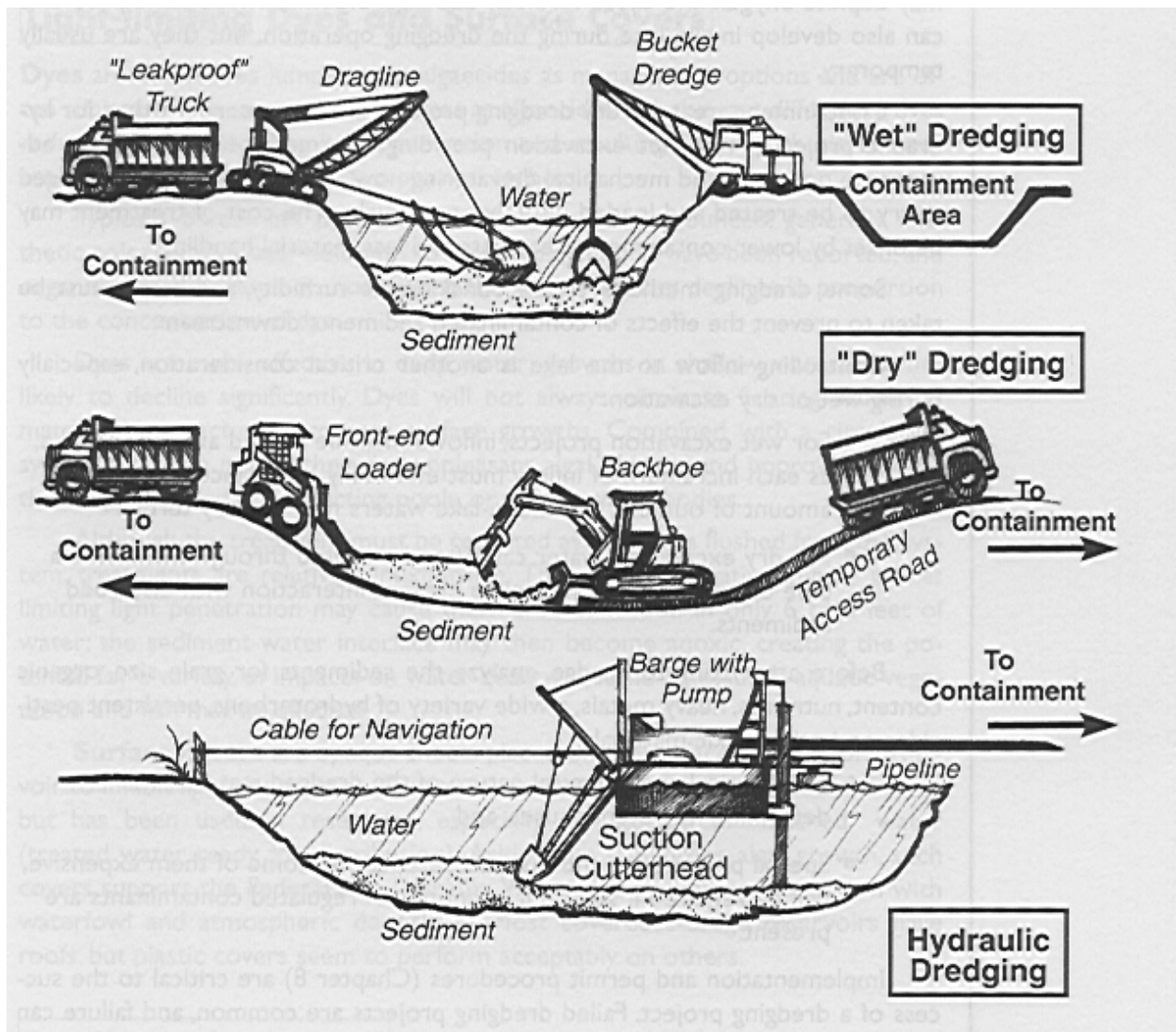
Dredging works as a plant control technique when either a light limitation on growth is imposed through increased water depth or when enough “soft” sediment (muck, clay, silt and fine sand) is removed to reveal a less hospitable substrate (typically rock, gravel or coarse sand). The amount of sediment removed, and hence the new depth and associated light penetration, is critical to successful long term control of rooted, submerged plants. There appears to be a direct relation between water transparency, as determined with a Secchi disk, and the maximum depth of colonization by macrophytes (Canfield et al., 1985). Dredging also removes the accumulated seed bed established by many vascular plants and the resting cysts deposited by a variety of algae.

Partial deepening may limit the amount of vegetation that reaches the surface, but may also favor species tolerant of low light, some of which are non-indigenous species with high nuisance potential, such as Eurasian watermilfoil. Where funding is insufficient to remove all soft sediment, it is more effective to create a depth or substrate limitation in part of the lake than to remove some sediment from all target areas of the lake, if rooted plant control is the primary objective of dredging.

If the soft sediment accumulations that are supporting rooted plant nuisances are not especially thick, it may be possible to create a substrate limitation before a light-limiting depth is reached. If dredging exposes rock ledge or cobble, and all soft sediment can be removed, there will be little rooted plant growth. Yet such circumstances are rare to non-existent; either the soft sediment grades slowly into coarser materials, or it is virtually impossible to remove all fine sediments from the spaces around the rock or cobble. Consequently, some degree of regrowth is to be expected when light penetrates to the bottom. With successful dredging, this regrowth may be only 25% of the pre-dredging density or coverage, and will not contain more recently invading species at a dominant level. Yet some rooted plant regrowth is expected, and is indeed desirable for proper ecological function of the lake as a habitat and for processing of future pollutant inputs.

A properly conducted dredging program removes accumulated sediment from a lake and effectively sets it back in time, to a point prior to significant sedimentation. Partial dredging projects are possible and may be appropriate depending upon management goals, but for maximum benefit it is far better to remove all “soft” sediment to achieve restoration objectives.

Figure 7-1 Dry, wet and hydraulic dredging approaches (from Wagner, 2001)





### 7.3.2.2 Applicability to representative target species

In the case of Eurasian watermilfoil, dredging may provide some near to long-term benefit via root crown removal, but it is rarely practical or possible to dredge to an adequate depth to achieve adequate light limitation to preclude reinfestation and regrowth (Cooke et al., 1993). Hydraulic dredging may also fragment and spread Eurasian watermilfoil, if dredging is undertaken when above ground stems are present. Dredging may provide effective long-term control of waterlilies with removal of rhizome systems, though because of the difficulty in removing all rhizome fragment and seeds, it would rarely if ever be 100% effective. Dredging, most likely dry excavation in shoreline and near shore areas, may provide control of purple loosestrife, but may raise issues of potential infestation elsewhere with the disposal of seed and root containing sediment. Difficulty with completely removing all sediments containing dormant seeds or small root fragments limits the likelihood that excavation will achieve complete eradication.

## 7.3.3 Dyes

### 7.3.3.1 Description

The use of dyes as algal or vascular plant control agents is often grouped with herbicides in lake management evaluations, but this can be very misleading with regard to how dyes work. Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow or the total amount of light available for algal growth. They are only selective in the sense that they favor species tolerant of low light or with sufficient food reserves to support an extended growth period (during which a stem could reach the lighted zone). Dyes are generally non-toxic to all aquatic species, including the target species of plants. In lakes with high transparency but only moderate depth and ample soft sediment accumulations, dyes may provide open water where little would otherwise exist. Repeated treatment will be necessary, as the dye eventually flushes out of the system. Dyes are typically permitted under the same process as herbicides, despite their radically different mode of action.

Although dyes can be an effective method of algae and plant control in small ornamental and golf course ponds, dyes have not provided consistently acceptable control in larger systems and are not generally applied as a control method for either rooted aquatic plants or algae in larger lakes. The dye should be applied early in the growing season for greatest effectiveness. Dyes can usually only be used in lakes and ponds without a flowing outlet, making it a logical choice for small, contained ornamental ponds. There is insufficient information available to evaluate field applications of dyes other than AQUASHADE®, but the light attenuating mechanism is the same for other commercially available dyes.

### 7.3.3.2 Applicability to representative target species

Light limitation using dyes may be effective for Eurasian watermilfoil control in small ponds without a flowing outlet. However, Eurasian watermilfoil is less light sensitive than some other species, and may survive dye treatment because of its ability to form a surface canopy under low light conditions. Dyes would not be expected to control a floating leaved plant such as the white waterlily. Dyes would have no appreciable benefit in the control of purple loosestrife or other emergent plants.

## 7.3.4 Harvesting

### 7.3.4.1 Description

There are several methods of harvesting with varying degree of scale costs. These techniques include hand pulling, suction harvesting, mechanical harvesting (cutting with and without collection), rototivation, and hydroraking. Each of these harvesting methods is described in detail below.

**Hand pulling** is exactly what it sounds like; a snorkeler or diver surveys an area and selectively pulls out unwanted plants on an individual basis. This is a highly selective technique, and a labor intensive one. It is well suited to vigilant efforts to keep out invasive species that have not yet become established in the lake or area of concern. Hand pulling can also effectively address non-dominant growths of undesirable species in mixed

assemblages, or small patches of plants targeted for removal (Eichler et al., 1991). This technique is not well suited to large-scale efforts, especially when the target species or assemblage occurs in dense or expansive beds.

Hand pulling can be augmented by various tools, including a wide assortment of rakes, cutting tools, water jetting devices, nets and other collection devices. McComas (1993) provides an extensive review of options. Suction dredging is also used to augment hand pulling, allowing a higher rate of pulling in a targeted area, as the diver/snorkeler does not have to carry pulled plants to a disposal point. Use of these tools transitions into more mechanized forms of harvesting.

**Suction harvesting**, or suction dredging, is mechanically augmented hand pulling. The diver hand pulls the unwanted plants and allows them to be transported through a vacuum hose to the surface into a mesh bag or other collection device. This technique accelerates the hand pulling process allowing pulling for denser assemblages but generally does not increase the area of control (Eichler et al., 1993; Mattson et al. 2004).

**Mechanical harvesting** is most often associated with large machines on pontoons that cut and collect vegetation, but encompasses a range of techniques from simply cutting the vegetation in place to cutting, collecting, and grinding the plants, to collection and disposal outside the lake. In its simplest form, cutting, a blade of some kind is applied to plants, severing the active apical meristem (location of growth) and possibly much more of the plant from the remaining rooted portion. Regrowth is expected, and in some species that regrowth is so rapid that it negates the benefits of the cutting in only a few weeks (Nichols and Lathrop, 1994). If the plant can be cut close enough to the bottom, or repeatedly, it will sometimes die, but this is more the exception than the rule. Cutting is defined here as an operation that does not involve collecting the plants once they are cut, so impacts to dissolved oxygen and nutrient release are possible in large-scale cutting operations.

Harvesting usually refers to more advanced technology cutting techniques involving the use of mechanized barges with harvesting operations, in which plants are collected for out-of-lake disposal. In its use as a cutting technology, the “harvester” cuts the plants but does not collect them. A modification in this technique employs a grinding apparatus that ensures that viable plant fragments are minimized after processing. There is a distinct potential for dissolved oxygen impacts and nutrient release as the plant biomass decays, much like what would be expected from many herbicide treatments.

Harvesting may involve collection in nets or small boats towed by the person cutting the weeds, or can employ smaller boat-mounted cutting tools that haul the cut biomass into the boat for eventual disposal on land. It can also be accomplished with larger, commercial machines with numerous blades, a conveyor system, and a substantial storage area for cut plants. Offloading accessories are available, allowing easy transfer of weeds from the harvester to trucks that haul the weeds to a composting area. Choice of equipment is really a question of scale, with larger harvesting operations usually employing commercially manufactured machines built to specifications suited to the job. Some lake associations choose to purchase and operate harvesters, while others prefer to contract harvesting services to a firm that specializes in lake management efforts.

**Rotovation** is basically the application of an underwater rototiller to an area of sediment, typically one with dense growths of an unwanted rooted aquatic plant. A rotovator is a hydraulically operated tillage device mounted on a barge. The tiller can be lowered to depths of 10 to 12 feet for the purpose of tearing up roots. On a much simpler scale, cultivation equipment or even old bed springs pulled behind tractors can accomplish much root disturbance. Rototilling and the use of cultivation equipment are highly disruptive procedures normally applied on a small scale. Rotovation has a limited track record, mostly in British Columbia. Use of a variety of cultivation equipment has been practiced in New England for many years, but is rarely documented. Potential impacts to non-target organisms and water quality are substantial, but where severe weed infestations exist, this technique could be appropriate.

**Hydroraking** involves the equivalent of a floating backhoe, usually outfitted with a york rake that looks like a farm implement for tilling or moving silage. The tines of the rake attachment are moved through the sediment, ripping out thick root masses and associated sediment and debris. A hydrorake can be a very effective tool for removing submerged stumps, water lily root masses, or floating islands. Use of a hydrorake is not a delicate operation, however, and will create substantial turbidity and plant fragments. Hydroraking in combination with a harvester can remove most forms of vegetation encountered in lakes.

Hydroraking is effective in the short-term in that it removes plants immediately. It is not an especially thorough or selective technique, and is therefore not well suited to submergent species that can reroot from fragments (e.g., milfoil) or mixed assemblages with desirable species present at substantial densities. It is particularly effective for water lilies (white or yellow) and other species with dense root masses. Hydroraking is also often used to remove subsurface obstructions such as stumps or logs.

#### **7.3.4.2 Applicability to representative target species**

Hand pulling and suction harvesting are suitable for control of Eurasian watermilfoil, for small infestations and localized areas. Collection and removal of all fragments is important with Eurasian watermilfoil to prevent spreading to other areas. Hand pulling with the assistance of rakes or hooks can be effective in soft sediments for waterlily control if rhizomes can be removed. In addition, repeated removal of all floating leaves has also been effective in killing off the plant including rhizomes, but requires consistent implementation over a period of two to three years (WDOE, 2009). Suction harvesting would not be effective for waterlilies. Hand pulling or digging of purple loosestrife may be effective for young plants or isolated plants in moist soils, but is not practical or effective for well established infestations (KCNWCP, 2005). Hand pulling and suction harvesting may be used to selectively remove invasive species where intermixed with other desirable species.

Mechanical harvesting can provide short term control for Eurasian watermilfoil, but may increase the risk of spreading through fragmentation. Containment curtains and diligent collection of fragments have been used to minimize issues with dispersal of fragments created by mechanical harvesting. Multiple harvests per season may be required to maintain control throughout the growing season. Similarly harvesting of waterlilies requires multiple cuttings per season to maintain control. Because lilies may grow in shallow waters, some areas may be inaccessible for control with harvesting. Mechanical harvesters used to remove aquatic vegetation would not be suitable for purple loosestrife control. Mowers or light-weight cultivating equipment may be used to remove vegetation, but cutting alone is not an adequate control measure for purple loosestrife (KCNWCP, 2005). In many cases mechanical methods have resulted in the promotion of further spread of the loosestrife (CDFA, 2006). Hand cutting of flower heads to prevent seed distribution can also be used, but requires repeat cutting of new flower heads until the first frost. Seed heads and plants should not be composted.

Rotovating and hydroraking have been used primarily as a means to control Eurasian watermilfoil in New York State, providing control for as long as two years (NYSDEC, 2005). The spread of the plants from uncut areas or incomplete removal of plant fragments created during rotovating or hydroraking may reduce longevity of results. Hydroraking and rotovating can be successfully used to remove waterlily, with long term control provided when repeated for two or three consecutive years. Hydroraking and rotovating can be used to remove purple loosestrife in shoreline areas, but may cause dormant seeds or root fragments to be distributed to non-infested areas. Hydroraking and rotovating non-selectively remove all vegetation within the control area.

### **7.3.5 Water level control**

#### **7.3.5.1 Description**

Control of rooted aquatic plants can be achieved through water level control. Two methods can be used, flooding and drawdown. Flooding, increasing water depth in an effort to achieve light limitation for aquatic plant control, is rarely used since water quantity and potential flooding impacts to urban areas limit the utility of this technique. Drawdown is often used, however, and is described below.

Drawdown is a process whereby the water level is lowered by gravity, pumping or siphoning and held at that reduced level for some period of time, typically several months and usually over the winter. Drawdown can provide control of plant species that overwinter in a vegetative state, and oxidation of sediments may result in lower nutrient levels with adequate flushing. Drawdowns also provide flood control and allow access for nearshore clean ups and repairs to structures. The ability to control the water level in a lake is affected by area precipitation pattern, system hydrology, lake morphometry, and the outlet structure. The base elevation of the outlet or associated subsurface pipe(s) will usually set the maximum drawdown level, while the capacity of the outlet to pass water and the pattern of water inflow to the lake will determine if that base elevation can be achieved and maintained. In some cases, sedimentation of an outlet channel or other obstructions may control the maximum drawdown level.

Several factors affect the success of drawdown with respect to plant control. While drying of plants during drawdowns may provide some control, the additional impact of freezing is substantial, making drawdown a more effective strategy during late fall and winter. However, a mild winter or one with early and persistent snow may not provide the necessary level of drying and freezing. The presence of high levels of groundwater seepage into the lake may mitigate or negate destructive effects on target submergent species by keeping the area moist and unfrozen. The presence of extensive seed beds may result in rapid re-establishment of previously occurring plant species, some of which may be undesirable. Recolonization from nearby areas may be rapid, and the response of macrophyte species to drawdown is quite variable.

Aside from direct impact on target plants, drawdown can also indirectly and gradually affect the plant community by changing the substrate composition in the drawdown zone. If there is sufficient slope, finer sediments will be transported to deeper waters, leaving behind a coarser substrate. If there is a thick muck layer present in the drawdown zone, there is probably not adequate slope to allow its movement. However, where light sediment has accumulated over sand, gravel or rock, repetitive drawdowns can restore the coarse substrate and limit plant growths. Expected response of target species (Table 7-2) is of particular importance when plant control is the major goal.

#### **7.3.5.2 Applicability to representative target species**

Overwinter drawdown has been effectively used for the control of Eurasian watermilfoil (Bates et al. 1985, NYSDEC, 2005), with results lasting for a few years. Drawdowns do not prevent recolonization from areas of the lake not impacted by drawdown, or nearby waterbodies (NYSDEC, 2005). White waterlily is susceptible to overwinter drawdown (Cooke et al., 1993). There have been no specific studies focused on overwinter drawdown control of purple loosestrife. However, biological characteristics of the plant suggest that control may be poor. Studies have demonstrated that seeds stored and frozen for 3 years germinated only two days later than fresh seeds (Thompson et al., 1987). Hence freezing and drying action on seeds would not provide control. Thompson et al. (1987) further cite that purple loosestrife's ability to adapt to varying environmental conditions, including adaptation to seasonal or semi-permanent changes in water levels, make it well suited to out compete other plants under similar conditions. The observed distribution and success of purple loosestrife into areas with only periodic to rare inundation which may be subject to freezing conditions further suggests that overwinter drawdown would not likely provide control by impacting root systems. In addition, a review of historical control efforts suggests that heaviest infestations appeared linked to drainage of deep-water basins, flooding of shallow basins, or seasonal drawdowns of impoundment pools (Thompson et al., 1987).

**Table 7-2 Anticipated response of some common aquatic plants to winter drawdown (adapted from Cooke et al., 1993)**

	Change in Relative Abundance		
	<u>Increase</u>	<u>No Change</u>	<u>Decrease</u>
<i>Acorus calamus</i> (sweet flag)	E		
<i>Alternanthera philoxeroides</i> (alligator weed)	E		
<i>Asclepias incarnata</i> (swamp milkweed)			E
<i>Brasenia schreberi</i> (watershield)			S
<i>Cabomba caroliniana</i> (fanwort)			S
<i>Cephalanthus occidentalis</i> (buttonbush)	E		
<i>Ceratophyllum demersum</i> (coontail)			S
<i>Egeria densa</i> (Brazilian Elodea)			S
<i>Eichhornia crassipes</i> (water hyacinth)		E/S	
<i>Eleocharis acicularis</i> (needle spikerush)	S	S	S
<i>Elodea canadensis</i> (waterweed)	S	S	S
<i>Glyceria borealis</i> (mannagrass)	E		
<i>Hydrilla verticillata</i> (hydrilla)	S		
<i>Leersia oryzoides</i> (rice cutgrass)	E		
<i>Lythrum salicaria</i> (purple loosestrife)	E		
<i>Myrica gale</i> (sweetgale)		E	
<i>Myriophyllum</i> spp. (milfoil)			S
<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)			S
<i>Najas flexilis</i> (bushy pondweed)	S		
<i>Najas guadalupensis</i> (southern naiad)			S
<i>Nuphar</i> spp. (yellow water lily)			E/S
<i>Nymphaea odorata</i> (white water lily)			S
<i>Polygonum amphibium</i> (water smartweed)		E/S	
<i>Polygonum coccineum</i> (smartweed)	E		
<i>Potamogeton epihydrus</i> (leafy pondweed)	S		
<i>Potamogeton robbinsii</i> (Robbins' pondweed)			S
<i>Potentilla palustris</i> (marsh cinquefoil)			E/S
<i>Scirpus americanus</i> (three square rush)	E		
<i>Scirpus cyperinus</i> (wooly grass)	E		
<i>Scirpus validus</i> (great bulrush)	E		
<i>Sium suave</i> (water parsnip)	E		
<i>Typha latifolia</i> (common cattail)	E	E	
<i>Zizania aquatic</i> (wild rice)	E		

E=emergent growth form

S=submergent growth form (includes rooted species with floating leaves)

E/S=emergent and submergent forms

### 7.3.6 Controlled Burns

#### 7.3.6.1 Description

Fire can be used to destroy vegetation and any associated seeds. Destruction of roots and any buried seeds is less certain, but is sometimes accomplished. Successful burns for invasive species control and related planning, precautions and impacts are discussed in the Nature Conservancy's Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas (Tu et al., 2001). Successful control of terrestrial species is more common than for aquatic or wetland species, and it is especially important to destroy the roots and any buried seeds if eradication is the goal. Control of aquatic species by fire is limited, but when it is attempted it is nearly always accompanied by a follow-up technique, most often herbicides. Control of reed canary grass, cattail, common reed and purple loosestrife has been reported (Tu et al., 2001). Risks to humans, their property, and non-target species of plants and animals greatly limits the use of this technique on a large scale, but where fire has historically been a factor in landscape features and has more recently been suppressed by human activities, it used is considered ecologically justifiable.

#### 7.3.6.2 Applicability to representative target species

Purple loosestrife has rarely been controlled by burning, with increased success when herbicides are used as a follow-up treatment. Eurasian watermilfoil and waterlilies are not susceptible to control by fire.

### 7.4 Chemical controls

Chemical treatment is one of the oldest methods used to manage nuisance aquatic weeds, and is still the most frequently applied approach. Other than perhaps drawdown, few alternatives to herbicides were widely practiced until relatively recently. Those considering chemical use should become aware of all possible benefits, known limitations and constraints, and possible negative impacts, and should carefully evaluate the applicability and efficacy for the target lake.

Herbicides and algaecides contain active ingredients that are toxic to target plants. For convenience, we will refer to this collective group of chemicals as herbicides here, with inclusion of algaecides inferred. Herbicides are typically classified as contact or systemic herbicides based on the action mode of the active ingredient. Contact herbicides are toxic to plants by uptake in the immediate vicinity of external contact, while systemic herbicides are taken up by the plant and are translocated throughout the plant. In general, contact herbicides are more effective against annuals than perennials because they may not kill the roots, allowing perennials to grow back. Seeds are also not likely to be affected, but with proper timing and perhaps several treatments, growths can be eliminated much the same way harvesting can eliminate annual plants.

Systemic herbicides tend to work more slowly than contact herbicides because they take time to be translocated throughout the plant. Systemic herbicides generally provide more effective control of perennial plants than contact herbicides, as they kill the entire plant under favorable application circumstances. Systemic herbicides will also kill susceptible annual species, but regrowth from seeds is usually substantial. If annual species are the target of control, additional treatment will be required, normally a year after initial treatment and for as long as the seed bank facilitates new growths.

Another way to classify herbicides is by whether the active ingredients are selective or broad spectrum. Selective herbicides are more effective on certain plant species than others, with control of that selectivity normally dependent on dose and exposure duration. Plant factors that influence selectivity include plant morphology, physiology and the stage of growth. Even a selective herbicide can kill most plants if applied at high rates. Likewise, contact herbicides may show some selectivity based on dose and plant features, but tend to induce impacts on a broad spectrum of plant species.

The choice of herbicide to manage an undesirable plant population depends on the properties of the herbicide, the relative sensitivity of the target and non-target plants and other organisms that will be exposed, water use restrictions after herbicide use, and cost. Effectiveness in controlling the target plant species is normally the

primary consideration. Other factors determine possible choice between two or more potentially effective herbicides, dose, and whether a treatment is actually feasible.

Herbicide effectiveness may be influenced by such factors as timing, rate and method of application, species present and weather conditions (Westerdahl and Getsinger, 1998a, b). Additionally, dose determination should consider hydraulic residence time, morphometry and water hardness to maximize effectiveness. Herbicide treatment can be an effective short-term (and sometimes, longer) management procedure to produce a rapid reduction in algae or vascular plants for periods of weeks to months. Although long-term effectiveness of herbicide treatments is possible, in most cases herbicide use is considered a short-term control technique.

Six aquatic herbicides currently approved for aquatic use by the United States Environmental Protection Agency (USACE 2002) and registered for use in New York State are described below. Information for individual herbicidal active ingredients in use today is further discussed in association with each active ingredient in subsequent parts of review. Copper is not generally used to control milfoil growth and is therefore not included in this discussion. The relative effectiveness of control by New York-registered herbicides on common nuisance aquatic plants is listed in Table 7-3 (NYSDEC, 2005).

The relative effectiveness in Table 7.3 has three possible ratings: high (very effective control), medium (moderate control) or low (poor or no control). Since Clearcast® can be applied either by foliar and submerged applications, the information on Table 7-3 for that herbicides includes the relative sensitivity for both. The foliar value is given first, followed by the submerged, such as high/low. This has also been done for submergent species, such as parrotfeather (*M. aquaticum*), which can have emergent foliage late in the season. If the response has not been well documented, it is indicated as an “?”.

#### **7.4.1 Diquat**

##### **7.4.1.1 Description**

Diquat is a fast acting contact herbicide, producing results within 2 weeks of application through disruption of photosynthesis. It is a broad-spectrum herbicide with potential risks to aquatic fauna, but laboratory indications of invertebrate toxicity have not been clearly documented in the field. A domestic water use restriction of 3 days is normally applied. Irrigation restrictions of 2 to 5 days are applied, depending on dose and crop to be irrigated. Regrowth of some species has been rapid (often within the same year) after treatment with diquat, but two years of control have been achieved in some instances.

Diquat is used as a general purpose aquatic herbicide, both as a primary control agent for a broad range of macrophytes and as a follow-up treatment chemical for control of plants (especially milfoil) missed by other herbicides or physical control techniques. Treatment with diquat is recommended early in the season to impact early growth stages, but can be applied any time. Diquat is less effective in turbid, muddy water due to adsorption onto sediments and other particles.

Since diquat is a broad spectrum herbicide, it can be expected to impact non-target plants when they are present. Loss of vegetative cover may have some impact on aquatic animals, but short-term effects are not expected. The acute toxicity of diquat for fish is highly variable depending on species, age, and hardness of water. Young fish are more sensitive than older fish. Toxicity is decreased as water hardness increases.

##### **7.4.1.2 Applicability to representative target species**

Diquat has a high impact on Eurasian watermilfoil, and limited effectiveness on white waterlily and purple loosestrife (Table 7-3).

**Table 7-3 Impact of NYS registered herbicides on common nuisance aquatic plants (adapted from NYSDEC, 2005)**

Susceptibility to Herbicide							
Aquatic Plant	Diquat	2,4-D	Endothall	Glyphosate	Fluridone	Triclopyr	Imazamox
<b>Emergent Species</b>							
<i>Lythrum salicaria</i> (purple loosestrife)	low	low	low	high	low	high	high/low
<i>Phragmites</i> spp (reed grass)	low	low	medium	high	low	medium	high/low
<i>Pontedaria cordata</i> (pickerelweed)	low	medium	low	medium	low	high	high/medium
<i>Sagittaria</i> spp (arrowhead)	low	high	low	high	low	medium	high/medium
<i>Scirpus</i> spp (bulrush)	medium	high	low	high	low	low	medium/medium
<i>Typha</i> spp (cattail)	medium	medium	low	high	medium	low	high/medium
<b>Floating Leaf Species</b>							
<i>Brasenia schreberi</i> (watershield)	medium	medium	medium	low	medium	medium	high/medium
<i>Lemna</i> spp (duckweed)	high	medium	medium	low	high	low	low/low
<i>Nuphar</i> spp yellow water lily)	low	medium	medium	high	medium	medium	medium/low
<i>Nymphaea</i> spp (white water lily)	low	medium	medium	high	medium	medium	high/low
<i>Trapa natans</i> (water chestnut)	low	medium	low	medium (foliar only)	low	medium	high/medium
<b>Submergent Species</b>							
<i>Ceratophyllum demersum</i> (coontail)	high	medium	high	low	high	low	low
<i>Cabomba caroliniana</i> (fanwort)	medium	medium	high	low	high	low	low
<i>Chara</i> spp (muskgrass)	low	low	low	low	low	low	low
<i>Elodea canadensis</i> (common waterweed)	high	medium	low	low	high	low	?
<i>Heteranthera dubia</i> (water stargrass)	high	high	medium	low	medium	low	high
<i>Myriophyllum aquaticum</i> (Parrotfeather)	-	-	-	-	-	-	medium/low
<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)	high	high	high	low	high	high	high
<i>Najas flexilis</i> (bushy pondweed)	high	medium	high	low	medium	low	?
<i>Potamogeton amplifolius</i> (largeleaf pondweed)	low	low	medium	low	medium	low	medium
<i>Potamogeton crispus</i> (curly-leaved pondweed)	high	low	high	low	high	low	medium
<i>Potamogeton robbinsii</i> (Robbins' pondweed)	low	low	medium	low	high	low	medium
<i>Stuckenia pectinatus</i> (Sago pondweed)	high	low	medium	low	medium	low	medium
<i>Utricularia</i> spp (bladderwort)	high	medium	low	low	medium	low	low
<i>Vallisneria spiralis</i> (wild celery)	low	low	medium	low	medium	low	low

Adapted from Holdren, et al, 2001; ENSR, 2007.

Control levels: high (very effective control), medium (moderate control) or low (poor or no control); where both foliar and submerged applications are possible, the foliar value is given first, followed by the submerged, such as high/low



## 7.4.2 Endothall

### 7.4.2.1 Description

Endothall is a contact herbicide, attacking a wide range of plants. The method of action of endothall is suspected to inhibit the use of oxygen for respiration. Only portions of the plant with which the herbicide can come into contact are killed. There are two forms of the active ingredient; the inorganic potassium salt that is found in the products Aquathol® Granular and Aquathol® K and the alkylamine salt formulations of Hydrothol® 191 Granular and Hydrothol® 191. Effective control can range from weeks to months. Most endothall compounds break down readily and are not persistent in the aquatic environment, disappearing from the water column in under 10 days and from the sediments in under 3 weeks.

Endothall acts quickly on susceptible plants, but does not kill roots with which it cannot come into contact, and recovery of many plants occurs. Rapid death of susceptible plants can cause oxygen depletion if decomposition exceeds re-aeration in the treated area, but this can be mitigated by conducting successive partial treatments. Toxicity to invertebrates, fish or humans is possible but not expected at typical doses, but endothall is not typically permitted for use in drinking water supplies.

Endothall is primarily a broad spectrum vascular plant control chemical. Endothall has not been very effective against milfoil, but works well on most species of pondweeds, coontail and naiads. It is used less than most other herbicides, mainly due to dose limits that are observed to avoid impacts to non-target fauna.

Hydrothol® 191 is an alkylamine salt formulation of endothall. This formulation is effective against algae as well as macrophytes, but is much more toxic to fish than Aquathol® K. The environmental hazards listed on the Hydrothol® 191 (Dimethylalkylamine endothall granular and liquid) labels warn that fish may be killed by dosages in excess of 0.3 ppm. Hydrothol® 191 is less toxic to fish in cool water (<65°F). However, Hydrothol® 191 granular is sometimes not used because of potential dust problems and possible toxicity to the applicator. Aquathol® K is much less toxic and is used more frequently than Hydrothol® 191. Aquathol® K application rates vary with water depth. Although usually applied at lower rates, the maximum rate of 269 lbs per 2 acre feet or 6.4 gallons per 2 acre-feet for spot treatment would result in a maximum concentration of 5 ppm according to the product labels.

### 7.4.2.2 Applicability to representative target species

Endothall has a high impact on Eurasian watermilfoil, a medium impact on white waterlily and low impact on purple loosestrife (Table 7-3).

## 7.4.3 Glyphosate

### 7.4.3.1 Description

Glyphosate is a systemic, broad spectrum herbicide. Glyphosate is used to control emergent vegetation and to create open areas for waterfowl or human use. Its mode of action is to disrupt the plant's shikimic acid metabolic pathway. Shikimic acid is a precursor in the biosynthesis of aromatic amino acids. The disruption in the pathway prevents the synthesis of aromatic amino acids and the metabolism of phenolic compounds. The net effect is that the plant is unable to synthesize protein and produce new plant tissue. Glyphosate penetrates the cuticle of the plant and moves to the phloem where it is translocated throughout the plant, including the roots. Its aquatic formulation is effective against most emergent or floating-leaved plant species, but not against most submergent species. Rainfall shortly after treatment can negate its effectiveness, and it readily adsorbs to particulates in the water column or to sediments and is inactivated. It is relatively non-toxic to aquatic fauna at recommended doses, and degrades readily into non-toxic components in the aquatic environment. The maximum concentration for treated water is typically about 0.7 mg/L, but a dose of no more than 0.2 mg/L is usually recommended.

The most common aquatic use of glyphosate is for control of emergent and floating leaf species, in particular water lilies (*Nuphar spp.*, *Nymphaea spp.*), reed grass (*Phragmites spp.*), purple loosestrife (*Lythrum salicaria*) and cattail (*Typha spp.*). Glyphosate is not effective for control of submerged macrophytes because it is water soluble and the concentration after dilution would be insufficient to damage a submergent plant. It is, however, recommended for control of many wetland and floodplain species that include trees, shrubs and herbs. Glyphosate effectiveness is greater in soft water. Additives such as ammonium phosphate are recommended for hard water glyphosate applications, and non-ionic surfactants are often recommended to increase overall effectiveness.

Because it is a broad spectrum herbicide, glyphosate should be expected to impact non-target emergent or floating leaf plants if the spray contacts them. Control of the spray can therefore greatly limit impacts to non-target vegetation. The LC<sub>50</sub> levels for fish species vary widely, perhaps due to variations in formulations tested (i.e., with or without surfactant). Most applications would result in aquatic concentrations far lower than any toxic threshold. Invertebrates do not appear to be harmed directly by the herbicide, but may be impacted by the alteration of vegetation.

Note that glyphosate-based herbicides would be the primary chemical alternative for imazamox for addressing emergent and floating leaf aquatic plant nuisances. Other herbicides are applicable to submerged plants, but glyphosate and imazamox are directly competing strategies for emergent and floating plants.

#### **7.4.3.2 Applicability to representative target species**

Glyphosate has a low impact on Eurasian watermilfoil, a high impact on white waterlily and purple loosestrife (Table 7-3).

### **7.4.4 2,4-D**

#### **7.4.4.1 Description**

2,4-D, the active ingredient in a variety of commercial herbicide products, has been in use for over 30 years. This is a systemic herbicide; it is absorbed by roots, leaves and shoots and disrupts cell division throughout the plant. Vegetative propagules such as winter buds, if not connected to the circulatory system of the plant at the time of treatment, are generally unaffected and can grow into new plants. Seeds are also not affected. It is therefore important to treat plants early in the season, after growth has become active but before such propagules form.

2,4-D is sold in liquid or granular forms as sodium and potassium salts, as amine salts, and as an ester. Doses of 50 to 150 pounds per acre are usually applied for the control of submersed weeds, most often of the dimethylamine salt (DMA) or the butoxyethanolester (BEE) in granular formulation. Lower doses are more selective but require more contact time; a range of one to three days of contact time is typically needed at the range of doses normally applied. 2,4-D has a short persistence in water but can be detected in the sediment for months.

Experience with granular 2,4-D in the control of nuisance macrophytes has generally been positive, with careful dosage management providing control of such non-indigenous nuisance species as Eurasian watermilfoil with only sublethal damage to many native species. 2,4-D has variable toxicity to fish, depending upon formulation, dose and fish species. The 2,4-D label does not permit use of this herbicide in water used for drinking or other domestic purposes, or for irrigation until the concentration is less than 0.1 ppm, typically about 3 weeks. While there is overlap in the species to which 2,4-D and imazamox would be applied, the drinking water use restrictions are much more limiting for 2,4-D.

#### **7.4.4.2 Applicability to representative target species**

Control of Eurasian watermilfoil with 2,4-D is high, whereas control is medium and low for white waterlily and purple loosestrife, respectively (Table 7-3).

## **7.4.5 Fluridone**

### **7.4.5.1 Description**

Fluridone is a systemic herbicide that comes in two general formulations, an aqueous suspension and a slow release pellet, although several forms of pellets are now on the market. This chemical inhibits carotene synthesis, which in turn exposes the chlorophyll to photodegradation. Most plants can be damaged by sunlight in the absence of protective carotenes, resulting in chlorosis of tissue and death of the entire plant with prolonged exposure to a sufficient concentration of fluridone. When carotene is absent the plant is unable to produce the carbohydrates necessary to sustain life. Some plants, including Eurasian watermilfoil, are more sensitive to fluridone than others, allowing selective control at low doses.

For susceptible plants, lethal effects are expressed slowly in response to treatment with fluridone. Existing carotenes must degrade and chlorosis must set in before plants die off; this takes several weeks to several months, with 30-90 days given as the observed range of time for die off to occur after treatment. The slow rate of plant die-off minimizes the risk of oxygen depletion. Fluridone concentrations should be maintained in the lethal range for the target species for at least 6 weeks, preferably 9 weeks, and ideally 13 weeks. This presents some difficulty for treatment in areas of substantial water exchange, and indicates the value of an alternative herbicide for many of the same target species, represented by imazamox.

The selectivity of fluridone for the target species depends on the timing and the rate of application. Early treatment (April/early May) with fluridone effectively controls overwintering perennials before some of the beneficial species of pondweed and naiad begin to grow. Variability in response has also been observed as a function of dose, with lower doses causing less impact on non-target species. However, lesser impact on target plants has also been noted in some cases, so dose selection involves balancing risk of failure to control target plants with risk of impact to non-target species.

Fluridone is considered to have low toxicity to invertebrates, fish, other aquatic wildlife, and mammals, including humans. The USEPA has set a tolerance limit of 0.15 ppm for fluridone or its degradation products in potable water supplies, although some state restrictions are lower. Substantial bioaccumulation has been noted in certain plant species, but not in animals.

### **7.4.5.2 Applicability to representative target species**

Fluridone has a high impact on Eurasian watermilfoil, a medium impact on white waterlily and low impact on purple loosestrife (Table 7-3).

## **7.4.6 Triclopyr**

### **7.4.6.1 Description**

Triclopyr is a systemic herbicide which contains a synthetic plant growth hormone (auxin) that interferes with plant metabolism. Bending and twisting of leaves and stems is evident almost immediately after application. Delayed symptom development includes root formation on dicot stems, misshapen leaves, stems, and flowers, and abnormal roots. Symptoms are evident on new growth first. Pigment loss (yellow or white), stoppage of growth, and distorted new growth are typical symptoms. Most injury appears in the period of several days to weeks (USEPA, 1998; Purdue, 1996). Following application to Eurasian watermilfoil (a primary target invasive species), chlorotic apices were noted in three days, defoliation and sinking to the sediment surface within 14 days, and necrosis occurring over the next two weeks (Poovey et al., 2004).

Various studies have shown triclopyr to be an effective herbicide for emersed, submersed and floating macrophyte control. Treatments can be done via foliar, sub-surface or granular applications. It is highly selective and effective against susceptible submerged species (i.e., watermilfoil spp.) and floating and emersed plant species at a dose range of 0.75 to 2.5 mg/L and 2 -8 quarts per acre respectively. Triclopyr provides selective control of woody and broadleaf species (Swadener, 1993). In aquatic ecosystems, this

differential response gives triclopyr the ability to remove milfoil and allow non-invasive native monocots and tolerant dicots to proliferate (Antunes-Kenyon and Kennedy, 2004).

It is recommended that triclopyr be applied when plants are actively growing, early spring into fall depending on target species. Eurasian watermilfoil initiates productivity and metabolic activity at an earlier time than native plants (Smith and Barko, 1990). Utilizing an early growing season application would allow for the treatment of Eurasian watermilfoil prior to dense biomass establishment and while the remaining plant community is still dormant.

Triclopyr is considered to have a low degree of systemic toxicity based on findings from acute and subchronic toxicology studies (WDOE, 2001). When the USEPA established the tolerance for combined residues of triclopyr and its metabolites it conducted a comprehensive risk assessment using modeling and risk assessment techniques to estimate maximum exposure potential from all sources (total aggregate exposure) including food, drinking water, and residential uses. This risk assessment concluded that there is a reasonable certainty that no harm will result to the general population and to infants and children from aggregate exposure to triclopyr and TCP (Antunes-Kenyon and Kennedy, 2004).

#### **7.4.6.2 Applicability to representative target species**

Triclopyr has a high impact on Eurasian watermilfoil and purple loosestrife, and a medium impact on white waterlily (Table 7-3).

### **7.5 Biological controls**

Interest has grown in biological control methods over the last two to three decades. Most methods are still experimental and have a limited degree of achieved effectiveness. Most methods have the potential to inflict negative impacts on the environment. Biological methods differ from other plant control methods in that there are more variables to consider and usually a longer time span needed to evaluate effectiveness. These methods are unusual in that the treatments consist of either altering conditions to favor certain organisms or introducing live organisms that may be difficult or impossible to control or recall once introduced. For this reason non-indigenous introductions are restricted in most cases. Biological control has the advantage that it is perceived as a more “natural” or “organic” plant control option, but it still represents human interference within an ecological system. The potential for long-term effectiveness with limited maintenance is attractive, but has been largely illusive with biological controls.

#### **7.5.1 Herbivorous fish**

##### **7.5.1.1 Description**

The sterile triploid form of grass carp (*Ctenopharyngodon idella*), also known as the white amur, is a species of fish that is permitted for use in the control of aquatic macrophytes in New York State (Stang, 1994). The native range of grass carp includes the Pacific slope of Asia from the Amur River of China and Siberia, south to the West River in southern China and Thailand. They are typically found in low gradient reaches of large river systems. Grass carp can grow to 4 feet long and attain weights of over 100 pounds, making them the largest member of the cyprinid family. They have a very high growth rate, with a maximum at about 6 pounds per year. They typically grow to a size of 15-20 pounds in North American waters and have adapted quite well to life in reservoirs where they are stocked for aquatic vegetation control.

As with other carp species, they are tolerant of wide fluctuations in water quality including water temperatures from 0 to 35°C, salinities up to 10 ppt, and oxygen concentrations approaching 0 mg/L. Grass carp do not feed when water temperatures drop below 11°C (52°F) and feed heavily when water temperatures are between 20°C and 30°C (68°F and 86°F). Dietary preference is an important aspect of grass carp, as pertains to their use as a plant control mechanism. Grass carp have exhibited a wide variety of food choices from study to study. In some cases grass carp have been reported to have a low feeding preference for *Myriophyllum spicatum*. Yet in a recently completed Connecticut study (Benson, 2002), grass carp did consume milfoil more

readily than other submergent species. Grass carp readily eat other non-indigenous plants such as *Cabomba caroliniana* and *Egeria densa* as well as various native species. In some cases grass carp will also eat and control filamentous algae (e.g., *Pithophora*). Generally, grass carp avoid cattails and water lilies, but the high level of variability in grass carp diet among lakes should be kept in mind.

The major difficulty in using grass carp to control aquatic plants is determining what rate will be effective and yet not so high as to eradicate the plants completely. Effective grass carp stocking rates are a function of grass carp mortality, water temperature, plant species composition, plant biomass and desired level of control. The fish usually live ten or more years but the typical plant control period is reported to be 3 to 4 years with some restocking often required. They are difficult to capture and remove unless the lake is treated with rotenone that will kill other fish species as well. Grass carp may also decrease the density or even eliminate vascular plants, although in a Connecticut study (Benson, 2002), the carp preferred milfoil to other plants. Algal blooms resulting from nutrients being converted from plant biomass by the grass carp have been common, even without elimination of vascular plants.

#### **7.5.1.2 Applicability to representative target species**

Diet preference demonstrated in various studies has been highly variable, some showing preferential feeding on Eurasian watermilfoil, while others have showed no preferential feeding on Eurasian watermilfoil. Studies have documented that grass carp avoid water lilies. Grass carp do not provide effective control of purple loosestrife.

### **7.5.2 Herbivorous invertebrates**

#### **7.5.2.1 Description**

Biological control has the objective of achieving control of plants without introducing toxic chemicals or using machinery. Yet it suffers from an ecological drawback; in predator-prey (or parasite-host) relationships, it is rare for the predator to completely eliminate the prey.

#### **7.5.2.2 Applicability to representative target species**

Augmentation of a native insect population has been studied with the milfoil midge (*Cricotopus myriophylli*), a moth (*Acentria ephemerella*) and the milfoil weevil (*Euhrychiopsis lecontei*). Releases in Massachusetts of the native weevil (*Euhrychiopsis lecontei*) for the control of Eurasian milfoil have occurred since 1995, and there are signs of success in two of the original test lakes (Creed and Sheldon, 1994; Sheldon, 1995; Sheldon and Creed, 1995; Sheldon and O'Bryan, 1996a,b).

*Euhrychiopsis lecontei* is a native North American insect species believed to have been associated with northern watermilfoil (*Myriophyllum sibiricum*), a species largely replaced by non-indigenous, Eurasian watermilfoil (*M. spicatum*) since the 1940's. It does not utilize non-milfoil species. In controlled trials, the weevil clearly has the ability to impact milfoil plants through structural damage to apical meristems (growth points) and basal stems (plant support). Adults and larvae feed on milfoil, eggs are laid on it, and pupation occurs in burrows in the stem. Field observations linked the weevil to natural milfoil declines in nine Vermont lakes and additional lakes in other states (Johnson et al., 2000).

Lakewide crashes of milfoil populations have generally not been observed in cases where the weevil has been introduced into only part of the lake, although localized damage has been substantial. Widespread control may require more time than current research and monitoring has allowed. As with experience with introduced insect species in the south, the population growth rate of the weevil is usually slower than that of its host plant, necessitating supplemental stocking of weevils for more immediate results. Just what allows the weevil to overtake the milfoil population in the cases where natural control has been observed is still unknown.

*Acentria ephemerella* is a European aquatic moth first reported in North America near Montreal in 1927 (Sheppard, 1945; as reported in Johnson and Blossey, 2002). While it is considered a generalist herbivore,

significant declines in Eurasian watermilfoil populations in Ontario and New York lakes have been associated with population explosions of the species (Johnson et al., 1998; Gross et al., 2001). Cayuga Lake is the best studied of these declines, with a greater than 90% reduction of Eurasian watermilfoil (Johnson et al., 1998; Gross et al., 2001); a reduction that has been maintained for 15 years since the initial decline (R. Johnson, pers. comm. 12/20/06). This selective suppression of Eurasian watermilfoil has led to a strong recovery by native macrophyte species, which now dominate the plant community (Johnson and Blossey, 2002). Further investigations of the effects of population augmentation and long-term control of watermilfoil by *A. ephemera* are being conducted in several New York lakes including Chautauqua, Otisco, and Owasco (R. Johnson, pers. comm. 12/20/06).

While there has been some research regarding aquatic insect herbivory on white waterlilies (Cronin et al., 1998, Dorn et al., 2001), there are no effective biological control options available at this time for white waterlily.

Biological control using invertebrates (mainly insects) from the same region as the introduced target plant species include the root boring weevil (*Hylobius transversovittatus*) and two leaf beetles (*Galerucella californiensis* and *G. pusilla*) for the control of purple loosestrife (*Lythrum salicaria*). For the control of purple loosestrife, a measure of success has been achieved with the introduction of two European leaf beetles (*Galerucella californiensis* and *G. pusilla*) (Blossey, 2002; MA CZM, 2006). Two other potential insect control agents for purple loosestrife (*Hylobius transversovittatus* and *Nanophes marmoratus*) have been identified, but their effectiveness has not been fully established.

Mass releases of the *Galerucella* sp. beetles have been successfully used in the United States to control purple loosestrife infestations since the early 1990s (approved in 1992 by U.S. Department of Agriculture for their use in biocontrol). While these natural beetle predators cannot eliminate purple loosestrife entirely, at several release sites complete defoliation of large stands have been reported with local reductions of more than 95% of the biomass (Blossey, 2002). Published literature indicates that the beetles are host-specific and no significant long-term significant impacts on native plant species have been observed (MA CZM, 2006). Several states and academic institutions have established programs to provide information and guidance on this form of biological control (e.g., MA CZM Purple Loosestrife Biocontrol Project, Cornell University Ecology and Management of Invasive Plants Program). Efforts are also being made to mass-produce the biocontrol beetles to make them available to interested parties or state agencies (MA CZM, 2006).

### 7.5.3 Plant competition

#### 7.5.3.1 Description

Although invasive nuisance plant species are just what the name implies, there is evidence that the presence of a healthy, desirable plant community can minimize or slow infestation rates. Most invasive species are favored by disturbance, so a stable plant community should provide a significant defense. Unfortunately, natural disturbances abound, and almost all common plant control techniques constitute disturbances. Therefore, if native and desirable species are to regain dominance after disturbance, it may be necessary to supplement their natural dissemination and growth with seeding and planting. The use of seeding or planting of vegetation is still a highly experimental procedure, but if native species are employed, it should yield minimal controversy.

Experiments indicate that the addition of dried seeds to an exposed area of sediment will result in rapid germination of virtually all viable seeds and rapid cover of the previously exposed area. However, if this is not done early enough in the growing season to allow annual plants to mature and produce seeds of their own, the population will not sustain itself into the second growing season. Transplanting mature growths into exposed areas has generally been found to be a more successful means of establishing a seed producing population. The use of cuttings gathered by a harvester has not been successful in establishing native species, so it appears that whole, viable plants must be added.

Areas of dense, healthy, indigenous plants tend to resist colonization by invasive species. Resistance may not be complete or lasting, but invasions have been greatly slowed where bare sediment is minimized. More research is needed, but establishment of desired vegetation is entirely consistent with the primary plant management axiom: if light and substrate are adequate, plants will grow. Rooted plant control should extend beyond the limitation of undesirable species to the encouragement of desirable plants.

#### **7.5.3.2 Applicability to representative target species**

Because restoration of native populations through planting remains largely experimental, documentation of successes in controlling specific invasive plant species is scant. However, available documentation suggests that this strategy may be effective for the control of Eurasian watermilfoil and white waterlily. The planting of native plants in disturbed areas has been shown to minimize colonization of nuisance aquatic plants such as watermilfoil (Doyle and Smart, 1993). Helsel et al. (1996) demonstrated that control of Eurasian watermilfoil and white waterlily with 2,4-D allowed for natural re-colonization by the native plant community, but had little success in achieving similar re-establishment of native plants in areas treated with benthic barriers followed by establishment of native plant beds from transplanted cuttings. The study suggested improved planting techniques were needed to improve potential success of replanting (Helsel et al., 1996).

Replanting with native species when purple loosestrife is hand pulled or dug has been recommended (KCNWCP, 2005). KCNWCP (2005) suggests using a mix of clover and grass species to improve resistance to re-infestation of cleared areas.

## **7.6 No-action alternative**

### **7.6.1.1 Description**

The no action or no management alternative for aquatic plants would exclude all active lake management programs, but would include normal monitoring and would also include normal operations such as drawdowns for flood control or dam repair and other activities as permitted or required by law. The normal tendency for lakes is to gradually accumulate sediments and associated nutrients and to generally become more eutrophic. Although macrophytes may be excluded from deeper areas of the lake due to light limitation, as sediments fill in the lake a greater proportion of the lake area becomes suitable for aquatic macrophytes. In consideration of this, the no management alternative would allow lakes to become ever more eutrophic in the future, even if no human additions of nutrients, sediments or non-indigenous plants were considered. In cases where there is development in the watershed leading to increased erosion and sediment transport to the lake, the rate of infilling and expansion of macrophyte beds would be expected to increase more rapidly.

In addition, activities that involve boat transport among lakes may introduce non-indigenous plant species into lakes that previously did not have infestations. One of the major modes of introduction is assumed to be boating activities. The no management alternative would provide neither prevention nor remediation efforts other than those required by current laws, which contain minimal provisions intended to stop the spread of invasive species or preserve the desirable features of lakes.

### **7.6.1.2 Applicability to representative target species**

The no-action alternative would not control the three representative target species. Because these representative target species are invasive, lack of intervention will result in continued spread, and concomitant loss of native species.

## **7.7 Alternatives analysis**

As discussed in Sections 2.0 and 3.0 of the SEIS, the uncontrolled growth of nuisance aquatic macrophyte species can substantially impact the natural diversity, ecological function, and recreational uses of a waterbody. However, as noted in Section 7.2, is important that the appropriate control techniques are selected which are appropriate for effectively removing the nuisance species, which minimize potential adverse

ecological effects (or mitigative measures can be included), that are practicable and cost-effective, and which reduces potential societal conflicts that can occur between groups of lake users. Therefore, it is important that the selection of any macrophyte control treatment, including herbicides, be conducted as a result of a well thought-out long-term IAVMP, consistent with NYSDEC guidance (NYSDEC, 2005). Part of the development of the IAVMP is an alternative analysis, which is considered in a series of steps below.

### **7.7.1 Management vs. no management**

The first consideration is the determination that a problem aquatic infestation is occurring within a waterbody of interest. This primary determination is typically the responsibility of a lake association or lake manager (if applicable) and should be based on current aquatic plant surveys and/or monitoring efforts. This information should include the areal size of the waterbody, the location, nature, and acreage of the infestation, the recreational uses of the waterbody, and the presence of sensitive species. This is analogous to the first step in development of a problem statement for the IAVMP (see Section 7.2). If, through these monitoring and information gathering efforts, the infestation of the waterbody by Eurasian watermilfoil or excessive growths of other potential targets species (see Section 2.4) is detected, then a decision to treat the waterbody is made.

Purple loosestrife occurs in a wide range of non-lake habitats as well as lakes. Therefore, while responsibility for control of purple loosestrife may fall to an organized lake or watershed association, it often times falls to other groups or agencies depending on where the infestation occurs. For example, infestations in drainage ditches along a highway may fall within the highway department's purview, while infestations in riparian areas along a major river might fall to individual shoreline property owners, a large watershed association, or local or county government agencies. While state agencies may have established invasive species control programs, such programs most often are intended to work with local groups for implementation.

In some cases, no treatment may be elected for the short-term, with a "wait-and-see" attitude taken, using monitoring efforts to track the size and impact of the infestation until further information, equipment, funding, etc., may be available. For some waterbodies, the no management approach may also be a long-term strategy, based on factors such as size of the waterbody, current and future uses, presence of sensitive receptors, proximity to residential or recreational uses, or other factors. However, for many ponds and lakes with important ecological and/or recreational uses, there is likely to be a decision to manage the macrophytes, particularly if this is an initial infestation of an invasive species and rapid response has the potential to eradicate it. As with any IAVMP, any subsequent decisions regarding macrophyte management approaches must consider all permit requirements.

### **7.7.2 Clearcast® vs. physical treatment alternatives**

As part of the development of a waterbody-specific IAVMP, the potential usefulness of physical treatment alternatives needs to be considered. As identified in Section 7.3., physical treatment alternatives include benthic barriers, dredging, dyes, harvesting, and water level controls. Any initial screening may be based on the scale of potential treatment required or practicable. Smaller scale treatments include installation of benthic barriers and harvesting (variable scale); while the other alternatives (dredging, dyes, water level control) tend to be conducted over a significant portion or the entire waterbody.

Since Clearcast® is anticipated to be used mostly for selective control of Eurasian watermilfoil, waterlily or invasive emergents, several physical treatment alternatives can be easily eliminated from the alternatives analysis. Dredging can be eliminated because it has significant impacts, is very costly, often requires a lengthy permitting process, and low light limitation may not be effective on watermilfoil. Dredging is not appropriate to riparian situations. Similarly, the use of dyes is inappropriate in larger waterbodies since the use of dyes is mostly restricted to small volume waterbodies due to the need to maintain high color concentrations; they may not be able to suppress watermilfoil with light limitation, and could impact other vegetation. Dyes may be appropriate for use in small contained ponds (i.e., ornamental ponds, golf course ponds). Conventional harvesting is not appropriate due to the potential for fragmentation and spreading of Eurasian watermilfoil (Painter, 1988). In areas with a monoculture or near monoculture of Eurasian watermilfoil, harvesting may be



appropriate to control surface canopy and promote recreational uses, but is not effective for reducing plant densities or preventing infestation of other areas. Hydroraking, a modified form of harvesting is sometimes used for water lily control. This method involves removal of both the surface plant biomass and the wood rhizomes (i.e., root stocks) from shallow sediments. If pursued vigorously, this method can temporarily suppress but not eliminate water lily populations.

Physical treatment alternatives that should be considered for control of Eurasian watermilfoil include small-scale harvesting, (hand pulling or diver-assisted removal with suction equipment), benthic barriers, and water level control (Eichler et al., 1991; 1993; 1995). The first two alternatives are potentially useful in the early invasion phase when the size of the infestation is spatially limited. These alternatives are often considered when formulating a rapid response to aquatic invasives. Both are labor-intensive and need significant involvement of either trained volunteers or professional lake management firms over a significant period of the growing season.

Water level control has been shown to be effective against Eurasian watermilfoil and some floating leaved species (see Table 7-2) but is dependent on the ability of lake managers to draw the lake down to the areas and depths where the milfoil is present. This may be limited by the lack of an impounding structure, the bottom elevation of the existing outlet or drainage pipe, or secondary restrictions within the lake to free drainage (e.g., internal pooling areas). In addition, the presence of sensitive plant or wildlife species or significant fishery resources in the waterbody or in adjacent wetlands may restrict the level, timing or frequency of drawdown permitted. Therefore, water level control may be considered as a tool for use in an IAVMP for suppression or general control of Eurasian watermilfoil or waterlily, but will rarely be sufficient as a stand-alone option. It is not generally considered as a rapid response technique for elimination of any early infestation.

Control of purple loosestrife by physical methods has generally proven problematic. Experience has shown that many mechanical and cultural methods (water level management, burning, manual removal, and cutting) have been tried and have proven ineffective in controlling purple loosestrife and are largely impractical on a large scale (MA CZM, 2006). In many cases mechanical methods and controlled burns have resulted in the promotion of further spread of the loosestrife (CDFA, 2006). For early infestations, small patches of young plants can be removed by hand with little effort, but care needs to be taken to remove all root fragments. It is necessary to dispose of plants and roots by drying and burning or by composting in an enclosed area, and important to take care to prevent further seed spread from clothing or equipment during the removal process. It is difficult to remove all of the roots in a single digging, so monitoring of the infestation area for several growing seasons is recommended to ensure that purple loosestrife has not regrown from roots or seed. In summary, physical control of purple loosestrife is possible for small isolated primary infestation areas, but is largely impractical at larger scales (> 0.5 acres).

### 7.7.3 Clearcast® vs. biological treatment alternatives

As part of the development of a waterbody-specific IAVMP, the potential usefulness of biological treatment alternatives needs to be considered. As identified in Section 7.5, biological treatment alternatives include herbivorous fish and invertebrates. For selective control of Eurasian watermilfoil, grass carp do not provide a good alternative treatment because they tend to be general grazers of available macrophytes (see Section 7.5.1) with no specialized preference for the watermilfoil. The use of grass carp would only provide an acceptable alternative in lakes where it was known that the carp would prefer to feed on Eurasian watermilfoil rather than other resident macrophytes. It is generally accepted that grass carp can not be effectively used for waterlily management (Washington State DOE website).

In contrast, the herbivorous weevils (see Section 7.5.2), have high specificity for Eurasian watermilfoil. However, the effectiveness of these introduced invertebrates is still largely uncertain, with localized success reported in some locales and little or no effect in others. Moreover, keeping weevil populations at levels capable of controlling watermilfoil populations has been problematic. There has been a well-documented rapid reduction and long-term suppression of Eurasian watermilfoil by larvae of the aquatic moth, *A. ephemera* in Cayuga Lake. Further investigations on the applicability of enhancing ambient populations by stocking of

larvae to create a quicker reduction response are being conducted in several other New York lakes (R. Johnson, pers. comm.) , but a full evaluation looking at results over several years is still not yet available. At the current time, Clearcast® would likely be preferred over herbivorous macroinvertebrates in a rapid response plan due to its greater reliability and replicability of macrophyte control. Further investigation and studies with herbivorous weevils in the Northeast may be required to see whether they are an effective long-term solution and/or should be incorporated into an IAVMP. Some limited research on biological control by aphids on waterlily has been conducted but no specific biological agent has been identified (Washington State DOE website).

As discussed in Section 7.5.2, the most likely biological treatment alternative for control of purple loosestrife is the mass introduction of *Galerucella* sp. beetles. Release of these beetles, possibly in combination with the root-eating weevil (*H. transversovittatus*) or the flower-eating weevil (*N. marmoratus*), may prove to be a very effective means of control. While results from early release sites indicate that successful suppression of purple loosestrife can be achieved, it is still not predictable which replacement communities will develop in their place. At several release locations in New York, a resurgence of cattails and other wetland plants has been observed, but this is not always the case as other invasives (*Phragmites australis*, *Phalaris arundinacea*) may expand (Blossey, 2002). Studies are being made to investigate whether a combination of biocontrol coupled with physical means (fire, disking, flooding, mowing, etc) may be useful in accelerating the return of nature plant communities. Nationwide, purple loosestrife biocontrol programs are conducting standardized long-term monitoring programs to follow and evaluate the effectiveness of releases and the secondary redevelopment of wetland plant populations (Blossey, 2002). Investigations are also on-going regarding changes in animal communities (insects, amphibians, birds) associated with changes in purple loosestrife populations. At the current time, Clearcast® would be a viable alternative to herbivorous macroinvertebrates in a rapid response plan due to its greater reliability and replicability of macrophyte control.

#### **7.7.4 Clearcast® vs. other chemical treatment alternatives**

As discussed earlier, aquatic herbicides can be very effective in controlling target plant species in lakes. Herbicides have advantages over most techniques when getting a problem species under control is an immediate goal. No other technique can address infestations over a wider area faster and at lower cost. Herbicides may also be particularly applicable in cases of recent invasions by non-indigenous plants, as more complete control can often be exercised with herbicides before invasive species become widespread. Clearcast® is anticipated to be used mostly in two applications: that for control of a few submergent species, most notably Eurasian watermilfoil, and that for control of a substantial number of floating leaf species or riparian invasive species. Each of these applications and alternative chemical treatment options is considered below.

##### **7.7.4.1 Comparison to other herbicides for submergent vegetation control**

Comparison of the effectiveness of the six aquatic herbicides registered in New York (Table 7-3) indicates that five are considered to have high effectiveness with *M. spicatum* – diquat, 2,4-D, endothall, fluridone, and triclopyr (ENSR, 2007). However, diquat and endothall are considered general purpose, broad-spectrum contact herbicides which are used when removal of most aquatic vegetation is desired and not selective for specific control of watermilfoil. In many cases, this broad-spectrum toxicity may limit application of diquat and endothall to spot treatments of limited area. In contrast, Clearcast® is more effective against Eurasian watermilfoil and other select species and has little to no effect on other common native species (e.g., *Ceratophyllum*, *Chara*, *Utricularia*, *Vallisneria*, etc). Therefore, these two aquatic herbicides would not be considered good alternatives to Clearcast® for selective treatment of Eurasian watermilfoil.

Clearcast® was therefore compared to the three herbicides more targeted for specific control of Eurasian watermilfoil: 2, 4-D, fluridone and triclopyr. When comparing these three herbicides, the factors which would favor selection of Clearcast® over 2,4-D and fluridone include: selectivity, requirement of a short contact time, short half-life, and low toxicity. Clearcast® may be preferred over triclopyr due to species selectivity and

flexibility to treat species in more than one media or application type, but these two herbicides provide a similar function with regard to Eurasian watermilfoil.

Both fluridone and 2,4-D are systemic herbicides that are effective against Eurasian watermilfoil, but may also cause collateral damage to other aquatic macrophytes (particularly at higher doses). For fluridone, this is typically avoided by maintaining a low effective concentration (high enough to impact milfoil but not high enough to impact many native species) for a lengthy period of time. Maintenance of the effective concentration may be problematic if the area to be treated is small, there is potential for dispersion and dilution (e.g., rapid flushing time of the waterbody) and due to unexpected meteorological events. Additionally, there is overlapping susceptibility among target and non-target species; getting the desired level of impact with fluridone without damaging non-target species can be difficult. In contrast, rapid uptake and short exposure requirement (hours to days) for effective macrophyte control with Clearcast® is a useful attribute for selecting an herbicide for treating a waterbody where water quality or hydrology may be dynamic (e.g., impoundment with significant stormwater inputs), and the selectivity appears greater, both in terms of species impacts and the ability to localize treatment.

Due to the rapid breakdown (i.e., short half-life for imazamox under photolytic conditions), lack of significant bioaccumulation, and low toxicity of imazamox and its major metabolites (see Section 7.4), Clearcast® is considered to pose very little risk of adverse risk to fish and higher wildlife receptors. Due to its selectivity and short-half life, there would be low concern regarding potential overexposure of the vegetation. The low toxicity of Clearcast® would be a useful attribute when selecting an aquatic herbicide where there are concerns with potential transport of treated water downstream to habitats of sensitive receptors.

Clearcast® may be used as the primary substitute for 2,4-D or diquat due to use restrictions which prohibit the use of these chemicals in waters with depth >6 ft (see applicable restrictions under Conservation Law 15-0313 Part 327 Pesticide Control Regulations). In addition, the selective properties of imazamox may result in Clearcast® as the primary tool in certain entire littoral specific treatment programs and/or as part of a IAVMP; for example, as a follow-up "spot" management (e.g., < 4 acres) of Eurasian watermilfoil following a lakewide fluridone management program.

Clearcast® provides an alternative to triclopyr in its selectivity among various plant species and its flexibility to be used either as a foliar or water-based application. It is more effective with regard to selected floating-leaf species such as white waterlily, water chestnut, and watershield (Table 7-3). Since commercial applications are not yet widespread, it is not possible to compare cost-effectiveness at this stage.

#### **7.7.4.2 Comparison to other herbicides for emergent and floating leaf vegetation control**

Careful use of aquatic herbicide has been reported to be an effective, efficient, and a less destructive (compared with physical techniques) means of removing large purple loosestrife stands in California (CDFA, 2006). Chemical control of purple loosestrife may be accomplished by application of glyphosate or imazamox. Glyphosate and triclopyr are the two currently- approved herbicides in New York shown to have high effectiveness for this species (see Table 7-3). Control of small purple loosestrife stands is reported by spot treatments with glyphosate commercial products (e.g., Rodeo) typically applied at a 1-1.5 % solution, during early to late bloom (CDFA, 2006). Clearcast® also provides an alternative, effective chemical control agent for purple loosestrife. However, as noted in Section 7.4.3, glyphosate is a broad spectrum (i.e., non-selective) herbicide which would potentially affect other emergent species. Application of Clearcast® provides selective control of broadleaf plants with minimal impact to many submerged species, and could be used for spot treatment of smaller loosestrife stands, particularly in areas which overlap aquatic waterbodies. Glyphosate can also be used for control of white and yellow waterlily, but is not effective against water chestnut or water shield (Table 7-3). Clearcast® is more effective with these species.

As noted earlier, watershed and waterbody specific characteristics, aquatic and/or wetland plant community coverage and composition, water uses and stakeholders' expectations and preferences will need to be considered when selecting any aquatic herbicide as part of an integrated aquatic vegetation management

plan. Finally, the strategic use of herbicides with different modes of action to reduce the potential selection for plant resistance to any specific herbicide is recommended to ensure long-term effectiveness of aquatic vegetation control programs.

## 8.0 Mitigation measures to minimize environmental and health impacts from Clearcast®

Mitigation measures describe guidelines or procedures used to mitigate or lessen the potential for impacts from the use of Clearcast® in the waters of New York State. While no impacts to humans are expected from the use of Clearcast® (see Section 6.0), there is the potential for some ecological effects (see Section 5.0). The mitigation measures described in this section will reduce, or mitigate that potential for ecological effects, without reducing the efficacy of the product.

### 8.1 Use controls

As of April 7, 1993, all pesticides labeled for use in aquatic settings were classified as restricted use products by regulation of the NYSDEC. Under this regulation, 6 NYCRR Parts 325 and 326, the use of aquatic pesticides is limited to persons privately certified, commercially certified in Category 5, or possessing a purchase permit for the specific application that is proposed. Additionally, only those persons who are certified applicators, commercial permit holders, or have a purchase permit may purchase aquatic use pesticides.

### 8.2 Label identification

The herbicide label is a USEPA required document describing the legal use of the registered product. Registrants are allowed to provide part of the label text in the form of a booklet or other "pull off" type labeling, when it is not feasible or possible to literally "fit" the entire label on the container [40 CFR 156.10.] Additional information regarding instructions for application in New York State would be listed separately on a NYSDEC 24(c) Special Local Need (SLN) Registration when issued. It is noted that BASF will also be looking for SLN registration for a granular form of Clearcast. The New York State and USEPA approved labels for Clearcast® are presented in Appendix A.

For the buyer, the label is the main source of information about how to use the product safely and legally. In addition, the label provides information for the user regarding any safety measures needed for appropriate use of the product (i.e., personal protective equipment, acceptable application methods).

#### 8.2.1 Label components

Final printed labels or labeling must be filed and accepted by the USEPA prior to product registration. In addition, products must be registered in New York State prior to their sale, use, offer for sale, and/or distribution in New York State. The following information is required by the USEPA to appear on the herbicide label:

- Product name;
- Ingredient statement including name and the percentage of each active and inert ingredient;
- "Keep Out of Reach of Children" statement;
- Signal word corresponding to appropriate USEPA toxicity categories;
- First Aid statement;
- "Skull & crossbones" symbol & the word "POISON" if the product is in Toxicity Category I;
- Net contents/Net weight;
- EPA registration and establishment numbers;
- Company name and address;

- Applicable precautionary statements related to hazards to humans and domestic animals and environmental, physical or chemical hazards;
- Directions for use;
- Storage and disposal;
- Warranty statement; and
- Worker protection labeling.

### 8.2.2 Label instructions

This section of the label provides instructions to the user on how to use the product, and identifies the pest(s) to be controlled, the application sites, application rates and any required application equipment. Label use precautions and directions for aquatic applications of Clearcast® label include the following:

- Obtain required state or local permits prior to application.
- Do not apply in a manner that adversely affects federally-listed endangered and threatened species.
- Limitations on the specific uses of irrigation waters/system after application of the product.
  - Do not use Clearcast®-treated water to irrigate greenhouse, nurseries, or hydroponics.
  - Do not use treated water for irrigation for 24 hours after Clearcast® application or until imazamox level is determined to be < 50 ppb by laboratory assay.
  - Do not plant sugar beets, onions, potatoes of certain canola strains in land that has been previously irrigated with Clearcast®-treated waters.
  - After application of Clearcast® to dry irrigation ditches/canals, the initial flush of water during recharge must not be used for irrigation purposes.
- There are no restrictions on swimming, fishing, domestic use, livestock consumption or use for agricultural in waters from the treatment area.
- For drinking water restrictions see section below.

### 8.3 Relationship to the NYS drinking water standard

The Clearcast® USEPA label indicates that Clearcast® may be used in potable water sources at a water concentration up to 500 ppb at distances of ¼ mile or greater from active intake. Clearcast® may also be used in potable water sources within ¼ mile from active intake, as long as water concentration does not exceed 50 ppb. If water concentrations exceed 50 ppb, the USEPA label recommends that potable water intakes be turned off until the imazamox concentration in the water is determined to be 50 ppb or less by laboratory analysis. As indicated in Section 6.2, the drinking water standard established in New York State for organic chemical compounds not specifically identified in the water quality standards is also 50 ppb.

### 8.4 Spill control

Care should be taken to use Clearcast® properly and in accordance with the approved labels. Any leaks or spills should be promptly addressed. Liquid spills on an impervious surface should be cleaned up using absorbent materials and disposed of as waste. Liquid spills on soil may be handled by removal of the affected soil, and disposal at an approved waste disposal facility. Leaking containers should be separated from non-leaking containers and either the container or its contents emptied into another properly labeled container.

## 8.5 Permitting and mitigation considerations

The State of New York regulates activities potentially affecting water resources and wetlands through several programs and multiple regulatory agencies. Section 15.0313(4) of the New York Environmental Conservation Law (ECL) requires a permit for the application of pesticides to any surface waters greater than one acre, or with an outlet to other surface waters of New York State. Pertinent to the application of aquatic herbicides for the control of invasive species are the Freshwater Wetland Program and Coastal Wetlands Program, both administered by NYSDEC.

Until recently, the Clean Water Act (CWA) and other programs administered by the U.S. Army Corps of Engineers did not directly regulate the application of herbicides for invasive species control. Consequently, the NYSDEC Freshwater and Coastal Wetlands Programs formerly represented the primary agency issuing permits for the use of herbicides and pesticides potentially affecting wetland areas. These permits and the associated conditions also represent the means by which site-specific characteristics and applicable mitigation measures can be incorporated.

The New York Freshwater Wetlands Act (Article 24 of ECL) provides the NYSDEC with the ability to regulate and issue permits for activities potentially affecting wetlands. Generally, this program exerts regulation over wetland areas that are mapped by the state (note: currently 12.4 acres or 5 hectares, but eventually to be reduced to 7.4 acres or 3 hectares as state wetland mapping is completed) or greater in size. Article 25 of New York Conservation Law represents the state's tidal wetland permit program. Similar to the freshwater wetland program, the state actively maps jurisdictional tidal wetlands, though there is no prescribed size limit for mapping and regulation.

Use of herbicides for invasive species control within wetlands, whether fresh or tidal, will likely require a permit from the NYSDEC. Such a permit is obtained through the general provisions of New York's Uniform Procedures Act (UPA), which allows for joint review among any state or federal agencies reviewing or commenting upon such applications in a timely manner. Permit applications must provide a clear description of the project purpose and details of the proposed activities, practicable alternatives to the activity, plans and specifications as needed, as well as proof of compliance (if applicable) with the state's Environmental Quality Review Act (SEQR) and Historic Preservation Act (SHPA). There are no applicable exemptions for either proactive invasive species control or filings conducted by government agencies under the freshwater or coastal wetland programs. New York State Environmental Conservation Law section 9-1503 provides protection for rare plant species. It is important to note that the application of herbicides to areas known to harbor rare plants is strictly controlled and may be subject to a long list of specific conditions (or, in some cases, may be simply prohibited). As noted in Section 5.1.7, information on the location and status of known rare plants may be obtained through the NYSDEC's Natural Heritage Program.

As part of the permitting activities identified above, application may be subject to limitations, constraints or modifications through which any adverse impacts may be reduced or eliminated by incorporation of mitigating measures into the permit provisions. The following measures may be considered on a site-specific basis as to their ability to further reduce, or mitigate any potential for environmental effects, without reducing the efficacy of the product.

### 8.5.1 Timing

When the aquatic plant management objective is to control Eurasian watermilfoil, while minimizing impacts to other aquatic macrophytes, Clearcast® may be used early in the season and throughout the active growth stage of target species. As was discussed in Section 3.4.1, Eurasian watermilfoil is essentially evergreen and begins to grow rapidly at the beginning of the growing season. This enables this plant to often develop significant biomass before native macrophyte species begin growing (Smith and Barko, 1990). The use of Clearcast® early in the growing season would target Eurasian watermilfoil, while minimizing the impact on other aquatic vegetation. Multiple applications may be made during the annual growth cycle to maintain desired vegetation control level. The selective nature of imazamox allows the resource manager to use

Clearcast® during mid-late season treatment programs with minimal impact to those less susceptible plants established in the treatment area.

For control of purple loosestrife in wetland areas, foliar application should be made in the early-mid growing season when the plant development is at the bud to mid-flowering stage of growth. It is recommended that follow-up applications of Clearcast® be conducted in the following year on any regrowth to achieve increased control of this species. Application during the early part of the growing season may encourage the development of suppressed native species.

### **8.5.2 Application techniques**

For removal of Eurasian watermilfoil, it is suggested that Clearcast® be uniformly applied across the entire waterbody, at the application rate of 10 or more gallons of diluted herbicide per acre in the area to be treated. Applicators should follow an application pattern that minimizes concentration of the product in local areas. In most cases for selective treatment of Eurasian watermilfoil, subsurface application is recommended. The maximum rate of application is 500 ppb (173 fluid ounces per acre foot). Foliar spot treatments of up to 5% Clearcast® may be applied, including under drawdown situation to provide post-emergence or pre-emergence control/suppression of aquatic vegetation. Under surface matted conditions, it is recommended that Clearcast® should be injected below the water surface, as practicable.

Purple loosestrife can be controlled with foliar applications of Clearcast®. Clearcast® may be applied aerially using fixed wing and helicopter. For broadcast applications, a use rate of 2 quarts of Clearcast® per acre is recommended. For further instructions and application details refer to Appendix A.

For the treatment of wetland species, injection and cut stump applications may be made using up to 100% Clearcast® by volume. These application techniques are good methods to deliver the active ingredient only to the target plant, helping to minimize unintended impacts on other vegetation.

### **8.5.3 Consideration of hydrologic setting / mixing regime**

When making lake-wide treatments it is recommended that application rates, calculated as ppb of imazamox, are based only on the water volume in which mixing is expected to occur. Rates should be selected according to the rate chart provided in the label as specified for a particular concentration and water depth and adjusted for mixing regime (see Appendix A).

For thermally stratified waterbodies, the application rate calculations should be based on the water depth of the epilimnion above any deep water areas, but it should not take into account the waters below the metalimnion or thermocline. This caution is necessary because the stratified conditions could effectively concentrate the Clearcast® in the upper waters (or delay diffusion into the hypolimnion sufficiently long that the product is typically biodegraded). In non-stratified conditions, the entire depth of the water column should be considered for the application rate calculations. A table indicating the proper volume of Clearcast to use as a function of treatment surface area and water depth is provided in the federal label (see Appendix A).

Adjustments to application rates will also need to be made for rapidly-flushed waterbodies (e.g., run-of-river impoundments, rivers, etc.). These application adjustments to flushing should be made on a waterbody-specific basis. The herbicide concentrations should be adjusted using estimates of water exchange or, in the case of a rapidly flushed waterbody, to consider the use of multiple applications (not to exceed total of 500 ppb). If the water exchange is too rapid, the applicator may wish to consider alternative means to control macrophytes or delay treatment until flushing of the waterbody slows seasonally or may be temporarily halted (e.g., installing flashboards at a dam) until treatment is completed. This last option should only be tried following careful consideration of related effects (e.g., flooding, downstream effects, etc).



## 9.0 Unavoidable environmental impacts if use of Clearcast® is implemented

The use of Clearcast® has been evaluated during the federal registration process and within this SEIS for various impacts to target plants and non-target organisms in an aquatic setting. There are several unavoidable impacts that will occur when Clearcast® is used in the waters of NYS to manage unwanted macrophytes such as Eurasian watermilfoil, white water lily, or purple loosestrife. It is important to note that the mitigation approaches described in Section 8.0 will lessen the magnitude and extent of these impacts. Those impacts are:

- **Impact to habitat** - When Clearcast® is introduced into a waterbody, it is intended to result in the death of the target macrophytes. Once these target macrophytes have dropped out of the water column, there may be a potential for decreased dissolved oxygen and impacts to aquatic wildlife. There will be a period of time before the native non-target macrophytes reestablish themselves in the vacant niches. During that period of time, before the non-target species reestablish themselves, the aquatic macrophyte community will be reduced in size and any associated habitat function will be reduced.
- **Impacts to non-target species** - A review of the literature indicates that there are some native macrophytes (e.g., native *Potamogeton* species) which could be impacted to some extent by the use of imazamox in a waterbody. However, many common native species (*Ceratophyllum*, *Chara*, *Utricularia*, *Vallisneria*) are less affected. The literature indicates that a plant community composed of native plant species will initiate reestablishment during the season following herbicide use.
- **Possible reinfestation** - In areas of significant water flow, such as lake inlets, Eurasian watermilfoil and other target plants may not be sufficiently controlled due to the dilution of applied Clearcast® with untreated water or rapid product biodegradation unless application rates and possible sequential treatments take this into account. Even after a successful application, reinfestation by Eurasian watermilfoil, white waterlily, or purple loosestrife may occur within one to two growing seasons, dependent on the level of control reached in the original application and the proximity of other, untreated populations. This may necessitate the re-application of Clearcast® and/or utilization of alternative means of controlling Eurasian watermilfoil, white waterlily, or purple loosestrife in those areas.

## 10.0 References

Adams, M. S., and R. T. Prentki. 1982. Biology, metabolism and functions of littoral submersed weed beds of Lake Ingra, Wisconsin, U.S.A.: a summary and review. Arch. Hydrobiol./Suppl. 62:333-409.

Aiken, S.G., P.R. Newroth, and I. Wiley. 1979. The biology of aquatic weeds. 34. *Myriophyllum spicatum* L. Can. J. Plant Sci. 59:201-215.

Andrews, S.J. 1989 Results of a Sonar herbicide treatment and fisheries survey at Dogwood Lake. Fisheries Section Indiana Department of Natural Resources, Indianapolis, Indiana.

Antunes-Kenyon, S.E., and G. Kennedy, 2004. A Review of the Toxicity and Environmental Fate of Triclopyr. Submitted to the Massachusetts Pesticide Board Subcommittee. Massachusetts Department of Agricultural Resources. November 12, 2004.

Archer, R.J. and J.A. Shaughnessy. 1963. Water Quality in the Delaware River Basin. U.S. Geological Survey.

Barko, J.W. and R.M. Smart. 1980. Mobilization of sediment phosphorus by submersed freshwater macrophytes. Freshwater Biol. 10:229-238.

Barko, J.W. and R.M. Smart. 1981. Sediment-based nutrition of submersed macrophytes. Aquatic Bot. 10:339-352.

Barko, J.W., C.S. Smith and P.A. Chambers. 1994. Perspectives on submersed macrophyte invasions and declines. Lake and Reservoir Management 10(1):1-3.

BASF Corporation. 2005a. Clearcast Supplemental Labeling Notice. (Florida only) For the control of Hydrilla (*Hydrilla verticillata*) in freshwater ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, streams, rivers, and other slow moving or quiescent bodies of water. EPA Reg. No 241-379. EPA SLN NO.: FL-060001.

BASF Corporation. 2005b. Imazamox: Screening Level Ecological Risk Assessment (SLERA) for Wildlife, Aquatic Organisms, Nontarget Plants, and Nontarget Insects. BASF Doc ID# 2005/7000811. Agricultural Products Division, Research Triangle Park, NC. 23 pp.

BASF Corporation. 2005c. Imazamox: Higher Tier Assessment for the Risk to Aquatic Plants. BASF Doc ID# 2005/7000812. Agricultural Products Division, Research Triangle Park, NC. 24 pp.

Bates, A.L., E. R. Burns, and D.H. Webb. 1985. Eurasian Watermilfoil (*Myriophyllum spicatum* L.) in the Tennessee-Valley: an update on the biology and control. Pages 104-115 in L.W.J. Anderson, editor. Proceedings of the first international symposium on watermilfoil (*Myriophyllum spicatum*) and related Haloragaceae species. Aquatic Plant Management Society, Washington D.C.

Benson, G. 2002. Control of plants with grass carp in Ball Pond CT. Presented at the 2002 NECNALMS conference, Springfield, MA. Benson Environmental, CT.

Berrill, M., S. Bertram, L. McGillivray, M. Kolohon, and B. Pauli. 1994. Effects of Low Concentrations of Forest-Use Pesticides on Frog Embryos and Tadpoles. Environ.Toxicol.Chem. 13(4):657-664.

Blossey, B. 2002. "Purple loosestrife" In Van Driesche, R. et al., Biological Control of Invasive Plants in Eastern United States, USDA Forest Service Publication FHTET-2002-04, 413 pp.

- Boylen C.W. and R.B. Sheldon. 1976. Submergent macrophytes: Growth under winter ice cover. *Science*:194:841-842.
- Boylen, C. L. Eichler and J. Sutherland. 1996. Physical control of Eurasian watermilfoil in an oligotrophic lake. *Hydrobiologia* 340: 213-218.
- Bratager, M., W. Cromwell, S. Enger, G. Montz, D. Perleberg, W. J. Rendall, L. Skinner, C. H. Welling, and D. Wright. 1996. Harmful Exotic Species of Aquatic Plants and Wild Animals in Minnesota. Annual Report. Minnesota Department of Natural Resources, St. Paul, MN. 99 pp.
- Brown, C.L., T.P. Poe, J.R. French, and D.W. Schlosser. 1988. Relationships of phytomacrofauna to surface area in naturally occurring macrophyte stands. *J. N. Am. Benthol. Soc.* 7:129-139.
- California Department of Food and Agriculture. 2006. Purple Loosestrife control website.
- Canfield, D.E., K. Langeland, S. Linda and W. Haller. 1985. Relations between water transparency and maximum depth of macrophyte colonization in lakes. *J. Aquat. Plant Manage.* 23:25-28.
- Coalition of Lakes Against Milfoil (COLAM). 1992. Eurasian Milfoil. Lake George, New York.
- Coffey, B.T. and C.D. McNabb. 1974. Eurasian water-milfoil in Michigan. *Michigan Botanist.* 13:159-165.
- Cooke, G.D., E.B. Welch, S.A. Peterson and P. R. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. Second Edition. Lewis Publishers, Boca Raton, FL. 548 pp.
- Couch, R., and E. Nelson. 1985. *Myriophyllum spicatum* in North America. Pp. 8-18 in L.W.J. Anderson (ed.). First International Symposium Watermilfoil and Related Haloragaceae. Species. 23-24 July 1985, Vancouver, B.C. Aquatic Plant Management Society, Vicksburg, MS.
- Crain, L.J. 1975. Chemical Quality of Groundwater in The Western Oswego River Basin, New York. U.S. Geological Survey.
- Creed, R., and S. Sheldon. 1994. The effect of two herbivorous insect larvae on Eurasian watermilfoil. *J. Aquat. Plant Manage.* 32:21-26.
- Cronin, G., K. Wissing, and D. Lodge. 1998. Comparative feeding selectivity of herbivorous insects on water lilies: aquatic vs. semi-terrestrial insects and submersed vs. floating leaves. *Freshwater Biology* 39(2):243 – 257.
- Crow, G.E. and C.B. Hellquist. 2000. Aquatic and Wetland Plants of Northeastern North America. Vol. I and II. Univ. Wisconsin Press, Madison, WI.
- Cyanamid. 1994a. Imazamox Bluegill Sunfish Toxicity Test. February 1994.
- Cyanamid. 1994b. Imazamox Mallard Duck Toxicity Test. March 1994.
- Cyanamid. 1995. Biotransformations of Imazamox under Aerobic Aquatic Conditions. June 1995
- Cyanamid. 1997. Degradation and Metabolism in Water Sediment Systems. September 1997.
- Daubenmire, R. 1968. Plant Communities. Harper & Row, Publishers, New York.

- Dionne, M. and C.L. Folt. 1991. An experimental analysis of macrophyte growth forms as fish foraging habitat. *Can. J. Fish. Aquat. Sci.* 48:123-131.
- Dorn, N.J., G. Cronin, D.M. Lodge. 2001. Feeding preferences and performance of an aquatic lepidopteran on macrophytes: plant hosts as food and habitat. *Oecologia* 128: 406-415.
- Doyle, R. D. and R. M. Smart. 1993. Potential use of native aquatic plants for long-term control of problem aquatic plants in Gunter'sville Reservoir, Alabama. Report 1. Establishing native plants, Miscellaneous Paper A-95-3, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Eichler, L.W. and C.W. Boylen. 2006. Aquatic Vegetation of Burr Pond and Lake Horton. Darrin Fresh Water Institute. Bolton Landing, NY. September 2006. 33 pp.
- Eichler, L.W., R.T. Bombard, J.W. Sutherland, and C.W. Boylen. 1991. Report on Hand Harvesting of Eurasian Watermilfoil in Lake George, New York, January 1989-December 1990. Rensselaer Fresh Water Institute Report #91-7, Rensselaer Polytechnic Institute, Troy, NY 27pp.
- Eichler, L.W., R.T. Bombard, J.W. Sutherland, and C.W. Boylen. 1993. Suction harvesting of Eurasian watermilfoil and its effect on native plant communities. *J. Aquat. Plant Manage.* 31:144-148.
- Eichler, L.W. and R. Bombard, 1994. Aquatic Plant Identification Program 1993 Annual Report. Rensselaer Fresh Water Institute Report. Rensselaer Polytechnic Institute, Troy, NY.
- Eichler, L.W., R.T. Bombard, J.W. Sutherland, and C.W. Boylen. 1995. Recolonization of the littoral zone by macrophytes following the removal of benthic barrier material. *J. Aquat. Plant Manage.* 33:51-54.
- Engel, S. 1995. Eurasian watermilfoil as a fishery management tool. *Fisheries* 20(3):20-27.
- ENSR Corporation. 2007. Use of Aquatic Herbicide Triclopyr Renovate in the State of New York. Supplemental Environmental Impact Statement. Final Report. Westford, MA. August 2007.
- Fairbrothers, D.E. and E.T. Moul. 1965. Part I Ecology and Identification, in *Aquatic Vegetation of New Jersey*, Extension Bulletin 382. Extension Service, College of Agriculture, Rutgers - The State University, New Brunswick, New Jersey.
- Fassett, N.C. 1966. *A Manual of Aquatic Plants*. The University of Wisconsin Press. Madison, WI. 405pp.
- Gangstad, E.O. 1986. *Freshwater Vegetation Management*. Thomas Publications, Fresno, CA. 380 pp.
- Giese, G.L. and W.A. Hobbs, Jr. 1970. Water Resources of the Champlain-Upper Hudson Basins in New York State. U.S. Geological Survey.
- Giesy, J.P. and L.E. Tessier. 1979. Distribution potential of *Myriophyllum spicatum* (Angiospermae, Haloragaceae) in soft-water systems. *Arch. Hydrobiol.* 85:437-447.
- Gotceitas, V. and P. Colgan. 1987. Selection between densities of artificial vegetation by young bluegills avoiding predation. *Trans. Am. Fish. Soc.* 116:40-49.
- Gross, E.M., R.L. Johnson, and N.G. Hairston, Jr. 2001. Experimental evidence for changes in submersed macrophyte species composition caused by the herbivore *Acentria ephemerella* (Lepidoptera). *Oecologia* 127:105-114.

Hacker, S.D. and R.S. Steneck. 1990. Habitat architecture and the abundance and body size-dependent habitat selection of a phytal amphipod. *Ecology* 71:2269-2285.

Hartleb, C.F., J.D. Madsen, and C.W. Boylen. 1993. Environmental factors affecting seed germination in *Myriophyllum spicatum* L. *Aquatic Botany* 45:15-25.

Hellquist, C.B. 1993. Taxonomic considerations in aquatic vegetation assessments. *Lake and Reservoir Management* 7:125-129.

D. Helsel, D. Gerber, and S. Engel. 1996. Comparing Spring Treatments of 2,4-D with Bottom Fabrics to Control a New Infestation of Eurasian Watermilfoil. *J. Aquat. Plant Manage.* 34: 68-71.

Holdren, C., W. Jones, and J. Taggart. 2001. Managing Lakes and Reservoirs. N. Am. Lake Manage. Soc. and Terrene Inst. in coop. with Off. Water Assess. Watershed Prot. Div. U.S. Environ. Prot. Agency, Madison, WI.

Honnell D, Madsen JD, Smart RM. 1992. Effects of aquatic plants on water quality in pond ecosystems. *In: Proceedings, 26 Annual Meeting, Aquatic Plant Control Research Program, Report A-92-2. US Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.*

Horne, A.J. and C.R. Goldman. 1994. *Limnology*, 2nd edition. McGraw-Hill, Inc. New York, NY. 576 pp.

Hoyer, M.V. and D.E. Canfield (eds). 1997. *Aquatic Plant Management in Lakes and Reservoirs*. NALMS/APMS/USEPA, Washington, DC.

Johnson, R. L., E.M. Gross, and N. G. Hairston, Jr. 1998. Decline of the invasive submersed macrophyte *Myriophyllum spicatum* (Halaragaceae) associated with herbivory by larvae of *Acentria ephemerella* (Lepidoptera). *Aquatic Ecology* 31:272-282.

Johnson, R. L., P. J. Van Dusen, J. A. Toner, and N. G. Hairston, Jr. 2000. Eurasian Watermilfoil Biomass Associated with Insect Herbivores in New York. *Journal of Aquatic Plant Management* 38:82-88.

Johnson, R. L., and B. Blossey. 2002. "Eurasian watermilfoil" In Van Driesche, R. et al., *Biological Control of Invasive Plants in Eastern United States*, USDA Forest Service Publication FHTET-2002-04, 413 pp.

Johnson, R. L., 2006. Personal communication of 12/20/06.

Kalff, J. 2002. *Limnology*. Prentice Hall, Upper Saddle River, NJ.

Keast, A. 1984. The introduced aquatic macrophyte, *Myriophyllum spicatum*, as habitat for fish and their invertebrate prey. *Can. J.* 2001. 62:1289-1303.

Kershner, M.W. and D.M. Lodge. 1995. Effects of littoral habitat and fish predation on the distribution of an exotic crayfish, *Orconectes rusticus*. *Journal of the North American Benthological Society* 14(3):414-422.

Kilgore, K. J., R.P. Morgan and N.B. Rybicki. 1989. Seasonal and temporal distribution and abundance of fishes association with submersed aquatic plants. *North Amer. J. Fish Manage.* 9:101-111.

Kimbel, J.C. 1982. Factors influencing potential intralake colonization by *Myriophyllum spicatum* L. *Aquatic Botany* 14:295-307.

King County Noxious Weed Program (KCNWP). 2005. Purple Loosestrife Best Management Practices. King County Noxious Weed Program, March 2005. [http://dnr.metrokc.gov/wlr/lands/weeds/pdf/purple\\_loosestrife-control.pdf](http://dnr.metrokc.gov/wlr/lands/weeds/pdf/purple_loosestrife-control.pdf)

Kishbaugh, S., J. Bloomfield, and A. Saltman. 1990. Diet For a Small Lake. New York Department of Environmental Conservation and the Federation of Lake Associations, Inc. Albany and Rochester, NY.

Kiviat, E. 1978. Vertebrate use of muskrat lodges and burrows. *Estuaries*, 1, 196–200.

Les, D. 2002. Non-indigenous aquatic plants: A garden of earthly delight? *LakeLine* 22 (2):20-24.

Lillie, R.A. and J. Budd. 1992. Habitat architecture of *Myriophyllum spicatum* L. as an index to habitat quality for fish and macroinvertebrates. *J. Fresh. Eco.* 7:113-125.

Lyman, L. and L. Eichler. 2005. Success and Limits of Hand Harvesting, Suction Harvesting, and Benthic Barriers in Lake George, NY. Presentation at the Northeast Aquatic Plant Management Society annual meeting, Saratoga Springs.

Madsen, J.D. 1994. Invasions and declines of submersed macrophytes in Lake George and other Adirondack lakes. *Lake and Reservoir Management*, 10(1):19-23.

Madsen, J. D. 1998. Predicting invasion success of Eurasian watermilfoil. *Journal of Aquatic Plant Management*. 36:28-32.

Madsen, J.D., L.W. Eichler, and C.W. Boylen. 1988. Vegetative spread of Eurasian watermilfoil in Lake George, New York. *J. Aquat. Plant Manage.* 26:47-50.

Madsen, J.D., C.F. Hartleb, and C.W. Boylen. 1991a. Photosynthetic characteristics of *Myriophyllum spicatum* and six submersed aquatic macrophyte species native to Lake George, New York. *Freshwater Biology* 26:233-240.

Madsen, J.D., J. W. Sutherland, J.A. Bloomfield, L. W. Eichler, and C. W. Boylen. 1991b. The decline of native vegetation under dense Eurasian watermilfoil canopies. *J. Aquat. Plant Manage.* 29: 94-99.

Madsen, J.D. and D. H. Smith. 1997. Vegetative spread of Eurasian watermilfoil colonies. *Journal of Aquatic Plant Management*. 35:63-68.

Madsen, J. D., and C. H. Welling. 2002. Eurasian Watermilfoil (*Myriophyllum spicatum* L.). *Lakeline* 58:29-30.

Malecki, R.A., B. Blossey, S.D. Hight, D. Schroeder, L.T. Kok and J.R. Coulson. 1994. Biological control of purple loosestrife. *BioScience* 43(10):680-686.

Massachusetts Office of Coastal Zone Management. 2006. Guidance Document for the Purple Loosestrife Biocontrol Project. Wetland Restoration Program. Aquatic Invasive Species Program. November 2006.

Mattson, M.D., P.J. Godfrey, R.A. Barletta and A. Aiello. (K.J. Wagner, Editor) 2004. Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report. Department of Environmental Protection and Department of Conservation and Recreation, Executive Office of Environmental Affairs, Commonwealth of Massachusetts.

McComas, S. 1993. Lake Smarts. The First Lake Maintenance Handbook. Terrene Institute and the United States Environmental Protection Agency. Washington, D.C.

McKeon, W. H. 1959. A preliminary report on the use of chemical herbicides to control purple loosestrife (*Lythrum salicaria*) on a small marsh. *Proc. Northeast. Weed Control Conf.* 13: 329332.

McNair, C.E. (Ed.) 1994. Dredging '94. Proceedings of the 2nd International Conference on Dredging and Dredged Material Placement. Volumes 1 and 2. ASCE, New York. 1561pp.

Mongin, M. 2005. Economic impact survey of Eurasian watermilfoil removal in Houghton Lake, Michigan. Presented at 6th annual conference of NEAPMS, submitted to Lake Reserv. Manage. (in review).

Nichols, S.A. and B.H. Shaw. 1986. Ecological life histories of three aquatic nuisance plants, *Myriophyllum spicatum*, *Potamogeton crispus*, and *Elodea canadensis*. *Hydrobiologia* 131:3-21.

Nichols, S.A. 1991. The interaction between biology and the management of aquatic macrophytes. *Aquatic Botany* 41:225-252.

Nichols, S.A. and R. Lathrop 1994. Impact of harvesting on aquatic plant communities. *J. Aquat. Plant Manage.* 32:33-36.

Nichols, S.A. and B. Shaw. 1983. Review of management tactics for integrated aquatic weed management. In: *Lake Restoration, Protection and Management*, EPA 440/5-83-001, USEPA, Washington, DC.

NYSDEC. 1967. Developing and Managing the Water Resources of New York State. Division of Water Resources. New York State Department of Environmental Conservation. Albany, New York.

NYSDEC. 1968. Erie-Niagara Basin Chemical Quality of Streams. Division of Water Resources. New York State Department of Environmental Conservation. Albany, New York.

NYSDEC. 1981a. Final Programmatic Environmental Impact Statement on Aquatic Vegetation Control Program of the Department of Environmental Conservation. Division of Lands and Forests. New York State Department of Environmental Conservation. Albany, New York.

NYSDEC. 1981b. Preliminary Report of Stream Sampling For Acidification Studies 1980. Division of Fish & Wildlife. New York State Department of Environmental Conservation. Albany, New York.

NYSDEC. 1987. Characteristics of New York State Lakes - Gazetteer of Lakes, Ponds and Reservoirs. Division of Water Resources. New York State Department of Environmental Conservation. Albany, New York.

NYSDEC. 2003. Imazamox (Raptor) NYS DEC Letter - Active Ingredient Registration 3/03. New York State Department of Environmental Conservation. Division of Solid and Hazardous Materials.

NYSDEC. 2005. A Primer on Aquatic Plant Management in New York State. Draft. Division of Water, Albany, New York. April 2005.

Olem, H. and G. Flock (eds.). 1990. Lake and Reservoir Restoration Guidance manual, 2nd edition. EPA 440/4-90-006. Prep. by N. Am. Lake Manage. Soc. for U.S. Environ. Prot. Agency, Washington, D.C.

Omernick, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). *Annals of the Association of American Geographers* 77:116-125.

Orchard, A. E. 1981. A revision of South American *Myriophyllum* (*Haloragaceae*), and its repercussions on some Australian and North American species. *Brunonia* 2:247-287

Painter, D.S. 1988. Long-term effects of mechanical harvesting on Eurasian watermilfoil. *J. Aquat. Plant Manage.* 26:25-29.

Pardue, W.J. and D.H. Webb. 1985. A comparison of aquatic macroinvertebrates occurring in association with Eurasian watermilfoil (*Myriophyllum spicatum* L.) with those found in the open littoral zone. *J. Fresh. Ecol.* 3:69-79.

Pearsall, W.H. 1920. The aquatic vegetation of English Lakes. *J. Ecol.* 8:163-199.

Petty, D.G., K.S. Getsinger, J.D. Madsen, J.G. Skogerboe, W.T. Haller, A.M. Fox and B.A. Houtman. 1998. Aquatic Dissolution of Herbicide Triclopyr in Lake Minnetonka, MN. U.S. Army Corps of Engineers. Technical Report A-98-1.

Poovey, A.G., K.D. Getsinger, J.G. Skogerboe, T.J. Koschnick, J.D. Madsen, and R.M. Stewart. 2004. Small-Plot, Low-Dose Treatments of Triclopyr for Selective Control of Eurasian Watermilfoil. *Lake Reserv. Manage.* 20:322-332.

Pullman, G.D. 1992. Aquatic Vegetation Management Guidance Manual, Volume 1, Version 1.1. The Midwest Aquatic Plant Management Society, Seymour, Indiana.

Pullman, G.D. 1993. The Management of Eurasian Watermilfoil in Michigan, Volume 2, Version 1.1. The Midwest Aquatic Plant Management Society, Seymour, Indiana.

Purdue University. 1996. Herbicide Mode-Of-Action Summary. Cooperative Extension Service, West Lafayette, IN. <http://www.ces.purdue.edu/extmedia/WS/WS-23-W.html>

Riemer, D.N. 1984. Introduction to Freshwater Vegetation. AVI Publishing Company, Inc. Westport CT. 207 pp.

Schneider, J.C. 2000. Evaluation of the Effects of the Herbicide SONAR on Sport Fish Populations in Michigan Lakes. MIDNR Fisheries Division Tech. Report No. 2000-2, Ann Arbor, MI

Schramm, H.L. and K.J. Jirka. 1989. Epiphytic macroinvertebrates as a food resource for bluegills in Florida lakes. *Trans. Am. Fish. Soc.* 118:416-426.

Sculthorpe, C.D. 1967. The Biology of Aquatic Vascular Plants. Koeltz Scientific Books, Königstein, West Germany.

Shearer, J.F. 1994. Potential role of plant pathogens in declines of submersed macrophytes. *Lake and Reservoir Management*, 10:9-12.

Sheldon, S.P. 1994. Invasions and declines of submerged macrophytes in New England, with particular reference to Vermont lakes and herbivorous invertebrates. *Lake and Reservoir Management* 10:13-17.

Sheldon, S. 1995. The Potential for Biological Control of Eurasian Watermilfoil (*Myriophyllum spicatum*) 1990-1995. Prepared for Region 1 U.S. Environmental Protection Agency, Boston, MA.

Sheldon, S. and L. O'Bryan. 1996a. The life history of the weevil, *Euhrychiopsis lecontei*, a potential biological control agent of Eurasian watermilfoil. *Entomological News* 107:16-22.

Sheldon, S. and L. O'Bryan. 1996b. The effects of harvesting Eurasian watermilfoil on the aquatic weevil *Euhrychiopsis lecontei*. *J. Aquat. Plant Manage.* 34:76-77.

Sheldon, S. and R. Creed. 1995. Use of a native insect as a biological control for an introduced weed. *Ecological Applications* 5:1122-1132.



- Sheppard, A. C. 1945. A new record for Canada (Lepidoptera). *Canadian Entomologist* 77: 55.
- Smith, C.S. and J.W. Barko. 1990. Ecology of Eurasian watermilfoil. *J. Aquat. Plant Manage.* 28:55-64.
- Smith, C.S., J.W. Barko, and D.G. McFarland. 1991. Ecological Considerations in the Management of Eurasian Watermilfoil in Lake Minnetonka, Minnesota. Aquatic Plant Control Research Program Technical Report A-9 1-3, U. S. Army Waterways Experiment Station, Vicksburg, Mississippi.
- Stang, D.L. 1994. Job 106: Control and Evaluation of Grass Carp Introductions. Final Job Completion Report. New York State Department of Environmental Conservation Division of Fish and Wildlife, Bureau of Fisheries.
- Suter, G.W. II. 1993. Ecological Risk Assessment. Lewis Publishers, Chelsea, MI.
- Swadener, C. 1993. Triclopyr. *Journal of Pesticide Reform*, 13(3):29-35.
- Thompson, D. Q., R. L. Stuckey, and E. B. Thompson. 1987. Spread, Impact, and Control of Purple Loosestrife (*Lythrum salicaria*) in North American Wetlands. U.S. Fish and Wildlife Service. 55 pages. Jamestown, ND: Northern Prairie Wildlife Research Center Online.  
<http://www.npwrc.usgs.gov/resource/1999/loosstrf/loosstrf.htm> (Version 04JUN99).
- Titus, J.E. and M.S. Adams. 1979. Coexistence and comparative light relations of the submersed macrophytes *Myriophyllum spicatum* L. and *Vallisneria americana* Michx. *Oecologia* 40:273-286.
- Titus, J.E. 1994. Submersed plant invasions and declines in New York. *Lake and Reservoir Management*, 10(1): 25-28.
- Tu, M, C. Hurd and J.M. Randall. 2001. Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas. The Nature Conservancy, Arlington, VA.
- USACE. 2002. Aquatic Plant Information System (APIS). Information downloaded March 2005.  
<http://el.erdc.usace.army.mil/aqua/apis/>
- USDA, 2002. Biological Control of Invasive Plants in the Eastern United States. Forest Service Publication FHTET-2002-04.
- USEPA, 1985. Hazard Evaluation Division, Standard Evaluation Procedure, and Acute Toxicity Test for Freshwater Fish. PB86-129277. EPA-540/9-85-006
- USEPA. 1997. Pesticide Fact Sheet. Imazamox (Raptor Herbicide). Date Issued: May 22, 1997.
- USEPA. 1998. Reregistration Eligibility Decision (RED): Triclopyr. EPA 738-R-98-011. United States Environmental Protection Agency. Washington, D.C. October.
- USEPA. 1999. Imazamox; Pesticide Tolerances for Emergency Exemptions. Federal Register: July 14, 1999 (Volume 64, Number 134).
- USEPA. 2000a. Nutrient Criteria Technical Guidance Manual, Lake and Reservoirs, Technical Guidance Manual, Interim Final Draft.
- USEPA. 2000b. Notice of Filing Pesticide Petition to Establish Tolerance for Certain Pesticide Chemicals in or on Food. Federal Register: March 29, 2000 (Volume 65, Number 61) [Page 16594-16598].

USEPA. 2003. Imazamox; Exemption from the Requirement of a Tolerance. Final Rule. Federal Register: February 14, 2003 (Volume 68, Number 31).

USEPA. 2007. Label Review Manual. Chapter 7: Precautionary Statements.  
<http://www.epa.gov/oppfead1/labeling/lrm/chap-07.htm#IIB>

USEPA. 2008a. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. U.S. Environmental Protection Agency, Cincinnati, OH. <http://cfpub.epa.gov/ncea/iris/index.cfm>

USEPA. 2008b. Environmental Fate and Ecological Risk Assessment. Environmental Fate and Effects Science Chapter for Registration of New Use Imazamox for the proposed new use for the control of vegetation in and around aquatic and noncropland sites. USEPA PC Code:129171 Environmental Risk Branch II Team. Office of Prevention, Pesticides and Toxic Substances. Washington, D.C.

Vermont Department of Environmental Conservation (VDEC). 1993. A Report From the Milfoil Study Committee on the Use of Aquatic Herbicides to Control Eurasian Watermilfoil in Vermont. Vermont Department of Environmental Conservation, Waterbury, Vermont.

Wade, P.M.. 1990. General biology and ecology of aquatic weeds. in A.H. Pieterse and K.J. Murphy (eds) Aquatic Weeds, The Ecology and Management of Nuisance Aquatic Vegetation. Oxford Science Publications, Oxford, England.

Wagner, K.J. 2001. Management techniques with the lake or reservoir. Chapter 6 in Managing Lakes and Reservoirs. 2nd ed. C. Holden and J. Taggart (eds). U.S. Environmental Protection Agency and North American Lakes Management Society, Madison, WI.

Wagner, K.J. 2004. The Practical Guide to Lake Management in Massachusetts. A companion to the Final Generic Environmental Impact Report on Eutrophication and Aquatic Plant Management in Massachusetts. Commonwealth of Massachusetts. Executive Office of Environmental Affairs, Boston, MA.

Washington State Department of Ecology (WDOE), 1994. A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans – First Edition. <http://www.ecy.wa.gov/pubs/93093.pdf>

Washington State Department of Ecology (WDOE), 2001. Supplemental Environment Impact Statement Assessments of Aquatic Herbicides Volume 5 Triclopyr. Study Number 00713. Department of Ecology. Publication Number 04-10-015.

Westerdahl, H.E., and K.D. Getsinger. 1988a. Aquatic Plant Identification and Herbicide Use Guide. Volume I. Aquatic Herbicides and Application Equipment. Technical Report A-88-9, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Westerdahl, H.E., and K.D. Getsinger. 1988b. Aquatic Plant Identification and Herbicide Use Guide. Volume II. Aquatic Plants and Susceptibility to Herbicides. Technical Report A-88-9, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Wetzel, R.G. 2001. Limnology. Lake and River Ecosystems. 3rd edition. Academic Press. San Diego. CA.

Whetstone, J. 2005. Aquatic Weed Control Overview. HGIC 1714. Prepared by Jack M. Whetstone, Extension Aquaculture Specialist, Clemson University.

Young, S.E. 2008. New York Rare Plant Status List, New York Natural Heritage Program, Delmar, NY. May 2004. <http://www.dec.state.ny.us/website/dfwmr/heritage/plants.htm>

## **Websites**

California Department of Food and Agriculture (CDFA). 2006. Purple Loosestrife Control Website. [http://www.cdfa.ca.gov/phpps/ipc/purpleloosestrife/purpleloosestrife\\_controlmethods.htm](http://www.cdfa.ca.gov/phpps/ipc/purpleloosestrife/purpleloosestrife_controlmethods.htm)

Center for Aquatic and Invasive Plants, University of Florida. 2008. <http://aquat1.ifas.ufl.edu>

Cornell University Ecology and Management of Invasive Plants Program. 2006. Purple Loosestrife Description. [www.invasiveplants.net/plants/purpleloosestrife.htm](http://www.invasiveplants.net/plants/purpleloosestrife.htm)

Massachusetts Office of Coastal Zone Management (MA CZM). 2006. Wetlands Restoration Program. Aquatic Invasive Species Program. <http://www.mass.gov/czm/invasives/index.htm>

Nature Serve. 2008. [www.natureserve.org](http://www.natureserve.org)

NYSDEC. 2008. List of federally-protected plants native to New York. <http://www.dec.ny.gov/animals/7133.html>

USACE. 2002. Aquatic Plant Information System (APIS). Information downloaded March 2005. Available on the world wide web. <http://el.erd.usace.army.mil/aqua/apis/>

USDA Plants Database. 2008. <http://plants.usda.gov>

USGS. Northern Prairie Wildlife Research Center. <http://www.npwrc.usgs.gov/resource/plants/loosstrf/index.htm>

USEPA. ECOTOX Database. 2008. <http://cfpub.epa.gov/ecotox/>

Washington State Department of Ecology (WDOE), 2008. Non-native, Invasive, Freshwater Plants. <http://www.ecy.wa.gov/programs/wq/plants/weeds/index.html>

WDOE. 2009. Non-native, Invasive, Freshwater Plants. Aquatic Plant Management. <http://www.ecy.wa.gov/programs/wq/links/plants.html#management>

Wisconsin Department of Natural Resources (WDNR) Invasive Species Website. 2008. Purple Loosestrife Fact Sheet. <http://dnr.wi.gov/invasiveS/fact/loosestrife.htm>

## **Appendix A**

**New York State approved Clearcast® label, federally approved Clearcast® container label, supplemental label, and MSDS sheet**

# CLEARCAST®

## herbicide

**For the control of vegetation in and around aquatic and noncropland sites**

**Active Ingredient:**

ammonium salt of imazamox 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid\* ..... 12.1%

**Other Ingredients:** ..... 87.9%

**Total:** ..... 100.0%

\*Equivalent to 11.4% 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid  
(1 gallon contains 1.0 pound of active ingredient as the free acid)

US Patent No. 5,334,576

EPA Est. No. 241-PR-002

EPA Reg. No. 241-437

## KEEP OUT OF REACH OF CHILDREN

## CAUTION/PRECAUCIÓN

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

In case of an emergency endangering life or property involving this product,  
call day or night 1-800-832-HELP (4357).

See inside for complete First Aid, Precautionary Statements, Directions For Use,  
Conditions of Sale and Warranty, and state-specific crop and/or use site restrictions.

**Net Contents: 1 gallon**

Product of U.S.A.

2081218 NVA 2008-05-299-0321

BASF Corporation  
26 Davis Drive  
Research Triangle Park, NC 27709

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**BASF**

The Chemical Company

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"RESTRICTED USE"  
IN NEW YORK STATE  
UNDER 6NYCRR PART 326

Doc ID 577459

## FIRST AID

<b>If on skin or clothing</b>	<ul style="list-style-type: none"> <li>• Take off contaminated clothing.</li> <li>• Rinse skin immediately with plenty of water for 15 to 20 minutes.</li> <li>• Call a poison control center or doctor for treatment advice.</li> </ul>
<b>If in eyes</b>	<ul style="list-style-type: none"> <li>• Hold eye open and rinse slowly and gently with water for 15 to 20 minutes.</li> <li>• Remove contact lenses, if present, after the first 5 minutes; then continue rinsing eye.</li> <li>• Call a poison control center or doctor for treatment advice.</li> </ul>
<b>If inhaled</b>	<ul style="list-style-type: none"> <li>• Move person to fresh air.</li> <li>• If person is not breathing, call 911 or an ambulance; then give artificial respiration, preferably mouth-to-mouth if possible.</li> <li>• Call a poison control center or doctor for further treatment advice.</li> </ul>

## HOT LINE NUMBER

Have the product container or label with you when calling a poison control center or doctor or going for treatment. You may also contact BASF Corporation for emergency medical treatment information: 1-800-832-HELP (4357).

## Precautionary Statements

### HAZARDS TO HUMANS AND DOMESTIC ANIMALS

#### CAUTION

Harmful if absorbed through skin or inhaled. Avoid breathing spray mist. Avoid contact with skin, eyes or clothing.

#### PERSONAL PROTECTIVE EQUIPMENT (PPE)

Some materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for **Category A** on an EPA chemical-resistance category selection chart.

#### Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Chemical-resistant gloves, such as butyl rubber  $\geq 14$  mils, or natural rubber  $\geq 14$  mils, or neoprene rubber  $\geq 14$  mils, or nitrile rubber  $\geq 14$  mils
- Shoes plus socks

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IN NEW YORK STATE  
UNDER 6NYCRR PART 326

Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables exist, use detergent and hot water. Keep and wash PPE separately from other laundry.

## USER SAFETY RECOMMENDATIONS

#### Users should:

- Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.

## ENVIRONMENTAL HAZARDS

This pesticide may be hazardous to plants outside the treated area. **DO NOT** apply to water except as specified in this label. **DO NOT** contaminate water when disposing of equipment washwaters and rinsate.

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## Directions For Use

It is a violation of federal law to use this product in a manner inconsistent with its labeling. This labeling must be in the possession of the user at the time of pesticide application.

**DO NOT** apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your state or tribe, consult the agency responsible for pesticide regulation.

Ensure spray drift to nontarget species does not occur.

**DO NOT** apply **Clearcast® herbicide** in any manner not specifically described in this label.

Observe all cautions and limitations on this label and on the labels of products used in combination with **Clearcast**. **DO NOT** use **Clearcast** other than in accordance with the instructions set forth on this label. Keep containers closed to avoid spills and contamination.

## STORAGE AND DISPOSAL

**DO NOT** contaminate food, feed or water by storage or disposal.

### PESTICIDE STORAGE

KEEP FROM FREEZING.

**DO NOT** store below 32° F.

**DO NOT** contaminate water, food or feed by storage or disposal.

**PESTICIDE DISPOSAL.** Wastes resulting from the use of this product may be disposed of on-site or at an approved waste disposal facility.

### CONTAINER DISPOSAL

**Nonrefillable Container. DO NOT reuse or refill this container.** Triple rinse or pressure rinse container (or equivalent) promptly after emptying; then offer for recycling, if available, or reconditioning, if appropriate, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures approved by state and local authorities.

### Triple rinse containers small enough to shake (capacity ≤ 5 gallons) as follows:

Empty the remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container 1/4 full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank, or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times.

### Triple rinse containers too large to shake (capacity > 5 gallons) as follows:

Empty the remaining contents into application equipment or a mix tank. Fill the container 1/4 full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Empty the rinsate into application equipment or a mix tank, or store rinsate for later use or disposal. Repeat this procedure two more times.

**Pressure rinse as follows:** Empty the remaining contents into application equipment or mix tank. Hold container upside down over application equipment or mix tank, or collect rinsate for later use or disposal. Insert pressure rinsing nozzle in the side of the container and rinse at about 40 PSI for at least 30 seconds. Drain for 10 seconds after the flow begins to drip.

## General Information

**Clearcast** is an aqueous formulation that may be diluted in water and either applied directly to water for the control/suppression of certain submerged aquatic vegetation or applied as a broadcast or spot spray to floating and emergent vegetation. Aquatic sites that may be treated include estuarine and marine sites, ponds, lakes, reservoirs, wetlands, marshes, swamps, bayous, arroyos, ditches, canals, streams, rivers, creeks and other slow-moving or quiescent bodies of water. **Clearcast** may

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also be used during drawdown conditions. **Clearcast® herbicide** may also be applied to noncropland sites for terrestrial and riparian vegetation control.

**Clearcast** is quickly absorbed by foliage and/or plant roots and rapidly translocated to the growing points stopping growth. Susceptible plants may develop a yellow appearance or general discoloration and will eventually die or be severely growth inhibited.

**Clearcast** is herbicidally active on many submerged, emergent and floating broadleaf and monocot aquatic plants. The relative levels of control and selectivity can be manipulated by using a choice of rates and herbicide placement (water injected or floating/emergent foliar application).

To help maintain the utility of herbicide programs, the use of herbicides with different modes of action are effective in managing weed resistance.

#### SPRAY ADJUVANTS

Applications of **Clearcast** targeting emergent, floating or shoreline species require the use of a spray adjuvant. Always use a spray adjuvant that is appropriate for aquatic sites.

**Nonionic Surfactants.** Use a nonionic surfactant at the rate 0.25% v/v or higher (see manufacturer's label) of the spray solution (0.25% v/v is equivalent to 1 quart in 100 gallons). For best results, select a nonionic surfactant with an HLB (hydrophilic to lipophilic balance) ratio between 12 and 17 with at least 70% surfactant in the formulated product (alcohols, fatty acids, oils, ethylene glycol or diethylene glycol should not be considered as surfactants to meet the above requirements).

**Methylated Seed Oils or Vegetable Oil Concentrates.** Instead of a surfactant, a methylated seed oil or vegetable-based seed oil concentrate may be used at the rate of 1.5 to 2 pints per acre. When using spray volumes greater than 30 gallons per acre, methylated seed oil or vegetable-based seed oil concentrates should be mixed at a rate of 1% of the total spray volume, or

alternatively use a nonionic surfactant as described above. Research indicates that these oils may aid in **Clearcast** deposition and uptake by plants under stress.

**Silicone-based Surfactants.** See manufacturer's label for specific rate recommendations. Silicone-based surfactants may reduce the surface tension of the spray droplet allowing greater spreading on the leaf surface as compared to conventional nonionic surfactants. However, some silicone-based surfactants may dry too quickly, limiting herbicide uptake.

**Invert Emulsions.** **Clearcast** can be applied as an invert emulsion. The spray solution results in an invert (water-in-oil) spray emulsion designed to minimize spray drift and spray runoff, resulting in more herbicide on the target foliage. The spray emulsion may be formed in a single tank (batch mixing) or injected (in-line mixing). Consult the invert chemical label for proper mixing directions.

**Other.** An antifoaming agent, spray pattern indicator, sinking agent or drift-reducing agent may be applied at the product labeled rate if necessary or desired.

#### Aquatic Use Directions

**Clearcast** may be applied directly to the water for the control of submerged aquatic plant species and some emergent and floating species, or as a foliar application specifically for emergent and floating species.

#### DO NOT exceed maximum use rate per application:

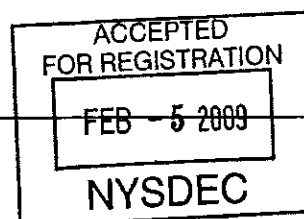
Water treatment - 500 ppb (173 fluid ozs of **Clearcast** per acre foot)

Foliar broadcast application - 2 quarts per acre (0.5 lb ae/A)

Foliar spot application - up to 5% **Clearcast** by volume.

**Clearcast** may be applied via surface and aerial equipment including both fixed wing aircraft and helicopter.

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### **Spray Drift Requirements For Aerial Application**

- Applicators are required to use a coarse or coarser droplet size (ASABE S572) or, if specifically using a spinning atomizer nozzle, applicators are required to use a volume mean diameter (VMD) of 385 microns or greater for release heights below 10 feet. Applicators are required to use a very coarse or coarser droplet size or, if specifically using a spinning atomizer nozzle, applicators are required to use a VMD of 475 microns or greater for release heights above 10 feet. Applicators must consider the effects of nozzle orientation and flight speed when determining droplet size.
- Applicators are required to use upwind swath displacement.
- The boom length must not exceed 60% of the wingspan or 90% of the rotor blade diameter to reduce spray drift.
- **DO NOT** apply when wind speed is greater than 10 mph.
- If applying at wind speeds less than 3 mph, the applicator must determine if
  - 1.) Conditions of temperature inversion exist **or**
  - 2.) Stable atmospheric conditions exist at or below nozzle height.

**DO NOT** make applications into areas of temperature inversions or stable atmospheric conditions.

### **Spray Drift Requirements For Ground Boom Applications**

- Applicators are required to use a nozzle height below 4 feet above the ground or plant canopy and coarse or coarser droplet size (ASABE S572) or, if specifically using a spinning atomizer nozzle, applicators are required to use a volume mean diameter (VMD) of 385 microns or greater.
- Applications with wind speeds greater than 10 mph are prohibited.
- Applications into temperature inversions are prohibited.

**DO NOT** apply when wind conditions may result in drift, when temperature inversion conditions exist, or when spray may be carried to sensitive areas.

See **Managing Off-target Movement** section for more drift reduction recommendations.

### **SURFACE APPLICATION**

**Application to targeted emergent and/or floating vegetation.** To make surface applications targeting emergent or floating vegetation, uniformly apply with properly calibrated broadcast or spot treatment equipment in 10 or more gallons of water per acre. Spot treatments can be made with up to 5% **Clearcast® herbicide** by volume. To ensure thorough spray coverage, higher spray volumes may be required when treating areas with large and/or dense vegetation. Use an appropriate spray pressure to minimize the drift potential depending upon spray equipment, conditions and application objectives.

### **Guidelines for Foliar Treatment of Emergent and Floating Vegetation**

- Always use a surfactant for foliar applications of emergent and floating weeds.
- Foliar applications of **Clearcast** may be made as a broadcast spray or as a spot spray with a percent spray solution ranging from 0.25% to 5% **Clearcast** by volume.
- Control will be reduced if spray is washed off foliage by wave action.

In aquatic sites, those application techniques described in the **Terrestrial Use Directions** section may be used to treat emergent vegetation.

**Application to water targeting submerged and/or emergent/floating vegetation.** **Clearcast** may be broadcast applied to the water surface or injected below the water surface. **Clearcast** may be applied as undiluted product or diluted with water prior to application. Under surface-matted conditions, **Clearcast** should be injected below the water surface to achieve better product distribution. Apply **Clearcast** to water to achieve a final concentration of the active ingredient of no more than 500 ppb. Multiple applications of **Clearcast** may be made during the annual growth cycle to maintain the desired vegetation response.

**Clearcast® herbicide Rates Per Treated Surface Acre**

Average Water Depth of Treatment Site (feet)	Desired Active Ingredient Concentration (ppb)*			
	50	100	200	500
	Clearcast Rate (fl ozs) per Treated Surface Acre			
1	17	35	69	173
2	35	69	138	346
3	52	104	207	518
4	70	138	277	691
5	87	173	346	864
6	104	207	415	1037
7	122	242	484	1210
8	139	277	553	1382
9	157	311	622	1555
10	174	346	691	1728

\*Clearcast contains 1.0 pound of active ingredient per gallon. There are 128 fl ozs in one gallon.

**AERIAL APPLICATION**

Clearcast may be applied by both fixed wing aircraft and helicopter. There is no minimum spray volume when making applications directly to the water. For applications targeting emergent and/or floating vegetation, uniformly apply with properly calibrated equipment in 5 or more gallons of water per surface acre. For best results, aerial applications should be made using a minimum of 20 gallons per acre.

**DRAWDOWN APPLICATION**

Clearcast may be used in drawdown situations to provide postemergence and/or preemergence control/suppression of aquatic vegetation. Apply Clearcast as a broadcast spray at rates up to 64 ozs/A or as a spot spray treatment with up to 5%

Clearcast by volume. Applications should be made when water has receded and exposed soil is moist to dry. For postemergence (foliar) applications, wait at least two weeks after application before reintroducing water. When treating irrigation canals, the initial flush of recharge water after application must not be used for irrigation purposes.

**Restrictions and Limitations**

**General Limitations**

**DO NOT** apply Clearcast to achieve a total active ingredient concentration in the water greater than 500 ppb.

**DO NOT** apply more than 2 quarts of Clearcast per surface acre for the control of emergent and floating vegetation.

**Irrigation Restrictions**

- **DO NOT** use treated water to irrigate greenhouses, nurseries or hydroponics.
- **DO NOT** plant non-CLEARFIELD® canola, onions, potatoes, or sugar beets in soils that have been previously irrigated with Clearcast-treated water until a soil bioassay successfully demonstrates acceptable levels of crop tolerance.
- **DO NOT** use any Clearcast-treated waters from still or quiescent sources for irrigation purposes less than 24 hours after Clearcast application is completed.
- Waters receiving Clearcast either as a water treatment or as a foliar treatment on emergent/floating plants may be used for irrigation as long as concentrations are  $\leq 50$  ppb. Treated waters resulting in concentrations  $> 50$  ppb may not be used for irrigation until residue levels have been shown to be  $\leq 50$  ppb by an acceptable method.
- Still and quiescent waters with an average depth of four (4) or more feet receiving a foliar application of Clearcast ( $\leq 2$  quarts per acre) to emergent/floating vegetation may be used for irrigation on allowable sites 24 hours after application is completed.

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- There are no irrigation restrictions on allowable sites for the use of treated water from flowing waters, such as irrigation canals with an average depth of four (4) or more feet, receiving a foliar application of **Clearcast® herbicide** (≤ 2 quarts per acre) to emergent/floating vegetation.
- After application of **Clearcast** to dry irrigation canals/ditches, the initial flush of water during recharge must not be used for irrigation purposes.

#### Other Water Use Restrictions

There are no restrictions on livestock watering, swimming, fishing, domestic use, or use of treated water for agricultural sprays.

**Potable Water.** **Clearcast** may be applied to potable water sources at concentrations up to 500

ppb to within a distance of 1/4 mile from an active potable water intake. Within 1/4 mile of an active potable water intake, **Clearcast** may be applied, but water concentrations resulting from injection and/or foliar applications may not exceed 50 ppb. If water concentrations greater than 50 ppb are required, the potable water intake must be shut and, if necessary, an alternate water supply be made available until the water concentration can be shown to be less than 50 ppb by an acceptable method.

#### Endangered Plant Species

To prevent potential negative impacts to endangered plant species, **DO NOT** apply **Clearcast** in a way that adversely affects federally listed endangered and threatened species.

#### Emergent, Floating, and Shoreline Species Controlled with Foliar Applications

Common Name	Scientific Name	Rate (ozs/A)	Comments
Alligatorweed	<i>Alternanthera philoxeroides</i>	64	Repeat applications may be necessary. Add 1 qt/A of <b>Rodeo® herbicide</b> for quicker brownout.
American lotus	<i>Nelumbo lutea</i>	64	
Arrowhead	<i>Sagittaria</i> spp.	32	
Cattail	<i>Typha</i> spp.	32 to 64	Apply after full green up through killing frost.
Chinese tallowtree	<i>Sapium sebiferum</i>	32 to 64	
Common reed	<i>Phragmites</i> spp.	64	Use 1 qt/A methylated seed oil (MSO); apply in late vegetative stage up to killing frost. May also be applied as a spot treatment using 1% to 2% <b>Clearcast</b> per spray volume. Older stands of phragmites and stands growing in water may be more difficult to control and will require follow-up applications.
Common salvinia	<i>Salvinia minima</i>	32 to 64	Apply with MSO or MSO + silicone-based surfactant; retreatment will be necessary.
Floating pennywort	<i>Hydrocotyle ranunculoides</i>	32 to 64	Repeat applications may be necessary.
Four-leaf clover	<i>Marsilea</i> spp.	32	

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**Emergent, Floating, and Shoreline Species Controlled with Foliar Applications (continued)**

Common Name	Scientific Name	Rate (ozs/A)	Comments
Frogbit	<i>Lymnobia spongia</i>	16 to 32	Water concentrations of 50 to 100 ppb will control frogbit.
Mexican lily	<i>Nymphaea mexicana</i>	32 to 64	
Parrotfeather	<i>Myriophyllum aquaticum</i>	64	Apply only to emergent vegetation.
Pickereelweed	<i>Pontederia cordata</i>	32	
Smartweed	<i>Polygonum</i> spp.	16 to 32	
Water hyacinth	<i>Eichhornia crassipes</i>	16 to 32	Water concentrations of 50 to 100 ppb will control water hyacinth.
Water primrose	<i>Ludwigia</i> spp.	32	Add 1 qt/A of <b>Rodeo</b> for quicker brownout.
Watershield	<i>Brasenia schreberi</i>	48 to 64	Water concentrations of 50 to 100 ppb will control watershield.
Water lily	<i>Nymphaea</i> spp.	32 to 64	
Spatterdock	<i>Nuphar lutea</i>	64	

**Submersed Species Controlled with Water-injected Applications**

Common Name	Scientific Name	Rate (ppb)	Comments
Bladderwort	<i>Utricularia floridana</i> <i>U. inflata</i>	50 to 100	
Eurasian watermilfoil <sup>2</sup>	<i>Myriophyllum spicatum</i>	100 to 200	See <b>Special Weed Control</b> for application directions.
Hydrilla <sup>1</sup>	<i>Hydrilla verticillata</i>	150 to 200	See <b>Special Weed Control</b> for application directions.
Northern watermilfoil	<i>Myriophyllum exalbescens</i>	100 to 200	

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**Submersed Species Controlled with Water-injected Applications (continued)**

Common Name	Scientific Name	Rate (ppb)	Comments
Pondweed, American flat stemmed leafy Illinois small variableleaf  clasping largeleaf	<i>Potamogeton</i> spp. <i>P. nodosus</i> <i>P. zosteriformis</i> <i>P. foliosus</i> <i>P. illinoensis</i> <i>P. pusillus</i> <i>P. gramineus</i> <i>P. diversifolius</i> <i>P. perfoliatus</i> <i>P. amplifolius</i>	50 to 100	
Pondweed, curlyleaf	<i>Potamogeton</i> <i>crispus</i>	50	
Pondweed, sago <sup>3</sup>	<i>Potamogeton</i> <i>pectinatus</i> ( <i>Stuckenia</i> <i>pectinatus</i> )	100	See <b>Special Weed Control</b> for application directions.
Spikerush	<i>Eleocharis</i> spp.	200	Apply as a submerged spot treatment, concentrating the application in the area of the spikerush. If emerged, then spot treat with 2% <b>Clearcast® herbicide</b> by volume at 50 GPA, or 1% at 100 GPA.
Variableleaf milfoil	<i>Myriophyllum</i> <i>heterophyllum</i>	100 to 200	
Water stargrass	<i>Heteranthera</i> <i>dubia</i>	100	
Widgeon grass	<i>Ruppia maritima</i>	200	

**Special Weed Control**

<sup>1</sup>**Hydrilla.** Apply **Clearcast** at 150 to 200 ppb to actively growing plants early in the growing season. Applications made prior to topped-out hydrilla may require repeat application.

A single application of 50 to 75 ppb can be used to suppress and growth regulate hydrilla for up to 10 to 12 weeks. If desired an additional 50 to 75 ppb can be applied to extend the period of growth suppression when normal hydrilla growth resumes.

<sup>2</sup>**Eurasian watermilfoil.** Apply **Clearcast** at 100 to 200 ppb to actively growing plants early in the growing season. Applications made to mature milfoil (vegetation topped out) may require multiple applications.

<sup>3</sup>**Sago pondweed.** Sago pondweed may be controlled in nonflowing water with water-injected applications at 100 ppb. In dry ditches (drainage and irrigation), sago pondweed may be controlled or growth suppressed with soil-applied **Clearcast** at 64 ozs/A. In irrigation canals, apply **Clearcast** after drawdown and prior to water recharge.

## Terrestrial Use Directions

**Clearcast® herbicide** may be applied with ground and aerial equipment including both fixed wing aircraft and helicopter. Applications may be made using foliar broadcast spray, foliar spot spray, injection (hack and squirt), frill and girdle, cut stump, or basal methods.

**BROADCAST SPRAY APPLICATION. DO NOT** apply more than 64 fl ozs **Clearcast** per acre.

**FOLIAR SPOT APPLICATION.** Apply **Clearcast** as a percent solution, containing up to 5% **Clearcast** by volume.

**INJECTION (HACK AND SQUIRT), FRILL AND GIRDLE, AND CUT STUMP APPLICATION.** Treatments may be made using up to 100% **Clearcast** by volume.

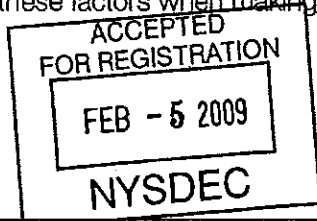
**BASAL APPLICATION.** Treatments can be made using up to 25% **Clearcast** by volume. Basal applications require the use of a good emulsion system to maintain **Clearcast** in a stable emulsion with the penetrating agent being used.

All foliar applications of **Clearcast** require the use of a spray adjuvant. Refer to **SPRAY ADJUVANTS** section for additional information.

### Managing Off-target Movement

The information that follows is general guidance for managing and minimizing off-target exposure of this product. Specific use recommendations in this label may vary from these general guidelines depending on the application method and objectives and should supersede the general information provided below.

Avoiding spray drift at the application site is the responsibility of the applicator. The interaction of many equipment- and weather-related factors determines the potential for spray drift. The applicator and the grower are responsible for considering all these factors when making decisions.



The following drift management requirements must be followed to avoid off-target drift movement from aerial applications:

1. The distance of the outermost nozzles on the boom must not exceed 3/4 the length of the wingspan or 90% of the rotor.
2. Nozzles must always point backward parallel with the airstream and never be pointed downward more than 45 degrees.
3. **DO NOT** apply if wind speed is greater than 10 mph, except when making injection or subsurface applications to water.

Where states have more stringent regulations, they must be observed.

The applicator must be familiar with and take into account the information covered in the aerial drift reduction advisory information presented below.

### Information On Droplet Size

The most effective way to reduce drift potential is to apply large droplets. The best drift management strategy is to apply the largest droplets that provide sufficient coverage and control. Applying larger droplets reduces drift potential but will not prevent drift if applications are made improperly or under unfavorable environmental conditions (see **Wind; Temperature and Humidity; and Temperature Inversions**).

### Controlling Droplet Size

- **Volume.** Use high flow rate nozzles to apply the highest practical spray volume. Nozzles with higher rated flows produce larger droplets.
- **Pressure. DO NOT** exceed the nozzle manufacturer's recommended pressures. For many nozzle types, lower pressure produces larger droplets. When higher flow rates are needed, use higher flow rate nozzles instead of increasing pressure.
- **Number of Nozzles.** Use the minimum number of nozzles that provides uniform coverage.
- **Nozzle Orientation.** Orienting nozzles so that the spray is released parallel to the airstream produces larger droplets than other orientations and is recommended practice. Significant deflection

from the horizontal will reduce droplet size and increase drift potential.

- **Nozzle Type.** Use a nozzle type that is designed for the intended application. With most nozzle types, narrower spray angles produce larger droplets. Consider using low-drift nozzles. Solid-stream nozzles oriented straight back produce the largest droplets and the lowest drift.

#### **Boom Length**

For some use patterns, reducing the effective boom length to less than 3/4 of the wingspan or 90% of rotor length may further reduce drift without reducing swath width.

#### **Application Height**

Applications must not be made at a height greater than 10 feet above the top of the largest plants unless a greater height is required for aircraft safety. Making applications at the lowest height that is safe reduces exposure of droplets to evaporation and wind.

#### **Swath Adjustment**

When applications are made with a crosswind, the swath will be displaced downwind. Therefore, on the upwind and downwind edges of the field, the applicator must compensate for this displacement by adjusting the path of the aircraft upwind. Swath adjustment distance should increase with increasing drift potential (higher wind, smaller droplets, etc.).

#### **Wind**

Drift potential is lowest between wind speeds of 2 to 10 mph. However, many factors, including droplet size and equipment type, determine drift potential at any given speed. Application should be avoided below 2 mph due to variable wind direction and high inversion potential.

**NOTE:** Local terrain can influence wind patterns. Every applicator should be familiar with local wind patterns and how they affect spray drift.

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#### **Temperature and Humidity**

When making applications in low relative humidity, set up equipment to produce larger droplets to compensate for evaporation. Droplet evaporation is most severe when conditions are both hot and dry.

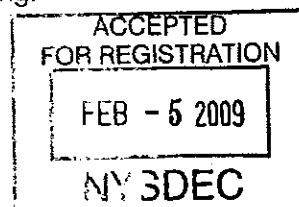
#### **Temperature Inversions**

Applications must not occur during a temperature inversion because drift potential is high. Temperature inversions restrict vertical air mixing, which causes small suspended droplets to remain in a concentrated cloud. This cloud can move in unpredictable directions due to the light, variable winds common during inversions. Temperature inversions are characterized by increasing temperatures with altitude and are common on nights with limited cloud cover and light-to-no wind. They begin to form as the sun sets and often continue into the morning. Their presence can be indicated by ground fog; however, if fog is not present, inversions can also be identified by the movement of smoke from a ground source or an aircraft smoke generator. Smoke that layers and moves laterally in a concentrated cloud (under low wind conditions) indicates an inversion, while smoke that moves upward and rapidly dissipates indicates good vertical air mixing.

#### **Sensitive Areas**

The pesticide must only be applied when the potential for drift to adjacent sensitive areas (e.g. residential areas, bodies of water, known habitat for threatened or endangered species, or crops) is minimal (e.g. when wind is blowing away from the sensitive areas).

Applicator is responsible for any loss or damage which results from spraying **Clearcast® herbicide** in a manner other than recommended in this label. In addition, applicator must follow all applicable state and local regulations and ordinances in regard to spraying.



**Clearcast® herbicide** may be used for the control of the following plant species. **Clearcast** may be effective for the control or suppression of additional plant species not listed below. The use of **Clearcast** for the control or suppression of undesirable plants not listed below may be done at the discretion of the user.

**To the extent consistent with applicable law, the user assumes responsibility for any lack of control or suppression associated with application to weeds not listed on this label.**

#### Weeds Controlled

Common Name	Scientific Name	Rate		Comments
Alligator weed	<i>Alternanthera philoxeroides</i>	64 fl ozs/A	Foliar	Addition of glyphosate will improve efficacy.
Annual ryegrass	<i>Lolium multiflorum</i>	16 to 32 fl ozs/A	Foliar	
Brazilian pepper; Christmasberry	<i>Schinus terebinthifolius</i>	2% v/v	Foliar	
California bullrush	<i>Schoenoplectus californicus</i>	64 fl ozs/A	Foliar	
Camphor tree	<i>Cinnamomum camphora</i>	2% v/v	Foliar	
Cattail	<i>Typha</i> spp.	32 to 64 fl ozs/A	Foliar	
Chinese tallowtree <sup>1</sup> ; Popcorn tree	<i>Sapium sebiferum</i>	32 to 64 fl ozs/A	Foliar	See <b>SPECIAL WEED CONTROL</b> section.
Giant ragweed*	<i>Ambrosia trifida</i>	32 to 64 fl ozs/A	Foliar	
Jamaican nightshade	<i>Solanum jamaicense</i>	2% v/v	Foliar	
Johnsongrass, seedling rhizome	<i>Sorghum halepense</i>	16 fl ozs/A 32 to 64 fl ozs/A	Foliar Foliar	
Old world climbing fern	<i>Lygodium microphyllum</i>	5% v/v	Foliar	

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### Weeds Controlled (continued)

Common Name	Scientific Name	Rate		Comments
Phragmites	<i>Phragmites australis</i>	64 fl ozs/A	Foliar	Use 1 qt/A methylated seed oil (MSO); apply in late vegetative stage up to killing frost. May also be applied as a spot treatment using 1% to 2% <b>Clearcast® herbicide</b> per spray volume. Older stands of phragmites and stands growing in water may be more difficult to control and will require follow-up applications.
Purple loosestrife	<i>Lythrum salicaria</i>	32 to 64 fl ozs/A	Foliar	
Sedge*, purple yellow	<i>Cyperus rotundus</i> <i>Cyperus esculentus</i>	32 fl ozs/A 32 fl ozs/A	Foliar Foliar	
Smartweed	<i>Polygonum</i> spp.	32 to 64 fl ozs/A	Foliar	
Spike rush	<i>Eleocharis</i> spp.	64 fl ozs/A	Foliar	
Taro	<i>Taro</i> spp.	64 fl ozs/A 5% v/v	Foliar Foliar	
Tropical soda apple	<i>Solanum viarum</i>	2% v/v	Foliar	
Water primrose	<i>Ludwigia</i> spp.	32 to 64 fl ozs/A	Foliar	Addition of glyphosate will improve efficacy.
Wetland nightshade	<i>Solanum tampicense</i>	2% v/v	Foliar	
Whitetop; Hoary cress	<i>Cardaria draba</i>	8 to 16 fl ozs/A	Foliar	

\*Suppression of larger, well-established plants

In general, the use of methylated seed oil (MSO) at 1% v/v will provide the best control with foliar applications.

#### Special Weed Control

<sup>1</sup>**Chinese tallowtree. Clearcast** at 32 to 64 fl ozs/A or 0.5 to 2.0% v/v may be applied as a foliar application for selective control of Chinese tallowtree in and around tolerant hardwood species. Chinese tallowtree will be controlled with foliar applications using aerial, handgun, or backpack application methods. When treating Chinese tallowtree in mixed stands of hardwoods, application method and spray volume should ensure adequate coverage of targeted Chinese tallowtree plants. Methylated seed oil should be added at 32 fl ozs/A for broadcast applications, or at 1% v/v for spot backpack and handgun applications. Tolerant hardwood species may exhibit varying degrees of leaf discoloration and temporary injury.

## Conditions of Sale and Warranty

The **Directions For Use** of this product reflect the opinion of experts based on field use and tests. The directions are believed to be reliable and must be followed carefully. However, it is impossible to eliminate all risks inherently associated with the use of this product. Crop injury, ineffectiveness or other unintended consequences may result because of such factors as weather conditions, presence of other materials, or use of the product in a manner inconsistent with its labeling, all of which are beyond the control of BASF CORPORATION ("BASF") or the Seller. To the extent consistent with applicable law, all such risks shall be assumed by the Buyer. BASF warrants that this product conforms to the chemical description on the label and is reasonably fit for the purposes referred to in the **Directions For Use**, subject to the inherent risks, referred to above.

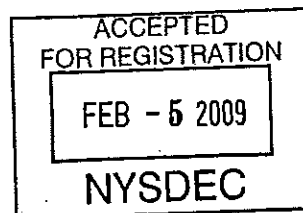
To the extent consistent with applicable law, BASF makes no other express or implied warranty of fitness or merchantability or any other express or implied warranty.

To the extent consistent with applicable law, Buyer's exclusive remedy and BASF's exclusive liability, whether in contract, tort, negligence, strict liability, or otherwise, shall be limited to repayment of the purchase price of the product.

To the extent consistent with applicable law, BASF and the Seller disclaim any liability for consequential, special or indirect damages resulting from the use or handling of this product.

BASF and the Seller offer this product, and the Buyer and User accept it, subject to the foregoing **Conditions of Sale and Warranty** which may be varied only by agreement in writing signed by a duly authorized representative of BASF.

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BASF Corporation  
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The Chemical Company

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# CLEARCAST®

herbicide

For the control of vegetation in  
and around aquatic and  
noncropland sites

**Active Ingredient:**

ammonium salt of Imazamox 2-[4,5-  
dihydro-4-methyl-4-(1-methylethyl)-5-  
oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-  
3-pyridinecarboxylic acid\* ..... 12.1%  
**Other Ingredients:** ..... 87.9%  
**Total:** ..... 100.0%

\*Equivalent to 11.4% 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid (1 gallon contains 1.0 pound of active ingredient as the free acid)

US Patent No. 5,334,576

EPA Reg. No. 241-437 EPA Est. No. 241-PR-002

**KEEP OUT OF REACH OF CHILDREN**  
**CAUTION/PRECAUCIÓN**

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

**FIRST AID: If on skin or clothing:** Take off contaminated clothing. Rinse skin immediately with plenty of water for 15 to 20 minutes. Call a poison control center or doctor for treatment advice. **If in eyes:** Hold eye open and rinse slowly and gently with water for 15 to 20 minutes. Remove contact lenses, if present, after the first 5 minutes; then continue rinsing eye. Call a poison control center or doctor for treatment advice. **If inhaled:** Move person to fresh air. If person is not breathing, call 911 or an ambulance; then give artificial respiration, preferably mouth-to-mouth if possible. Call a poison control center or doctor for further treatment advice. **HOT LINE NUMBER:** Have the product container or label with you when calling a poison control center or doctor or going for treatment. You may also contact BASF Corporation for emergency medical treatment information: 1-800-832-HELP (4357). **Precautionary Statements: HAZARDS TO HUMANS AND DOMESTIC ANIMALS: CAUTION:** Harmful if absorbed through skin or inhaled. Avoid breathing spray mist. Avoid contact with skin, eyes or clothing.

**ENVIRONMENTAL HAZARDS:** This pesticide may be hazardous to plants outside the treated area. **DO NOT** apply to water except as specified in this label. **DO NOT** contaminate water when disposing of equipment washwaters and rinsate. **Directions For Use:** It is a violation of federal law to use this product in a manner inconsistent with its labeling. This labeling must be in the possession of the user at the time of pesticide application. **DO NOT** apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your state or tribe, consult the agency responsible for pesticide regulation. Ensure spray drift to nontarget species does not occur.

## STORAGE AND DISPOSAL

**DO NOT** contaminate food, feed or water by storage or disposal. **PESTICIDE STORAGE:** KEEP FROM FREEZING. **DO NOT** store below 32° F. **DO NOT** contaminate water, food or feed by storage or disposal. **PESTICIDE DISPOSAL.** Wastes resulting from the use of this product may be disposed of on-site or at an approved waste disposal facility. **CONTAINER DISPOSAL:** Nonrefillable Container. **DO NOT** reuse or refill this container. Triple rinse or pressure rinse container (or equivalent) promptly after emptying; then offer for recycling, if available, or reconditioning, if appropriate, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures approved by state and local authorities. See attached booklet for complete container disposal directions including triple rinsing and pressure rinsing instructions.

**In case of an emergency endangering life or property involving this product, call day or night 1-800-832-HELP (4357).**

See attached booklet for complete **First Aid, Precautionary Statements, Directions For Use, Conditions of Sale and Warranty**, and state-specific crop and/or use site restrictions.

**Net Contents: 1 gallon**

Product of U.S.A.

2081218

NVA 2008-05-299-0321

BASF Corporation

26 Davis Drive, Research Triangle Park, NC 27709

**■ - BASF**

The Chemical Company

# CLEARCAST™

herbicide

**For the control of vegetation in and around aquatic and noncropland sites.**

**Active Ingredient:**

ammonium salt of imazamox 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid\* ..... 12.1%

**Other Ingredients:** ..... 87.9%

**Total:** ..... 100.0%

\*Equivalent to 11.4% 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid  
(1 gallon contains 1.0 pound of active ingredient as the free acid)

**US Patent No. 5,334,576**

**EPA Est. No. is indicated by the fifth letter of the code**

**EPA Reg. No. 241-437**

**printed on this container: M=241-PR-002 RR=51036-GA-002**

**KEEP OUT OF REACH OF CHILDREN  
CAUTION/PRECAUCION**

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

**In case of an emergency endangering life or property involving this product,  
call day or night 1-800-832-HELP (4357).**

See inside for complete **First Aid, Precautionary Statements, Directions For Use, Conditions of Sale and Warranty**, and state-specific crop and/or use site restrictions.

**Net Contents: 1 gallon**

Product of U.S.A.

**NVA 2008-05-299-0099**

BASF Corporation  
26 Davis Drive  
Research Triangle Park, NC 27709

 **BASF**  
The Chemical Company

FIRST AID	
<b>If on skin or clothing</b>	<ul style="list-style-type: none"> <li>• Take off contaminated clothing.</li> <li>• Rinse skin immediately with plenty of water for 15 to 20 minutes.</li> <li>• Call a poison control center or doctor for treatment advice.</li> </ul>
<b>If in eyes</b>	<ul style="list-style-type: none"> <li>• Hold eye open and rinse slowly and gently with water for 15 to 20 minutes.</li> <li>• Remove contact lenses, if present, after the first 5 minutes; then continue rinsing eye.</li> <li>• Call a poison control center or doctor for treatment advice.</li> </ul>
<b>If inhaled</b>	<ul style="list-style-type: none"> <li>• Move person to fresh air.</li> <li>• If person is not breathing, call 911 or an ambulance; then give artificial respiration, preferably mouth-to-mouth if possible.</li> <li>• Call a poison control center or doctor for further treatment advice.</li> </ul>
HOT LINE NUMBER	
<p>Have the product container or label with you when calling a poison control center or doctor or going for treatment. You may also contact BASF Corporation for emergency medical treatment information: 1-800-832-HELP (4357).</p>	

## PRECAUTIONARY STATEMENTS

### HAZARDS TO HUMANS AND DOMESTIC ANIMALS CAUTION

Harmful if absorbed through skin or inhaled. Avoid breathing spray mist. Avoid contact with skin, eyes or clothing.

#### PERSONAL PROTECTIVE EQUIPMENT (PPE)

Some materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for **Category A** on an EPA chemical-resistance category selection chart.

#### Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Chemical-resistant gloves, such as butyl rubber ≥14 mils, or natural rubber ≥ 14 mils, or neoprene rubber ≥14 mils, or nitrile rubber ≥ 14 mils
- Shoes plus socks

Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables exist, use detergent and hot water. Keep and wash PPE separately from other laundry.

### USER SAFETY RECOMMENDATIONS

#### Users should:

- Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.

## ENVIRONMENTAL HAZARDS

This pesticide may be hazardous to plants outside the treated area. **DO NOT** apply to water except as specified in this label. **DO NOT** contaminate water when disposing of equipment washwaters and rinsate.

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## DIRECTIONS FOR USE

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It is a violation of federal law to use this product in a manner inconsistent with its labeling. This labeling must be in the possession of the user at the time of pesticide application.

**DO NOT** apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your state or tribe, consult the agency responsible for pesticide regulation.

Ensure spray drift to nontarget species does not occur.

**DO NOT** apply **Clearcast™ herbicide** in any manner not specifically described in this label.

Observe all cautions and limitations on this label and on the labels of products used in combination with **Clearcast**. **DO NOT** use **Clearcast** other than in accordance with the instructions set forth on this label. Keep containers closed to avoid spills and contamination.

## STORAGE AND DISPOSAL

**DO NOT** contaminate food, feed or water by storage or disposal.

### PESTICIDE STORAGE

KEEP FROM FREEZING.

**DO NOT** store below 32° F.

**DO NOT** contaminate water, food or feed by storage or disposal.

**PESTICIDE DISPOSAL.** Wastes resulting from the use of this product may be disposed of on-site or at an approved waste disposal facility.

### CONTAINER DISPOSAL

**Nonrefillable Container. DO NOT reuse or refill this container.** Triple rinse or pressure rinse container (or equivalent) promptly after emptying; then offer for recycling, if available, or reconditioning, if appropriate, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures approved by state and local authorities.

**Triple rinse containers small enough to shake (capacity ≤ 5 gallons) as follows:** Empty the remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container 1/4 full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank, or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times.

**Triple rinse containers too large to shake (capacity > 5 gallons) as follows:** Empty the remaining contents into application equipment or a mix tank. Fill the container 1/4 full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Empty the rinsate into application equipment or a mix tank, or store rinsate for later use or disposal. Repeat this procedure two more times.

**Pressure rinse as follows:** Empty the remaining contents into application equipment or mix tank. Hold container upside down over application equipment or mix tank, or collect rinsate for later use or disposal. Insert pressure rinsing nozzle in the side of the container and rinse at about 40 PSI for at least 30 seconds. Drain for 10 seconds after the flow begins to drip.

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## GENERAL INFORMATION

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**Clearcast** is an aqueous formulation that may be diluted in water and either applied directly to water for the control/suppression of certain submerged aquatic vegetation or applied as a broadcast or spot spray to floating and emergent vegetation. Aquatic sites that may be treated include estuarine and marine sites, ponds, lakes, reservoirs, wetlands, marshes, swamps, bayous, arroyos, ditches, canals, streams, rivers, creeks and other slow-moving or quiescent bodies of water. **Clearcast** may also be used during drawdown

conditions. **Clearcast™ herbicide** may also be applied to noncropland sites for terrestrial and riparian vegetation control.

**Clearcast** is quickly absorbed by foliage and/or plant roots and rapidly translocated to the growing points stopping growth. Susceptible plants may develop a yellow appearance or general discoloration and will eventually die or be severely growth inhibited.

**Clearcast** is herbicidally active on many submerged, emergent and floating broadleaf and monocot aquatic plants. The relative levels of control and selectivity can be manipulated by using a choice of rates and herbicide placement (water injected or floating/emergent foliar application).

To help maintain the utility of herbicide programs, the use of herbicides with different modes of action are effective in managing weed resistance.

## SPRAY ADJUVANTS

Applications of **Clearcast** targeting emergent, floating or shoreline species require the use of a spray adjuvant. Always use a spray adjuvant that is appropriate for aquatic sites.

**Nonionic Surfactants.** Use a nonionic surfactant at the rate 0.25% v/v or higher (see manufacturer's label) of the spray solution (0.25% v/v is equivalent to 1 quart in 100 gallons). For best results, select a nonionic surfactant with an HLB (hydrophilic to lipophilic balance) ratio between 12 and 17 with at least 70% surfactant in the formulated product (alcohols, fatty acids, oils, ethylene glycol or diethylene glycol should not be considered as surfactants to meet the above requirements).

**Methylated Seed Oils or Vegetable Oil Concentrates.** Instead of a surfactant, a methylated seed oil or vegetable-based seed oil concentrate may be used at the rate of 1.5 to 2 pints per acre. When using spray volumes greater than 30 gallons per acre, methylated seed oil or vegetable-based seed oil concentrates should be

mixed at a rate of 1% of the total spray volume, or alternatively use a nonionic surfactant as described above. Research indicates that these oils may aid in **Clearcast** deposition and uptake by plants under stress.

**Silicone-based Surfactants.** See manufacturer's label for specific rate recommendations. Silicone-based surfactants may reduce the surface tension of the spray droplet allowing greater spreading on the leaf surface as compared to conventional nonionic surfactants. However, some silicone-based surfactants may dry too quickly, limiting herbicide uptake.

**Invert Emulsions.** **Clearcast** can be applied as an invert emulsion. The spray solution results in an invert (water-in-oil) spray emulsion designed to minimize spray drift and spray runoff, resulting in more herbicide on the target foliage. The spray emulsion may be formed in a single tank (batch mixing) or injected (in-line mixing). Consult the invert chemical label for proper mixing directions.

**Other.** An antifoaming agent, spray pattern indicator, sinking agent or drift-reducing agent may be applied at the product labeled rate if necessary or desired.

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## APPLICATION INFORMATION

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**Clearcast** may be applied directly to the water for the control of submerged aquatic plant species and some emergent and floating species, or as a foliar application specifically for emergent and floating species.

**DO NOT exceed maximum use rate per application:**

Water treatment - 500 ppb (173 fluid ozs of **Clearcast** per acre foot)

Foliar broadcast application - 2 quarts per acre (0.5 lb ae/A)

Foliar spot application - up to 5% **Clearcast** by volume.

**Clearcast** may be applied via surface and aerial equipment including both fixed wing and helicopter.



## SPRAY DRIFT REQUIREMENTS

### Aerial Applications

- Applicators are required to use a coarse or coarser droplet size (ASABE S572) or, if specifically using a spinning atomizer nozzle, applicators are required to use a volume mean diameter (VMD) of 385 microns or greater for release heights below 10 feet. Applicators are required to use a very coarse or coarser droplet size or, if specifically using a spinning atomizer nozzle, applicators are required to use a VMD of 475 microns or greater for release heights above 10 feet. Applicators must consider the effects of nozzle orientation and flight speed when determining droplet size.
- Applicators are required to use upwind swath displacement.
- The boom length must not exceed 60% of the wingspan or 90% of the rotor blade diameter to reduce spray drift.
- **DO NOT** apply when wind speed is greater than 10 mph.
- If applying at wind speeds less than 3 mph, the applicator must determine if a) Conditions of temperature inversion exist, or b) Stable atmospheric conditions exist at or below nozzle height.

**DO NOT** make applications into areas of temperature inversions or stable atmospheric conditions.

### Ground Boom Applications

- Applicators are required to use a nozzle height below 4 feet above the ground or plant canopy and coarse or coarser droplet size (ASABE S572) or, if specifically using a spinning atomizer nozzle, applicators are required to use a volume mean diameter (VMD) of 385 microns or greater.
- Applications with wind speeds greater than 10 mph are prohibited.
- Applications into temperature inversions are prohibited.

**DO NOT** apply when wind conditions may result in drift, when temperature inversion conditions exist, or when spray may be carried to sensitive areas. See **MANAGING OFF-TARGET MOVEMENT** section for more drift reduction recommendations.

## SURFACE APPLICATION

**Application to targeted emergent and/or floating vegetation.** To make surface applications targeting emergent or floating vegetation, uniformly apply with properly calibrated broadcast or spot treatment equipment in 10 or more gallons of water per acre. Spot treatments can be made with up to 5% **Clearcast™ herbicide** by volume. To ensure thorough spray coverage, higher spray volumes may be required when treating areas with large and/or dense vegetation. Use an appropriate spray pressure to minimize the drift potential depending upon spray equipment, conditions and application objectives.

**Application to water targeting submerged and/or emergent/floating vegetation. Clearcast** may be broadcast applied to the water surface or injected below the water surface. **Clearcast** may be applied as undiluted product or diluted with water prior to application. Under surface-matted conditions, **Clearcast** should be injected below the water surface to achieve better product distribution.

Apply **Clearcast** to water to achieve a final concentration of the active ingredient of no more than 500 ppb. Multiple applications of **Clearcast** may be made during the annual growth cycle to maintain the desired vegetation response.



## Clearcast™ herbicide Rates Per Treated Surface Acre

Average Water Depth of Treatment Site (feet)	Desired Active Ingredient Concentration (ppb)*			
	50	100	200	500
	Clearcast Rate (fl ozs) per Treated Surface Acre			
1	17	35	69	173
2	35	69	138	346
3	52	104	207	518
4	70	138	277	691
5	87	173	346	864
6	104	207	415	1037
7	122	242	484	1210
8	139	277	553	1382
9	157	311	622	1555
10	174	346	691	1728

\***Clearcast** contains 1.0 pound of active ingredient per gallon. There are 128 fl ozs in one gallon.

## AERIAL APPLICATIONS

**Clearcast** may be applied by both fixed wing and helicopter aircraft. There is no minimum spray volume when making applications directly to the water. For applications targeting emergent and/or floating vegetation, uniformly apply with properly calibrated equipment in 5 or more gallons of water per surface acre.

## DRAWDOWN APPLICATIONS

**Clearcast** may be used in drawdown situations to provide postemergence and/or preemergence control/suppression of aquatic vegetation. Apply **Clearcast** as a broadcast spray at rates up to 64 ozs/A or as a spot spray treatment with up to 5%

**Clearcast** by volume. Applications should be made when water has receded and exposed soil is moist to dry. For postemergence (foliar) applications, wait at least two weeks after application before reintroducing water. When treating irrigation canals, the initial flush of recharge water after application must not be used for irrigation purposes.

## LIMITATIONS AND RESTRICTIONS

### General Limitations

- **DO NOT** apply **Clearcast** to achieve a total active ingredient concentration in the water greater than 500 ppb.
- **DO NOT** apply more than 2 quarts of **Clearcast** per surface acre for the control of emergent and floating vegetation.

### Irrigation Restrictions

1. **DO NOT** use treated water to irrigate greenhouses, nurseries or hydroponics.
2. **DO NOT** plant sugar beets, onions, potatoes or non-**CLEARFIELD**® canola in soils that have been previously irrigated with **Clearcast**-treated water until a soil bioassay successfully demonstrates acceptable levels of crop tolerance.
3. **DO NOT** use any **Clearcast**-treated waters from still or quiescent sources for irrigation purposes less than 24 hours after **Clearcast** application is completed.
4. Waters receiving **Clearcast** either as a water treatment or as a foliar treatment on emergent/floating plants may be used for irrigation as long as concentrations are  $\leq 50$  ppb. Treated waters resulting in concentrations  $> 50$  ppb may not be used for irrigation until residue levels have been shown to be  $\leq 50$  ppb by an acceptable method.
5. Still and quiescent waters with an average depth of four (4) or more feet receiving a foliar application of **Clearcast** ( $\leq 2$  quarts per acre) to emergent/floating vegetation may be used for irrigation on allowable sites 24 hours after application is completed.

6. There are no irrigation restrictions on allowable sites for the use of treated water from flowing waters, such as irrigation canals with an average depth of four (4) or more feet, receiving a foliar application of **Clearcast™ herbicide** (≤ 2 quarts per acre) to emergent/floating vegetation.
7. After application of **Clearcast** to dry irrigation canals/ditches, the initial flush of water during recharge must not be used for irrigation purposes.

#### Other Water Use Restrictions

There are no restrictions on livestock watering, swimming, fishing, domestic use, or use of treated water for agricultural sprays.

**Potable Water. Clearcast** may be applied to potable water sources at concentrations up to 500 ppb to within a distance of 1/4 mile from an active potable water intake. Within 1/4 mile of an active potable water intake, **Clearcast** may be applied, but water concentrations resulting from injection and/or foliar applications may not exceed 50 ppb. If water concentrations greater than 50 ppb are required, then the potable water intake must be

shut and, if necessary, an alternate water supply be made available until the water concentration can be shown to be less than 50 ppb by an acceptable method.

#### Endangered Plant Species

To prevent potential negative impacts to endangered plant species, **DO NOT** apply **Clearcast** in a way that adversely affects federally listed endangered and threatened species.

### VEGETATION CONTROL RECOMMENDATIONS

#### Guidelines for Foliar Treatment of Emergent and Floating Vegetation

- Always use a surfactant for foliar applications of emergent and floating weeds.
- Foliar applications of **Clearcast** may be made as a broadcast spray or as a spot spray with a percent spray solution ranging from 0.25% to 5% **Clearcast** by volume.
- Control will be reduced if spray is washed off foliage by wave action.

#### Emergent, Floating, and Shoreline Species Controlled with Foliar Applications

Common Name	Scientific Name	Rate (ozs/A)	Comments
Alligatorweed	<i>Alternanthera philoxeroides</i>	64	Repeat applications may be necessary. Add 1 qt/A of <b>Rodeo® herbicide</b> for quicker brownout.
American lotus	<i>Nelumbo lutea</i>	64	
Arrowhead	<i>Sagittaria</i> spp.	32	
Cattail	<i>Typha</i> spp.	32 to 64	Apply after full green up through killing frost.
Chinese tallowtree	<i>Sapium sebiferum</i>	32 to 64	
Common reed	<i>Phragmites</i> spp.	64	Use 1 qt/A MSO; apply in late vegetative stage up to killing frost.
Common salvinia	<i>Salvinia minima</i>	32 to 64	Apply with MSO or MSO + silicone-based surfactant; retreatment will be necessary.

### Emergent, Floating, and Shoreline Species Controlled with Foliar Applications (*continued*)

Common Name	Scientific Name	Rate (ozs/A)	Comments
Floating pennywort	<i>Hydrocotyle ranunculoides</i>	32 to 64	Repeat applications may be necessary.
Four-leaf clover	<i>Marsilea</i> spp.	32	
Frogbit	<i>Lymnobia spongia</i>	16 to 32	Water concentrations of 50 to 100 ppb will control frogbit.
Giant reed	<i>Arundo donax</i>	64	Apply 1 qt/A MSO.
Mexican lily	<i>Nymphaea mexicana</i>	32 to 64	
Parrotfeather	<i>Myriophyllum aquaticum</i>	64	Apply only to emergent vegetation.
Pickerelweed	<i>Pontederia cordata</i>	32	
Smartweed	<i>Polygonum</i> spp.	16 to 32	
Water hyacinth	<i>Eichhornia crassipes</i>	16 to 32	Water concentrations of 50 to 100 ppb will control water hyacinth.
Water primrose	<i>Ludwigia</i> spp.	32	Add 1 qt/A of <b>Rodeo</b> for quicker brownout.
Watershield	<i>Brasenia schreberi</i>	48 to 64	Water concentrations of 50 to 100 ppb will control watershield.
Water lily	<i>Nymphaea</i> spp.	32 to 64	
Spatterdock	<i>Nuphar lutea</i>	64	

### Submersed Species Controlled with Water-injected Applications

Common Name	Scientific Name	Rate (ppb)	Comments
Bladderwort	<i>Utricularia floridana</i> <i>U. inflata</i>	50 to 100	
Hydrilla <sup>1</sup>	<i>Hydrilla verticillata</i>	150 to 200	See section on <b>Special Weed Control</b> for application directions.
Eurasian watermilfoil <sup>2</sup>	<i>Myriophyllum spicatum</i>	100 to 200	See section on <b>Special Weed Control</b> for application directions.

### Submersed Species Controlled with Water-injected Applications (*continued*)

Common Name	Scientific Name	Rate (ppb)	Comments
Northern watermilfoil	<i>Myriophyllum exalbescens</i>	100 to 200	
Variableleaf milfoil	<i>Myriophyllum heterophyllum</i>	100 to 200	
Pondweed, American flat stemmed leafy Illinois small variableleaf  clasping largeleaf	<i>Potamogeton</i> spp. <i>P. nodosus</i> <i>P. zosteriformis</i> <i>P. foliosus</i> <i>P. illinoensis</i> <i>P. pusillus</i> <i>P. gramineus</i> <i>P. diversifolius</i> <i>P. perfoliatus</i> <i>P. amplifolius</i>	50 to 100	
Pondweed, curlyleaf	<i>Potamogeton crispus</i>	50	
Pondweed, sago <sup>3</sup>	<i>Potamogeton pectinatus</i> ( <i>Stuckenia pectinatus</i> )	100	See section on <b>Special Weed Control</b> for application directions.
Water stargrass	<i>Heteranthera dubia</i>	100	
Widgeon grass	<i>Ruppia maritima</i>	200	

### Special Weed Control

- <sup>1</sup> **Hydrilla.** Apply **Clearcast™ herbicide** at 150 to 200 ppb to actively growing plants early in the growing season. Applications made prior to topped-out hydrilla may require repeat application. Single applications of <150 ppb or multiple sequential treatments with <150 ppb per application can be used to suppress and growth regulate hydrilla to reduce the impact of hydrilla growth on recreation opportunities.
- <sup>2</sup> **Eurasian watermilfoil.** Apply **Clearcast** at 100 to 200 ppb to actively growing plants early in the growing season. Applications made to mature milfoil (vegetation topped out) may require multiple applications.
- <sup>3</sup> **Sago pondweed.** Sago pondweed may be controlled in nonflowing water with water-injected applications at 100 ppb. In dry ditches (drainage and irrigation), sago pondweed may be controlled or growth suppressed with soil-applied **Clearcast** at 64 ozs/A. In irrigation canals, apply **Clearcast** after draw-down and prior to water recharge.

## MANAGING OFF-TARGET MOVEMENT

The information that follows is general guidance for managing and minimizing off-target exposure of this product. Specific use recommendations in this label may vary from these general guidelines depending on the application method and objectives and should supersede the general information provided below.

Avoiding spray drift at the application site is the responsibility of the applicator. The interaction of many equipment- and weather-related factors determines the potential for spray drift. The applicator and the grower are responsible for considering all these factors when making decisions.

The following drift management requirements must be followed to avoid off-target drift movement from aerial applications:

1. The distance of the outermost nozzles on the boom must not exceed  $\frac{3}{4}$  the length of the wingspan or 90% of the rotor.
2. Nozzles must always point backward parallel with the airstream and never be pointed downward more than 45 degrees.
3. **DO NOT** apply if wind speed is greater than 10 mph, except when making injection or subsurface applications to water.

Where states have more stringent regulations, they must be observed.

The applicator must be familiar with and take into account the information covered in the aerial drift reduction advisory information presented below.

### INFORMATION ON DROPLET SIZE

The most effective way to reduce drift potential is to apply large droplets. The best drift management strategy is to apply the largest droplets that provide sufficient coverage and control. Applying larger droplets reduces drift potential but will not prevent drift if applications are made improperly or under unfavorable environmental conditions (see

**WIND; TEMPERATURE AND HUMIDITY; and TEMPERATURE INVERSIONS).**

### CONTROLLING DROPLET SIZE

- **Volume.** Use high flow rate nozzles to apply the highest practical spray volume. Nozzles with higher rated flows produce larger droplets.
- **Pressure. DO NOT** exceed the nozzle manufacturer's recommended pressures. For many nozzle types, lower pressure produces larger droplets. When higher flow rates are needed, use higher flow rate nozzles instead of increasing pressure.
- **Number of Nozzles.** Use the minimum number of nozzles that provides uniform coverage.
- **Nozzle Orientation.** Orienting nozzles so that the spray is released parallel to the airstream produces larger droplets than other orientations and is recommended practice. Significant deflection from the horizontal will reduce droplet size and increase drift potential.
- **Nozzle Type.** Use a nozzle type that is designed for the intended application. With most nozzle types, narrower spray angles produce larger droplets. Consider using low-drift nozzles. Solid-stream nozzles oriented straight back produce the largest droplets and the lowest drift.

### BOOM LENGTH

For some use patterns, reducing the effective boom length to less than  $\frac{3}{4}$  of the wingspan or 90% of rotor length may further reduce drift without reducing swath width.

### APPLICATION HEIGHT

Applications must not be made at a height greater than 10 feet above the top of the largest plants unless a greater height is required for aircraft safety. Making applications at the lowest height that is safe reduces exposure of droplets to evaporation and wind.

### SWATH ADJUSTMENT

When applications are made with a crosswind, the swath will be displaced downwind. Therefore, on

the upwind and downwind edges of the field, the applicator must compensate for this displacement by adjusting the path of the aircraft upwind. Swath adjustment distance should increase with increasing drift potential (higher wind, smaller droplets, etc.).

## **WIND**

Drift potential is lowest between wind speeds of 2 to 10 mph. However, many factors, including droplet size and equipment type, determine drift potential at any given speed. Application should be avoided below 2 mph due to variable wind direction and high inversion potential. **NOTE:** Local terrain can influence wind patterns. Every applicator should be familiar with local wind patterns and how they affect spray drift.

## **TEMPERATURE AND HUMIDITY**

When making applications in low relative humidity, set up equipment to produce larger droplets to compensate for evaporation. Droplet evaporation is most severe when conditions are both hot and dry.

## **TEMPERATURE INVERSIONS**

Applications must not occur during a temperature inversion because drift potential is high. Temperature inversions restrict vertical air mixing, which causes small suspended droplets to remain in a concentrated cloud. This cloud can move in unpredictable directions due to the light, variable

winds common during inversions. Temperature inversions are characterized by increasing temperatures with altitude and are common on nights with limited cloud cover and light-to-no wind. They begin to form as the sun sets and often continue into the morning. Their presence can be indicated by ground fog; however, if fog is not present, inversions can also be identified by the movement of smoke from a ground source or an aircraft smoke generator. Smoke that layers and moves laterally in a concentrated cloud (under low wind conditions) indicates an inversion, while smoke that moves upward and rapidly dissipates indicates good vertical air mixing.

## **SENSITIVE AREAS**

The pesticide must only be applied when the potential for drift to adjacent sensitive areas (e.g. residential areas, bodies of water, known habitat for threatened or endangered species, or crops) is minimal (e.g. when wind is blowing away from the sensitive areas).

Applicator is responsible for any loss or damage which results from spraying **Clearcast™ herbicide** in a manner other than recommended in this label. In addition, applicator must follow all applicable state and local regulations and ordinances in regard to spraying.



## Conditions of Sale and Warranty

The **Directions For Use** of this product reflect the opinion of experts based on field use and tests. The directions are believed to be reliable and must be followed carefully. However, it is impossible to eliminate all risks inherently associated with the use of this product. Crop injury, ineffectiveness or other unintended consequences may result because of such factors as weather conditions, presence of other materials, or use of the product in a manner inconsistent with its labeling, all of which are beyond the control of BASF CORPORATION ("BASF") or the Seller. To the extent consistent with applicable law, all such risks shall be assumed by the Buyer. BASF warrants that this product conforms to the chemical description on the label and is reasonably fit for the purposes referred to in the **Directions For Use**, subject to the inherent risks, referred to above.

TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, BASF MAKES NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS OR MERCHANTABILITY OR ANY OTHER EXPRESS OR IMPLIED WARRANTY. TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, BUYER'S EXCLUSIVE REMEDY AND BASF'S EXCLUSIVE LIABILITY, WHETHER IN CONTRACT, TORT, NEGLIGENCE, STRICT LIABILITY, OR OTHERWISE, SHALL BE LIMITED TO REPAYMENT OF THE PURCHASE PRICE OF THE PRODUCT. TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, BASF AND THE SELLER DISCLAIM ANY LIABILITY FOR CONSEQUENTIAL, SPECIAL OR INDIRECT DAMAGES RESULTING FROM THE USE OR HANDLING OF THIS PRODUCT. BASF and the Seller offer this product, and the Buyer and User accept it, subject to the foregoing **Conditions of Sale and Warranty** which may be varied only by agreement in writing signed by a duly authorized representative of BASF. 1107

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**Clearcast** is a trademark of BASF.

**Rodeo** is a registered trademark of Dow AgroSciences LLC.

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000241-00437.20070410c.NVA 2006-04-299-0309

BASF Corporation  
26 Davis Drive  
Research Triangle Park, NC 27709



The Chemical Company



**For the control of vegetation in  
and around aquatic and  
noncropland sites.**

**Active Ingredient:**

ammonium salt of imazamox 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid\* ..... 12.1%

**Other Ingredients:** ..... 87.9%

**Total:** ..... 100.0%

\*Equivalent to 11.4% 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid (1 gallon contains 1.0 pound of active ingredient as the free acid)

**US Patent No. 5,334,576**

**EPA Reg. No. 241-437**

**EPA Est. No. is indicated by the fifth letter of the code printed on this container: M=241-PR-002 RR=51036-GA-002**

**KEEP OUT OF REACH OF CHILDREN  
CAUTION/PRECAUTION**

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

**FIRST AID: If on skin or clothing:** Take off contaminated clothing. Rinse skin immediately with plenty of water for 15 to 20 minutes. Call a poison control center or doctor for treatment advice. **If in eyes:** Hold eye open and rinse slowly and gently with water for 15 to 20 minutes. Remove contact lenses, if present, after the first 5 minutes; then continue rinsing eye. Call a poison control center or doctor for treatment advice. **If inhaled:** Move person to fresh air. If person is not breathing, call 911 or an ambulance; then give artificial respiration, preferably mouth-to-mouth if possible. Call a poison control center or doctor for further treatment advice. **HOT LINE NUMBER:** Have the product container or label with you when calling a poison control center or doctor or going for treatment. You may also contact BASF Corporation for emergency medical treatment information: 1-800-832-HELP (4357). **PRECAUTIONARY STATEMENTS: HAZARDS TO HUMANS AND DOMESTIC ANIMALS: CAUTION:** Harmful if absorbed through skin or inhaled. Avoid breathing spray mist. Avoid contact with skin, eyes or clothing. **PERSONAL PROTECTIVE EQUIPMENT (PPE):** Some materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for **Category A** on an EPA chemical-resistance category selection chart. **ENVIRONMENTAL HAZARDS:** This pesticide may be hazardous to plants outside the treated area. **DO NOT** apply to water except as specified in this label. **DO NOT** contaminate water when disposing of equipment washwaters and rinsate. **DIRECTIONS FOR USE:** It is a violation of federal law to use this product in a manner inconsistent with its labeling. This labeling

must be in the possession of the user at the time of pesticide application. **DO NOT** apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your state or tribe, consult the agency responsible for pesticide regulation. Ensure spray drift to nontarget species does not occur. **STORAGE AND DISPOSAL: DO NOT** contaminate food, feed or water by storage or disposal. **PESTICIDE STORAGE:** KEEP FROM FREEZING. **DO NOT** store below 32° F. **DO NOT** contaminate water, food or feed by storage or disposal. **PESTICIDE DISPOSAL.** Wastes resulting from the use of this product may be disposed of on-site or at an approved waste disposal facility. **CONTAINER DISPOSAL: Nonrefillable Container. DO NOT reuse or refill this container.** Triple rinse or pressure rinse container (or equivalent) promptly after emptying; then offer for recycling, if available, or reconditioning, if appropriate, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures approved by state and local authorities. **Triple rinse containers small enough to shake (capacity ≤ 5 gallons) as follows:** Empty the remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container 1/4 full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank, or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times. **Triple rinse containers too large to shake (capacity > 5 gallons) as follows:** Empty the remaining contents into application equipment or a mix tank. Fill the container 1/4 full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Empty the rinsate into application equipment or a mix tank, or store rinsate for later use or disposal. Repeat this procedure two more times. **Pressure rinse as follows:** Empty the remaining contents into application equipment or mix tank. Hold container upside down over application equipment or mix tank, or collect rinsate for later use or disposal. Insert pressure rinsing nozzle in the side of the container and rinse at about 40 PSI for at least 30 seconds. Drain for 10 seconds after the flow begins to drip.

**In case of an emergency endangering life or property involving this product, call day or night 1-800-832-HELP (4357).**

See attached booklet for complete **First Aid, Precautionary Statements, Directions For Use, Conditions of Sale and Warranty,** and state-specific crop and/or use site restrictions.

**Net Contents: 1 gallon**

Product of U.S.A.

**NVA 2008-05-299-0099**

BASF Corporation  
26 Davis Drive, Research Triangle Park, NC 27709

 **BASF**  
The Chemical Company





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## Supplemental Label

### FOR VEGETATION CONTROL IN TERRESTRIAL NONCROPLAND SITES

EPA Reg. No. 241-437

**Active Ingredient:**

**ammonium salt of imazamox:** 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid\*..... 12.1%

**Other Ingredients:**..... 87.9%

**Total:** ..... 100.0%

\*Equivalent to 11.4% 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid

(1 gallon contains 1.0 pound of active ingredient as the free acid)

**Follow all applicable directions, restrictions, Worker Protection Standard requirements, and precautions on the EPA-approved product label for Clearcast® herbicide, EPA Reg. No. 241-437.**

**This supplemental label must be in the possession of the user at the time of application.**

#### DIRECTIONS FOR USE

It is a violation of federal law to use this product in a manner inconsistent with its labeling.

Observe all cautions and limitations on this label and on the labels of products used in combination with **Clearcast**. **DO NOT** use **Clearcast** other than in accordance with the instructions set forth on this label. Keep containers closed to avoid spills and contamination.

Read the **First Aid, Precautionary Statements, Environmental Hazards, and Storage and Disposal** statements appearing on the container label.

#### GENERAL INFORMATION

**Clearcast** may be applied on terrestrial noncropland sites for the control of undesirable vegetation.

Applications may be made to public, private, and military lands as follows: uncultivated nonagricultural

areas (such as airports, highway, railroad and utility rights-of-way, levees, dams, flood control structures, natural areas, etc); industrial sites (such as lumberyards, railroad yards, tank farms, sewage disposal areas, pumping stations, etc.); uncultivated agricultural areas - noncrop producing (such as farmyards, fuel storage areas, fence rows, ditch banks, barrier strips, etc). **Clearcast** may be used for the control or maintenance of undesirable vegetation in and around swamps, bogs, marshes, riparian zones, drainage areas, ditches, canals, stream and river banks, and flood zones.

**Clearcast** may also be used in terrestrial noncropland sites for the control or maintenance of undesirable vegetation for the purposes of wildlife habitat management and enhancement.

#### APPLICATION INSTRUCTIONS

**Clearcast** may be applied with ground and aerial equipment including both fixed wing and helicopter. Applications may be made using foliar broadcast spray, foliar spot spray, injection (hack and squirt), frill and girdle, cut stump, or basal methods.

For broadcast applications, **DO NOT** apply more than 64 fl ozs **Clearcast** per acre.

For foliar spot applications, apply **Clearcast** as a percent solution, containing up to 5% **Clearcast** by volume.

Injection (hack and squirt), frill and girdle, and cut stump treatments may be made using up to 100% **Clearcast® herbicide** by volume.

Basal treatments can be made using up to 25% **Clearcast** by volume.

Foliar applications of **Clearcast** require the use of a spray adjuvant. Refer to the container label **SPRAY ADJUVANTS** section for additional information. Basal applications require the use of a good emulsion system to maintain **Clearcast** in a stable emulsion with the penetrating agent being used.

## WEEDS CONTROLLED

**Clearcast herbicide** may be used for the control of the following plant species. **Clearcast** may be effective for the control or suppression of additional plant species not listed below. The use of **Clearcast** for the control or suppression of undesirable plants not listed below may be done at the discretion of the user.

**TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, THE USER ASSUMES RESPONSIBILITY FOR ANY LACK OF CONTROL OR SUPPRESSION ASSOCIATED WITH APPLICATION TO WEEDS NOT LISTED ON THIS LABEL.**

Common Name	Scientific Name	Rate		Comments
Alligator weed	<i>Alternanthera philoxeroides</i>	64 fl ozs/A	Foliar	Addition of glyphosate will improve efficacy.
Annual ryegrass	<i>Lolium multiflorum</i>	16 to 32 fl ozs/A	Foliar	
Brazilian pepper; Christmasberry	<i>Schimus terebinthifolius</i>	2% v/v	Foliar	
California bullrush	<i>Schoenoplectus californicus</i>	64 fl ozs/A	Foliar	
Camphor tree	<i>Cinnamomum camphora</i>	2% v/v	Foliar	
Cattail	<i>Typha</i> spp.	32 to 64 fl ozs/A	Foliar	
Chinese tallowtree; Popcorn tree	<i>Sapium sebiferum</i>	32 to 64 fl ozs/A	Foliar	See <b>SPECIAL WEED CONTROL</b> section.
Giant ragweed*	<i>Ambrosia trifida</i>	32 to 64 fl ozs/A	Foliar	
Giant reed; Wild cane	<i>Arunodo donax</i>	64 fl ozs/A	Foliar	Addition of glyphosate will improve efficacy. May require application the following year.
Jamaican nightshade	<i>Solanum jamaicense</i>	2% v/v	Foliar	
Johnsongrass, seedling rhizome	<i>Sorghum halepense</i>	16 fl ozs/A 32 to 64 fl ozs/A	Foliar Foliar	
Old world climbing fern	<i>Lygodium microphyllum</i>	5% v/v	Foliar	
Phragmites	<i>Phragmites australis</i>	64 fl ozs/A	Foliar	Fall timing provides better control. Addition of glyphosate will improve efficacy.
Purple loosestrife	<i>Lythrum salicaria</i>	32 to 64 fl ozs/A	Foliar	
Sedge*, purple yellow	<i>Cyperus rotundus</i> <i>Cyperus esculentus</i>	32 fl ozs/A 32 fl ozs/A	Foliar Foliar	
Smartweed	<i>Polygonum</i> spp.	32 to 64 fl ozs/A	Foliar	
Spike rush	<i>Eleocharis</i> spp.	64 fl ozs/A	Foliar	
Taro	<i>Taro</i> spp.	64 fl ozs/A 5% v/v	Foliar Foliar	
Tropical soda apple	<i>Solanum viarum</i>	2% v/v	Foliar	
Water primrose	<i>Ludwigia</i> spp.	32 to 64 fl ozs/A	Foliar	Addition of glyphosate will improve efficacy.
Wetland nightshade	<i>Solanum tampicense</i>	2% v/v	Foliar	
Whitetop; Hoary cress	<i>Cardaria draba</i>	8 to 16 fl ozs/A	Foliar	

\*Suppression of larger, well-established plants

In general, the use of methylated seed oil (MSO) at 1% v/v will provide the best control with foliar applications.

## SPECIAL WEED CONTROL

**Chinese tallowtree:** Clearcast® herbicide at 32 to 64 fl ozs/A or 0.5 to 2.0% v/v may be applied as a foliar application for selective control of Chinese tallowtree in and around tolerant hardwood species. Chinese tallowtree will be controlled with foliar applications using aerial, handgun, or backpack application methods. When treating Chinese tallowtree in mixed stands of hardwoods, application method and spray volume should ensure adequate coverage of targeted Chinese tallowtree plants. Methylated seed oil should be added at 32 fl ozs/A for broadcast applications, or at 1% v/v for spot backpack and handgun applications. Tolerant hardwood species may exhibit varying degrees of leaf discoloration and temporary injury.

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BASF warrants that this product conforms to the chemical description on the label and is reasonably fit for the purposes referred to in the **Directions For Use**, subject to the inherent risks, referred to above.

To the extent consistent with applicable law, BASF makes no other express or implied warranty of fitness or merchantability or any other express or implied warranty.

To the extent consistent with applicable law, Buyer's exclusive remedy and BASF's exclusive liability, whether in contract, tort, negligence, strict liability, or otherwise, shall be limited to repayment of the purchase price of the product.

To the extent consistent with applicable law, BASF and the Seller disclaim any liability for consequential, special or indirect damages resulting from the use or handling of this product.

BASF and the Seller offer this product, and the Buyer and User accept it, subject to the foregoing **Conditions of Sale and Warranty** which may be varied only by agreement in writing signed by a duly authorized representative of BASF. 0408

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000241-00437.20080530.NVA 2008-04-299-0173

BASF Corporation  
26 Davis Drive  
Research Triangle Park, NC 27709



The Chemical Company



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## Safety data sheet

### CLEARCAST™ HERBICIDE

Revision date : 2008/01/31  
Version: 2.0

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#### 1. Substance/preparation and company identification

Company  
BASF CORPORATION  
100 Campus Drive  
Florham Park, NJ 07932, USA

24 Hour Emergency Response Information  
CHEMTREC: 1-800-424-9300  
BASF HOTLINE: 1-800-832-HELP

Substance number: 000000136003  
Molecular formula: C<sub>15</sub> H<sub>18</sub> N<sub>3</sub> O<sub>4</sub> . N H(4)  
Molecular weight: 322.4 g/mol  
Chemical family: imidazole derivative  
Synonyms: ammonium salt of imazamox

#### 2. Composition/information on ingredients

<u>CAS Number</u>	<u>Content (W/W)</u>	<u>Chemical name</u>
247057-22-3	12.1 %	ammonium salt of imazamox (active ingredient)
	87.9 %	Proprietary ingredients

#### 3. Hazard identification

##### Emergency overview

CAUTION: HARMFUL IF ABSORBED THROUGH SKIN.  
HARMFUL IF INHALED.  
Avoid contact with the skin, eyes and clothing.  
Avoid inhalation of mists/vapours.

##### Potential health effects

See Product Label for additional precautionary statements.

##### Primary routes of exposure

Routes of entry for solids and liquids include eye and skin contact, ingestion and inhalation. Routes of entry for gases include inhalation and eye contact. Skin contact may be a route of entry for liquified gases.

##### Acute toxicity:

Relatively nontoxic after single ingestion. Slightly toxic after short-term skin contact. Relatively nontoxic after short-term inhalation.

##### Irritation:

May cause slight irritation to the skin. May cause moderate but temporary irritation to the eyes.

##### Repeated dose toxicity:

No known chronic effects.

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### Medical conditions aggravated by overexposure:

No data available.

### Potential environmental effects

#### Aquatic toxicity:

There is a high probability that the product is not acutely harmful to aquatic organisms.

#### Terrestrial toxicity:

With high probability not acutely harmful to terrestrial organisms.

---

## 4. First-aid measures

### General advice:

First aid providers should wear personal protective equipment to prevent exposure. Remove contaminated clothing. Move person to fresh air. If person is not breathing, call 911 or ambulance, then give artificial respiration, preferably mouth-to-mouth if possible. Call a poison control center or physician for treatment advice. Have the product container or label with you when calling a poison control center or doctor or going for treatment.

### If inhaled:

Remove the affected individual into fresh air and keep the person calm. Assist in breathing if necessary.

### If on skin:

Rinse skin immediately with plenty of water for 15 - 20 minutes.

### If in eyes:

Hold eyes open and rinse slowly and gently with water for 15 to 20 minutes. Remove contact lenses, if present, after first 5 minutes, then continue rinsing.

### If swallowed:

Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to by a poison control center or doctor. Never induce vomiting or give anything by mouth if the victim is unconscious or having convulsions.

### Note to physician

#### Hazards:

Accidental or deliberate ingestion of this product/substance in excess of 2 fluid ounces in a child or 8 fluid ounces in an adult, may produce signs and symptoms of propylene glycol poisoning, including severe metabolic acidosis, oxaluria, hypocalcemia and renal failure due to crystalluria.

#### Antidote:

No known specific antidote.

#### Treatment:

Treat according to the symptoms under clinical conditions. Treatment with intravenous bicarbonate to combat acidosis and treatment with ethanol to inhibit the metabolism of the glycol to oxalat may be necessary.

---

## 5. Fire-fighting measures

### Flash point:

No data available.

### Suitable extinguishing media:

foam, dry extinguishing media, carbon dioxide, water spray

### Hazards during fire-fighting:

carbon monoxide, carbon dioxide, nitrogen oxide, nitrogen dioxide, Ammonium, Hydrocarbons, If product is heated above decomposition temperature, toxic vapours will be released. The substances/groups of substances mentioned can be released if the product is involved in a fire.

### Protective equipment for fire-fighting:

Firefighters should be equipped with self-contained breathing apparatus and turn-out gear.

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### Further information:

Evacuate area of all unnecessary personnel. Contain contaminated water/firefighting water. Do not allow to enter drains or waterways.

---

## 6. Accidental release measures

### Personal precautions:

Take appropriate protective measures. Clear area. Shut off source of leak only under safe conditions. Extinguish sources of ignition nearby and downwind. Ensure adequate ventilation. Wear suitable personal protective clothing and equipment.

### Environmental precautions:

Do not discharge into the subsoil/soil. Do not discharge into drains/surface waters/groundwater. Contain contaminated water/firefighting water.

### Cleanup:

Dike spillage. Pick up with suitable absorbent material. Place into suitable containers for reuse or disposal in a licensed facility. Spilled substance/product should be recovered and applied according to label rates whenever possible. If application of spilled substance/product is not possible, then spills should be contained, solidified, and placed in suitable containers for disposal. After decontamination, spill area can be washed with water. Collect wash water for approved disposal.

---

## 7. Handling and storage

### Handling

#### General advice:

RECOMMENDATIONS ARE FOR MANUFACTURING, COMMERCIAL BLENDING, AND PACKAGING WORKERS. PESTICIDE APPLICATORS & WORKERS must refer to the Product Label and Directions for Use attached to the product for Agricultural Use Requirements in accordance with the EPA Worker Protection Standard 40 CFR part 170. Ensure adequate ventilation. Provide good ventilation of working area (local exhaust ventilation if necessary). Keep away from sources of ignition - No smoking. Keep container tightly sealed. Protect contents from the effects of light. Protect against heat. Protect from air. Handle and open container with care. Do not open until ready to use. Once container is opened, content should be used as soon as possible. Avoid aerosol formation. Avoid dust formation. Provide means for controlling leaks and spills. Do not return residues to the storage containers. Follow label warnings even after container is emptied. The substance/ product may be handled only by appropriately trained personnel. Avoid all direct contact with the substance/product. Avoid contact with the skin, eyes and clothing. Avoid inhalation of dusts/mists/vapours. Wear suitable personal protective clothing and equipment.

#### Protection against fire and explosion:

No explosion proofing necessary.

### Storage

#### General advice:

Keep only in the original container in a cool, dry, well-ventilated place away from ignition sources, heat or flame. Protect containers from physical damage. Protect against contamination. The authority permits and storage regulations must be observed.

#### Storage incompatibility:

General: Segregate from incompatible substances. Segregate from foods and animal feeds. Segregate from textiles and similar materials.

#### Storage stability:

If substance/product crystallizes, thaw at room temperature.

#### Temperature tolerance

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Protect from temperatures below: 32 °F

Changes in the properties of the product may occur if substance/product is stored below indicated temperature for extended periods of time.

### 8. Exposure controls and personal protection

Users of a pesticidal product should refer to the product label for personal protective equipment requirements.

#### Advice on system design:

Whenever possible, engineering controls should be used to minimize the need for personal protective equipment.

#### Personal protective equipment

#### RECOMMENDATIONS FOR MANUFACTURING, COMMERCIAL BLENDING, AND PACKAGING WORKERS:

##### Respiratory protection:

Wear respiratory protection if ventilation is inadequate. Wear a NIOSH-certified (or equivalent) TC23C Chemical/Mechanical type filter system to remove a combination of particles, gas and vapours. For situations where the airborne concentrations may exceed the level for which an air purifying respirator is effective, or where the levels are unknown or Immediately Dangerous to Life or Health (IDLH), use NIOSH-certified full facepiece pressure demand self-contained breathing apparatus (SCBA) or a full facepiece pressure demand supplied-air respirator (SAR) with escape provisions.

##### Hand protection:

Chemical resistant protective gloves, Protective glove selection must be based on the user's assessment of the workplace hazards.

##### Eye protection:

Safety glasses with side-shields. Tightly fitting safety goggles (chemical goggles). Wear face shield if splashing hazard exists.

##### Body protection:

Body protection must be chosen depending on activity and possible exposure, e.g. head protection, apron, protective boots, chemical-protection suit.

##### General safety and hygiene measures:

Wear long sleeved work shirt and long work pants in addition to other stated personal protective equipment. Work place should be equipped with a shower and an eye wash. Handle in accordance with good industrial hygiene and safety practice. Personal protective equipment should be decontaminated prior to reuse. Gloves must be inspected regularly and prior to each use. Replace if necessary (e.g. pinhole leaks). Take off immediately all contaminated clothing. Store work clothing separately. Hands and/or face should be washed before breaks and at the end of the shift. No eating, drinking, smoking or tobacco use at the place of work. Keep away from food, drink and animal feeding stuffs.

### 9. Physical and chemical properties

Form:	liquid	
Odour:	acidic, mild	
pH value:	5.8 - 6.2	
Boiling point:	approx. 100 °C	( 760 mmHg)
Density:	1.05 g/cm3	( 20 °C)
Relative density:	1.05	
Partitioning coefficient n-octanol/water (log Pow):		Not applicable

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### 10. Stability and reactivity

**Conditions to avoid:**

Avoid all sources of ignition: heat, sparks, open flame. Avoid extreme temperatures. Avoid prolonged exposure to extreme heat. Avoid contamination. Avoid electro-static discharge. Avoid prolonged storage.

**Substances to avoid:**

oxidizing agents

**Hazardous reactions:**

The product is chemically stable.

Hazardous polymerization will not occur. No hazardous reactions if stored and handled as prescribed/indicated.

**Decomposition products:**

Hazardous decomposition products: No hazardous decomposition products if stored and handled as prescribed/indicated., Prolonged thermal loading can result in products of degradation being given off.

Hazardous decomposition products:

**Thermal decomposition:**

Possible thermal decomposition products:

carbon monoxide, carbon dioxide, nitrogen oxide, nitrogen dioxide, Ammonium, Hydrocarbons

Stable at ambient temperature. If product is heated above decomposition temperature toxic vapours may be released. If product is heated above decomposition temperature hazardous fumes may be released.

**Corrosion to metals:**

Corrosive effects to metal are not anticipated. Not corrosive to: mild steel

---

### 11. Toxicological information

**Acute toxicity**

**Oral:**

LD50/rat: > 5,000 mg/kg

Slightly toxic to practically nontoxic.

**Inhalation:**

LC50/rat: > 5 mg/l / 4 h

Moderately toxic.

LC50/rat: > 20 mg/l / 1 h

**Dermal:**

LD50/rat: > 4,000 mg/kg

Slightly toxic.

**Skin irritation:**

rabbit: non-irritant (FHSA Guideline)

**Eye irritation :**

rabbit: non-irritant

**Sensitization:**

modified Buehler test/guinea pig: Skin sensitizing effects were not observed in animal studies.

**Genetic toxicity:**

Information on: imazamox

No mutagenic effect was found in various tests with microorganisms and mammals.

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### **Carcinogenicity:**

*Information on: imazamox*

*In long-term studies in rats and mice in which the substance was given by feed, a carcinogenic effect was not observed.*

### **Reproductive toxicity:**

*Information on: imazamox*

*The results of animal studies gave no indication of a fertility impairing effect.*

### **Developmental toxicity/teratogenicity:**

*Information on: imazamox*

*No indications of a developmental toxic / teratogenic effect were seen in animal studies.*

---

## 12. Ecological information

*Information on: imazamox*

*Evaluation: Not readily biodegradable (by OECD criteria).*

### **Environmental toxicity**

*Information on: imazamox*

*Acute and prolonged toxicity to fish:*

*Rainbow trout/LC50 (96 h): = > 122 ppm*

*Information on: imazamox*

*Acute toxicity to aquatic invertebrates:*

*Daphnia magna/EC50: >122 ppm*

*Information on: imazamox*

*Toxicity to aquatic plants:*

*algae/EC50 (120 h): > 0.037 mg/l*

*Information on: imazamox*

*Other terrestrial non-mammals:*

*mallard duck/LC50: > 5,572 ppm*

*Honey bee/LD50: > 100 ug/bee*

### **Other ecotoxicological advice:**

The ecological data given are those of the active ingredient. Do not release untreated into natural waters.

---

## 13. Disposal considerations

### **Waste disposal of substance:**

Pesticide wastes are regulated.

Improper disposal of excess pesticide, spray mix or rinsate is a violation of federal law.

If pesticide wastes cannot be disposed of according to label instructions, contact the State Pesticide or Environmental Control Agency or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.

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### Container disposal:

Rinse thoroughly at least three times (triple rinse) in accordance with EPA recommendations. Consult state or local disposal authorities for approved alternative procedures such as container recycling. Recommend crushing, puncturing or other means to prevent unauthorized use of used containers.

**RCRA:** This product is not regulated by RCRA.

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## 14. Transport information

Reference Bill of Lading

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## 15. Regulatory information

### Federal Regulations

#### Registration status:

TSCA, US released / exempt

**OSHA hazard category:** Not hazardous

**SARA hazard categories (EPCRA 311/312):** Not hazardous

### State regulations

#### CA Prop. 65:

There are no listed chemicals in this product.

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## 16. Other information

**Refer to product label for EPA registration number.**

Recommended use: herbicide

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### Local contact information

Product Stewardship  
919 547-2000

IMPORTANT: WHILE THE DESCRIPTIONS, DESIGNS, DATA AND INFORMATION CONTAINED HEREIN ARE PRESENTED IN GOOD FAITH AND BELIEVED TO BE ACCURATE, IT IS PROVIDED FOR YOUR GUIDANCE ONLY. BECAUSE MANY FACTORS MAY AFFECT PROCESSING OR APPLICATION/USE, WE RECOMMEND THAT YOU MAKE TESTS TO DETERMINE THE SUITABILITY OF A PRODUCT FOR YOUR PARTICULAR PURPOSE PRIOR TO USE. NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE MADE REGARDING PRODUCTS DESCRIBED OR DESIGNS, DATA OR INFORMATION SET FORTH, OR THAT THE PRODUCTS, DESIGNS, DATA OR INFORMATION MAY BE USED WITHOUT INFRINGING THE INTELLECTUAL PROPERTY RIGHTS OF OTHERS. IN NO CASE SHALL THE DESCRIPTIONS, INFORMATION, DATA OR DESIGNS PROVIDED BE CONSIDERED A PART OF OUR TERMS AND CONDITIONS OF SALE. FURTHER, YOU EXPRESSLY UNDERSTAND AND AGREE THAT THE DESCRIPTIONS, DESIGNS, DATA, AND INFORMATION FURNISHED BY BASF HEREUNDER ARE GIVEN GRATIS AND BASF ASSUMES NO OBLIGATION OR LIABILITY FOR THE DESCRIPTION, DESIGNS, DATA AND INFORMATION GIVEN OR RESULTS OBTAINED, ALL SUCH BEING GIVEN AND ACCEPTED AT YOUR RISK.

# **Safety data sheet**

## **CLEARCAST™ HERBICIDE**

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END OF DATA SHEET

## **Appendix B**

### **New York Natural Heritage Program rare plant status list**

# **New York Natural Heritage Program Rare Plant Status Lists**

June 2008

Edited by:  
Stephen M. Young

**This list is also published at the website:**  
[www.nynhp.org](http://www.nynhp.org)

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To report sightings of rare species, contact our office or fill out and mail or email us the Natural Heritage reporting form provided at the end of this publication.

**The New York Natural Heritage Program is a partnership with the New York State Department of Environmental Conservation and by The Nature Conservancy. Major support comes from the NYS Biodiversity Research Institute, the Environmental Protection Fund, and Return a Gift to Wildlife.**

## Protected Native Plants

### 193.3 Protected native plants.

(a) All plants enumerated on the lists of endangered species in subdivision (b) of this section, threatened species in subdivision (c) of this section, rare species in subdivision (d) of this section, or exploitably vulnerable species in subdivision (e) of this section are protected native plants pursuant to section 9-1503 of the Environmental Conservation Law. The common names contained on these lists are included for information purposes only; the scientific name shall be used for the purpose of determining any violation. Site means a colony or colonies of plants separated from other colonies by at least one-half mile.

(b) The following are **endangered** native plants in danger of extirpation throughout all or a significant portion of their ranges within the state and requiring remedial action to prevent such extinction. Listed plants are those with five or fewer extant sites, or fewer than 1,000 individuals, or restricted to fewer than four U.S.G.S. 7 1/2 minute series maps, or species listed as endangered by the United States Department of Interior in the *Code of Federal Regulations*.

Species	Common Name
<i>Acalypha virginica</i> var. <i>virginica</i>	VIRGINIA THREE-SEEDED MERCURY
<i>Adoxa moschatellina</i>	MOSCHATEL
<i>Agalinis acuta</i>	SANDPLAIN GERARDIA
<i>Allium burdickii</i>	WILD LEEK
<i>Amaranthus pumilus</i>	SEABEACH AMARANTH
<i>Amelanchier nantucketensis</i>	NANTUCKET JUNE BERRY
<i>Ammophila champlainensis</i>	CHAMPLAIN BEACHGRASS
<i>Amphicarpum purshii</i>	PEANUT GRASS
<i>Angelica lucida</i>	ANGELICA
<i>Anthoxanthum monticolum</i> ssp. <i>orthanthum</i>	ALPINE SWEETGRASS
<i>Aplectrum hyemale</i>	PUTTYROOT
<i>Arabis drummondii</i>	DRUMMOND'S ROCK CRESS
<i>Arabis shortii</i>	TOOTHED ROCK-CRESS
<i>Aristolochia serpentaria</i>	VIRGINIA SNAKE ROOT
<i>Arnica lanceolata</i>	ARNICA
<i>Artemisia campestris</i> var. <i>borealis</i>	WILD SAGE
<i>Asclepias variegata</i>	WHITE MILKWEED
<i>Asplenium bradleyi</i>	BRADLEY'S SPLEENWORT
<i>Asplenium trichomanes-ramosum</i>	GREEN SPLEENWORT
<i>Aster ciliolatus</i>	LINDLEY'S ASTER
<i>Aster concolor</i>	SILVERY ASTER
<i>Aster laevis</i> var. <i>concinus</i>	SMOOTH BLUE ASTER
<i>Aster lanceolatus</i> var. <i>interior</i>	TALL WHITE ASTER
<i>Aster lateriflorus</i> var. <i>hirsuticaulis</i>	CALICO ASTER
<i>Aster oolentangiensis</i>	SKY-BLUE ASTER
<i>Aster puniceus</i> var. <i>firmus</i>	CORNEL-LEAVED ASTER
<i>Aster radula</i>	SWAMP ASTER
<i>Astragalus neglectus</i>	COOPER'S MILKVETCH
<i>Atriplex glabriuscula</i>	SEASIDE ORACH
<i>Atriplex subspicata</i>	ORACHE
<i>Bartonia paniculata</i>	SCREW-STEM



## *Protected Native Plants*

<i>Betula glandulosa</i>	TUNDRA DWARF BIRCH
<i>Betula minor</i>	DWARF WHITE BIRCH
<i>Bidens hyperborea</i>	ESTUARY BEGGAR-TICKS
<i>Blephilia ciliata</i>	DOWNY WOOD-MINT
<i>Botrychium campestre</i>	PRAIRIE DUNEWORT
<i>Botrychium lunaria</i>	MOONWORT
<i>Botrychium minganense</i>	MINGAN MOONWORT
<i>Botrychium oneidense</i>	BLUNT-LOBE GRAPE FERN
<i>Botrychium rugulosum</i>	RUGULOSE GRAPE FERN
<i>Bouteloua curtipendula</i>	SIDE-OATS GRAMA
<i>Buchnera americana</i>	BLUE-HEARTS
<i>Cacalia suaveolens</i>	SWEET-SCENTED INDIAN-PLANTAIN
<i>Calamagrostis perplexa</i>	WOOD REEDGRASS
<i>Calamagrostis porteri</i> ssp. <i>porteri</i>	PORTER'S REEDGRASS
<i>Calamagrostis stricta</i> ssp. <i>stricta</i>	NORTHERN REEDGRASS
<i>Callitriche hermaphrodita</i>	AUTUMNAL WATER-STARWORT
<i>Calypso bulbosa</i>	CALYPSO
<i>Cardamine rotundifolia</i>	MOUNTAIN WATERCRESS
<i>Carex aggregata</i>	GLOMERATE SEDGE
<i>Carex amphibola</i> var. <i>amphibola</i>	NARROW-LEAVED SEDGE
<i>Carex arcta</i>	NORTHERN CLUSTERED SEDGE
<i>Carex atherodes</i>	AWNED SEDGE
<i>Carex atratiformis</i>	BLACK SEDGE
<i>Carex barrattii</i>	BARRATT'S SEDGE
<i>Carex bullata</i>	BUTTON SEDGE
<i>Carex capillaris</i>	HAIR-LIKE SEDGE
<i>Carex caroliniana</i>	CAROLINA SEDGE
<i>Carex collinsii</i>	COLLINS' SEDGE
<i>Carex conjuncta</i>	SOFT FOX SEDGE
<i>Carex decomposita</i>	CYPRESS-KNEE SEDGE
<i>Carex emoryi</i>	EMORY'S SEDGE
<i>Carex flaccosperma</i> var. <i>glaucoidea</i>	GLAUCOUS SEDGE
<i>Carex frankii</i>	FRANK'S SEDGE
<i>Carex garberi</i>	ELK SEDGE
<i>Carex gynocrates</i>	NORTHERN BOG SEDGE
<i>Carex haydenii</i>	CLOUD SEDGE
<i>Carex laxiflora</i> var. <i>serrulata</i>	LOOSE-FLOWERED SEDGE
<i>Carex livida</i> var. <i>radicans</i>	LIVID SEDGE
<i>Carex meadii</i>	MEAD'S SEDGE
<i>Carex mesochorea</i>	MIDLAND SEDGE
<i>Carex nigra</i>	BLACK SEDGE
<i>Carex nigromarginata</i>	BLACK-EDGE SEDGE
<i>Carex retroflexa</i>	REFLEXED SEDGE
<i>Carex scirpoidea</i>	CANADIAN SINGLE-SPIKE SEDGE
<i>Carex shortiana</i>	SHORT'S SEDGE
<i>Carex straminea</i>	STRAW SEDGE
<i>Carex striatula</i>	LINED SEDGE



## *Protected Native Plants*

<i>Carex styloflexa</i>	BENT SEDGE
<i>Carex sychnocephala</i>	MANY-HEAD SEDGE
<i>Carex tenuiflora</i>	SPARSE-FLOWERED SEDGE
<i>Carex tinctoria</i>	TINGED SEDGE
<i>Carex vaginata</i>	SHEATHED SEDGE
<i>Carex venusta</i> var. <i>minor</i>	GRACEFUL SEDGE
<i>Carex wiegandii</i>	WIEGAND'S SEDGE
<i>Castilleja coccinea</i>	SCARLET INDIAN-PAINTBRUSH
<i>Ceanothus herbaceus</i>	PRAIRIE REDROOT
<i>Chaerophyllum procumbens</i>	SPREADING CHERVIL
<i>Chasmanthium laxum</i>	SLENDER SPIKEGRASS
<i>Cheilanthes lanosa</i>	WOOLY LIP-FERN
<i>Chenopodium album</i> var. <i>missouriense</i>	MISSOURI GOOSEFOOT
<i>Chenopodium berlandieri</i> var. <i>macrocalycinum</i>	LARGE CALYX GOOSEFOOT
<i>Collinsia verna</i>	BLUE-EYED-MARY
<i>Corallorhiza striata</i>	STRIPED CORALROOT
<i>Corema conradii</i>	BROOM CROWBERRY
<i>Cornus drummondii</i>	ROUGH-LEAF DOGWOOD
<i>Crassula aquatica</i>	PIGMYWEED
<i>Crataegus berberifolia</i>	HAWTHORN
<i>Crataegus compacta</i>	COMPACT HAWTHORN
<i>Crataegus mollis</i>	DOWNY HAWTHORN
<i>Crataegus uniflora</i>	DWARF HAWTHORN
<i>Crotalaria sagittalis</i>	RATTLEBOX
<i>Cuscuta cephalanthi</i>	BUTTON-BUSH DODDER
<i>Cuscuta obtusiflora</i> var. <i>glandulosa</i>	SOUTHERN DODDER
<i>Cuscuta polygonorum</i>	SMARTWEED DODDER
<i>Cynoglossum virginianum</i> var. <i>boreale</i>	NORTHERN WILD COMFREY
<i>Cynoglossum virginianum</i> var. <i>virginianum</i>	WILD COMFREY
<i>Cyperus echinatus</i>	GLOBOSE FLATSEDGE
<i>Cyperus flavescens</i> var. <i>flavescens</i>	YELLOW FLATSEDGE
<i>Cyperus polystachyos</i> var. <i>texensis</i>	COAST FLATSEDGE
<i>Cyperus retrofractus</i>	RETROSE FLATSEDGE
<i>Cypripedium candidum</i>	SMALL WHITE LADYSLIPPER
<i>Cypripedium parviflorum</i> var. <i>parviflorum</i>	SMALL YELLOW LADYSLIPPER
<i>Cystopteris protrusa</i>	LOWLAND FRAGILE FERN
<i>Descurainia pinnata</i> ssp. <i>brachycarpa</i>	NORTHERN TANSEY-MUSTARD
<i>Desmodium humifusum</i>	SPREADING TICK-CLOVER
<i>Desmodium laevigatum</i>	SMOOTH TICK-CLOVER
<i>Desmodium nuttallii</i>	NUTTALL'S TICK-CLOVER
<i>Desmodium obtusum</i>	BEGGAR-LICE
<i>Desmodium paniculatum</i>	SMALL-FLOWERED TICK-CLOVER
<i>Diarrhena obovata</i>	BEAKGRASS
<i>Diplachne maritima</i>	SALT-MEADOW GRASS
<i>Draba glabella</i>	ROCK-CRESS
<i>Dracocephalum parviflorum</i>	AMERICAN DRAGONHEAD
<i>Dryopteris celsa</i>	LOG FERN





## Protected Native Plants

<i>Dryopteris fragrans</i>	FRAGRANT CLIFF FERN
<i>Eclipta prostrata</i>	YERBA-DE-TAGO
<i>Elatine americana</i>	AMERICAN WATERWORT
<i>Eleocharis elliptica</i> var. <i>pseudoptera</i>	SLENDER SPIKERUSH
<i>Eleocharis engelmannii</i>	ENGELMANN'S SPIKERUSH
<i>Eleocharis fallax</i>	CREEPING SPIKERUSH
<i>Eleocharis obtusa</i> var. <i>ovata</i>	BLUNT SPIKERUSH
<i>Eleocharis quadrangulata</i>	ANGLED SPIKERUSH
<i>Eleocharis tricostrata</i>	THREE-RIBBED SPIKERUSH
<i>Empetrum eamesii</i> ssp. <i>atropurpureum</i>	PURPLE CROWBERRY
<i>Epilobium ciliatum</i> ssp. <i>glandulosum</i>	WILLOW-HERB
<i>Epilobium hornemannii</i>	ALPINE WILLOW-HERB
<i>Equisetum laevigatum</i>	SMOOTH SCOURING RUSH
<i>Erechtites hieracifolia</i> var. <i>megalocarpa</i>	FIREWEED
<i>Erigeron bulbosa</i>	HARBINGER-OF-SPRING
<i>Erigeron hyssopifolius</i>	DAISY FLEABANE
<i>Eriophorum angustifolium</i> ssp. <i>scabrinusculum</i>	NARROW-LEAF COTTONGRASS
<i>Euonymus americana</i>	AMERICAN STRAWBERRY-BUSH
<i>Eupatorium aromaticum</i>	SMALL WHITE SNAKEROOT
<i>Eupatorium leucolepis</i> var. <i>leucolepis</i>	WHITE BONESET
<i>Eupatorium rotundifolium</i> var. <i>ovatum</i>	ROUND-LEAF BONESET
<i>Eupatorium rotundifolium</i> var. <i>rotundifolium</i>	ROUND-LEAF BONESET
<i>Eupatorium serotinum</i>	LATE BONESET
<i>Euphorbia ipecacuanhae</i>	IPECAC SPURGE
<i>Festuca saximontana</i>	SHEEP FESCUE
<i>Galium concinnum</i>	SHINING BEDSTRAW
<i>Galium kamtschaticum</i>	NORTHERN WILD-LICORICE
<i>Gaylussacia dumosa</i> var. <i>bigeloviana</i>	DWARF HUCKLEBERRY
<i>Gentiana saponaria</i>	SOAPWORT GENTIAN
<i>Gentianopsis procera</i>	LESSER FRINGED GENTIAN
<i>Geocaulon lividum</i>	PURPLE COMANDRA
<i>Geum vernum</i>	SPRING AVENS
<i>Geum virginianum</i>	ROUGH AVENS
<i>Gnaphalium helleri</i> var. <i>micradenium</i>	CATFOOT
<i>Gnaphalium purpureum</i>	PURPLE EVERLASTING
<i>Gnaphalium sylvaticum</i>	WOODLAND CUDWEED
<i>Gymnocladus dioica</i>	KENTUCKY COFFEE TREE
<i>Hackelia deflexa</i> var. <i>americana</i>	NORTHERN STICKSEED
<i>Halenia deflexa</i>	SPURRED GENTIAN
<i>Hippuris vulgaris</i>	MARE'S-TAIL
<i>Houstonia purpurea</i> var. <i>calycosa</i>	PURPLE BLUEETS
<i>Houstonia purpurea</i> var. <i>purpurea</i>	PURPLE BLUEETS
<i>Hyperzia selago</i>	FIR CLUBMOSS
<i>Hydrangea arborescens</i>	WILD HYDRANGEA
<i>Hydrocotyle ranunculoides</i>	FLOATING PENNYWORT
<i>Hydrocotyle verticillata</i>	WATER-PENNYWORT
<i>Hypericum adpressum</i>	CREEPING ST. JOHN'S-WORT



## Protected Native Plants

<i>Hypericum densiflorum</i>	BUSHY ST. JOHN'S-WORT
<i>Hypericum denticulatum</i>	COPPERY ST. JOHN'S-WORT
<i>Hypericum hypericoides</i> ssp. <i>multicaule</i>	ST. ANDREW'S CROSS
<i>Ipomoea pandurata</i>	WILD POTATO-VINE
<i>Isoetes riparia</i>	QUILLWORT
<i>Isotria medeoloides</i>	SMALL WHORLED POGONIA
<i>Juncus ambiguus</i>	DOUBTFUL TOAD-RUSH
<i>Juncus brachycarpus</i>	SHORT-FRUIT RUSH
<i>Juncus debilis</i>	WEAK RUSH
<i>Juncus ensifolius</i>	ENSIFORM RUSH
<i>Juncus marginatus</i> var. <i>biflorus</i>	LARGE GRASS-LEAVED RUSH
<i>Juncus scirpoides</i>	SCIRPUS-LIKE RUSH
<i>Juncus stygius</i> ssp. <i>americanus</i>	MOOR-RUSH
<i>Juncus subcaudatus</i>	WOODS-RUSH
<i>Juniperus horizontalis</i>	PROSTRATE JUNIPER
<i>Lachnanthes caroliniana</i>	CAROLINA REDROOT
<i>Lactuca floridana</i>	FALSE LETTUCE
<i>Lactuca hirsuta</i>	DOWNY LETTUCE
<i>Lathyrus venosus</i>	ROUGH VEINY VETCHLING
<i>Lechea pulchella</i> var. <i>moniliformis</i>	BEAD PINWEED
<i>Lemna perpusilla</i>	MINUTE DUCKWEED
<i>Lemna valdiviana</i>	PALE DUCKWEED
<i>Leucospora multifida</i>	LEUCOSPORA
<i>Liatris cylindracea</i>	SLENDER BLAZING-STAR
<i>Ligusticum scoticum</i>	SCOTCH LOVAGE
<i>Lilium michiganense</i>	MICHIGAN LILY
<i>Linum medium</i> var. <i>medium</i>	WILD FLAX
<i>Liparis lilifolia</i>	LARGE TWAYBLADE
<i>Lipocarpus micrantha</i>	DWARF BULRUSH
<i>Listera auriculata</i>	AURICLED TWAYBLADE
<i>Listera australis</i>	SOUTHERN TWAYBLADE
<i>Listera convallarioides</i>	BROAD-LIPPED TWAYBLADE
<i>Lithospermum carolinense</i> ssp. <i>croceum</i>	GOLDEN PUCCOON
<i>Littorella uniflora</i>	AMERICAN SHORE-GRASS
<i>Loiseleuria procumbens</i>	ALPINE AZALEA
<i>Luzula spicata</i>	SPIKED WOODTHRUSH
<i>Lycopodiella caroliniana</i>	CAROLINA CLUBMOSS
<i>Lycopodium complanatum</i>	NORTHERN RUNNING-PINE
<i>Lycopodium sitchense</i>	SITKA CLUBMOSS
<i>Lycopus rubellus</i>	GYPSY-WORT
<i>Lygodium palmatum</i>	CLIMBING FERN
<i>Lysimachia hybrida</i>	LANCE-LEAVED LOOSESTRIFE
<i>Lysimachia quadriflora</i>	FOUR-FLOWERED LOOSESTRIFE
<i>Lytbrum lineare</i>	SALTMARSH LOOSESTRIFE
<i>Magnolia virginiana</i>	SWEETBAY MAGNOLIA
<i>Malaxis bayardii</i>	BAYARD'S MALAXIS
<i>Malus glaucescens</i>	AMERICAN CRAB



## Protected Native Plants

<i>Melanthium virginicum</i>	VIRGINIA BUNCHFLOWER
<i>Monarda clinopodia</i>	BASIL-BALM
<i>Myriophyllum pinnatum</i>	GREEN PARROT'S-FEATHER
<i>Najas guadalupensis</i> var. <i>muenscheri</i>	MUENSCHER'S NAIAD
<i>Najas guadalupensis</i> var. <i>olivacea</i>	SOUTHERN NAIAD
<i>Najas marina</i>	HOLLY-LEAVED NAIAD
<i>Oenothera laciniata</i>	CUT-LEAVED EVENING-PRIMROSE
<i>Oldenlandia uniflora</i>	CLUSTERED BLUEETS
<i>Onosmodium virginianum</i>	VIRGINIA FALSE GROMWELL
<i>Oryzopsis canadensis</i>	CANADA RICEGRASS
<i>Oxypolis rigidior</i>	STIFF COWBANE
<i>Panicum leibergii</i>	LEIBERG'S PANIC GRASS
<i>Panicum oligosanthes</i> var. <i>oligosanthes</i>	FEW-FLOWERED PANIC GRASS
<i>Panicum scabrinusculum</i>	PANIC GRASS
<i>Panicum scoparium</i>	VELVET PANIC GRASS
<i>Panicum stipitatum</i>	TALL FLAT PANIC GRASS
<i>Panicum wrightianum</i>	WRIGHT'S PANIC GRASS
<i>Paspalum laeve</i> var. <i>circulare</i>	ROUND FIELD BEADGRASS
<i>Paspalum laeve</i> var. <i>pilosum</i>	HAIRY FIELD BEADGRASS
<i>Paspalum setaceum</i> var. <i>psammophilum</i>	SLENDER BEADGRASS
<i>Petasites frigidus</i> var. <i>palmatus</i>	SWEET COLTSFOOT
<i>Phlox maculata</i>	WILD SWEET-WILLIAM
<i>Phlox pilosa</i>	DOWNY PHLOX
<i>Physalis pubescens</i> var. <i>integrifolia</i>	GROUND-CHERRY
<i>Physalis virginiana</i>	VIRGINIA GROUND-CHERRY
<i>Physocarpus opulifolius</i> var. <i>intermedius</i>	NINEBARK
<i>Pinus virginiana</i>	VIRGINIA PINE
<i>Platanthera ciliaris</i>	ORANGE FRINGED ORCHIS
<i>Platanthera cristata</i>	CRESTED FRINGED ORCHIS
<i>Platanthera hookeri</i>	HOOKE'S ORCHID
<i>Platanthera leucophaea</i>	PRAIRIE FRINGED ORCHID
<i>Poa cuspidata</i>	BLUEGRASS
<i>Poa fernaldiana</i>	FERNALD BLUEGRASS
<i>Poa glauca</i>	WHITE BLUEGRASS
<i>Poa interior</i>	INLAND BLUEGRASS
<i>Poa paludigena</i>	SLENDER MARSH BLUEGRASS
<i>Poa sylvestris</i>	WOODLAND BLUEGRASS
<i>Polygala lutea</i>	YELLOW MILKWORT
<i>Polygonum buxiforme</i>	SMALL'S KNOTWEED
<i>Polygonum erectum</i>	ERECT KNOTWEED
<i>Polygonum setaceum</i> var. <i>interjectum</i>	SWAMP SMARTWEED
<i>Polymnia uvedalia</i>	BEAR'S-FOOT
<i>Polystichum lonchitis</i>	NORTHERN HOLLY-FERN
<i>Potamogeton diversifolius</i>	WATER-THREAD PONDWEED
<i>Potamogeton filiformis</i> var. <i>alpinus</i>	SLENDER PONDWEED
<i>Potamogeton filiformis</i> var. <i>occidentalis</i>	SHEATHED PONDWEED
<i>Potamogeton odenii</i>	OGDEN'S PONDWEED



## *Protected Native Plants*

<i>Potamogeton strictifolius</i>	STRAIGHT-LEAF PONDWEED
<i>Potentilla paradoxa</i>	BUSHY CINQUEFOIL
<i>Prenanthes boottii</i>	BOOTT'S RATTLESLAKE-ROOT
<i>Prenanthes crepidinea</i>	NODDING RATTLESLAKE-ROOT
<i>Prenanthes nana</i>	DWARF RATTLESLAKE-ROOT
<i>Prunus pumila</i> var. <i>pumila</i>	LOW SAND-CHERRY
<i>Ptelea trifoliata</i>	WAPER-ASH
<i>Pterospora andromedea</i>	GIANT PINE-DROPS
<i>Pycnanthemum clinopodioides</i>	MOUNTAIN-MINT
<i>Pycnanthemum torreyi</i>	TORREY'S MOUNTAIN-MINT
<i>Pycnanthemum verticillatum</i> var. <i>pilosum</i>	WHORLED MOUNTAIN-MINT
<i>Pyrola minor</i>	MOUNTAIN PYROLA
<i>Pyxidanthera barbulate</i>	PIXIES
<i>Quercus phellos</i>	WILLOW OAK
<i>Ranunculus cymbalaria</i>	SEASIDE CROWFOOT
<i>Ranunculus hispidus</i> var. <i>nitidus</i>	SWAMP BUTTERCUP
<i>Rhododendron lapponicum</i>	LAPLAND ROSEBAY
<i>Rhynchospora torreyana</i>	TORREY'S BEAKRUSH
<i>Rosa acicularis</i> ssp. <i>sayi</i>	PRICKLY ROSE
<i>Rosa nitida</i>	SHINING ROSE
<i>Rubus cuneifolius</i>	SAND BLACKBERRY
<i>Rudbeckia hirta</i> var. <i>hirta</i>	BLACK-EYED-SUSAN
<i>Rumex hastatulus</i>	HEART'S SORREL
<i>Rumex maritimus</i> var. <i>sueginius</i>	GOLDEN DOCK
<i>Sabatia angularis</i>	ROSE-PINK
<i>Sabatia campanulata</i>	SLENDER MARSH-PINK
<i>Sagina decumbens</i>	SMALL-FLOWERED PEARLWORT
<i>Sagittaria teres</i>	QUILL-LEAF ARROWHEAD
<i>Salix cordata</i>	SAND DUNE WILLOW
<i>Salix herbacea</i>	DWARF WILLOW
<i>Salvia lyrata</i>	LYRE-LEAF SAGE
<i>Saxifraga oppositifolia</i>	PURPLE MOUNTAIN-SAXIFRAGE
<i>Saxifraga paniculata</i>	WHITE MOUNTAIN-SAXIFRAGE
<i>Schizaea pusilla</i>	CURLYGRASS
<i>Scirpus clintonii</i>	CLINTON'S CLUBRUSH
<i>Scirpus georgianus</i>	GEORGIA BULRUSH
<i>Scirpus heterochaetus</i>	SLENDER BULRUSH
<i>Scirpus maritimus</i>	SEASIDE BULRUSH
<i>Scirpus novae-angliae</i>	SALTMARSH BULRUSH
<i>Scleria minor</i>	SLENDER NUTRUSH
<i>Scleria pauciflora</i> var. <i>caroliniana</i>	FEWFLOWER NUTRUSH
<i>Scleria reticularis</i> var. <i>pubescens</i>	RETICULATE NUTRUSH
<i>Scleria verticillata</i>	LOW NUTRUSH
<i>Scutellaria incana</i>	HOARY SKULLCAP
<i>Scutellaria integrifolia</i>	HYSSOP-SKULLCAP
<i>Sedum integrifolium</i> ssp. <i>leedyi</i>	LEEDY'S ROSEROOT
<i>Sedum rosea</i>	ROSEROOT



## *Protected Native Plants*

<i>Sedum telephoides</i>	LIVE-FOR-EVER
<i>Sesuvium maritimum</i>	SEA PURSLANE
<i>Sisyrinchium mucronatum</i>	MICHAUX'S BLUE-EYED-GRASS
<i>Smilax pseudo-china</i>	FALSE CHINA-ROOT
<i>Smilax pulverulenta</i>	JACOB'S-LADDER
<i>Solidago elliotii</i>	COASTAL GOLDENROD
<i>Solidago houghtonii</i>	HOUGHTON'S GOLDENROD
<i>Solidago rugosa</i> ssp. <i>aspera</i>	ROUGH GOLDENROD
<i>Solidago rugosa</i> var. <i>sphagnophila</i>	TALL HAIRY GOLDENROD
<i>Solidago sempervirens</i> var. <i>mexicana</i>	SEASIDE GOLDENROD
<i>Solidago simplex</i> var. <i>racemosa</i>	MOUNTAIN GOLDENROD
<i>Sphenopholis obtusata</i> var. <i>obtusata</i>	PRAIRIE WEDGEGRASS
<i>Sphenopholis pennsylvanica</i>	SWAMP OATS
<i>Spiraea septentrionalis</i>	MOUNTAIN MEADOWSWEET
<i>Spiranthes vernalis</i>	SPRING LADIES'-TRESSES
<i>Sporobolus clandestinus</i>	ROUGH RUSH-GRASS
<i>Strophostyles umbellata</i>	PINK WILD BEAN
<i>Suaeda linearis</i>	NARROW-LEAF SEA-BLITE
<i>Suaeda rolandii</i>	ROLAND'S SEA-BLITE
<i>Subularia aquatica</i> var. <i>americana</i>	WATER AWLWORT
<i>Thalictrum venulosum</i>	VEINY MEADOW-RUE
<i>Tipularia discolor</i>	CRANEFLY ORCHID
<i>Tofieldia glutinosa</i>	STICKY FALSE ASPHODEL
<i>Trichomanes intricatum</i>	FILMY FERN
<i>Trichostema setaceum</i>	TINY BLUE-CURLS
<i>Trillium flexipes</i>	NODDING TRILLIUM
<i>Trillium sessile</i>	TOAD-SHADE
<i>Triphora trianthophora</i>	NODDING POGONIA
<i>Trisetum melicoides</i>	MELIC-OATS
<i>Utricularia inflata</i>	LARGE FLOATING BLADDERWORT
<i>Uvularia puberula</i> var. <i>nitida</i>	MOUNTAIN BELLWORT
<i>Vaccinium cespitosum</i>	DWARF BLUEBERRY
<i>Valeriana uliginosa</i>	MARSH VALERIAN
<i>Valerianella chenopodiifolia</i>	GOOSEFOOT CORN-SALAD
<i>Valerianella umbilicata</i>	CORN-SALAD
<i>Vernonia gigantea</i>	TALL IRONWEED
<i>Viburnum nudum</i> var. <i>nudum</i>	POSSUM-HAW
<i>Viola brittoniana</i> var. <i>brittoniana</i>	COASTAL VIOLET
<i>Viola hirsutula</i>	SOUTHERN WOOD VIOLET
<i>Viola nephrophylla</i>	NORTHERN BOG VIOLET
<i>Viola novae-angliae</i>	NEW ENGLAND VIOLET
<i>Vitis vulpina</i>	WINTER GRAPE
<i>Vittaria appalachiana</i>	APPALACHIAN VITTARIA
<i>Woodsia alpina</i>	ALPINE WOODSIA
<i>Woodsia glabella</i>	SMOOTH WOODSIA



## *Protected Native Plants*

(c) The following are **threatened** native plants that are likely to become endangered within the foreseeable future throughout all or a significant portion of their ranges in the state. Listed plants are those with six to fewer than 20 extant sites, or 1,000 to fewer than 3,000 individuals, or restricted to not less than four or more than seven U.S.G.S. 7 1/2 minute series maps, or species listed as threatened by the United State Department of Interior in the Code of Federal Regulations.

Species	Common Name
<i>Aconitum noveboracense</i>	NORTHERN MONK'S-HOOD
<i>Agalinis paupercula</i> var. <i>borealis</i>	NORTHERN GERARDIA
<i>Agastache nepetoides</i>	YELLOW GIANT-HYSSOP
<i>Agrimonia rostellata</i>	WOODLAND AGRIMONY
<i>Agrostis mertensii</i>	NORTHERN BENTGRASS
<i>Aletris farinosa</i>	STARGRASS
<i>Allium cernuum</i>	WILD ONION
<i>Arabis missouriensis</i>	GREEN ROCK-CRESS
<i>Arethusa bulbosa</i>	SWAMP PINK
<i>Asclepias viridiflora</i>	GREEN MILKWHEED
<i>Asimina triloba</i>	PAWPAW
<i>Asplenium montanum</i>	MOUNTAIN SPLEENWORT
<i>Asplenium scolopendrium</i> var. <i>americanum</i>	HART'S-TONGUE FERN
<i>Aster borealis</i>	RUSH ASTER
<i>Aster pilosus</i> var. <i>pringlei</i>	HEATH ASTER
<i>Aster solidagineus</i>	FLAX-LEAF WHITETOP
<i>Aster spectabilis</i>	SHOWY ASTER
<i>Aster subulatus</i>	SALTMARSH ASTER
<i>Betula pumila</i>	SWAMP BIRCH
<i>Bidens laevis</i>	SMOOTH BUR-MARIGOLD
<i>Calamagrostis stricta</i> ssp. <i>inexpansa</i>	NORTHERN REEDGRASS
<i>Callitriche terrestris</i>	TERRESTRIAL STARWORT
<i>Cardamine longii</i>	LONG'S BITTERCRESS
<i>Carex abscondita</i>	THICKET SEDGE
<i>Carex backii</i>	ROCKY MOUNTAIN SEDGE
<i>Carex bicknellii</i>	BICKNELL'S SEDGE
<i>Carex bigelowii</i>	BIGELOW'S SEDGE
<i>Carex bruxbaumii</i>	BROWN BOG SEDGE
<i>Carex chordorrhiza</i>	CREeping SEDGE
<i>Carex crawei</i>	CRAWL'S SEDGE
<i>Carex cumulata</i>	CLUSTERED SEDGE
<i>Carex davisii</i>	DAVIS' SEDGE
<i>Carex formosa</i>	HANDSOME SEDGE
<i>Carex hitchcockiana</i>	HITCHCOCK'S SEDGE
<i>Carex hormathodes</i>	MARSH STRAW SEDGE
<i>Carex houghtoniana</i>	HOUGHTON'S SEDGE
<i>Carex jamesii</i>	NEBRASKA SEDGE
<i>Carex merritt-fernaldii</i>	FERNALD'S SEDGE
<i>Carex mitchelliana</i>	MITCHELL'S SEDGE
<i>Carex molesta</i>	TROUBLESOME SEDGE



## Protected Native Plants

<i>Carex sartwellii</i>	SARTWELL'S SEDGE
<i>Carex schweinitzii</i>	SCHWEINITZ' SEDGE
<i>Carex seorsa</i>	WEAK STELLATE SEDGE
<i>Carex typhina</i>	CAT-TAIL SEDGE
<i>Carex willdenowii</i>	WILDENOW'S SEDGE
<i>Carya laciniosa</i>	BIG SHELLBARK HICKORY
<i>Cenchrus tribuloides</i>	DUNE SANDSPUR
<i>Ceratophyllum echinatum</i>	PRICKLY HORNWORT
<i>Chamaelirium luteum</i>	BLAZING-STAR
<i>Chenopodium rubrum</i>	RED PIGWEED
<i>Corydalis aurea</i>	GOLDEN CORYDALIS
<i>Cyperus lupulinus</i> ssp. <i>lupulinus</i>	HOP SEDGE
<i>Cypripedium arietinum</i>	RAM'S-HEAD LADYSLIPPER
<i>Desmodium ciliare</i>	LITTLE-LEAF TICK-TREFOIL
<i>Diapensia lapponica</i>	DIAPENSIA
<i>Digitaria filiformis</i>	SLENDER CRABGRASS
<i>Diospyros virginiana</i>	PERSIMMON
<i>Draba arabisans</i>	ROCK-CRESS
<i>Draba reptans</i>	CAROLINA WHITLOW-GRASS
<i>Eleocharis equisetoides</i>	KNOTTED SPIKERUSH
<i>Eleocharis halophila</i>	SALT-MARSH SPIKERUSH
<i>Eleocharis tuberosa</i>	LONG-TUBERCLED SPIKERUSH
<i>Equisetum pratense</i>	MEADOW HORSETAIL
<i>Equisetum palustre</i>	MARSH HORSETAIL
<i>Eupatorium album</i> var. <i>subvenosum</i>	WHITE BONESET
<i>Eupatorium hyssopifolium</i> var. <i>laciniatum</i>	FRINGED BONESET
<i>Fimbristylis castanea</i>	MARSH FIMBRY
<i>Frasera carolinensis</i>	GREEN GENTIAN
<i>Geranium carolinianum</i> var. <i>sphaerospermum</i>	CAROLINA CRANESBILL
<i>Geum triflorum</i>	PRAIRIE-SMOKE
<i>Hedeoma hispidum</i>	MOCK-PENNYROYAL
<i>Helianthemum dumosum</i>	BUSHY ROCKROSE
<i>Helianthus angustifolius</i>	SWAMP SUNFLOWER
<i>Hottonia inflata</i>	FEATHERFOIL
<i>Hyperzia appalachiana</i>	APPALACHIAN FIRMOS
<i>Hydrastis canadensis</i>	GOLDEN-SEAL
<i>Hypericum prolificum</i>	SHRUBBY ST. JOHN'S WORT
<i>Iris prismatica</i>	SLENDER BLUE FLAG
<i>Jeffersonia diphylla</i>	TWIN-LEAF
<i>Juncus trifidus</i>	ARCTIC RUSH
<i>Lechea tenuifolia</i>	SLENDER PINWEED
<i>Lespedeza stuevei</i>	VELVETY LESPEDEZA
<i>Liatris borealis</i>	NORTHERN BLAZING-STAR
<i>Lilaeopsis chinensis</i>	LILAEOPSIS
<i>Linum intercursum</i>	SANDPLAIN WILD FLAX
<i>Linum medium</i> var. <i>texanum</i>	SOUTHERN YELLOW FLAX
<i>Linum sulcatum</i>	YELLOW WILD FLAX



## Protected Native Plants

<i>Ludwigia sphaerocarpa</i>	GLOBE-FRUITED LUDWIGIA
<i>Megalodonta beckii</i> var. <i>beckii</i>	WATER-MARIGOLD
<i>Minuartia glabra</i>	APPALACHIAN SANDWORT
<i>Myriophyllum alterniflorum</i>	WATER MILFOIL
<i>Myriophyllum farwellii</i>	FARWELL'S WATER MILFOIL
<i>Oenothera parviflora</i> var. <i>oakesiana</i>	EVENING PRIMROSE
<i>Orontium aquaticum</i>	GOLDEN CLUB
<i>Oxalis violacea</i>	VIOLET WOOD-SORREL
<i>Panicum flexile</i>	WIRY PANIC GRASS
<i>Paspalum setaceum</i> var. <i>setaceum</i>	SLENDER BEADGRASS
<i>Pedicularis lanceolata</i>	SWAMP LOUSEWORT
<i>Pellaea glabella</i>	SMOOTH CLIFF BRAKE
<i>Pinguicula vulgaris</i>	BUTTERWORT
<i>Plantago cordata</i>	HEARTLEAF PLANTAIN
<i>Plantago maritima</i> ssp. <i>juncoides</i>	SEASIDE PLANTAIN
<i>Podostemum ceratophyllum</i>	RIVERWEED
<i>Polygonum careyi</i>	CAREY'S SMARTWEED
<i>Polygonum douglassii</i>	DOUGLAS' KNOTWEED
<i>Polygonum hydropiperoides</i> var. <i>opelousanum</i>	OPELOUSA SMARTWEED
<i>Populus heterophylla</i>	SWAMP COTTONWOOD
<i>Potamogeton alpinus</i>	NORTHERN PONDWEED
<i>Potamogeton confervoides</i>	ALGAE-LIKE PONDWEED
<i>Potamogeton hillii</i>	HILL'S PONDWEED
<i>Potamogeton pulcher</i>	SPOTTED PONDWEED
<i>Potentilla anserina</i> ssp. <i>egedii</i>	SILVERWEED
<i>Primula mistassinica</i>	BIRD'S-EYE PRIMROSE
<i>Proserpinaca pectinata</i>	COMB-LEAVED MERMAID-WEED
<i>Prunus pumila</i> var. <i>depressa</i>	DWARF SAND-CHERRY
<i>Pycnanthemum muticum</i>	BLUNT MOUNTAIN-MINT
<i>Pycnanthemum verticillatum</i> var. <i>verticillatum</i>	WHORLED MOUNTAIN-MINT
<i>Pyrola asarifolia</i>	PINK WINTERGREEN
<i>Ranunculus micranthus</i>	SMALL-FLOWERED CROWFOOT
<i>Rhododendron canadense</i>	RHODORA
<i>Rhynchospora inundata</i>	DROWNED HORNED BUSH
<i>Rhynchospora nitens</i>	SHORT-BEAKED BALD-RUSH
<i>Rorippa aquatica</i>	LAKE-CRESS
<i>Rotala ramosior</i>	TOOTH-CUP
<i>Sabatia stellaris</i>	SEA-PINK
<i>Sagittaria calycina</i> var. <i>spongiosa</i>	SPONGY ARROWHEAD
<i>Salicornia bigelovii</i>	DWARF GLASSWORT
<i>Salix pyrifolia</i>	BALSAM WILLOW
<i>Salix uva-ursi</i>	BEARBERRY WILLOW
<i>Saxifraga aizoides</i>	YELLOW MOUNTAIN-SAXIFRAGE
<i>Scirpus cespitosus</i>	DEER'S HAIR SEDGE
<i>Scleria triglomerata</i>	WHIP NUTRUSH
<i>Solidago multiradiata</i> var. <i>arctica</i>	ALPINE GOLDENROD
<i>Solidago ohioensis</i>	OHIO GOLDENROD





## *Protected Native Plants*

<i>Solidago rigida</i>	STIFF-LEAF GOLDENROD
<i>Solidago simplex</i> var. <i>randii</i>	MOUNTAIN GOLDENROD
<i>Sparganium nutans</i>	SMALL BUR-REED
<i>Sporobolus heterolepis</i>	NORTHERN DROPSIED
<i>Stachys byssopifolia</i>	ROUGH HEDGE-NETTLE
<i>Stellaria longipes</i>	STARWORT
<i>Triglochin palustre</i>	MARSH ARROW-GRASS
<i>Tripsacum dactyloides</i>	NORTHERN GAMMA GRASS
<i>Ulmus thomasii</i>	CORK ELM
<i>Utricularia juncea</i>	RUSH BLADDERWORT
<i>Utricularia minor</i>	LESSER BLADDERWORT
<i>Utricularia radiata</i>	SMALL FLOATING BLADDERWORT
<i>Utricularia striata</i>	BLADDERWORT
<i>Vaccinium boreale</i>	HIGH-MOUNTAIN BLUEBERRY
<i>Verbesina alternifolia</i>	WINGSTEM
<i>Veronicastrum virginicum</i>	CULVER'S ROOT
<i>Viburnum dentatum</i> var. <i>venosum</i>	SOUTHERN ARROWWOOD
<i>Viburnum edule</i>	SQUASHBERRY
<i>Viola primulifolia</i>	PRIMROSE VIOLET
<i>Zigadenus elegans</i> ssp. <i>glaucus</i>	WHITE CAMAS

(d) The following are rare native plants that have from 20 to 35 extant sites or 3,000 to 5,000 individuals statewide.

Species	Common Name
<i>Agalinis fasciculata</i>	FASCICLED GERARDIA
<i>Bidens bidentoides</i>	ESTUARY BEGGAR-TICKS
<i>Carex lupuliformis</i>	FALSE HOP SEDGE
<i>Chamaecyparis thyoides</i>	ATLANTIC WHITE CEDAR
<i>Coreopsis rosea</i>	ROSE COREOPSIS
<i>Cyperus schweinitzii</i>	SCHWEINITZ'S FLATSEDGE
<i>Drosera filiformis</i>	DEWTHREAD
<i>Empetrum nigrum</i> ssp. <i>hermaphroditicum</i>	BLACK CROWBERRY
<i>Fuirena pumila</i>	DWARF UMBRELLA-SEDGE
<i>Isoetes lacustris</i>	LARGE-SPORED QUILLWORT
<i>Lechea racemulosa</i>	ILLINOIS PINWEED
<i>Lespedeza angustifolia</i>	BUSH CLOVER
<i>Lespedeza repens</i>	TRAILING LESPEDEZA
<i>Lespedeza violacea</i>	VIOLET LESPEDEZA
<i>Limosella australis</i>	MUDWORT
<i>Linum striatum</i>	STIFF YELLOW FLAX
<i>Lobelia nuttallii</i>	NUTTALL'S LOBELIA
<i>Mimulus alatus</i>	WINGED MONKEYFLOWER
<i>Minuartia caroliniana</i>	PINE-BARREN SANDWORT
<i>Pinus banksiana</i>	JACK PINE
<i>Polemonium vanbruntiae</i>	JACOB'S-LADDER



## *Protected Native Plants*

<i>Polygonum glaucum</i>	SEABEACH KNOTWEED
<i>Polygonum tenue</i>	SLENDER KNOTWEED
<i>Rhynchospora scirpoides</i>	LONG-BEAKED BALD-RUSH
<i>Scheuchzeria palustris</i>	POD GRASS
<i>Trollius laxus</i> ssp. <i>laxus</i>	SPREADING GLOBEFLOWER
<i>Vaccinium uliginosum</i>	BOG BILBERRY

(e) The following are **exploitably vulnerable** native plants likely to become threatened in the near future throughout all or a significant portion of their ranges within the state if causal factors continue unchecked.

<i>Species</i>	<i>Common Name</i>
<i>Actaea pachypoda</i>	WHITE BANEERRY
<i>Actaea spicata</i> ssp. <i>rubra</i>	RED BANEERRY
<i>Arisaema dracontium</i>	GREEN DRAGON
<i>Asclepias tuberosa</i>	BUTTERFLY-WEED
<i>Campanula rotundifolia</i>	HAREBELL
<i>Celastrus scandens</i>	AMERICAN BITTERSWEET
<i>Chelone glabra</i>	TURTLE-HEADS
<i>Chimaphila maculata</i>	SPOTTED WINTERGREEN
<i>Chimaphila umbellata</i>	PIPSISSEWA
<i>Clintonia umbellulata</i>	SPECKLED WOODLILY
<i>Conopholis americana</i>	SQUAWROOT
<i>Cornus florida</i>	FLOWERING DOGWOOD
<i>Drosera intermedia</i>	SUNDEW
<i>Drosera rotundifolia</i>	SUNDEW
<i>Epigaea repens</i>	TRAILING ARBUTUS
<i>Euonymus obovata</i>	RUNNING STRAWBERRY-BUSH
<i>Gentiana andrewsii</i>	CLOSED GENTIAN
<i>Gentiana clausa</i>	BLIND GENTIAN
<i>Gentiana linearis</i>	CLOSED GENTIAN
<i>Gentianella quinquefolia</i>	STIFF GENTIAN
<i>Gentianopsis crinita</i>	FRINGED GENTIAN
<i>Ilex glabra</i>	GALLBERRY
<i>Ilex laevigata</i>	SMOOTH WINTERBERRY
<i>Ilex montana</i>	MOUNTAIN WINTERBERRY
<i>Ilex opaca</i>	AMERICAN HOLLY
<i>Ilex verticillata</i>	BLACK ALDER
<i>Juglans cinerea</i>	BUTTERNUT
<i>Kalmia angustifolia</i>	SHEEP LAUREL
<i>Kalmia latifolia</i>	MOUNTAIN LAUREL
<i>Kalmia polifolia</i>	BOG LAUREL
<i>Lilium canadense</i>	CANADA LILY
<i>Lilium philadelphicum</i>	WOODLILY
<i>Lilium superbum</i>	TURK'S-CAP LILY
<i>Limonium carolinianum</i>	SEA LAVENDER
<i>Lobelia cardinalis</i>	CARDINAL-FLOWER



## *Protected Native Plants*

<i>Lobelia dortmanna</i>	WATER LOBELIA
<i>Lobelia siphilitica</i>	GREAT LOBELIA
<i>Mertensia virginica</i>	VIRGINIA BLUEBELLS
<i>Monarda didyma</i>	BEE-BALM
<i>Myrica pensylvanica</i>	BAYBERRY
<i>Opuntia humifusa</i>	EASTERN PRICKLY PEAR
<i>Panax quinquefolius</i>	GINSENG
<i>Parnassia glauca</i>	GRASS-OF-PARNASSUS
<i>Rhododendron arboreum</i>	SMOOTH AZALEA
<i>Rhododendron maximum</i>	GREAT LAUREL
<i>Rhododendron periclymenoides</i>	PINKSTER
<i>Rhododendron prinophyllum</i>	EARLY AZALEA
<i>Rhododendron viscosum</i>	SWAMP AZALEA
<i>Sanguinaria canadensis</i>	BLOODROOT
<i>Sarracenia purpurea</i>	PITCHER-PLANT
<i>Silene caroliniana</i>	WILD PINK
<i>Trillium cernuum</i>	NODDING TRILLIUM
<i>Trillium erectum</i>	PURPLE TRILLIUM
<i>Trillium grandiflorum</i>	WHITE TRILLIUM
<i>Trillium undulatum</i>	PAINTED TRILLIUM
<i>Viola pedata</i>	BIRD'S-FOOT VIOLET

### **All native clubmosses, including:**

<i>Hyperzia lucidula</i>	SHINING FIRMOS
<i>Lycopodiella alopecuroides</i>	FOXTAIL CLUBMOSS
<i>Lycopodiella appressa</i>	SWAMP CLUBMOSS
<i>Lycopodiella inundata</i>	NORTHERN BOG CLUBMOSS
<i>Lycopodium annotinum</i>	BRISTLY CLUBMOSS
<i>Lycopodium clavatum</i>	RUNNING CEDAR
<i>Lycopodium dendroideum</i>	NORTHERN TREE CLUBMOSS
<i>Lycopodium digitatum</i>	RUNNING-PINE
<i>Lycopodium obscurum</i>	GROUND PINE
<i>Lycopodium tristachyum</i>	GROUND CEDAR

### **All native ferns, (except Bracken, *Pteridium aquilinum*, Hay-scented, *Dennstaedtia punctilobula*, and Sensitive fern, *Onoclea sensibilis*), including:**

<i>Adiantum pedatum</i>	MAIDENHAIR FERN
<i>Asplenium platyneuron</i>	EBONY SPLEENWORT
<i>Asplenium rhizophyllum</i>	WALKING FERN
<i>Asplenium ruta-muraria</i>	WALL-RUE SPLEENWORT
<i>Asplenium trichomanes</i>	MAIDENHAIR SPLEENWORT
<i>Athyrium filix-femina</i>	LADY FERN
<i>Azolla caroliniana</i>	MOSQUITO-FERN
<i>Botrychium dissectum</i>	CUT-LEAF GRAPE FERN
<i>Botrychium lanceolatum</i>	LANCE-LEAF GRAPE FERN



## *Protected Native Plants*

<i>Botrychium matricariifolium</i>	MATRICARY GRAPE FERN
<i>Botrychium multifidum</i>	LEATHERY GRAPE FERN
<i>Botrychium simplex</i>	LEAST MOONWORT
<i>Botrychium virginianum</i>	RATTLESNAKE FERN
<i>Cryptogramma stelleri</i>	SLENDER CLIFF BRAKE
<i>Cystopteris bulbifera</i>	BULBLET FERN
<i>Cystopteris fragilis</i>	COMMON FRAGILE FERN
<i>Cystopteris tenuis</i>	FRAGILE FERN
<i>Deparia acrostichoides</i>	SILVERY SPLEENWORT
<i>Diplazium pycnocarpon</i>	GLADE FERN
<i>Dryopteris canpyloptera</i>	MOUNTAIN WOOD FERN
<i>Dryopteris carthusiana</i>	SPINULOSE WOOD FERN
<i>Dryopteris clintoniana</i>	CLINTON'S SHIELD FERN
<i>Dryopteris cristata</i>	CRESTED WOOD FERN
<i>Dryopteris goldiana</i>	GIANT WOOD FERN
<i>Dryopteris intermedia</i>	COMMON WOOD FERN
<i>Dryopteris marginalis</i>	MARGINAL WOOD FERN
<i>Gymnocarpium dryopteris</i>	OAK FERN
<i>Matteuccia struthiopteris</i>	OSTRICH FERN
<i>Ophioglossum pusillum</i>	ADDER'S-TONGUE
<i>Osmunda cinnamomea</i>	CINNAMON FERN
<i>Osmunda claytoniana</i>	INTERRUPTED FERN
<i>Osmunda regalis</i>	ROYAL FERN
<i>Pellaea atropurpurea</i>	PURPLE CLIFF BRAKE
<i>Phegopteris connectilis</i>	NORTHERN BEECH FERN
<i>Phegopteris hexagonoptera</i>	BROAD BEECH FERN
<i>Polypodium virginianum</i>	ROCK POLYPODY
<i>Polystichum acrostichoides</i>	CHRISTMAS FERN
<i>Polystichum braunii</i>	BRAUN'S HOLLY FERN
<i>Salvinia minima</i>	WATER-FERN
<i>Thelypteris noveboracensis</i>	NEW YORK FERN
<i>Thelypteris palustris</i>	MARSH FERN
<i>Thelypteris simulata</i>	MASSACHUSETTS FERN
<i>Woodsia ilvensis</i>	RUSTY WOODSIA
<i>Woodsia obtusa</i>	BLUNT-LOBED WOODSIA
<i>Woodwardia arvolata</i>	NETTED CHAIN FERN
<i>Woodwardia virginica</i>	VIRGINIA CHAIN FERN

### All native orchids, including:

<i>Calopogon tuberosus</i>	GRASS PINK
<i>Coeloglossum viride</i>	LONG-BRACTED ORCHID
<i>Corallorhiza maculata</i>	SPOTTED CORALROOT
<i>Corallorhiza odontorhiza</i>	AUTUMN CORALROOT
<i>Cypripedium acaule</i>	PINK LADYSLIPPER
<i>Cypripedium parviflorum</i> var. <i>makasin</i>	SMALL YELLOW LADYSLIPPER
<i>Cypripedium parviflorum</i> var. <i>pubescens</i>	YELLOW LADYSLIPPER



## Protected Native Plants

<i>Cypripedium reginae</i>	SHOWY LADYSLIPPER
<i>Galearis spectabilis</i>	SHOWY ORCHIS
<i>Goodyera pubescens</i>	DOWNY RATTLESNAKE-PLANTAIN
<i>Goodyera repens</i>	DWARF RATTLESNAKE-PLANTAIN
<i>Goodyera tessellata</i>	RATTLESNAKE-PLANTAIN
<i>Isotria verticillata</i>	LARGE WHORLED POGONIA
<i>Liparis loeselii</i>	BOG TWAYBLADE
<i>Listera cordata</i>	HEARTLEAF TWAYBLADE
<i>Malaxis monophyllos</i>	WHITE ADDER'S-MOUTH
<i>Malaxis unifolia</i>	GREEN ADDER'S-MOUTH
<i>Platanthera aquilonis</i>	NORTHERN GREEN ORCHID
<i>Platanthera blephariglottis</i>	WHITE FRINGED ORCHID
<i>Platanthera clavellata</i>	GREEN WOODLAND ORCHID
<i>Platanthera dilatata</i>	BOG-CANDLE
<i>Platanthera flava</i>	TUBERCLED ORCHID
<i>Platanthera grandiflora</i>	LARGE PURPLE FRINGED ORCHID
<i>Platanthera huronensis</i>	TALL NORTHERN GREEN ORCHID
<i>Platanthera lacera</i>	RAGGED FRINGED ORCHID
<i>Platanthera obtusata</i>	BLUNT-LEAVED ORCHID
<i>Platanthera orbiculata</i>	LARGE ROUND-LEAVED ORCHID
<i>Platanthera psychodes</i>	SMALL PURPLE FRINGED ORCHID
<i>Pogonia ophioglossoides</i>	ROSE POGONIA
<i>Spiranthes casei</i>	LADY'S-TRESSES
<i>Spiranthes cernua</i>	NODDING LADY'S-TRESSES
<i>Spiranthes lacera</i>	SLENDER LADY'S-TRESSES
<i>Spiranthes lucida</i>	WIDE-LEAVED LADY'S-TRESSES
<i>Spiranthes ochroleuca</i>	CREAMY LADY'S-TRESSES
<i>Spiranthes romanzoffiana</i>	HOODED LADY'S-TRESSES
<i>Spiranthes tuberosa</i>	LITTLE LADY'S-TRESSES

(f) It is a violation for any person, anywhere in the state, to pick, pluck, sever, remove, damage by the application of herbicides or defoliants, or carry away, without the consent of the owner, any protected plant. Each protected plant so picked, plucked, severed, removed, damaged or carried away shall constitute a separate violation.



## **Appendix C**

### **A primer on aquatic plant management in New York**

**NYSDEC**  
**Division of Water**

**A Primer on Aquatic Plant Management  
in New York State**

**April 2005**

**- DRAFT -**

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## Getting the Most (Out) Of Your Aquatic Plants

A rose by any other name is still a rose. But for plants residing under water or along the fringes of streams, ponds, and lakes, a name implies much more. For frightened young fish, it means shelter from predator peril. For frogs and backswimmers, it means floats for life and leisure. And for minnows, moose, and mollusks, it means food, from the smallest alga to the soggiest lily.

For a frustrated lake resident, aquatic plants may all be called seaweeds, while a scientist may call them macrophytes (rooted aquatic plants) and extol their virtues. Still others hold each name in shrouded reverence, marveling at the gentle swell of the purple bladderwort or the primitive majesty of the horsetail. Yet although each person may view the plant kingdom with unequal parts idolatry and contempt, all those who spend time around lakes share a core set of reasons for understanding aquatic plants.

### Aquatic Plants- Where Do They Belong?

This chapter mainly focuses on the control strategies that have been used to minimize the impacts of invasive plants on lake uses. The term “minimize” is appropriate, for invasive plants, particularly non-native plants, can rarely if ever be eradicated from lake systems. Since plants will grow where light reaches the lake floor, and since most of these plants have reproductive structures- seeds, roots, rhizomes, etc.- that cannot be fully exterminated, the goal of most management plans is to minimize invasive plant populations and/or the impacts associated with nuisance growths of these plants.

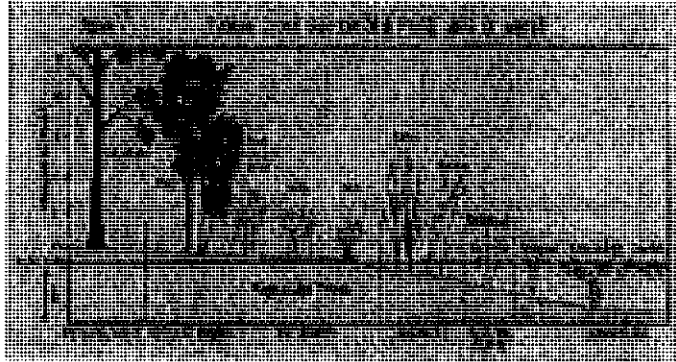
Before tackling the problem of over abundance, it is important to understand that aquatic plants play an absolutely essential role in the maintenance of a healthy lake ecosystem. Lakes devoid of aquatic plants not only look a bit like swimming pools- they behave the same way. They only support very limited functional uses associated with contact recreation, and may not even support potable water usage, since aquatic plants frequently filter pollutants out of the water. While recreationally pleasing, plant-less lakes are aesthetically rather vanilla.

The larger rooted plants that inhabit lakes are referred to as **macrophytes**, although there are macroalgae that can at least superficially resemble these rooted plants. Macrophytes are really better described as either **bryophytes** (primarily mosses and liverworts) and **vascular** plants, which transport nutrients and water to their stems. They resemble the plants that grow on land since they usually have roots, stems, leaves, flowers and seeds, although there are exceptions. A few species of macrophytes found in New York that lack true roots are coontail (*Ceratophyllum* spp.) and bladderwort (*Utricularia* spp.). This is one means to distinguish macrophytes; others include growing season (spring plants versus summer plants) and method of reproduction (seed producers versus tuber producers). However, the most common method for distinguishing macrophytes is by their location in the lake.

**Emergent plants** grow out of the water at the water's edge, in the boundary between dry land or wetlands and the open water littoral zone of lakes, although they are actually part of the littoral zone. They are rooted within the water and have stems and leaves above the water, and grow in water less than 1-2 feet deep. The robust root and stem structures in

these plants befit the only plants that can survive the harsh conditions found within this area- highly variable water level, dessication, and sediment scouring from ice and erosion. There are a large number of emergent plant species found throughout New York State, with grasses, sedges and rushes the most abundant, although cattails and exotic emergent plants such as purple loosestrife and phragmites are perhaps the most prominent. The latter are considered invasive plants, although their impacts are more related to ecological diversity and function than to human use impairment.

Just beyond the emergent plants, **floating-leaf plants**, such as water lilies, watershield, and more delicate unrooted plants such as duckweed and watermeal, are found. Like emergent plants, they are rooted under the water (sometimes with thick, hearty rootstocks (**rhizomes**)), but the floating



leaves usually constitute the bulk of the plant mass. These floating leaves shield out the light transmitted below the plant, reducing the amount of underwater plant growth (within the stems of the floating leaf plants as well as other low-lying plants). These plants grow in water from a few inches deep (the duckweed and watermeal, which look like surface algae from a distance) to as much as 6-8 feet deep. Although floating-leaf plants tend to grow in the most heavily used parts of lakes and ponds, they are usually not associated with nuisance conditions.

Beyond this area occur **submersed plants** such as pondweeds and milfoil. These are perhaps the most diverse of the aquatic plants, ranging from tiny grass-like plants that barely peek above the sediment layer, well-hidden in up to 20 feet of water, to very tall, very conspicuous leafy plants that look a little like redwoods when viewed from the lake bottom. Some of these plants sprout a floating leaf or rosetta of leaves, and even a spike of flowers above the surface, although the bulk of the plant still resides under the water surface. Others grow to the lake surface and then spread laterally, forming a dense canopy that ultimately prevents other plants from growing under their shade. These observations reinforce the notion that the definitions of **submersed** and **floating-leaf** are somewhat arbitrary, for several plants could easily be considered as members of both groups, and plants in both groups still take up residence in the littoral zone. Several submergent plant species are regularly associated with nuisance conditions, owing to their status as exotic plants.

The presence of aquatic plants in lake environments can be summarized in a single statement:

***"If light reaches the bottom, plants will grow."***

Of course, it is not as simple as that. Aquatic plant populations are governed by a complex interaction of physical, chemical, and biological factors. These vary from lake to lake, one part of a lake to another and one time of year to another. While limnologists and knowledgeable lakefront residents recognize that the equation "phosphorus + lake =

algae” holds in most parts of the state, the equation dictating the growth of aquatic plants is much more complex, and may not even exist. The Grand Unification Theory of Aquatic Plants in NYS Lakes continues to be elusive. The existing base of knowledge does not explain why some plants do well in many New York State lakes. We have a pretty good idea about which factors contribute to the spread of aquatic plants in a lake (sediment type, light transmission, water and sediment chemistry, space, the introduction or presence of invasive plants, etc.). And since light can and should be shed on lakes and ponds, and since the entire ecological web is critically dependent on photosynthesizing organisms native to these lakes and ponds, it follows that aquatic plants “belong” in lakes. But to what end?

The functions served by aquatic plants are extensive and impressive. They harbor aquatic insects that serve as the foodstuff for fish, often providing a launching pad from the water to the air. They provide hiding, nurseries and spawning areas for zooplankton, amphibians and fish. They provide food for waterfowl and other creatures of the wild. They hold sediment in place and otherwise control flow patterns and dampen wave action, reducing erosion and the transit of turbidity and nutrients into the open waters. They create oxygen for those who live in and above the waterline, aiding in the water purification process (by providing habitat for microbial degradation and converting toxic compounds to useful raw materials). And, at least from an aesthetic standpoint, many of these macrophytes are quite beautiful, whether observed by the colorful flowers of the pickerelweed or water lilies, the delicate but dangerous nets cast by the carnivorous bladderwort, or the fern-like simplicity of the Robbins pondweed. In short, aquatic plants are absolutely essential to the proper maintenance and function of a healthy and attractive lake or pond.

Weed control to improve swimming or aesthetic quality may have undesirable consequences. If some uses of the lake, such as fishing, require moderate to high levels of standing weeds then efforts to reduce weed populations will necessarily be in conflict with these uses. Both anglers and swimmers would certainly agree that too many weeds, particularly monocultures of canopy-forming or surface-covering exotic weeds, are not good for any lake uses. However, user conflicts about “How much is too much?” need to be reconciled before aquatic plant management strategies are to be considered necessary.

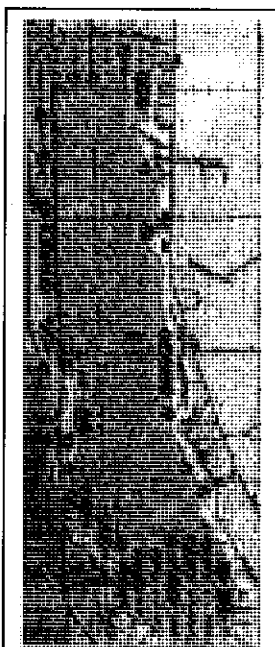
### **What Are Those Things?**

An integral part of any management or prevention program is identifying the targeted plants. Why is this important? Isn’t a weed just a weed? Well... while a weed is simply too much of a plant growing in the wrong place, many of the strategies for controlling those nuisance weeds are selectively effective for specific aquatic plants. For example, seed producing plants, such as some varieties of *Potamogeton* (pondweed) and naiads, are less impacted by water level manipulation, due to the ability of the seed banks to weather the deep freeze associated with winter drawdown. These plants may actually increase after a drawdown, at the expense of some plants that reproduce vegetatively (through fragments or rhizomes). Some beneficial native plants that look very similar to exotic, invasive plants may not survive an aggressive campaign to control the exotics, leaving a barren (under)waterscape for the new colonization and spread of opportunistic plants, like the same exotics targeted in the beginning. Grass carp like the taste or texture of some plants (such as soft ribbon or wide-leafed plants, like eelgrass and many of the

native pondweeds), but not others (such as coarser plants like milfoil), and their preferences are often inconsistent and unpredictable. Long-term control of nutrients within the water column, while likely to result in clearer water to better support contact recreation, might allow sediment-anchored aquatic plants to thrive in the absence of light inhibiting algae or weakly rooted plants. Some plants are strongly rooted (such as lilies and hardy watermilfoil plants) and derive the majority of their nutrition from the bottom sediments, while other plants such as coontail and bladderwort are weakly rooted, and absorb nutrients from the surrounding water.

### Macrophyte surveys and mapping

The amount and coverage of vegetation, both emergent and submerged, can have a significant affect on the recreational access, quality of fisheries, and overall aesthetic appeal of a lake. Vegetation surveys usually involve some combination of measures or estimates of plant quantities and locations within the lake; this information can go a long way toward a better understanding of the water quality and use impairment in a lake. The full spectrum of aquatic vegetation surveys, from the Cadillac to the cart, has been described elsewhere (Bloomfield and Madsen, 1996). The high end version is to lay transect lines (running perpendicular from the shoreline to just beyond the maximum depth of aquatic plant growth) throughout the lake and measure plant densities and population composition (species identification) in quadrants placed in regular intervals along the line. These quadrants can range in size from 0.1 (appx 1 foot by 1 foot) to 1 square meter, and can be frequently evaluated to determine change in plant densities and coverages). At the other end, simple surface maps can be drawn without regard to plant



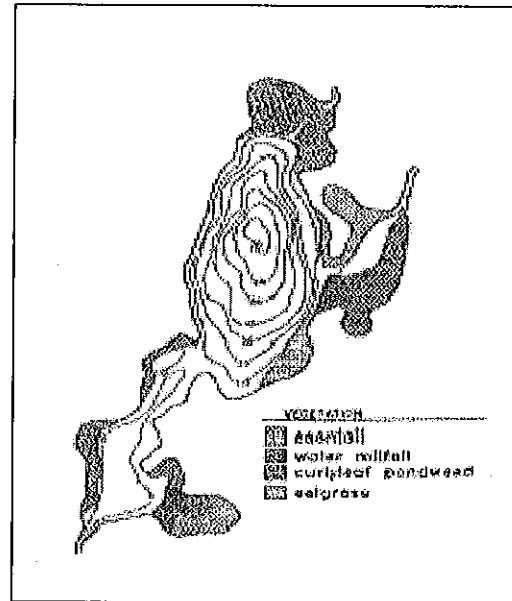
Aquatic Plant Survey  
Map of Waneta Lake  
(Lord, 2005)

type. However, extensive macrophyte surveys can be extremely expensive, and may require the time and expertise of qualified specialists, including divers. Individual plant species must be positively identified and verified to completely address the relationship between macrophyte communities and lake water quality and use impairment. As noted above, this is commonly done as part of volunteer plant monitoring programs.

The most common survey methods usually involve techniques for collecting plants from the surface, usually using rakes attached to ropes tethered to the shoreline, boat, or wrist of the sampler, or observations of plant communities using diver swimovers or identifications from boats. These rake tosses or observations can occur at various depths in the weediest areas, but are best standardized or reproduced by sampling via the "point-intercept" method, which divides the lake into a series of points, usually in the center of grids overlying the surface of the lake. These points can be sampled randomly, and recent surveys have indicated a strong connection between biomass measurements and semi-quantitative assessments from point-intercept measurements, as discussed below (Lord et al., 2004).

The point-intercept measurements can generate coverage maps that provide a readily understandable snapshot of plant conditions in a lake (see Figure on the left), and can, if used in methods described below, can be used as a surrogate for detailed biomass survey maps.

In lieu of an extensive macrophyte survey, individuals and lake associations can map the extent of vegetation coverage over the course of the year, usually during late spring to early summer and again in the fall. This can be done through aerial photography, or from on-site inspection by lake residents (preferably those who can view the lake from their rooftops!). The most common maps indicate the major plant species in each part of the lake, with little differentiation between thick beds and scattered plants. These can be seen in the figure on the right.



It is frequently measured as percent coverage, or as a qualitative assessment of density, usually rare/trace, scarce/sparse, moderate/ medium/ common, and dense/abundant. Cornell University researchers have developed simple semi-quantitative metrics to evaluate density using these easily-understood labels applied to the results from two or three rake tosses, as quantified below (Lord et al, 2005):

Plant Coverage	Average Quantity from 2-3 Rake Tosses	Estimated Plant Biomass
No plants	Nothing	0 g/m <sup>2</sup>
Trace	Ring full (of plants)	10 to 20 g/m <sup>2</sup>
Sparse	Handful	0.1 to 20 g/m <sup>2</sup>
Medium	Rakeful	20 to 100 g/m <sup>2</sup>
Dense	Can't Bring In Boat	100 to 400 g/m <sup>2</sup>

### So what's the problem?

While most lake residents and users recognize the importance of aquatic plants, if grudgingly at times, they also recognize that too many of the wrong type of plants in the wrong place at the wrong time are no longer beneficial aquatic plants. They are WEEDS! While any aquatic plant that meets at least some of these criteria may qualify as a "weed", most of the aquatic plant problems in New York State lakes are generated from those **submergent** aquatic plants that are **not native (exotic)** to a lake (and in most cases to a region or the state as a whole). These plants tend to grow **invasively** in the absence of natural competitors or predators. Once these invasive populations inhibit the uses of these lakes, these plants become a **nuisance** and the target of active management.

**Aquatic plant management should not be taken lightly! The potential impacts to the aquatic ecology of a lake from a poorly thought-out "brush-fire" response to a weed problem can be significant and difficult to reverse. Likewise, inaction in the face of rapidly escalating weed problems, particularly those triggered by invasive exotic**

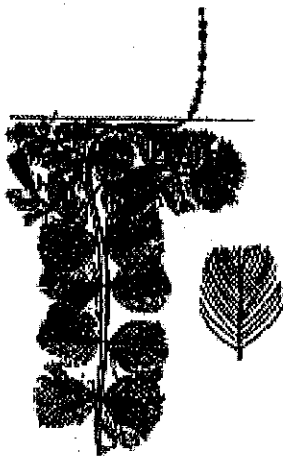
weeds, can also create ecological problems. In short, the future management challenges stemming from poor management decisions can increase exponentially. The best way to prevent these poor decisions is to develop a comprehensive aquatic plant management plan that addresses the objectives of aquatic plant management and reasonable strategies for reaching those objectives for your lake. Appendix A includes an outline for developing such a plan.

The rest of this chapter will largely focus on a summary of the control strategies that have been used to minimize the impacts of invasive plants on lake uses. The term “minimize” is appropriate, for invasive plants, particularly non-native plants, can rarely if ever be eradicated from lake systems. Since plants will grow if light reaches the lake floor, and since most of these plants have reproductive structures- seeds, roots, rhizomes, etc.- that cannot be fully exterminated, the goal of most management plans is to minimize invasive plant populations and/or the impacts associated with nuisance growths of these plants.

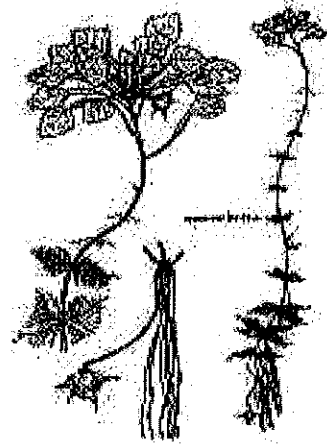
It should also be noted that one swimmer’s weed is another angler’s edge. Weed control to improve swimming or aesthetic quality may have an undesirable impact on fishing. If some uses of the lake require moderate to high levels of standing weeds, such as fishing, then aquatic plant management activities implemented to reduce weed populations will necessarily be in conflict with these uses. While both anglers and swimmers would certainly agree that too many weeds, particularly monocultures of canopy-forming or surface-covering exotic weeds, are not good for any lake uses, user conflicts about “how much is too much” need to be reconciled before aquatic plant management strategies are to be considered necessary.

Although New York State lakes continue to be threatened by a growing number of invading plants from neighboring states (practically next door as the crow flies, or in this case the duck...), states from the not-too-distant south where longer growing seasons and access to tropical travelers breeds a larger mix of aquatic invaders, and even boats traveling through international gateways into the state, only a small number of exotic plant species can be indicted for the majority of invasive plant problems in these lakes. The worst invaders in New York State waterways can be summarized in an invasive aquatics Most Wanted List (line drawings from Crowe and Hellquist, 2000):

1. Eurasian watermilfoil (*Myriophyllum spicatum*) was introduced into New York State in the 1940s, probably in the Finger Lakes region, and has since spread to every region of the state except for Long Island. It is characterized by dense canopies that spread laterally across the surface of the lake, and propagates primarily by fragmentation in pieces as small as one inch. Like most invasive exotic plants, it grows opportunistically in a wide variety of depths, water quality conditions, and sediment types, although it is mostly commonly found in sandy to mucky soils in a depth range of 3 to 12 feet. It is the most invasive submergent aquatic plant throughout New York State.



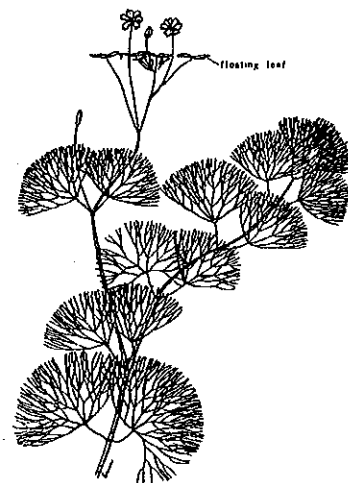
2. (Eurasian) water chestnut (*Trapa natans*) was introduced in North American and New York State in Collins Lake in Scotia in 1882, although it was found a few years earlier in an herbarium in Massachusetts. From this "epicenter", it has largely migrated along the Lake Champlain, Mohawk River and Hudson River systems (and problems associated with water chestnut are mostly restricted to these areas), although it has been increasingly found in small lakes and ponds. It is conspicuous for a surface rosetta of leaves and a woody, spiked nutlet that serves as a seed for future generations of the plant (and is viable in bottom sediments for several decades). Water chestnut grows primarily in sluggish shallow water in mucky sediments.



3. Curly-leaved pondweed (*Potamogeton crispus*) was probably introduced in the mid-1800s in the northeastern United States, and is found sporadically throughout the state. It is characterized by a lasagna-like curled leaf and a very early growing season. In New York lakes, the plants usually start growing under the ice and die back by late June. It spreads by seeds and sprigs. It grows in a variety of settings, but generally grows best in relatively shallow water. Curly-leaved pondweed control strategies are most often employed in the eastern and southern portions of the state.



4. Fanwort (*Cabomba caroliniana*) is native to the southern states but not native to New York State or the northeastern states. It has historically been limited to Long Island (although the first sightings in New York State may have occurred in Orange County in the early 1930s), where it grows primarily in shallow water, as in most other New England states. However, in recent years it has been found in deepwaters of the isolated lakes in the southeastern Adirondacks and on both sides of the Lower Hudson River basin. It has thread-like leaves that fan out on opposite sides of the stem; while it has white or pink flowers, these rarely appear in fanwort in New York state lakes. It spreads by seeds, not by fragmentation or other asexual means. Fanwort control is mostly limited to Long Island.



Problems with nuisance weeds vary from one part of the state to another, resulting in management approaches and regulatory issues that are also highly variable. Although Eurasian watermilfoil has recently spread to the interior Adirondacks, the mostly isolated lakes and ponds away from the perimetry of (and major travel corridors within) the Adirondack Park, as well as the unaffected ponds in Long Island, have largely been spared nuisance-level infestations of most aquatic plants. While fanwort is common and grows invasively in many Long Island lakes and ponds, most of the ponds are so shallow that invasive plant growth also occurs with many native plant species. The percentage of lakes in the interior Adirondacks for which some recreational uses are impacted by excessive weed growth is much smaller than in most other parts of the state, at least relative to the large number of lakes in that region. The incidences of weed problems are highest in the Central New York region, although it is also clear that this also reflects a higher percentage of lakes reporting these problems (due to active lake associations, strong local involvement in lake residents in state and county reporting mechanisms, and active monitoring programs).

Lake Region	% NYS Lakes in Region	% NYS Lakes With Exotic Plants+	% NYS Lakes Impacted By Weeds*
Long Island / NYC	5	5	10
Downstate	18	15	20
Central New York	12	40	30
Adirondacks	58	20	20
Finger Lakes	5	10	10
Western New York	2	10	10

+ - based on inventories compiled through 2004

\* - as documented on the NYS Priority Waterbody Lists compiled in the late 1990s to early 2000s

In other regions of the state, nuisance weed problems tend to be focused on more heavily used lakes near large roadways, although this is probably due to a combination of the greater exposure to vectors for transmitting these exotic plants (boats and trailers), the ease of access to these lakes, the larger population base using these lakes, and the greater likelihood of local communities reporting invasive weed problems in these high profile lakes.

### An Ounce of Prevention

The best control strategy for nuisance aquatic plants is prevention. If the plant isn't in your lake, there is no need to control it. While preaching prevention in a weed-infested lake might be akin to closing the barn door after the horses have escaped, it might be the best way to keep the rest of the horses in the barn.

So what are the best measures for preventing the transit and spread of nuisance aquatic plants? New introductions of plants are often found near public access sites and heavily used entryways. Therefore, lake residents should focus their attention on boat propellers and trailers. Propellers, hitches, and trailers frequently get entangled by weeds and weed fragments. Boats not cleaned of fragments after leaving a colonized lake may introduce plant fragments to another location. Additionally, not feeding the ducks is a good idea, since plant fragments and seeds frequently enter lakes on the feet and wings of these



feathered visitors. Vigilantly patrolling all waterways entering the lake for plant fragments, seeds, and other bits of plant stuff may help, although neither strategy is likely to keep out most of the hitchhikers.



Inspection programs are a useful strategy and have been introduced at boat launch sites in several locations in the state. These can range from providing handouts and information to boaters about the connection between boats and invasive exotic plants to encouraging the removal of stray plants from propellers and trailers to preventing infected boats from entering the lake until offending plants are removed. The most common inspection programs are self-inspections suggested by “hitchhiker” signs posted at public and private launches by the NYSDEC and advocacy groups.

These frequently provide pictures of the most significant invaders (water chestnuts, zebra mussels, and sometime Eurasian watermilfoil), the places on boat props and trailers where straggling plants grab, and some simple strategies for removing these plants. Several lake communities sponsor “weed watcher” programs that teach volunteers how to look out for exotic plants. At the other extreme, boat wash stations (ranging from simple hoses to pressurized hot washes) have been used primarily at private launches to remove both nuisance plants and zebra mussel *veligers* (and any other exotic organisms that hitchhike onto boats or in bilge water).

Plants should not be discarded or introduced from one water source to another. For example, bilge or bait bucket water may contain traces of exotic plants or animals, and should be emptied prior to introduction into a new lake.

Another common mode of infestation is the purchased and deliberate introduction by aquaria and gardening hobbyists. Many problem exotic plant species can be readily purchased for fish tanks or water gardens. At present, only the planting or transit of water chestnut plants and seeds is prohibited within the state. Without stricter federal or state laws that ban or restrict the sale of highly invasive exotic plants in New York State, prevention rests with informing aquaria owners of the risks of discarding aquaria waters into lakes (not to mention the exotic fish or diseases that can also be introduced through this vector).

Exotic plants tend to thrive where water quality conditions and especially sediment characteristics have significantly changed. Establishing no-wake zones can reduce shoreline erosion and local turbidity, and may help to reduce disturbance of bottom sediments.

### Who's In Charge?

Perhaps in recognition of the regional variability in environmental sensitivity in general and aquatic plant problems specifically, regulatory structures within New York State play an important role in aquatic plant management. Chapter 11 discusses the interaction of state law and lake management with a focus on the regulatory authority that directs the various functions of government agencies, but these can be discussed here in greater detail as they relate to aquatic weeds.

In most parts of the state, the New York State Department of Environmental Conservation (NYSDEC) maintains responsibility for regulating aquatic plant management. Most of the plant management strategies discussed in this chapter are not regulated activities. Permits are not required for managing aquatic plant problems, particularly by an individual landowner. A notable exception to this is if all or any portion of a lake is classified (under Article 24 of the Environmental Conservation Law) as a wetland. In this case, some activities are regulated and thus require at least a permit; some also require environmental assessments and evaluations of potential environmental impact. The NYSDEC regional offices can assist lakefront property owners or lake associations in determining if any portion of their lake is a classified wetland. In addition, the bottom of many New York State lakes is owned by

### Case Study- Preventative Measures

**Lake Setting:** Otsego Lake is a 4100 acre lake found in the Leatherstocking (Central) region of New York state, perched at the northern end of the Village of Cooperstown.

**The Problem:** Lake residents and user groups have become increasingly concerned about the introduction of invasive exotic organisms through public boat launches and other entry points to the lake

**Response:** The Otsego Lake Association (OLA), the SUNY Oneonta Biological Field Station (BFS) on Otsego Lake, the Otsego County Conservation Association, Otsego 2000 (a local planning group interested in local quality of life issues) and other local partners worked with the neighboring towns to initiate a voluntary boat inspection and boat wash program, initially to address concerns about zebra mussels. By 2003, the Village of Cooperstown passed a local law requiring these inspections. More than \$13,000 in foundation grants and town resources were provided via the Cooperstown Town Board to purchase, install, and staff a boat wash station, resulting in more than 1600 boat and trailer inspections in 2003 and about 1400 inspections in 2004 (about half of which occurred on weekends). Launch fees (\$10 per launch, with reduced rates for multiple launches), grants and other contributions offset the approximate cost of \$35,000 to run and maintain the launch. Boaters failing inspection are directed to a free boat wash at the Village Highway garage.

While this program was devised for zebra mussel control, these same partners were also involved in a water chestnut management and prevention program. A single specimen was discovered during a field survey conducted by a SUNY Oneonta student in 1999. \$7,000 was provided by Otsego 2000 for searching for and removing small populations of water chestnuts. The OLA and BFS sponsor an Exotic Species Day each year for citizens to search for exotics. The BFS provides an information sheet (regarding the search and removal of exotic plants) and solicits community volunteers for annual monitoring, capped by a barbeque and social gathering for the volunteers. The BFS also conducts training workshops with inspectors at the boat launches each spring.

The OLA and BFS are working with the town of Springfield (north end of the lake) to expand beyond an inspection program (and limiting launching to town residents) to site a wash station. They are also working with local bass associations and yacht clubs to mandate boat washes prior to tournaments and races on the lake, respectively.

**Results:** Initial reports indicate that boaters strongly supported the boat and trailer inspections and a Chlorox spray of lines and bilges, although several boats required power washing prior to launching. As a result, as of 2004, no zebra mussels were found in the lake or on boats pulled at the end of the season. Aquatic plant surveys conducted by SUNY Oneonta found two additional water chestnut specimens. These were hand harvested, and no plants have been found since.

**Lessons Learned:** This example shows that rapid response to threats of exotic invasions (or actual pioneering introductions) can be effective in slowing or delaying the spread of invasives and the ecological and human use problems associated with this invasion

**Source:** Otsego Lake Association website ([www.otsegolakeassociation.org](http://www.otsegolakeassociation.org)) and Willard Harman-personal communication

the state of New York. Regulations associated with plant management activities that may significantly impact the lake bottom are administered by the Office of General Services.

The Adirondack Park Agency also maintains regulating authority on waterbodies within the Adirondack Park, primarily under their wetland regulations (which differ from state and federal wetland definitions). In other parts of the state, different government entities have authority over some aquatic plant management activities. For example, the authorities that regulate water level in the state (the Canal Authority within the State Thruway Authority, the Hudson River-Black River Regulating District, etc.) may dictate whether water level can be varied within the feeders to the canals or larger river systems. This authority extends to control of water level in many New York State lakes. Other government agencies that possess regulating authority that may ultimately require permits for aquatic plant management include the US Army Corps of Engineers, the NYS Department of State (for "wetland" lakes with direct connections to designated coastal areas), Lake George Park Commission, the Saratoga Lake Protection and Improvement District, the NYS Office of Parks, Recreation, and Historic Preservation (for those lakes and ponds that have both private ownership and state park land), and local government agencies delegated responsibilities by NYSDEC for regulating wetlands.

While aquatic plant management permit applications- primarily for aquatic herbicides and herbivorous fish (grass carp)- are evaluated on a case-by-case basis, and while regulatory requirements and environmental constraints dictate some variations in application reviews, regional patterns have emerged. For example, although aquatic herbicides can be used within the Adirondack Park, at present aquatic herbicides have not been applied to any lakes within the Park. Aquatic herbicide use is also very limited on Long Island. It is perhaps not coincidental that these regions have had lower incidences of aquatic plant problems, at least historically (particularly in the interior Adirondacks). However, both regions appear to have a stronger level of opposition to the use of herbicides than in most other regions of the state. The stronger regulatory framework for protecting wetlands also appears to result in fewer herbicide and grass carp permits in the Adirondacks; grass carp are most frequently stocked on Long Island lakes. On the other hand, a very large number of aquatic herbicide and grass carp permits are issued in the Downstate region, although this is also due in part to the large number of weed infested lakes and the large population base affected by excessive weed growth. In most other regions of the state, the proclivity toward issuing permits for aquatic herbicides and grass carp is neither high nor low. However, greater restrictions exist in some regions. This includes the larger number of wetland lakes in the eastern portion of the Central NY region, the relatively short retention-time (wide river) lakes in the southwestern Adirondacks, and water supply reservoirs throughout the state.

### **What Works?**

Weed problems have plagued New York State for many years. Despite the long history of successes and failures for each of the management strategies to be discussed below, weed management in New York State has offered no single fix for each kind of lake, each kind of nuisance weed, or every lakefront owner with a vague mix of "seaweeds" outside their docks.

There also remains, perhaps hidden under the surface, the great risk of making a problem worse. Each management strategy has some risks associated with their use in these dynamic, unpredictable biological settings. Where possible, these oft-unexpected consequences are anticipated in this chapter, and discussed within the “Disadvantages” portion of the method summary.

That said, there is a core group of aquatic plant management strategies that have a relatively long history of use in New York State lakes and thus a record of success or failure. These can be categorized by cost or permitting requirements, although plant management strategies are usually characterized by mode of action:

Mode of Action:

- physical control strategies that impact the physical growth patterns of the weeds through disturbing the sediment, altering light transmission through the water or to the plants, and water level manipulation.
- mechanical control strategies that remove the plants and root systems, such as cutting, harvesting, and rotovating
- chemical control strategies, such as herbicides
- biological control strategies, such as herbivorous fish and insects

However, perhaps the most appropriate way to differentiate plant management strategies is by whether the control is “local”- outside a dock or otherwise manageable by an individual lakefront owner- or “lakewide”- strategies that impact most or all of a lake and therefore require a greater consensus among lake residents. While some of the local management activities can be applied in large portions or the entirety of a lake, the logistic difficulties in expanding these activities to a larger area are usually insurmountable.

The techniques listed below are not specifically endorsed by NYSFOLA or regulatory agencies. Rather, this is a list of recognized methods for addressing specific aquatic plant problems. Because prices vary with place, time and circumstance, the cost listings are relative at the time of printing. Additional information about each of these techniques can be explored from a variety of sources (Holdren et al., 2001; Cooke et al., 1993; Baker et al., 1993). Case studies on the use of some of these techniques in New York State lakes are also reported. **It must be stated that these do not necessarily represent the normal or expected results from the use of these techniques, although these summary case studies are among the better documented cases in New York State. These summaries are intended to provide the reader with some information about the actual use of these techniques in a wide range of lakes throughout the state, but do not constitute an endorsement of the use of these techniques in any New York State lake. For example, while there have been lake management projects in New York lakes involving the use of stocked aquatic weevils and different herbicides, the documentation in the lake studies reported here is more detailed than in these other projects. The authors hope that additional information about the use of these aquatic plant management techniques in New York State will be collected and become available to those interested in utilizing or learning more about aquatic plant management within the state.**

## **Local / Shoreline Management Activities** (listed by increasing order of “complexity”)

### **1. Hand Harvesting and Suction Harvesting**

- *Principle*

This is very much akin to weeding your garden. Hand harvesting involves grasping the plant material as close to the sediment layer as possible, even digging into the sediment to grab the root crown, and pulling the intact plant out of the bottom sediment. Plants are pulled slowly to minimize fragmentation, and the entire root system should be removed from the sediment if possible.

If hand harvesting is carried out by a lake resident trying to keep his own shorefront free from plants, plants and roots should be deposited away from the shore to minimize transit back to the lake. This technique is largely restricted to small areas, although only the time, patience and amount of elbow grease prevents a lake resident from keeping a very large area clear. Generally, for large beds of plants, or for plants growing in water greater than a few feet deep (invasive exotics like Eurasian watermilfoil can grow in water up to 20 feet deep), scuba divers will likely be required. In these cases, harvested plant materials, including root systems, stems, leaves, and fruiting structures, are placed in mesh bags and taken away from the lake.

In more extensive diver-operated hand harvesting, a barge on the lake surface with a dredge hose connected to an industrial engine creates suction. The other end of the dredge hose is carried to the lake bottom by a scuba diver. The hose sucks up the plants, roots and top sediments that go into a spoils collection basket on the barge. The basket traps the plants and root fragments, allowing the sediments and water to drain back into the lake. This process is usually referred to as **suction harvesting or diver dredging**.

Collected plants can be disposed of at a site away from the lake, or dewatered or dried and used for mulch or fertilizers. Disposal may be confined to small, individual sites, in the case of small dredging operations. Suction harvesting collects a much smaller biomass than does larger-scale mechanical harvesting operations (discussed later), because only small targeted areas are dredged, and because only the nuisance plants are removed, not all of the native and exotic plants.

- *Target Plants and Non-Target Plants*

Hand-harvesting is the ultimate selective plant management technique, since it removes individual plants a single plant at a time. Only those plants that are identified as exotic, invasive, or otherwise contributing to nuisance conditions are removed. Suction harvesting may also remove some nearby plants and sediment, although selective control is still largely achievable.

- *Advantages*

Unlike large scale, lake-wide management techniques, hand harvesting can be conducted on a single plant or a small bed at a minimal expense, if not minimal labor. Anyone can hand-harvest, although only the cautious can hand-harvest well. It targets only those plants that create use impairments or contribute to nuisance conditions. If properly performed (SLOW removal from under the roots or the base of the plant when the plants

are still robust), side effects, such as turbidity and bottom disturbance, are minimized and usually temporary. It is also very useful at preventing re-infestations after a larger-scale plant management strategy, particularly when combined with a vigilant surveillance program. For target plants that do not reproduce vegetatively, hand harvesting (as well as mechanical harvesting) can provide some longer-term control of these plants if the plants are removed prior to the formation and fall of the seeds.

Such harvesting can be directed, but not be limited, to clearing swimming areas and opening navigational channels. The technique can be used in open-water and most near-shore areas. Since the diver, and not the barge, controls the operation in suction harvesting, plants can be removed between docks, shallow water, or other areas with physical constraints to boat access. The only limit imposed on the application of suction harvesting is the length of the dredge hose, although multi-diver operations may also have surface air and safety lines linked to the barge.

- *Disadvantages*

Very effective, hand-harvesting is cumbersome and tiring. It is difficult to hand pull large beds of target plants, and inconvenient (from the pullers perspective) to hand pull scattered plants, although this may be the best way to prevent the expansion of single plants into small beds. Efforts to speed up the process, by hand pulling clumps of plants away from the sediment interface at a rapid pace, often results in fragmentation, incomplete plant removal, high turbidity and bottom disturbance. Even when performed properly, hand harvesting frequently results in some fragments and floating bits of root and seed and other plant parts, the vegetative stock for new generations of plants when these materials eventually fall back down to the lake bottom. Moreover, since many nuisance plants spread vegetatively through runners and rhizomes, the inability to remove deeper plants may result in rapid reinfestation from contiguous beds outside the range of shoreline harvesting. It is not very effective on plants that have extensive root systems, such as lily pads, although these plants are usually not (or should usually not be) the target of selective plant control efforts. These limitations effectively result in only local control of nuisance plants with this method.

Suction harvesting operations can have some significant side effects. High turbidity, reduced clarity, and algae blooms from nutrient release can result from either the disturbance of bottom sediments, or the release of the sediment slurry from the on-barge collection basket. This may lead to reduced oxygen conditions, and, ultimately, may affect the ecosystem communities.

Suction harvesting also disrupts the bottom sediments while removing the plants and roots. This control method can have a deleterious effect on the animals living in the sediments and on the plants not dredged but living within the dredged area. Sediments may also contain heavy metals or other potentially hazardous materials. If these materials are present, and proper precautions are not taken, the dredging operation may release these metals into the water, which could have severe repercussions throughout the food web.

Suction harvesting is very costly, as much as two to ten times the cost of mechanical harvesting. While part of the overall cost is incurred at the beginning in capital expenditures, the most significant cost is in operations, due to the slow rate at which

## 1. Case Study- Hand Harvesting

**Lake Setting:** Upper Saranac Lake is a 5200 acre lake with more than 44 miles of shoreline found near the northern edge of the Adirondack Park.

**The Problem:** Eurasian watermilfoil was first discovered in 1996, and local residents and lake users have been concerned that it may take over large portions of the lake.

**Response:** A locally funded control effort using benthic mats and hand harvesting with four divers was initiated in 1998 by a partnership of organizations, including the Upper Saranac Lake Foundation, the Adirondack Aquatic Institute, Cedar Eden Environmental, and Paul Smiths College. This three-year effort achieved local control of large milfoil beds primary in front of state lands (which nearly 50% of the lake shoreline), and resulted in the annual removal of about 50 acres of milfoil across 3-4 miles of shoreline, at the cost of about \$60,000 annually. This level of effort was insufficient to prevent the spread or re-establishment of the plant. The benthic barriers and harvesting kept plant densities from being high enough to consider other management efforts for managing extensive milfoil beds. In addition, political considerations prevented the use of some of these management tools, such as aquatic herbicides. As a result, a three year program extensive hand-harvesting and benthic matting program was initiated in May of 2004 to remove and control Eurasian watermilfoil to acceptable levels in the lake.

Based on the experience of other large-scale hand harvesting programs in other NYS lakes, a team of 20 divers was assembled- two divers for approximately every 500 acres of lake area. These divers were trained in a one day training session involving plant identification and safety, followed by in-water training for additional Eurasian watermilfoil identification and removal technique. Each diving team had an experienced dive leader to coordinate diving operations. Divers hand-pulled Eurasian watermilfoil plants in a systematic path around the lake, while other team members tracked locations with Global Positioning System (GPS) units, recorded detailed survey information about the presence of milfoil and native plants, and transported bagged milfoil to a remote location. Additional resources used to support this hand-harvesting effort included 10 "top-water" team members, 4 dive platform boats, 2 tank dive boats, dinghies, kayaks, and a patrol boat. Divers hand harvested milfoil plants for 5 days a week for 55 days, starting on June 1<sup>st</sup> and ending by August 15<sup>th</sup>. Benthic barriers were also placed on the lake bottom in the middle of May.

The project was completed at a cost of approximately \$535,000 in 2004, or approximately \$200 per acre of infestation. Labor costs were about \$1,000 per hour, and constituted about 75 percent of the overall project cost. The project managers devised a unique compressed air distribution system to reduce the extensive overhead (financial and logistic) associated with supplying and replenishing air tanks to such a large team of divers. This also provided a more effective means for mass plant removal in large beds. However, more conventional diving operations (using SCUBA dive tanks) were also needed for more mobile operations to access and removal smaller or more remote beds. Future costs will likely be reduced since capital costs (purchases of boats and other equipment) will be lowered. It is difficult to compare these numbers to costs of other management activities, since the density of plants targeted in hand harvesting (low to moderate) was different than those encountered in other plant management efforts. Based on the number divers, quantity of harvested plants and project costs, this is the most extensive hand-harvesting project to date in New York State.

**Results:** Long-term evaluation of the effectiveness of the project will not be completed until after the third year of the project in 2006. Preliminary results from 13 transects surveyed around the lake in late 2004 demonstrated milfoil removal ranging from 27 percent to 100 percent of the pre-harvesting plants. The majority of the sites exhibiting greater than 60 percent removal, and removal rates were not closely related to either the plant densities or the number of times plants were hand harvested. Milfoil plants remaining at the end of the growing season resulted from either incomplete hand harvests or regrowth within the growing season; most of this occurred in depths between 8 and 12 feet.

**Lessons Learned:** This project demonstrates that hand-harvesting can be effective at controlling even large-scale milfoil infestations, but control in large or heavily infested lakes requires significant resources and a well-devised plan of attack.

*Source: Martin, M.R. and C. Stiles. 2005. The use of hand-harvesting to control Eurasian milfoil in Upper Saranac Lake, Franklin County, NY. Presentation at the NEAPMS annual conference, Saratoga Springs, NY.*

diver dredges can be operated. The operations cost also includes skilled labor. Unlike some control techniques, suction harvesting will probably require at least three specialists; one barge operator and at least two scuba divers, all with some experience in these activities. Even if a lake association can pay for the equipment, it is likely that the harvesting cannot be done without additional outside financial assistance. Thus, suction harvesting is far from a "self-help" control technique.

### • Costs

By far the most significant expense associated with hand harvesting is labor costs, since this is perhaps the most labor-intensive plant management technique available. For professional control, plants can be hand harvested by scuba divers at a rate of about 90 plants per hour (per diver) for an area first harvested, and about 40 plants per hour for a re-harvested area. This includes diving time, finding and removing only targeted plants, bagging, and disposal. The entire operation costs about \$0.25-\$1.00 per plant, or upwards of \$400-\$1000 per acre (Holdren et al, 2001),

based on a "typical" density of aquatic plants in a lake with targeted beds of target plants (recognizing that very dense beds are very difficult to control with this method).

The cost of the suction harvesting equipment is about \$20,000 to \$30,000. The operation requires one or more scuba divers, a dredge operator and a person to assist in the disposal of the plants. This could add an additional \$500-1000 per person per day to the cost of the operation. Depending on the size of the weed plots to be harvested, a one acre site could take from 2 to 40 days to dredge, or from \$1,000 to \$25,000 per acre, exclusive of the equipment costs

- *Regulatory Issues*

In most regions of the state, hand harvesting is not a regulated activity, although some NYSDEC Regional Offices may require permits or approval to perform larger-scale hand-harvesting. Within lakes outside of the Adirondack Park that are partially or wholly encompassed within wetlands, a wetland permit may be required.

Larger scale hand harvesting operations require an Adirondack Park Agency (APA) permit within the Adirondack Park. As per recent changes in the APA regulations, hand-harvesting does not require a permit for control of nuisance plants by individuals in lakes within the Adirondack Park if the hand harvesting:

- is conducted by hand in open water (less than 2 meters deep)
- leaves at least 200 ft<sup>2</sup> of contiguous indigenous wetland in the immediate vicinity of the owners shoreline
- does not involve more than 1000 ft<sup>2</sup> of native freshwater wetland plants
- does not involve rare or endangered species
- is conducted only on an individual's property, or with the permission of the property owner
- involves no pesticides or any other form of aquatic plant management, including mechanical plant harvesting methods or matting
- involves no dredging, removal of stumps or rocks, or other disturbance to the bed and banks of the waterbody

The regulations covering suction harvesting are similar to those encountered when proposing a dredging project (see below). A permit will have to be obtained from the NYSDEC and possibly from the Army Corps of Engineers. Inside the Adirondack Park, the APA will also require a permit. As with all dredging project, the process for obtaining a permit can be extensive and very difficult. Projects may require a public notification period; if the local community does not completely support the project, poor publicity can delay and even stop the implementation of the project. While suction harvesting does not usually command the same attention, either good or bad, as the larger-scale sediment removal dredging projects, the potential for public disagreement must still be considered

- *History and Case Studies in NYS*

This strategy has a long history of use in New York State, probably dating back to the first canoe paddle that inadvertently (or maybe not) pulled weeds out of the way and lake. But although it is likely that nearly every lakefront resident has performed hand harvesting, the vast majority of these efforts have gone undocumented. It also cannot be stated with any certainty that these have been successful- while pulling plants clearly



remove them, at least from the site on which these offending plants have anchored, it is not clear if the spread of fragmenting plants has been significantly exacerbated by indiscriminate hand harvesting. Hand harvesting has successfully controlled small patches of Eurasian watermilfoil in Lake George, Mountain Lake, and Indian Lake, and larger plant beds in Upper Saranac Lake. Small beds of water chestnut have been controlled by the New York State Canal Corporation in Lake Champlain (although most of this work was done with a mechanical harvester) and by Boy Scout groups and private citizens in Oneida Lake (and surrounding waterways) and Sodus Bay. While most of these efforts have successfully controlled the targeted plants, re-infestation from nearby plant beds and other vectors has required continuing efforts to stem the tide.

Suction harvesting projects have occurred with some success in Lake George, East Caroga Lake, and Saratoga Lake. The higher cost and more significant permit issues encountered in many regions of the state, as well as the need for highly trained personnel to operate the hoses and the boat, has precluded the extensive use of this technique in other parts of the state.

• *Is That All?*

Hand harvesting is no doubt the most common management technique used to control nuisance weeds in New York State, particularly if modifications to the “proper” techniques, such as those involving using running boat props or rakes or mattress springs to cut through weed beds, are also included in the count (although these may be more properly identified as “mechanical cutters”). It is increasingly difficult to survey the shoreline of many New York State lakes without finding deposited piles of raked or pulled or cut weeds, although this is probably a greater reflection on the increased use of these lakes and the escalating problem with invasive weeds rather than an accelerating use of this management technique. As perhaps the only plant management strategy that, in general, requires no permits, no significant expertise,

### *An Insiders Guide to Aquatic Plant Hand-Harvesting*

So you wanna pick some weeds? How hard can that be? Well, if you’re collecting a bouquet of picturesque aquatic plants to offer to an amour, it may be very similar to gathering wildflowers from an endless meadow. But if you’re trying to prevent these pesky plants from returning or spreading, the process is not quite so simple. There are many guides that tell you, in general, how to hand-harvest aquatic plants while minimizing fragmentation and removing most of the plant. This publication provides some of this general guidance. However, there are some tricks of the trade that have proven very successful in effectively controlling the propagation and regrowth of Eurasian watermilfoil and water chestnut, perhaps the two most heavily plucked plants. Below are a few helpful hints from a few of the insiders:

For Eurasian watermilfoil (Martin, 2005 and Eichler, 2005):

- Each sediment type creates unique challenges for hand harvesters- muckier sediments are easily disturbed, resulting in turbidity that can inhibit divers abilities to locate plants. Harder sediments can be rough on the divers hands.
- Beds are generally best harvested by working in from the outside edge, usually moving from greater to lesser depth to minimize disturbance of milfoil beds by boats (assuming they migrate to the harvesting site from the open water)
- Plant stems should be removed by prying the root crown out of the sediments, rather than pulling or tugging on the stems. Divers should insert their fingers into the sediments around the root crown, which may be the size of a tennis ball for mature milfoil plants, and should exert a steady pull. It has been described as similar to pulling an onion out of the soil, although the milfoil plants have more fine roots

For Water Chestnut (Samuels, 2005)

- Wear old shoes and gloves- the nutlets are very sharp!
- Water chestnut reproduce from the nutlets. If you remove the plants before the nutlets drop, you’ll eliminate the seed base for the following year growth, although the nutlets can survive in sediments for up to 20 years. However, if you remove the plants too early, new plants may crop up and produce seeds, and the nutlets are only loosely attached to the plant by late summer. The best window for removing water chestnuts are between mid June and mid August.
- Since infestations start from the outer edge of the plant beds, start removing plants from the outside and work your way into the center of the beds.
- Dispose of the plant in the trash or by composting on land away from shore (hut watch out for the nutlets!).

Sources: *Martin, M. 2005. Personal communication*  
*Eichler, L. 2005. Personal communication*  
*Samuels, A. 2005. Personal communication*

and little risk of side effects, it is not surprising that hand harvesting remains the weed control strategy of choice throughout the state. But for many of the New York lakes with pervasive weed problems and active lake associations, hand harvesting frequently occupies the niche of "intermediate" control strategies- used as an interim measure until a larger consensus of tired arms and sore backs supports the use of larger-scale plant management techniques.

Any harvesting operation, while perhaps the easiest of the physical plant removal strategies, create significant fragmentation and a surface "bloom" of cut plants which can migrate around the lake until either sinking to the bottom or depositing on the shoreline of the unfortunate lake resident who is most frequently downwind from his neighbors. Unless rapidly removed, these large piles of cut weeds will decay and create an unseemly mess, although once air dried will condense into a much smaller pile that might be usable as compost. It should be noted that many dried aquatic plants will ultimately be too nutrient poor to be useful as compost.

The slow rate of operation also can prompt some dissatisfaction from residents whose weed beds have not been controlled. Since the funds for operating the dredge will probably come, at least in part, from association fees or directly from the residents, the dissatisfaction resulting from a single year of operation may result in a funding shortfall during future years. Other methods, either faster or less costly, that may have more significant ecological side effects ultimately may be favored over diver dredging.

## **2. Benthic Barriers**

- *Principle*

Benthic barriers, sometimes called benthic screens or bottom barriers, prevent plant growth by blocking out the light required for growth. The barriers also provide a physical barrier to growth by reducing the space available for expansion. Most aquatic plants under these screens will be controlled if they are light-deprived for at least 30 days (Perkins et al, 1980).

Benthic barriers are made of plastic, fiberglass, nylon, or other non-toxic materials, and are often permeable to gases produced during the degradation of plant material. In some instances, burlap, or materials such as sand or gravel, have also been used as barriers. Most of these materials come in rolls 100ft long, anywhere from 8 to 75 feet wide, and 3-10 mm thick. Some, but not all, materials are heavier than water.

In shallow water, barriers can be installed by two or three people from the shore. The roll can also be placed on a small boat and unwound as the boat is rowed away from shore. Overlapping barriers by four to six inches will allow wider areas to be controlled. Barriers should be securely fastened to the bottom with stakes or anchors. Heavy plant growth can make installation difficult; it may be necessary to time the barrier placement with a low growth period, usually in early spring after ice-out. During the summer, barriers can be applied after a harvester has cleared the area.

Benthic barriers should be limited to areas of either intensive use or significant concern, due to the difficulty of installation and cost of the materials. They are most often used around docks, in swimming areas, or to open and maintain boat access channels. Since

barriers can be used to control the growth of specific weed beds or geographical areas, they are effective at maintaining native and controlled plant communities.

The screening materials and anchors should be removed at the end of the growing season so that they can be cleaned off and protected against ice damage during the winter, although some lake residents keep the barriers permanently anchored. In deeper water, or

in situations where the barriers are to be kept in place all year, the barriers should be periodically cleaned to remove organic material in order to prevent new plants from growing on top of the barriers. With proper maintenance, the screening materials can last several seasons.

#### Case Study- Integrated Physical Management Techniques

**Lake Setting:** Lake George is a 28,000 acre lake located in the southeast corner of the Adirondack Park.

**The Problem:** Eurasian watermilfoil was first identified at three locations in 1985, and by 1998, the aquatic plant had spread to 127 known sites, 31 of which contain dense growth. Preventing additional spread of the milfoil, and control of existing beds, has been the focus of significant local efforts for many years.

**Response:** Lakewide aquatic plant surveys and experimental use of selected control strategies were conducted between 1987 and 1992 by a consortium of state and local agencies and the Darrin Freshwater Institute (DFWI). In 1995, physical management efforts were incorporated into an Integrated Aquatic Plant Management Program with management efforts the responsibility of the DFWI. In 2002, Lycott Environmental, Inc. and the Lake George Park Commission conducted the integrated management program at Lake George.

**Results:** During 2004, a total of 148 milfoil sites were identified throughout the lake. Of these, 64 were cleared through a combination of management techniques and an additional 54 sites were found cleared by the end of 2004 (although, as in previous years, some of these "cleared" sites exhibited milfoil growth by the following summer). "Cleared" refers to no visible milfoil remaining. Six more sites are used by DFWI for research purposes and have not actively been managed. The number of known milfoil sites increased by an average of 8 sites per year from 1987 through 2001, with a total of 141 milfoil sites identified. From 2002 through 2004, there was an increase of only 2-3 sites per year, but whether this represents a slowing of the rate of dispersal of milfoil in Lake George, or simply reflects the limited survey effort to locate new sites of invasion, is unknown. However, in 2004, approximately 40% of previously managed sites remained free of milfoil.

Between 2002 and 2004, 9,300 to 16,400 milfoil plants were removed by hand each year from 64-76 locations. In 2004, approximately 40,000 square feet Palco® pond liner was installed. 1,500 square feet of pond liner was also reclaimed and relocated in 2004, from a site managed in 2003. In addition, 45 to 50 30-gallon barrels of milfoil were removed by suction harvesting in 2002 and 2003 (approximately 35,000 plants each year) at a single site. In 2004, no suction harvesting took place since it was decided that the possible negative impacts and efficiency of suction harvesting relative to barrier methods was not cost effective. Hand harvesting efficiency, as estimated by repeat harvesting, exceeded 85% in all years, and 97% in some years.

**Lessons Learned:** Benthic barriers can be an effective management strategy, particularly when plant densities are low. When integrated with hand harvesting, these efforts can clear significant portions of the lake bottom. Active annual maintenance is necessary to prevent milfoil regrowth and recolonization in these areas. While these methods have been successful under certain circumstances, there are many considerations for implementation including water clarity, substrate conditions, species and density of the aquatic plant growth, and depth of the plant growth.

**Source:** Lyman, L. and L. Eichler. 2005. *Successes and Limits of Hand Harvesting, Suction Harvesting, and Benthic Barriers in Lake George, NY. Presentation at the Northeast Aquatic Plant Management Society annual meeting, Saratoga Springs, NY.*

#### • *Target Plants and Non-Target Plants*

Since all aquatic plants require sunlight, benthic barriers will inhibit photosynthesis and will ultimately control (kill) all plants underneath the barriers; as such, it is a non-selective control strategy. However, proper siting of the barriers will result in selectively controlling only those plants under the barrier, not desirable neighboring plants.

#### • *Advantages*

While benthic barriers do not selectively control the underlying plants, the placement of the mats can effectively provide selective control by limiting the inhibition of photosynthesis to **monoculture** beds of invasive plants and areas of nuisance plant growth. Ecological side effects can be practically insignificant. Benthic barriers do not introduce toxic or hazardous chemicals, and do not involve extensive machinery. Some materials are said to photodegrade in ultraviolet light, but the degradation products are quite innocuous. Although cumbersome to place and anchor,

benthic barriers can be applied by laypeople (almost as) well as professionals, although the process is greatly simplified and more effective using specially designed (read: expensive) materials and scuba divers.

- *Disadvantages*

The bottom covering may eliminate some species of benthic invertebrates, and it is possible that the barriers may interfere with some warmwater fish spawning. However, it does not appear that any other components of the food web are adversely affected. Although this strategy can be used throughout the lake (or at least the littoral zone), the cost of the materials and the difficulties in installation can quickly limit the spatial extent of this method, and permitting issues may become more significant. If target plants are intermixed with desirable native plants, it will be difficult to achieve selective control, particularly since the expansion of these desirable plants will greatly enhance the longevity of this management strategy.

- *Costs*

Benthic barriers can be applied "on the cheap". The bottom materials can be comprised of opaque (usually green or black) garden tarps, while PVC frames can be constructed to hold the tarp in place. Rocks can be used to hold the tarps down as weights, while rebar can be used as stakes. For professional installation, the cost of benthic barriers ranges from \$10,000 to \$20,000 per acre, depending on the choice of screening material and whether the application involves initial installation or re-employment. This may be much higher than the costs for several other physical control methods. The ability to reuse the materials over several years will help to amortize these costs. Scuba divers will be required to install and secure the barriers, at least in water depths over 6 feet. Plots with steep slopes, natural obstructions, or heavy plant growth may require additional assistance.

- *Regulatory Issues*

In most regions of the state, the use of benthic barriers is not a regulated activity, although some NYSDEC regions may require approval or permits to prevent disruption of fisheries habitat, particularly for large-scale operations covering a large portion of the lake bottom. Within lakes outside of the Adirondack Park that are partially or wholly encompassed within wetlands, a wetland permit is required. Benthic barriers require a general permit for lakes within the Adirondack Park, issued by the Adirondack Park Agency.

- *History and Case Studies in NYS*

Although benthic barriers have been commonly used throughout the state for many years, most of the applications of this method have been by individual lakefront residents who extended the principle from their garden to their lakefront, and most of these practitioners have not reported their findings. The application of benthic barriers in Conesus Lake has been summarized in "*The Conesus Lake Dockside/Near-Shore Lake Weed and Algae Treatment Guide*", while the recolonization of aquatic plants following the removal of benthic barriers in Lake George has been discussed in the *Journal of Aquatic Plant Management* (Eichler et al, 1995). In both of these lakes, benthic barriers have effectively controlled nuisance plants, albeit in relatively small areas. Other New York

State lakes that have been "treated" with benthic barriers include Brant Lake, Schroom Lake, and Skaneateles Lake.

- *Is That All?*

Benthic barriers are among the safest and most ecologically sound in-lake physical control techniques. They have been effectively used in a wide variety of conditions and for many varieties of nuisance vegetation. Because they can blend in with the natural environment, are usually not noticeable from the shoreline, and don't interfere with many recreational activities, benthic barriers often afford the greatest public satisfaction. The materials and methods are usually effective for several years (since the materials are not subject to significant ultraviolet light while underwater, photodegradation is not a significant problem in practice). Unfortunately, many lake associations cannot afford the cost of professional materials and installation, except perhaps on the most critical weed beds. Control should therefore be limited to small areas with nuisance vegetation, although less expensive alternatives are commonly used by non-professionals.

Installation and maintenance will require significant thought and time. Although the materials may be heavier than water, due to the natural buoyancy of the covered vegetation and water currents, the screening material can easily come undone. Any large application will probably require additional anchoring and reinforcement, such as steel reinforcing rod (rebar). This is especially important when the screens rest on steep slopes, uneven terrain, or heavy plant cover. Buoyancy due to gas formation from degrading plants must be prevented to avoid "ballooning" or screen movement. Should these barriers drift to the surface, they can be difficult and perhaps embarrassing to replace. These problems can be avoided by cutting small slits in the materials; these slits should be sufficiently large to allow gas escape, but not large enough to allow growth through the holes.

Maintenance is critical to minimize plant regrowth due to sediment or silt deposits on top of the screens. Some materials such as burlap easily allow root structures from deposited plant fragments to take hold. Some manufacturers claim that any new growths can be easily removed from the screen surface, while other manufacturers recommend that their materials be removed and cleaned yearly. The potential for tearing, and the difficulty of re-installation makes removal of the screen for cleaning impractical for large applications. Screens should be left in-place during cleaning. Great care must be taken if screening materials must be moved or relocated. However, removing individual plants fragments from the barriers underwater can be very tedious, and will almost certainly require the use of scuba divers. The overall cost of installation and maintenance can be great, and must be considered as a necessary expense (or a real hassle) when using benthic barriers as a control technique.

### **3. Hydroraking / Rotovating**

- *Principle*

Rotovating (also called rototilling) is a relatively new form of mechanical control for aquatic vegetation that uses a rototilling machine to cut and dislocate aquatic plants and roots from the sediment, and then removes the cut plants from the lake. Hydroraking is

essentially the same technique that uses a mechanical rake, and collects and removes some of the cut material.

A rototilling machine is usually mounted on a barge. The machine has a large rotating head with several protruding tines that churn up the sediments, dislodging the roots and plants. The rotating head can be easily positioned with a hydraulic boom winch and winch cable (as hydroraking). The plants are either brought up on the rotator and disposed of on shore, or the floating vegetation is raked up for proper disposal.

- *Target Plants and Non-Target Plants*

Although rotovating and hydroraking have been used primarily as a means to control Eurasian watermilfoil in New York State, selectivity is limited to targeting only monocultural beds. These techniques are generally non-selective, since the rototillers or hydrorakes cannot be easily maneuvered to selectively remove target plant species within diverse beds, and since the cutting implements can equally cut all plants and root material, from weakly rooted plants to water lilies with thick underground tubers.

- *Advantages*

Rotovating removes the roots as well as the plant, thus providing a longer control strategy than mechanical harvesting (to be discussed later), although new plant growth can easily occur if root stock is not completely macerated or if seeds are readily dispersed. This technique has controlled Eurasian watermilfoil for as long as two years, although the spread of the plants from uncut areas may reduce this longevity. These techniques provide immediate relief and tend to work faster than large scale harvesting operations.

- *Disadvantages*

Many of the side effects described under hand- or mechanical- harvesting apply to rotovating, but are magnified. Rotovating and hydroraking significantly disturb lake bottoms, churning out a brew of sediment, root masses, vegetation, and other debris that may decay on and in the lake. The potential for re-infestation from fragments or seeds of uncollected cut vegetation can be significant for several plant species. Under windy conditions, or in a strong current, plant fragments can easily spread beyond the treatment area unless they are collected immediately.

Plant and animal communities living on the bottom of the lake can be affected significantly by sediment disturbances from rotovating. Non-selective removal of plant species can easily change the plant community and ecosystem balance, often by allowing faster-growing exotic species to re-colonize an area following the rotovating. Disturbing the bottom sediment can destroy the invertebrate and benthic habitats. Sediment disturbances also may result in localized turbidity and transparency problems, as well as providing an ideal habitat for colonization by opportunistic plants, such as exotic macrophytes (rooted aquatic plants).

- *Costs*

The capital costs for a rotovating operation are generally equivalent to the capital costs for mechanical harvesting (\$100,000 - \$200,000). Operating costs are generally lower, on the order of \$200-300 per acre; 1-3 acres can be rotovated per day. If contracted out, the approximate cost of these techniques is on the order of \$1500 per acre. This operating

cost is slightly lower than for harvesting, though the operation takes can take twice as long. These costs and time estimates do not consider retrieval and disposal of cut plants.

- *Regulatory Issues*

Due to the disruption of the bottom sediments during operation, the use of the rotovator (or equivalent) will require an Article 15 permit to be issued by the local NYSDEC office. Inside the Adirondack Park, the Adirondack Park Agency (APA) requires a permit for any activity that disrupts the plant community in a wetland. This includes the area within a lake that supports the growth of plants.

- *History and Case Studies in NYS*

There is only a short history of the use of rotovating and hydroraking in New York State, and specific examples have not been reported for any New York State lakes. The most extensive use of these techniques has occurred in British Columbia, with some intermediate-term success in controlling Eurasian watermilfoil.

- *Is That All?*

Rotovating is not a commonly used control technique in New York State. It is a relatively new procedure that has not been used frequently enough to evaluate its effectiveness (Newroth and Soar, 1986). It has the potential to be more effective than mechanical harvesting, since it involves cutting and removing the roots, in addition to the plant. However, it can have much more significant side effects. Unless fragmentation is controlled, the vegetation problem can become worse due to the regrowth and infestation in areas of the lake away from the treatment area. The disturbed sediment may cause excessive turbidity and contribute to nutrient release from either recently exposed sediment (underneath the removed sediment) or suspended rototilled sediment. Unlike the equipment used in several other physical control techniques, the rototiller displaces the plants from the sediment without removing the cut plants and roots from the water. Provisions must be made to remove the cut plants from the surface of the water before they are transported downstream or disperse great distances.

Rotovating is primarily used for vegetation control around docks and swimming areas. Larger areas usually are not rototilled due to the increased potential for fragmentation from uncollected cut stems and roots. In areas inaccessible to the rototiller barge, the rototiller boom may be maneuvered between docks and otherwise shallow areas. Any limits to the maximum depth for rotovating are imposed by the height of the rototiller boom and/or winch cable.

This technique may need to be performed several times per year, depending on the density of weed beds, growth rates, and types of vegetation. Regrowth can be somewhat lower for rototilled weed beds, since the root systems have been removed more completely than does hydroraking.

Many of the negatives associated with mechanical control of vegetation, such as heavy machinery, potentially high cost, and slow methods, will contribute to potential public dissatisfaction with rotovating. Floating weeds from rotovating may be more noticeable than with the mechanical harvesting and diver dredging techniques. Unless the cut weeds are removed quickly, the public may perceive rotovating as a "messy" management technique that detracts from the aesthetic appeal of the lake. Even if this distraction is

only temporary, it may be either untimely or left embedded in the memories of the residents whose support is critical for any lake management strategy.

#### 4. Dredging

- *Principle*

Sediment removal involves dredging bottom sediment from a lake to increase the depth, control of nuisance aquatic vegetation and nutrient release from sediments, and removal of toxic substances.

Dredging projects take the form of either drawdown excavation or in-lake dredging. During drawdown excavation, water must be pumped or drained from the lake basin and the resulting muds dewatered (dried) sufficiently to accommodate heavy earth-moving equipment. The exposed sediments can then be dredged.

Where it is difficult or impossible to drain a lake, hydraulic and bucket dredges have proved effective in removing nutrient-rich sediments that can promote excessive weed growth. Cutterhead hydraulic pipeline dredges are most commonly used to remove lake sediments as an in-lake dredging operation. These dredges can operate anywhere on the lake, cutting to a depth of 18 meters. The system is operated from a floating steel hull, moved by raising and lowering vertical pipes ("spuds") to "walk" the dredge forward. The cutterhead typically consists of three to six smooth or toothed conical blades, mounted on a movable steel boom or ladder at the bow of the platform. When the cutterhead is lowered to the lake bottom and moved from side to side, the rotating blades loosen the sediments, which are transported to the pickup head by suction from the dredge pump. The sediment slurry (10-20% sediment and 80-90% water) is then pumped through a pipeline for discharge at the disposal site. Such slurries require relatively large disposal sites, designed to allow adequate residence time for the water to evaporate.

Most cutterheads have been designed to loosen sand, silt, clay or even rock. Few, if any, conventional cutterheads have been designed to remove soft, loosely clumped sediments. Although they are effective, most of these machines are not the most efficient means of dredging lakes. However, specialized dredges have been designed specifically for use in lakes, and can be trailered from lake to lake. Some of these use a horizontal auger to move the sediments to the suction pipe, reducing resuspension and turbidity associated with other cutterhead dredges.

Grab-type bucket dredges use a bucket rather than a cutterhead, and remove drier sediments rather than concentrated slurries. They are used only in special situations, most commonly around docks, marinas and shoreline areas. They can be easily transported to different areas within a lake or to different lakes. Their performance is not hampered by stumps and other debris that may impede cutterhead dredges. Bucket dredges have some disadvantages, however. The sediment must be dumped within the radius of the crane arm, onto a barge or into a truck on shore. It is a time-consuming process. The operation also creates turbidity and can leave the bottom "chewed up" and uneven.

Equipment selection will depend upon factors that include availability, cost, time constraints, the distance over which the slurry must be transported, and the characteristics



of the dredge spoils. The design of the disposal area depends upon the amount of dredge spoils that must be contained. In addition, the size of sediment grains and the settling characteristics of the dredged materials are important factors to consider if any suspended solids will be discharged in water from the disposal site. The project will need a permit for such discharges.

- *Target Plants and Non-Target Plants*

As with most of the other strategies that mechanically remove plants, selectivity is limited to targeting only monocultural beds. However, selectivity is also affected by the logistic considerations associated with the dredging project- whether it is limited to shallow water, or certain sediment types, or the depth of material removed. Each of these considerations may result in selectively removing only those plants growing in these circumstances.

- *Advantages*

Dredging may help control weed growth in several ways. Plants and the nutrients entrapped within the plants are physically removed by the dredging process. The bottom sediment, which contains the root system of the plant and serves as a nutrient reservoir for plant and algae growth, is also removed. In addition, dredging serves to reduce rooted vegetation growth by increasing the lake depth and reducing the amount of sunlight that reaches the sediment. Since plants require sunlight for growth, reducing the light levels will reduce the plant levels. This will be "permanent" as long as light transmission is limited by water depth, although a shift in aquatic plant communities (from shallow water to deepwater -dominating plants) may change plant growth patterns.

In lakes where nutrient loading from sediments is a major factor affecting nuisance weed and algae growth, sediment removal may improve the overall water quality. Dredging removes the top layer of sediment, which contains the most biologically available nutrients and participates most readily in sediment-water interactions and exchanges. If heavy metals and other toxic materials are present in bottom sediments, dredging these sediments can reduce the concentration of these hazardous substances in the sediments, and ultimately in the overlying water and organisms living in the sediment and water.

Dredging has proven to be an effective control technique for many lakes for increasing mean depth, reducing excessive vegetation levels, controlling nutrient release from sediments, and reducing the concentrations of toxic substances in sediment. It has been used for the entire lake basin in small lakes, or only a small portion of the basin for large lakes.

It is one of the few multi-purpose aquatic plant control strategies. Sediment removal is used to deepen a lake for recreational and navigational purposes. Deepening a lake may be the only recourse when the lake has become too shallow for boat navigation, swimming and fishing. Other control methods such as adding chemicals or installing bottom barriers are of little use when water depth is no longer sufficient for the lake's intended uses.

- *Disadvantages*

If dredging is not done properly, it can actually make lake conditions worse by causing excessive turbidity, fishkills and algal blooms. As a result, dredging projects should be

accompanied by an extensive water quality monitoring program. The main problems occur when bottom sediments mix with lake water during the dredging process. This can happen while the sediments are being removed or when return water from a hydraulic dredging settling basin is discharged back into the lake. Nutrients, toxics and other contaminants may be carried back into the lake. Many of the problems of resuspension can be minimized by the proper selection of specialized dredges.

Dredging can harm fish, not only by causing turbidity but also by eliminating the benthic organisms upon which the fish feed. After the dredging of a lake, it could take two or three years for benthic fauna to become re-established. For this reason, it is advisable to leave a portion of the lake undredged.

Disposal areas for dredged sediments ("spoils") should be selected carefully. Because the muck will blanket vegetation and can kill it, disposal is unsuitable in woodlands, floodplains or wetlands. A carefully engineered and diked upland area may be the best option. Any disposal site should be fenced to keep out people and animals. In addition, dredging is usually very expensive, and the permitting process can be quite significant (and may ultimately result in the denial of a dredging permit for a variety of reasons).

- **Costs**

Costs vary depending upon site conditions, desired depth of excavation, available access, nature of the sludge, disposal, transport and monitoring arrangements. Treatment costs per acre of surface area (typically cut to a depth of about 3 feet) range from about \$1,000 to \$40,000; the latter figure represents a situation in which sediment spoils must be transported out of the area, as may be the case for municipal lakes.

- **Regulatory Issues**

Any dredging requires a permit from the regional DEC office. Depending upon various factors, the project could require multiple permits, particularly if all or part of the dredged lake is classified as a wetland. In general, permitting for dredging projects involving less

#### Case Study- Dredging

**Lake Setting:** Ann Lee Pond, once known as Saw Mill Pond, is a 10 acre pond outside of Albany used for agricultural and commercial operations for the first Shaker settlement in America in the late 1700s. In recent years, it has been used solely for non-contact recreational purposes- fishing and ice skating- and supports wildlife observation and nature walks.

**The Problem:** By the early 1970s, the lake was highly productive, with a dense surface coverage of submergent, floating, and emergent aquatic plants throughout the lake, primarily water lilies (white and yellow), curly-leafed pondweed, coontail, and common waterweed. The lake was also characterized by algal blooms, and an accelerating sedimentation and filling rate. After evaluating a number of lake management alternatives, the Albany County Environmental Management Council authorized a hydraulic dredging project for the lake to facilitate the reduction of nuisance aquatic plant growth in the lake, to be supplemented by a mechanical harvesting program after the dredging was completed.

Immediately prior to dredging, the typical water depth of the lake was about 0.7 meters; the hydraulic dredging removed about 16,500 cubic meters of mostly organic sediment in about 7 acres of the lake in 1980, increasing the average depth of the lake to about 2 meters.

**Results:** Water quality changes in Ann Lee Pond were not significant during or after the dredging operation. Dissolved oxygen levels increased, whether due to the removal of oxygen demand exerted by the sediment organic matter or the rooted aquatic plants. The density and coverage of water lilies decreased as a result of the dredging project. All of the common submergent plants became re-established after the lake stabilized after the dredging operation was completed in the fall of 1980. The curly-leaf pondweed recolonized at levels comparable to those measured before the dredging. Coontail densities decreased significantly, while the common waterweed levels increased in abundance.

**Lessons Learned:** Dredging is not likely to reduce submergent aquatic plant coverage unless the final water depth prevents sunlight from reaching large portions of the lake bottom, although there may be a shift in the kinds of plants growing in the lake. However, the density of plants limited by greater water depth- such as lilies- may be reduced as a result of the dredging.

**Source:** *Enviromed Associates, 1982. Final report: the monitoring of the restorational dredging of Ann Lee Pond, Colonie, New York. USEPA Phase II final report. Scotia, NY.*

than 400 cubic meters of sediment is somewhat simpler for lakes regulated under Article 24 of the Environmental Conservation law (related to wetlands). The DEC Regional Permit Administrator should be contacted as early as possible when a dredging project is contemplated. In all cases, sediments should be analyzed for toxicity.

Dredging projects have been approved in most regions of the state, although those lakes for which overlapping regulatory agencies, or divisions within single agencies, require permits, such as those in the Adirondacks or whole-lake wetlands, these projects are rarely conducted. US Army Corps of Engineers permits may also be required if the project takes place in a "navigable" waterway.

#### Case Study- Dredging

**Lake Setting:** Collins Lake is a 70 acre urban lake in the village of Scotia (Capital District), used primarily for swimming and passive recreation by Village residents.

**The Problem:** The lake suffered from dense aquatic weed growth. While the lake was perhaps the first in North America with a confirmed identification of the exotic macrophyte water chestnut, which covered most of the lake surface in the early 1990s, aquatic herbicides and hand pulling shifted plant dominance to curly-leaved pondweed, another exotic plant species. The macrophytes beds eventually covered about 60% of the lake surface to a depth of about 10 feet. The significant recreational impacts (bathing and boating) and the high sedimentation rate (1 cm/year) triggered the need to dredge the lake to the depth of the littoral zone (10 feet).

The lake was hydraulically dredged intermittently from 1977 to 1994 (> 50,000 m<sup>3</sup> from about 10% of the lake bottom) as part of a federal Clean Lakes project (after nearly 10 years of resolving permitting issues) for controlling nuisance levels of curly-leaved pondweed.

**Results:** Prior to dredging, curly-leaved pondweed densities were approximately 170 stems per square meter during the peak of the growing season (mid May). In the portions of the lake not dredged, plant densities by 1988 were similar to measured prior to dredging- about 150 stems per square meter. The dredging dropped pondweed densities to less than 1 stem per square meter in 1979, one year after dredging. Densities were still less than 6 stems per square meter by 1988. By the early 1990s, however, aquatic plant communities in the lake were controlled by Eurasian watermilfoil.

**Lessons Learned:** While the dredging was successful in dramatically reducing existing plant populations, this ultimately resulted in a shift from curly-leaved pondweed to deeper-dwelling plants (Eurasian watermilfoil). This is one of many examples of how unintended (and often undesired) consequences result from even well-designed projects. Lakefront residents and recreational users should be aware of the potential for a shift from one type of plant (either trading different kinds of "weeds" or a shift from weeds to algae or vice versa) in response to active management. This also shows that in-lake management without active watershed management may limit the effectiveness of the control measures.

**Source:** Tobiesen, P., Swart, J. and S. Benjamin. 1992. *Dredging to control curly-leaved pondweed: A decade later. J. Aquat. Plant Manage.* 30: 71-72.

- *History and Case Studies in NYS*  
Small-scale dredging projects, particularly drawdown excavation, are much more common than in-lake or hydraulic dredging projects, although navigational dredging (to deepen a waterway to open or enhance navigation) and dredging to clean up contaminants is more common in river systems and some portions of lakes. These projects including dredging on the Great Lakes and Cumberland Bay in Lake Champlain, and Collins Lake (see box). Excavation dredging was performed at Belmont Lake in Long Island for the control of fanwort in the early 1970s, and a number of lakes in the past (Central Park Lake, Hyde Park Lake and Van Cortlandt Park Lake in New York City, Steinmetz Lake in Schenectady, Delaware Park Lake in Buffalo, Washington Park Lake, Tivoli Lake, Buckingham Lake, and Hampton Manor Lake in the Albany area, Scudders Pond in Long Island, etc.). There have also been proposed dredging projects (Lake Montauk, Glen Lake, Lake George, Cuba Lake, Tannery Pond, Quaker/Red House Lake, etc.) in recent years for navigation or water quality improvement rather than for weed control (NYSDEC, 2002). The removal of sediment as a medium to enhance weed growth (and water deepening) may result in reduction in nuisance weed growth.

- *Is That All?*

Dredging projects are probably the most difficult lake restoration technique to successfully complete. The costs are much higher than practically any other technique, while the potential for negative impacts can be extremely high. While the benefits of dredging can persist for much longer than these other techniques, most lake communities have not been willing to endure the entire environmental review and permitting process.

The public perception of such a drastic control technique is usually unfavorable. If mechanical harvesting can be equated to cosmetic surgery, then sediment removal is akin to a lobotomy. Even if lobotomies are shown to be successful, most people do not favor such radical treatments. Like a lobotomy, dredging can have profound effects on the entire body, in this case the lake ecosystem. Many of these effects are temporary or can be easily predicted, but many cannot be easily determined. Since many of these effects will depend on the specific conditions at a lake, it is extremely difficult to say if dredging is the correct treatment for a lake. It is radical, but it can be very effective.

Since dredging projects will not easily elicit the support of the local community, other management strategies should be considered first. Excessive rooted vegetation may be more simply controlled by mechanical harvesting, herbicides, or diver dredging. Nutrient release can be controlled by phosphorus precipitation and inactivation, and toxic materials may be more easily contained with sand and bottom barriers or chemical inactivation. Unfortunately, there may not be any other feasible management alternative for increasing the lake depth.

If, after considering all other options, dredging is still the preferred control technique, then a number of considerations may ease the process. The most important decisions are those dealing with public acceptance, equipment selection and disposal area design. To avoid future delays and ensure cooperation from all local environmental organizations and officials, it is critical to involve the lake community in the planning process. Residents who feel removed from, or ignored in, the design phase may serve to turn public opinion against the project. Dredging projects, especially those involving toxic materials, will always be confronted by people who attend the NIMBY ("Not In My Back Yard") school. This may become very apparent in the discussions concerning the site for the spoils disposal. Unanimous or near complete approval in any phase of the project may be needed in order to move to the next phase.

## **5. Biological Control: Herbivorous Insects**

- *Principle*

In the 1980s, it was reported that the populations of Eurasian watermilfoil had crashed in the northern end of Cayuga Lake, one of the larger Finger Lakes, resulting in a shift in the plant communities from invasives to desirable native plants (see box below). Such a dramatic change in plant densities could have in theory been attributable to some combination of wishful thinking, illegal herbicide treatments, bad data, or better weather (an observation: when there doesn't appear to be a logical explanation for a change in the status quo, for better or worse, it is often attributed to "the weather", and sometimes that is actually correct!). However, in this case, an evaluation by Cornell University determined that the milfoil populations were being significantly preyed upon by an

herbivorous aquatic moth, *Acentria ephemerella*, which, while not considered native to the area, was actually found in most nearby New York State lakes. Meanwhile, research on several fronts, including Vermont and Minnesota, found that similar damage was being inflicted on milfoil plants by a native herbivorous weevil, *Euhrychiopsis lecontei* and other insects in lakes and ponds in other locations in North America (Johnson, 2002; Creed, 1998).

The mode of action of these various herbivores varies somewhat. The aquatic moth lays its eggs down near the bottom of Eurasian watermilfoil plants. When the caterpillars hatch, they crawl up the plant and feed on the growing tips (**meristems**) of the plants through various stages of development. Research suggests that nearly one moth per stem of milfoil is necessary to significantly impact the plant populations. Once achieving adulthood (for two days only!), the adult males mate with the mostly wingless females, and then the female swims down to lay her eggs on lower plant leaflets. Two life cycles are generally completed during the summer. The caterpillars overwinter on plants near the lake bottom, and begin feeding in May.

The milfoil weevil adults swim and climb from plant to plant, feeding on leaflets and stem material. Females lay one egg per watermilfoil meristem per stem, usually two stems per day. Once hatched, the larvae first feed on the growing tip, and then mine down into the stem of the plant, consuming internal stem tissue along the way (Sheldon and O'Bryan, 1996). Weevils pupate inside the stem, and adults emerge from the pupal chamber to mate and lay eggs. In the autumn, adults travel to the shore where they overwinter on land. The weevils generally spawn 2 to 4 generations per year.

In recent years, a number of researchers and commercial interests have reared these herbivorous insects in the laboratory and have introduced these organisms through controlled stocking projects in a number of lakes in the northern United States, including several in New York State. The insects are attached to small bundles of Eurasian watermilfoil and placed within a small plot of targeted plant beds. Stocked areas are often quarantined from the rest of the lake, via buoys and signs, to minimize disturbance from boat traffic. It is anticipated that the insects migrate from the bundled plants to the beds and begin their growth cycles.

- *Target Plants and Non-Target Plants*

The milfoil weevil uses Eurasian watermilfoil as its sole host; while historically (as discovered during the earliest research in British Columbia) the weevil utilized northern watermilfoil (*Myriophyllum sibiricum*) as its host, it appears to have adapted or evolved to Eurasian watermilfoil. The aquatic moth has been shown to inflict damage on several submergent aquatic plants, but the damage to other plants (besides Eurasian watermilfoil) appears to be superficial.

- *Advantages*

Herbivorous insects appear to be the ideal control agent. They are small and unobtrusive, often invisible to even interested observers. Both the weevil and moth impact the growth of Eurasian watermilfoil, with no or very minimal damage to native plants that might thrive in the absence of the Eurasian watermilfoil, and no apparent damage to other parts of the aquatic ecosystem. This makes this plant management strategy unique among all of the control methods discussed here. The relative slow reduction in plant biomass

minimizes the risk of inducing significant oxygen loss through microbial breakdown of the decaying plant matter.

This is a very “low maintenance” control strategy- once the insects are stocked, and buoys or signage sited to minimize disturbance, no work is required to allow the insects to do their work.

Monitoring conducted by Cornell University researchers have found both the milfoil moth and weevil to be either native or **naturalized** in most of the surveyed lakes in New York State. Although the aquatic moth is not considered to be a native herbivore in New York, this naturalized organism appears to have adapted to New York lakes, and thus large-scale stockings or planned introductions are unlikely to create significant disruptions.

#### Case Study- Herbivorous Insects- Natural Control

**Lake Setting:** The 43,000 acre Cayuga Lake is one of the largest lakes in the state, and is the largest Finger Lake by surface area.

**The Problem:** Eurasian watermilfoil was first reported in the lake in the 1960s, and grew abundantly after Hurricane Agnes in 1972, dominating the aquatic plant community until the early 1990s.

**Findings:** Aquatic vegetation surveying conducted from 1987 to the late 1990s identified a crash of Eurasian watermilfoil populations in the early 1990s. While mechanical harvesting (through the state-funded Aquatic Vegetation Control Program) occurred in several locations in the lake at this time, the milfoil decline was attributed to herbivory caused by the milfoil moth, *Acentria ephemerella*. Native plant populations in the lake increased dramatically over the same period, resulting in no measurable change in overall aquatic plant biomass after the onset of moth herbivory (overall plant populations were found at a greater density in the southwest end, and a lower density in the northwest ends of the lake):

Plant Species	Community Composition Before Herbivory	Community Composition After Herbivory
Eurasian watermilfoil	58-95%	<1-11%
Water lilies	24% (northwest end)	42% (northwest end)
Common waterweed	3% (southwest end)	50% (southwest end)
Native plant biomass	100%	70% (northwest end) to 300% (southwest end)

\*herbivory first reported as significant around 1991

Eurasian watermilfoil populations steadily decreased in the northwest end of the lake, stabilizing at very low densities (< 0.5 grams per square meter) after 1995, while milfoil populations rebounded slightly by the late 1990s in the southwest end of the lake, although milfoil biomass remained < 10% of the overall aquatic plant community throughout this “recovery” period.

**Lessons Learned:** Although this was not a case involving a planned introduction of herbivorous insects- this reflects native populations and natural control- it does demonstrate the potential for control of Eurasian watermilfoil by these insects

**Source:** Johnson, R.L., P.J. Van Dusen, J.A. Toner, and N.G. Hairston. 2000. Eurasian watermilfoil biomass associated with aquatic herbivores in New York. *J. Aquat. Plant Manage.* 38: 82-88.

Perhaps most importantly, they are considered a “natural” control mechanism that avoids the introduction of noisy and ungainly machines, plant killing chemicals, or other conspicuous signs of the intensive efforts that often accompany the battle against invasive weeds. These natural populations may have the ability to adapt to small changes in the natural environment (shifts in water quality or temperature) and may be immune to other lake changes that negatively impact other management techniques, such as change in bottom substrate, shifts in native plant communities, or high flow (Solarz and Newman, 1996).

#### • Disadvantages

The practice of rearing, transporting, and stocking herbivorous insects has not successfully replicated what Mother Nature has done in several New York State lakes. Part of this problem has been due to a problem with scale. The lakes that have experienced successful milfoil control via indigenous populations of these herbivorous insects have shown to have upwards of 2 insects per milfoil plant, which can be extrapolated to literally millions of these insects chomping away at these plants, numbers several orders of magnitude

larger than what has been "produced" in all of the labs and commercial operations in the business of making bugs. Moreover, even if these bugs could be more readily mass produced (and a lake community would be willing to pay for all those bugs), it could be argued that the reason that many of these lakes do not have naturally high densities of these insects is that these lake environments are simply not hospitable to large populations, either due to competitors, predators, or other impediments to their survival. Moreover, some New York State lakes with naturally high levels of these insects still are overwhelmed with Eurasian watermilfoil beds, suggesting that more than just lots of insects are needed to control milfoil growth.

Lakes experiencing milfoil damage due to weevils have often experienced a rebound in the fall, when regrowth and re-establishment of milfoil beds results from diminished predation from the weevils, and the onset of milfoil damage can be delayed beyond the start of the recreational season.

Herbivory is greatly (negatively) affected by harvesting, since this removes the habitat (and in many cases the actual organisms) for the insects. The same may also be true with extensive boat traffic, although this rarely results in widespread destruction of near-surface plant communities. Since the weevils overwinter along the shoreline, the lack of shoreline substrate (vegetation, leaf litter, etc.), or the use of management techniques that alters either the water level (drawdown) or the makeup of the shoreline (benthic barriers, dredging), threatens their long-term survival.

- *Costs*

The costs for whole lake plant management using these insects cannot be easily determined, since none of the stocking projects have seen either the stocked insects spread to the entire lake or milfoil control beyond the limited stocking area. As a general rule, stocking costs have been approximately \$1 per insect (weevil or moth), and about 1000 insects have been stocked per acre of milfoil, translating to about \$1000 per acre.

#### Case Study- Herbivorous Insects- Active Management

Lake Setting: Lincoln Pond is a 600 acre lake along the eastern edge of the Adirondack Park, less than 10 miles from Lake Champlain.

The Problem: Like many Adirondack lakes, Lincoln Pond enjoyed highly favorable water quality conditions for many years, but (also in an increasing number of Adirondack Lakes), by the late 1980s, Eurasian watermilfoil was introduced into the lake through one of the public launch sites. By 1999, detailed surveys of the lake showed that milfoil grew densely (400-1200 grams per square meter) in about 120 acres in water up to 15 feet deep, resulting in impairment of recreational uses of the lake (bathing, boating, and other forms of non-contact recreation). Comparison of these results to historical data suggested that milfoil was taking over the lake at a rate of about 20 acres per year, potentially subjecting another 300 acres of littoral zone to weed infestation. These surveys also found native or naturalized populations of the milfoil weevil (*Euhrychiopsis lecontei*) and the milfoil moth (*Acentria ephemerella*), although both were found in insufficient numbers to significantly impact milfoil populations (generally < 0.2 per stem).

Response: The Lincoln Pond Association expressed strong interest in exploring natural (biological) means for managing the milfoil problem. The lake association, the Natural Resources Department at Cornell University, Cornell Cooperative Extension in Essex County, the Lake Champlain Basin Program and other partners collaborated on a project in the spring of 2000 to release approximately 20,000 second and third instar caterpillars (at a rate of 2 caterpillars per stem) in hopes of building a lakewide population of more than 0.7 moth caterpillars per milfoil tip. Prior to the caterpillar stocking, moth populations increased at some sites in the lake (though not in the stocked areas), as high as 0.4/stem, but they largely disappeared by the end of 2000. The same pattern was observed in 2001. Weevil populations, on the other hand, which were very low prior to the stocking, increased more substantially, to as high as 0.8/stem in several locations in the lake in both 2000 and 2001. It is believed that the weevils were naturally present in higher densities than found in previous surveys, and occupied and impacted the milfoil stems prior to the augmentation of the moths, preventing the moths from propagating on the milfoil host. There also appeared to be some difficulties in the moths surviving and "evolving" after the augmentation, perhaps due to problems in transit to the lake bottom. Other research conducted by Cornell University suggests that predation by pumpkinseeds may have impacted recruitment of future generations of the moths.

Lessons Learned: We still have a lot to learn about augmented biological control (supplementing existing weevil or moth populations to enhance milfoil control), although continued research will ultimately help to improve the application of this promising lake management tool

Source: Lincoln Pond Study Group. 2002. Personal communication.

- *Regulatory Issues*

Herbivorous insects fall under the NYSDEC stocking policy, which requires an Article 11 permit. As of the time of this writing, a single annual permit has been issued for the stocking entity (academic researchers, commercial firm, etc.), with each stocking site (lake) identified on the permit. Although at present there has not been any distinction between stocking native insects (such as the milfoil weevil) and non-native insects (such as the milfoil moth), there may ultimately be some regulatory differences in projects that use these agents.

- *History and Case Studies in NYS*

Although recent surveys have indicated that both the milfoil weevil and moth are found in most surveyed New York State lakes, the history of herbivorous insect stockings in New York State lakes dates back only to the late 1990s. Aquatic weevils have been stocked in small plots in several small New York State lakes, including Lake Moraine in Madison County, Sepasco Lake in Dutchess County, Findley Lake in Chautauqua County, and Millsite Lake in Jefferson County, as well as an experimental stocking in Saratoga Lake. Each of these projects has exhibited some very limited successes, but in no cases have migration out of the treatment plots, or long-term reductions of milfoil beds, been observed. A more significant research project has involved the stocking of the aquatic moth in Lincoln Pond in Essex County (see above). This has been closely monitored for several years, although longer-term successes have also not been observed.

- *Is That All?*

Biological control in general, and herbivorous insect stockings specifically, remain a very promising but thus far elusive aquatic plant control strategy. **While in theory this should be identified as a lakewide control strategy, the limited use stocked insects in New York State lakes has resulted in only limited control of plants in small beds close to the areas where the insects have been stocked.** The potential benefits are substantial, and the promise of a "natural" control method, particularly in light of the very minimal side effects, remain very high. Nonetheless, it cannot be stated with any certainty that this promise will ultimately translated into a viable control strategy. The logistics of producing and distributing the very large quantities of insects required to reach a critical mass necessary to sustain a permanent population of herbivores have not yet been figured. The only limited on-going research has not achieved any significant breakthroughs in recent years, although it is anticipated that greater attention dedicated to invasive plant problems and management in recent years will ultimately translate into more research and funding dedicated to these methods.

So what does that mean for New York lakes? In short, none of the stocking projects in New York have led to milfoil control that can be attributed to the stocking, even in those lakes in which some milfoil control has been achieved through herbivory by indigenous populations. It is not yet known if this is due to inadequate stocking rates, predation on stocked insects by native fish, or premature evaluation of the results. It is hoped that continued research, larger scale stocking projects, and continued evaluation of existing projects will bring reports of successful stockings. Until then, however, it must be stated that herbivorous insect stocking remains at best a means toward plant management rather than an on-going success story.



## Lakewide / Whole Lake Management Activities

### 1. Mechanical Harvesting

- *Principle*

Mechanical harvesting is the physical removal of rooted aquatic plants (macrophytes) from the lake using a mechanical machine to cut and transport the vegetation to shore for proper disposal. This is one of the most common methods of aquatic vegetation control in New York State.

The physical removal of macrophytes serves to eliminate the symptom of excessive vegetation growth. Immediately after harvesting, swimming and boating conditions are improved. Harvesting also serves to remove the nutrients, primarily phosphorus, stored in the plant structure thereby addressing one contributor to the cause of excessive rooted vegetation growth.

There are two different types of mechanical harvesting operations, single-stage harvesting and multistage harvesting. Typically single-stage mechanical harvester cuts a swath of aquatic plants from six to ten feet in width and from six to eight feet in depth. The harvester usually has two upright cutting bars and a vertical cutting bar. The cut vegetation is transported up a conveyer belt and stored on the harvester. The maximum capacity of the harvesting barge is usually between 6,000 to 8,000 pounds (wet weight) of aquatic plants. The harvester transports the plants to shore where they are unloaded via a shore conveyer to a truck for disposal.

The multistage harvester refers to two or more specialized pieces of equipment. The first machine moves through the lake with cutting bars similar to the single stage harvester, cutting the vegetation and allowing the plant's natural buoyancy to bring it to the surface. A second machine follows the cutter and rakes up the cut fragments for disposal. The cutting capabilities for the multistage harvester can be greater than the single-stage harvester; the depth can extend as far as ten feet and the width can be up to twelve feet.

With either harvesting method, the growth rates of some species of aquatic plants may require two or more harvests during the recreational season. This increases the costs and, especially when outside contractors are involved, can create scheduling challenges.

- *Target Plants and Non-Target Plants*

These techniques are generally non-selective since the mechanical harvesters cut most to all plants contacting the cutting bar. The machines cannot be easily maneuvered to selectively remove target plant species within diverse beds, particularly near the lake shoreline. Selectivity is limited to targeting only plant beds comprised of a single plant species. In recent years, most mechanical harvesting operations in New York State have targeted Eurasian watermilfoil. Historically a wide range of native plants, from submergent plant species such as *Potamogeton amplifolius* (large-leafed pondweed), and floating leaf plants such as water lilies, have been the target of harvesting efforts.

- *Advantages*

Simply stated, mechanical harvesting works to remove excess vegetation. Management of macrophytes can be limited to boat channels, launch sites, swimming areas, other high use areas or areas where weeds cause safety concerns.

### Case Study- Mechanical Harvesting

**Lake Setting:** Saratoga Lake is a 4000 acre, heavily used recreational lake in Saratoga County, at the foothills of the Adirondack Park.

**The Problem:** High development pressure and recreational use in the 1960s and 1970s resulted in degraded water quality and impaired use of the lake for most recreational activities. At the time, more than 50% of recreational users of the lake objected to the algae levels and water clarity (Koojoomjian and Clesari, 1973), and water clarity had dropped from about 5 meters in 1932 (with fully oxygenated conditions throughout the lake) to about 1.5 meters in 1967, with oxygen deficits beginning at a depth of about 6 meters.

In the 1970s, water quality improvements resulted from the diversion of municipal wastewater out of the watershed (one of the inflows was locally called "Gas Brook" due to the persistent sewage smell), the implementation of non-point source control measures on agricultural lands, and nutrient inactivation- these activities were funded in part by a federal Clean Lakes Project. However, in response to the increased water clarity, nuisance growth of Eurasian watermilfoil and curly-leaved pondweed dominated the littoral zone to a depth of about 4 meters. This resulted in a shift from an algae- to a macrophyte-dominated system, without significant improvement in recreational conditions (although walleye and bass fisheries may have improved). However, 75% of the lake residents indicated that the lake was "somewhat" to "much" clearer (Boyle et al., 1995). Water clarity improved from about 1.5 meters in 1967 to more than 3 meters by the mid-1990s (and higher in the late 1990s due to the introduction of zebra mussels).

**Response:** The Saratoga Lake Protection and Improvement District (SLPID), a local management and taxing authority authorized by the NYS Legislature in 1986, oversaw the use of two mechanical weed harvesters purchased in 1984 that cut from 500-750 acres of nuisance vegetation per year, operating daily from May through September. The biomass of the major macrophyte species in the lake did not experience significant change between 1982 and 1994, when an aquatic plant survey was conducted by Darrin Freshwater Institute:

Species	Biomass 1982	Biomass 1994
Eurasian watermilfoil	40-1000 g/m <sup>2</sup>	0-700 g/m <sup>2</sup>
Curly-leaved pondweed	0-170 g/m <sup>2</sup>	0-230 g/m <sup>2</sup>
Southern naiad	10-400 g/m <sup>2</sup>	0-450 g/m <sup>2</sup>
Sparganium	0-40 g/m <sup>2</sup>	0-600 g/m <sup>2</sup>
Water stargrass	0-140 g/m <sup>2</sup>	0-30 g/m <sup>2</sup>

Although mechanical harvesters are slow-moving beasts, they provide immediate relief from surface canopies and dense underwater growth of nuisance plants. The tops of the aquatic plants are cut, removing the growing leaves, nutlets and flowering parts of strongly rooted plants. Weakly rooted plants may be uprooted. For aquatic plants that propagate primarily from seed banks or nutlets, such as water chestnut, removing the top of the plant (which usually carries the seeds) prior to the maturation of the seeds can eliminate the following year of growth. Multiple years of harvesting may serve to gradually deplete the bank of seeds in the sediments. Harvesting operations, as opposed to cutting, will remove the nutrients stored within the plant material. It has been estimated that this may comprise as much as 50% of the internal (sediment-bound) load of nutrients that might otherwise migrate into the overlying water and become available for algae growth.

Harvesting will usually result in continued blanketing of the lake floor by the lower portion of standing aquatic plants. This will provide continued cover and habitat for fish and other aquatic life at the same time that recreational uses are supported by the reduction or loss of the plant canopy.

### • Disadvantages

The most significant side effect of mechanical harvesting is fragmentation. Fragments of cut plants that are not picked up and removed can move from the treatment area by wind or currents, spreading the plant to other portions of the lake or to downstream water bodies. This can result in enhanced propagation of those plants that spread primarily from fragmentation, such as milfoil.

#### Case Study- Mechanical Harvesting (cont)

Some species were more abundant in 1982, while others were more abundant in 1994. Eurasian watermilfoil populations were substantially reduced in shallower water- up to depths of about 1 meter- but this was probably due to the winter drawdown regularly conducted each year. By the early 1990s, in the midst of the harvesting program (and supplemental work in shallower areas with a suction harvester), more than 90% of the lake residents identified rooted aquatic plants as at least a minor problem. This included impacts due to weed decomposition and floating weeds cut by boats or harvesters. 40% identified this problem as significant. However, about 60% viewed the harvesting program as successful (versus about 70% for the sewerage and drawdown conducted through the Clean Lakes Program).

The harvesters were replaced by larger, more efficient machines in the late 1990s, and the SLPID has been investigating an integrated approach to aquatic plant management, conducting small-scale experiments since 2000 on the use of aquatic herbicides and herbivorous insects (while continuing the use of the mechanical harvesters).

Lessons Learned: Mechanical harvesting may not result in a significant reduction in aquatic plant density or coverage, but it may be viewed favorably by many lake residents, particularly in light of (what may be perceived as) less palatable alternatives. For a lake this size, however, it is an expensive operation.

*Sources: Boylen, C.W., L.W. Eichler, and T.B. Clear. 1995. An aquatic plant assessment of Saratoga Lake. RPI publication. Troy, NY.*

*Hardt, F.W., G. Hodgson, and G.F. Mikol. 1983. Saratoga Lake Phase I Diagnostic-Feasibility Study and Management Plan. USEPA Clean Lakes Program. 236pp*

*Kooyoonjian, K.J. and N.L. Clesari. 1973. Perception of water quality by selected groupings in inland water-based recreational environments. Rensselaer Polytechnic Institute report 73-7. Troy, NY.*

Plant communities may be altered by harvesting. If both native and fast-growing exotic plants are cut to the same degree, the exotic plants, often the original target for harvesting, may grow faster and dominate the plant community. This is especially true for plants that propagate by fragmentation.

An improperly designed or executed harvest can have other unnecessary side efforts. Small, slowmoving fish may be trapped in the cutting blades or removed by the conveyor. If all cut vegetation is not removed, oxygen levels may temporarily fall and nutrient levels, such as phosphorus, may rise. Turbidity resulting from the harvesting process is also usually short-term.

The logistics involved with harvesting result in some disadvantages to the use of this technique. Many lakefront property owners are frustrated with the inability of the harvesting equipment to operate in shallow areas near docks and shorelines. Suitable launch sites for the harvester, or locations to park the conveyor, can be hard to locate in very shallow lakes or

lakes with steep banks. If the conveyor is located far away from the areas to be harvested, a lot of time is spent traveling between the sites.

Mechanical harvesting is not universally accepted. Many lake residents recognize that it is, for the most part, a cosmetic treatment, treating only the symptoms of a more pervasive water quality problem. An appropriate analogy to mechanical harvesting is mowing the lawn. Neither harvesting nor mowing will prevent re-growth, or even provide any significant long-term control. Both methods are used to provide a cosmetic control of excessive growth and sustain popular recreational uses. The long-term benefits derived from harvesting do not approach the benefits of other cause-, or source-based management strategies.

Due to the slow cutting rates and relatively narrow cutting band, the harvester may need to be on the lake throughout the summer during most daylight hours. The perpetual presence of the machine is objectionable to some residents and may be an obstacle to jet skiers and water skiers. Others may become frustrated over the time required to get local weed beds harvested. This problem is exacerbated by the limited areas available for harvesting due to shallow water or confined navigational corridors, unfavorable weather conditions, and down-time for mechanical repairs. Both capital and operating costs can be quite high due to the large equipment expenditures and the technical expertise

necessary to run or repair the machinery. Leasing a harvester can reduce the overall costs; however, since harvesting may be required at least once yearly, leasing costs will quickly overtake purchasing costs.

- *Costs*

The cost at time of printing for the equipment averages between \$100,000 and \$200,000 for the harvester and shore conveyer. The harvester can cut approximately one acre of aquatic plants every 4-8 hours, depending on the size of the harvester and density of plants, and costs about \$200-300 per acre to operate. The time and costs will vary greatly depending upon the type and densities of the aquatic plants being harvested. The numbers shown here are averages for North American lakes infested predominately with Eurasian watermilfoil.

Mechanical harvesters can also be leased. A typical leasing price in New York State is approximately \$150-300 per hour, usually with an additional set-up, transport, and sitting fee of about \$300.

- *Regulatory Issues*

The regulations governing mechanical harvesting vary within the state. Inside the Adirondack Park, the Adirondack Park Agency (APA) requires a permit for any activity that disrupts the plant community in a wetland, including the area within a lake that supports the growth of plants. Harvesting outside of the Adirondack Park is not regulated except in cases where the harvesting is within or adjacent to classified wetlands. In these circumstances, a permit from the local NYSDEC regional office may be necessary. Contact the Environmental Permits staff at the local DEC office for further information.

- *History and Case Studies in NYS*

Mechanical harvesters have been seen on lakes large and small throughout the state for many years, although in recent years the use of herbicides has largely superseded harvesting as the most common means for "whole lake" control of nuisance plants. While the use of harvesters in New York State dates back at least to the 1950s, the most significant regional activities originated with the advent of the Aquatic Vegetation Control Program in the Finger Lakes region in the late 1980s. In this program, state (member item) funds were provided to several counties in the Finger Lakes Region to conduct a variety of lake management activities. In some counties, this included the purchase of mechanical weed harvesters or harvesting services for several Finger Lakes, embayments to Lake Ontario, and some smaller waterbodies in these counties. The harvesting program at Chautauqua Lake has been used to evaluate nutrient removal from harvesting operations. Large lakes outside of the Finger Lakes region that have been harvested include Lake Champlain and Oneida Lake (for water chestnut) and Saratoga Lake and Greenwood Lake (for Eurasian watermilfoil). A statewide inventory of lakes that utilize mechanical harvesters has not been compiled, in large part due to the lack of regulatory oversight (and therefore a paper trail of permits) in most parts of the state.

- *Is That All?*

In summary, harvesting is one of the most common and publicly-acceptable methods for controlling rooted aquatic vegetation. Harvesting opens most recreational areas and navigation channels, and removes unwanted vegetation covering the surface of the lake. The few ecological side effects are considered minor relative to the overall benefits,

activities in other portions of the lake are not greatly affected, and in many communities, the harvested plants are dried and used as compost and lawn fertilizers.

Since an aquatic harvesting program is aimed at controlling nuisance levels of vegetation, the species of plants and their growth patterns should be identified before harvesting. This will help target the areas that should be controlled, with an approximate date when the aquatic plants will begin to cause some impairment to use. When a harvesting schedule is set up, the lake shore property owners should be informed of where and approximately when harvesting will take place. Several criteria should be examined before establishing this schedule.

Initially, harvesting should involve the areas where the greatest public use is impaired. The type of use will determine the extent and type of harvesting. Fishing areas only need open lanes, but swimming and most boating activities will require large areas free from plants at or near the surface. Areas with significant weed beds will take longer to harvest due to time lost in unloading the conveyer away from the treatment area.

Certain areas should be restricted from harvesting either because they are important as a fishery or wetland area or because they receive little or no use. These areas should be identified before the harvesting program begins each year. The regional DEC office can help determine the location of any important fisheries or wetland areas.

The location of unloading sites should be identified and mapped before the harvesting season begins. If a site is located on private property, it may be prudent to sign a contract with the owner to protect against liability claims. These sites should have suitable conditions to enable the harvester to get close to shore and allow a truck access to load the harvested weeds for disposal. The selection of these sites may dictate where you can or cannot efficiently harvest on the waterbody.

## **2. Drawdown (Water Level Manipulation)**

- *Principle*

Drawdown involves manipulating the water level of a lake to expose rooted aquatic vegetation and sediments to freezing and drying conditions, which serves to affect the growth of the plants. When the lake level is lowered in winter, some species of rooted plants and their seeds can be severely damaged or killed by two to four weeks of freezing and drying. However, other species that are resistant to freezing are unaffected, and some species may actually be enhanced by this technique, either through increased growth rates, or decreased competition from other species. Drawdown is best used once or twice every three years to discourage the establishment of resistant plant species, which are often the non-native or exotic plants that were originally the target of the drawdown.

In New York State, drawdown usually occurs between December and April. For drawdown to have any significant effect, the water level must be lowered at least three feet, exposing the plants to winter conditions for at least four weeks and exposing the sediments to the freezing and drying action of cold air. The bottom sediments must freeze to a depth of at least four inches. In mild winters, snow cover may insulate the sediments and prevent freezing.

Ice may help control weeds by loosening roots and loose organic material on the exposed lake bottom. The drying action may also serve to limit the availability of nutrients, particularly under low oxygen conditions, by compacting the loose upper layer of sediment. This reduces the potential for resuspension of this sediment and the nutrients adhering to the sediment.,.

- *Target Plants and Non-Target Plants*

Since this mode of control involves freezing and desiccation, seed producing plants, in general are not as strongly impacted as those that reproduce vegetatively (fragments and rhizomes). Some seed-dependent (seed-abundant?) plants may increase in density or coverage during and after the drawdown. The following is an incomplete list of common submergent aquatic plants in New York State and the impact of winter drawdown on their populations:

- *Advantages*

Drawdown is a fairly simple management strategy, particularly for residents of relatively small lakes with full control over water level. This method creates an unfavorable environment for many of the nuisance aquatic plant species, such as Eurasian watermilfoil and fanwort, and selects for beneficial plants. Depending on the slope of the lake and the depth of the littoral zone, drawdown only impacts the near-shore area while maintaining sufficient volume of water to support wildlife.

The water level can be (re-) manipulated as frequently as needed, by adding or removing boards or controlling the valve, although the lake response time will almost certainly not be immediate. This also allows time for other lake management activities, such as cleaning up the shoreline, repairing docks or retaining walls, and cleaning or otherwise maintaining erosion control structures.

- *Disadvantages*

Drawdown is limited to lakes that have either a dam structure, or some other mechanism for controlling lake level.

#### Case Study- Drawdown

Lake Setting: Galway Lake is a 500 acre lake in the Capital District region of New York, represented by a lake association of approximately 500 members in mostly seasonal dwellings. The maximum depth of the lake is about 25 feet, and a good portion of the lake is comprised of areas flooded by a dam constructed in the 1850s to provide power and water for the downstream textile mills.

The Problem: Extensive milfoil beds took over large portions of the littoral zone, within a band between 7 and 14 feet deep, in the late 1980s, impacting recreational uses of the lake (despite the lack of motorized boat traffic). The formation of surface canopies in much of the littoral zone resulted in an infestation of more than 100 acres lakewide.

Response: Based on an evaluation that milfoil was light limited at depths greater than 14 feet and frozen out at depths below 7 feet, the lake association elected to draw the water level down to a depth of about 16 feet in 1989 (this was also conducted to repair the dam). Deep drawdowns were relatively common in the lake prior to the 1940s, and engineering studies concluded that the likelihood of the lake refilling to full capacity by the following spring was greater than 50%. Channels were cut by volunteers to prevent ponding.

Results: By the summer of 1990, milfoil densities had substantially dropped throughout the lake, limited to a very small number of isolated plants. The lake association did not receive any reports of fishkills (fishing was thought to be normal), and native plant populations (coontail, common waterweed, clasping-leaf pondweed, and macroalgae) were growing in the areas previously occupied by the milfoil. By the late 1990s, aquatic plant populations had steadily increased, reaching the lake surface during much of the summer. An additional deep lake drawdown in 2000 resulted in a substantial drop in aquatic plant densities and coverage for the next several years, based on information collected at Galway Lake through the NY Citizens Statewide Lake Assessment Program (CSLAP).

Lessons Learned: Drawdown effectively controlled Eurasian watermilfoil populations, and there may have been some selective control, but the effect only lasted for a few years after the drawdown. However, even deep drawdowns (not practical in many lakes) will not prevent recolonization of milfoil, particularly if the target plants are found in neighboring lakes or otherwise continue to enter the lake.

*Source: Aronstein, J. 1998. Personal communication.*

Drawdown can result in the loss of a substantial volume of lake water when the deeper portions of the littoral zone are exposed, especially in shallow to moderately deep lakes with large littoral zones. This can also result in substantial impacts to adjacent wetlands or other areas with desirable vegetation, although the impacts to many traditional wetland plant species can be variable.

**Effect of Winter Drawdown on Common NYS Macrophytes\***

Deep Water Species	Shallow Water Species	Emergent Species
<i>Ceratophyllum demersum</i> (Ceratophyllum)	<i>Cyperus papyrus</i> (Cyperus)	<i>Potamogeton amplifolius</i> (Potamogeton)
<i>Elodea canadensis</i> (Elodea)	<i>Najas sp.</i> (Najas)	<i>Sagittaria arifolia</i> (Sagittaria)
<i>Potamogeton amplifolius</i> (Potamogeton)	<i>Chara sp.</i> (Chara)	
<i>Najas sp.</i> (Najas)	<i>Elodea canadensis</i> (Elodea)	
<i>Utricularia sp.</i> (Utricularia)	<i>Brasenia schrebleri</i> (Brasenia)	
<i>Ceratophyllum demersum</i> (Ceratophyllum)	<i>Elodea canadensis</i> (Elodea)	

\* - adapted from Hickman et al., 2001

If the lake is shallow and the sediments and inflow have a high oxygen demand, winter drawdown can deplete oxygen, and fishkills may result. Nutrient release may also be enhanced, causing algal blooms. In such cases, hypolimnetic [define] aeration may be necessary.

The removal of macrophytes along the shore may increase turbidity due to wind-induced erosion and/or re-suspension of sediments. Some lakes with complete drawdown can experience algae blooms after refilling. Another problem could be the emergence of new, or previously unnoticed, plant species that are enhanced or unaffected by drawdown. These plant species may prevent the regrowth of native plants, and without competing species, may grow to levels greater than those prior to drawdown.

Drawdown that does not result in timely refilling of the lake may leave water intake pipes exposed to the same elements as the targeted plants. This might result in the pipes freezing or not being below the water level during the winter and spring (and perhaps later).

- *Costs*

If the lake has means for controlling lake level, such as a dam or controllable spillway, costs are negligible unless pumping is needed to reduce the lake level, or if aeration is necessary.

- *Regulatory Issues*

Article 15, Title 8 of the Environmental Conservation Law defines regulations relating to the volume, timing, and rate of change of reservoir releases. These specifications are designed to ensure that an adequate supply of water is available for public and personal use and for power production, and to provide for the health and safety of local residents

in the event of drought or emergency conditions. Title 8 also specifies requirements in monitoring, inspection, and maintenance of records, in addition to reporting and investigations by NYSDEC. When drawdown significantly affects navigability of these waters, the NYS Navigation Law may also apply. These regulations may be appropriate for either drawdown or hypolimnetic withdrawal [what is there, not previously covered in this chapter – if not relevant here delete sentence..

In addition, wetlands regulations require a permit for the use of this technology, particularly since in many cases drawdown may be incompatible with the benefits derived from wetlands. [when wetlands nearby but not contiguous with the lake are affected by the change in water level? Shoreline wetlands?]

- *History and Case Studies in NYS*

Drawdown has been commonly utilized at many New York State lakes, most often for benefits not associated (or directly geared toward) aquatic plant control. The NYS lakes for which drawdown was used as a weed control method include Galway Lake (Saratoga County), Saratoga Lake, and Greenwood Lake (on the New Jersey/New York border), and some of the lakes in the Fulton Chain of Lakes (interior Adirondacks) for controlling Eurasian watermilfoil, Forest Lake in the southern Adirondacks to control Elodea and pondweed, and Minerva Lake (southern Adirondacks) for the control of native plants. Most of these have been fairly successful, although immediately after drawdown a different mix of invasive plants have often colonized and dominated the aquatic plant community before the lakes reached equilibrium after a few years. For example, the dominant plants in Robinson Pond (Columbia County) shifted from Eurasian watermilfoil to bushy pondweed after the lake was regularly drawn down (for maintaining fisheries habitat downstream rather than for weed control), although this shift reversed several years later.

- *Is That All?*

In summary, water level manipulation is one of the most common lake management techniques, not only for the control of nuisance aquatic vegetation, but also for repairing dams and docks, and as part of dredging and bottom screening techniques. It is a simple and readily acceptable control technique, due to the low cost and the timing (corresponding to the winter, not the summer recreational season). Since most nuisance vegetation problems occur in the shallow littoral zone these area can be managed by drawdown without having a significant effect on the open water portion of the lake. Since no chemicals or significant mechanical equipment is used, there may be no visible changes in the lake besides the changes in vegetation levels.

In periods of normal or high precipitation, the potential side effects of drawdown are usually overridden by the benefits. However, if the lake is drawn too low, or during periods of drought,, water levels may take a long time to return to acceptable levels. It is critical to plan for a low precipitation summer when devising a drawdown schedule, for the residents and lake users may otherwise be denied use of the lake for much of the summer. This can reduce resident acceptance of this technique, and summer revenues from recreation and tourism. The concerns over "putting in another board" to raise the summer level will often dominate lake association meetings, and any management decisions to lower lake levels may be second-guessed if not ultimately rewarded by decreased weed growth and restored water levels.



### 3. Biological Control- Grass Carp

- *Principle*

Grass carp (*Ctenopharyngodon idella*, or white amur) physically remove vegetation from lakes. Beyond removing the nutrients entrapped within the plant, the grass carp does not reduce nutrient levels, or afford any control of the source of these nutrients. These are essentially "biomanipulation" tools- as a general class of lake management tools, biomanipulation is discussed in greater detail in Chapter 7.

Originally, they were imported to Arkansas and Alabama from Malaysia in 1962. The carp, less than one pound in weight and two feet in length (less than one foot may be preyed upon by largemouth bass), are stocked at a rate of about 15-40 per acre of surface area. They can grow up to 6 pounds per year, and may ultimately consume 20-100% of their body weight each day in vegetation. Carp can grow to several hundred pounds.

The fish will selectively feed on particular types of plants; although the carp are reported to have particular favorites among the plant species, these preferences may be a function of specific lake conditions, and eating habits may not be reproducible from lake to lake.

Only sterile grass carp (called triploid) are presently allowed for stocking in New York state, as in 14 other states (15 states allow both sterile and fertile carp, and 19 states do not allow importation of these fish). Grass carp have the potential to reproduce and eradicate all vegetation in lakes, and can escape downstream to other waterbodies and induce unwanted vegetation control or eradication. Grass carp have a strong tendency to follow flowing water, such as inlet and outlet streams. Unless these streams are adequately screened, the fish are likely to move out of the lake. Not only is the investment in fish lost, but the nuisance weeds remain in the lake, and the carp may destroy desirable aquatic plants in the streams.

In most of the 35 or so states that allow their use, grass carp are restricted to lakes with no sustainable outflow, to reduce the possibility of escape, and to maximize the control of vegetation within the target lake. However, fish cannot be expected to control weeds at a specific part of a lake, such as a beach or an individual dock. Since fish have access to the entire lake, grass carp treatment is necessarily a full-lake treatment.

Vegetation control with grass carp is necessarily slow, but could be effective over a long period of time. If only sterile carp are used, the time required for the carp to effectively control vegetation will depend on the density of vegetation, stocking rate, and growth rate of the carp. Projects using non-sterile carp will have to consider the reproduction rate, and the ultimate carrying capacity of the lake.

- *Target Plants and Non-Target Plants*

In general, most grass carp prefer most species of *Hydrilla*, *Potamogeton*, *Ceratophyllum*, *Najas*, *Elodea* and some filamentous algae, while some specific plants, such as *Myriophyllum spicatum* and *Potamogeton natans*, are considered less palatable (Cooke and Kennedy, 1989). However, in many cases, the grass carp will consume these less desired plant species in the absence of their favorites. Grass carp stockings in most New York State lakes have been directed toward control of Eurasian watermilfoil, in spite of the plant preferences indicated by the carp (perhaps this is akin to using children to reduce the world's supply of liver and onions).

#### Case Study- Grass Carp

**Background:** The majority of the grass carp treatments in New York State have occurred in the downstate region between New York City and the mid-Hudson. This is due in part to the proximity of these lakes to areas (Long Island and Orange County) where the work was conducted by the NYSDEC to evaluate the use (and permitting requirements) of these fish. However, this also reflects the higher degree of comfort lake residents in this area seem to exhibit for the use of this management tool. As such, the case studies evaluated here all come from this region.

**Lake Setting:** Walton Lake, a 120 acre lake in Orange County in the Lower Hudson River region of New York.

**The Problem:** Excessive growth of Eurasian watermilfoil

**Response:** In 1987, 400 grass carp were introduced at a rate of 10 fish per vegetated acre as an experimental project to evaluate the use of grass carp. The objective of the stocking was to reduce the vegetation biomass by 75%. Rooted aquatic vegetation levels, water clarity, and fish populations were monitored after the introduction, and stocking rates were varied to evaluate lake response to increasing predation by the grass carp.

**Results:** The initial stocking, and a supplemental stocking in 1989, resulted in an estimated abundance of 15 to 19 fish per vegetated acre and a biomass reduction of about 30% within two years. Selective grazing on preferred species increased Eurasian watermilfoil coverage on established transects by about 30% and resulted in a virtual monoculture of Eurasian watermilfoil. A third stocking increased the density of fish to 21-27 fish per vegetated acre and resulted in the complete removal of the remaining milfoil. Floating and submergent plants, such as water lily and spatterdock, were less dense than prior to stocking. In comparison, grass carp nearly eradicated rooted aquatic vegetation when stocked at 15 fish per acre in at least five nearby lakes and ponds. Rooted aquatic plant coverage had not substantially recovered more than ten years later.

During the initial study period, water clarity readings generally remained between 9 and 11 feet, suggesting macrophytes reduction did not result in increased algal blooms. Filamentous algae were also virtually absent. The take of largemouth bass (measured as catch per unit effort, or CPUE) declined from 1986 to 2001, for both large (greater than 12 inch) and small fish. Bluegill catch also decreased over this period, while the percentage of sunfish as part of the overall fish catch increased.

**Lessons Learned:** Grass carp stocking at lower rates (<15-20 fish per vegetated acre) results in initial submergent plant reductions, but milfoil and other less preferred species may actually increase in response to the greater available substrate. Higher stocking rates may result in eradication, with little long-term recovery. Fish densities and the makeup of the fish community may also change.

*Source: NYSDEC. 2001. Experiences with using grass carp for aquatic vegetation control in DEC Region 3 with emphasis on Walton Lake.*

#### • *Advantages*

Grass carp are perceived as a "natural" aquatic plant control agent (and are certainly among the "less visible" plant control strategies), even if they are not native to a lake, and as such this plant control method avoids some of the opposition to other more invasive or controversial control strategies. If stocked at a high enough rate, grass carp can significantly reduce weed populations within a year, although most acceptable (i.e. permissible) stocking rates in New York State are not high enough to result in significant first season control. In fact, many of the less successful experiments with grass carp have resulted from not waiting long enough for the carp to effectively control excessive weed growth, particularly in lakes with stocking rates kept fairly low to prevent eradication of all plants. As long as grass carp populations, particularly voracious younger fish, remain high, multiple years of control can be expected. Population dynamics can be well controlled due to the sterilization required for fish stocked in New York State lakes.

#### • *Disadvantages*

Grass carp do not meet any of the criteria for an "ideal" candidate for introduction to an aquatic system: they do not co-adapt with other aquatic species, do not have a narrow niche, are not easily controlled after escape, and are not free from exotic diseases and parasites.

The most significant drawback of using grass carp is the potential for complete eradication of vegetation. A complete removal of all types of vegetation may occur after the grass carp have exhausted the supply of target plants, and would have severe detrimental effects on the plant community and entire ecosystem. This is a distinct possibility in the event of overstocking; however, excessive growth of smaller populations of fish could cause the same problem. At the other extreme, understocking or

insufficient consumption of vegetation may result in the control or eradication of non-target plants, since the eating habits of grass carp are not completely predictable. In the absence of competitive native species, this could allow the exotic target plants to dominate the plant community. Destruction of either native or exotic species could also have significant effects on the aquatic animals whose habitat (niche) is based on these plants. Altering fish habitats could have severe effects on zooplankton and phytoplankton populations.

Eutrophic conditions could be enhanced through a number of mechanisms. More than 50% of the ingested plant material could be reintroduced through excretion by the carp, primarily as particulate organic matter and urinary nitrogen. This nutrient recycling could stimulate algae blooms and oxygen depletion. Algae blooms may also result from the actual removal of rooted plants, since these plants may compete with algae for available nutrients. Even if the nutrient levels remain constant, algae populations may be enhanced due to the greater availability of these nutrients.

As an exotic, non-native fish species, grass carp may also introduce exotic diseases or parasites to a lake. *Cestodes*, a type of parasitic tapeworm, or flatworm, has been found in lakes in which grass carp were introduced. However, infestation can be minimized with the use of praziquantel ( $C_{19}H_{24}N_2O_2$ ).

Grass carp can also escape downstream, particularly given their propensity to migrate to moving water, although permits are only issued in larger New York State lakes with inlets or outlets if steps are taken to prevent movement of the fish out of the lake (through screening or other means).

#### Case Study- Grass Carp: Lake Mahopac, and Lake Carmel

**Lake Setting:** Lake Mahopac is a 560 acre lake in Putnam County, north of New York City. Lake Carmel is a 200 acre lake in the same area. Both lakes are heavily used for swimming and other recreational activities

**The Problem:** Excessive growth of Eurasian watermilfoil. Lake Mahopac had a dense monoculture of Eurasian watermilfoil inhabiting most of the lake shoreline to a depth of 12-15 feet. Lake Carmel suffered water quality problems related to excessive nutrient and algae levels and poor water clarity for many years, and by the early 1990s, nuisance weed growth (primarily common waterweed and coontail) also plagued use of the lake. The lake was dredged in the late 1980s, and mechanical plant harvesting after 1986 enjoyed some success. Residents of the town served by the lake were opposed to the use of aquatic herbicides. Plant biomass surveys by the mid 1990s found biomass of 150-400 g/m<sup>2</sup> throughout about 100 acres of lake bottom.

**Response:** In October, 1994, 2565 triploid grass carp were privately stocked in Lake Mahopac at a rate of 15 fish per vegetated acre. The objective of the treatment was to provide 70% control of the vegetation. In 1999, 10 grass carp per vegetated acre were stocked in Lake Carmel. At the time of stocking, water clarity was about 3.5 feet, typical of historical readings for the lake.

**Results: Lake Mahopac:** A private consulting biologist monitoring the results of the treatment report that, by 1995, the biomass of aquatic vegetation (including filamentous algae) had been reduced by 73% from pre-stocking levels. By 1996, vegetation had been reduced by 86% from baseline. In addition, reports through the NY Citizens Statewide Lake Assessment Program (CSLAP) indicated that aquatic plant coverage had dropped from "dense" at the lake surface in the mid-1990s to "not visible" from the lake surface- this continued through at least 2001.

NYSDEC fisheries surveys of the lake in the late 1990s revealed virtually no submerged rooted aquatic vegetation. Catch rates for largemouth bass (the lake's principal gamefish) were high compared to most neighboring lakes before and after treatment, although by 1999 there was a decline of almost 50% for bass over 15 inches. It is not known if this decline can be attributed to the grass carp, although many local anglers blame the decline to the loss of aquatic vegetation.

**Lake Carmel:** By 2002, biomass dropped under 50 g/m<sup>2</sup> in the northeast cove (which had less pre-treatment biomass) and under 100 g/m<sup>2</sup> in the southern cove. Water clarity dropped to about 2.5 feet, due to more frequent blue-green algae blooms (*Coelosphaerium* and *Microcystis*). Although largemouth bass continued to be the dominant fish species, about 15% of the fish were greater than 6" long; this suggests that the loss of refuge habitat for the young fish may affect future age classes of the fish.

**Lessons Learned:** Moderate stocking rates (10-15 fish per vegetated acre) can be effective at removing nuisance vegetation, but near total eradication of plants can occur at the higher end of this range. Water quality changes and fisheries impacts may also occur, although the few studies of the effects of grass carp have not been adequate to attribute observed changes solely to the loss of vegetation (and conversion of rooted plants to nutrients).

**Source:** NYSDEC Bureau of Fisheries 1999/2000 Annual Report-Warmwater Lakes and Ponds.

Grim, J. Personal communications. 2003.

#### Case Study- Antidotal Reports

The effectiveness of lake management activities are best evaluated through well-designed scientific studies that compare documented conditions prior to the treatment to conditions after the "treatment" has stabilized, particularly relative to conditions in nearby control lakes. That doesn't happen much. Most water quality problems or impairments to lake uses are well known but not well documented before locals decide to do something about it, and few control measures are supplemented with sufficient funds to analyze whether they worked (particularly given, or perhaps despite, the high cost of lake management). At some level, while this is understandable, it is also unacceptable, since without information about what worked and what didn't, it is difficult for the next generation of lake managers to make informed decisions about planned management activities.

Simple surveys can provide at least some of the information future managers need to evaluate the success and failure of a particular management strategy. One such survey is provided below, used by local residents of Plymouth Reservoir, an 80 acre impoundment in the Southern Tier (Central) region of New York with excessive weed growth (primarily Eurasian watermilfoil), to evaluate the use of grass carp one year after stocking, in 1994. This was followed up by the same survey, completed by the same lake residents, in 2004- the 1994 answers are reported as A1994, while the 2004 answers are reported as A2004:

**Q. Did the carp adapt to their settings?**

*A1994. The carp appear to have adapted to their surroundings, as, only 1-2 dead fish were found*

*A2004. Yes, the carp seem to adapt well. They have been observed at approx. 3+ feet in length feeding along the shorelines*

**Q. Did you notice a preference for any food type (plant), and was this the target species?**

*A1994. We did observe (that) in areas where curly and floating pondweed had been abundant, the weeds were not as concentrated. Previously the weed growth had been dense and floating on the surface. Certain sections of the lake where milfoil had been dense, there was an obvious decrease in density. Grasses were found floating that appeared to have been pulled out by the roots....*

*A2004. There appears to be a decrease in pondweed (various species), eel grass and elodea.*

**Q. Was the physical condition of the lake... notably clearer, about the same, or not as clear...?**

*A1994. The physical condition of the lake was about the same as in previous summers.*

*A2004. The lake was not clear with considerable more brownness. Our lake has a natural brown color. The increased amount of rain and snow the past 2 years may have contributed to this. We have had a problem with an excessive amount of nutrient flow into the lake since the 1998 Tornado destroyed 1000 + acres of State forest adjacent to our lake*

**Q. Were the (overall) aquatic plant populations, in the areas where people swim and boat, ... denser, about the same, or less dense?**

*A1994. The aquatic plant populations were people swim and boat were noticeably less dense and thick.*

*A2004. The weeds are noticeably less dense and thick.*

*Hopefully, this is due to our weed control efforts but we have had heavier snowfalls in recent years, reducing the winter greenhouse effect on our shallow lake. Also with the darker color and particulates in the lake this may be diminishing the amount of sunlight filtering through to the plants*

#### • Costs

Grass carp offer one of the least expensive lake management techniques for controlling nuisance aquatic vegetation. Costs are a function of vegetation density and stocking rate, and usually run from \$50 to \$100 per acre, based on a "standard" allowable New York State stocking rate of about 10-15 fish per vegetated acre. These costs can be amortized over several years, since the grass carp application requires only capital expenses.

#### • Regulatory Issues

The New York State DEC regulates the stocking of grass carp through Article 11 of the Environmental Conservation Law. The NYSDEC maintains the existing policy of using sterile grass carp only for projects approved through a complete and thorough State Environmental Quality Review Act (SEQRA) process.

New York State's present policy indicates the following:

- No person or organization shall possess or introduce any grass carp into waters of the state without having obtained a stocking permit from the Department of Environmental Conservation.

- Only sterile, triploid grass carp will be considered for introduction into the waters of the state. All fish must be certified as triploids by competent taxonomists retained by the applicant before being released.

- All proposed introductions of sterile, triploid grass carp into New York must be supported by a complete EIS (Environmental Impact Statement). Within the EIS review process, DEC could deny a permit to stock grass carp.

- In NY, DEC policy is to limit stocking rates to no more than 15 fish

per surface acre for those ponds of 5 acres or less and size and when contained wholly

**Case Study- Antidotal Reports- Grass Carp in Plymouth Reservoir (cont)**

**Q. Was the recreational condition of the lake... improved, unchanged, or degraded?**

*A1994. Overall, the ability to use the lake improved... Fishing and boating were greatly improved.*

*A2004. In 2003 and 2004 the lake did not improve or degrade*

**Q. In retrospect, was there any unanticipated lake effects from the stocking, and were they positive or negative?**

*A1994. Too early to make any determinations, but we were pleased with the water quality and aesthetics of our lake*

*A2004. The general consensus has been the Carp have had a positive impact on the lake. We have maintained moderate stocking of the carp. It is difficult to determine the number remaining in the lake*

**Q. Would you say the carp provide effective control, provide no noticeable control, make the problem worse, or it is too early to gauge effectiveness?**

*A1994. Too early to gauge effectiveness*

*A2004. We feel the carp have provided effective control*

within the boundaries of land privately owned or leased by the applicant and the following conditions are met;

- Aquatic plants must significantly impair the intended use of the pond (and should

- No endangered, threatened or species of special concern shall be present in the proposed stocking area.

- The lake/pond is not contiguous to part of a NYS regulated wetland.

- The lake/pond is not a natural or manmade impoundment on a permanent streams shown on USGS topographic maps.

- At least two years have elapsed from the date of the last stocking unless

demonstrated that previous stocking had high mortality.

Any proposed plans for using grass carp should be discussed with the DEC Regional Fisheries Manager. The manager is responsible for issuing the stocking permit and may be able to warn an association beforehand of any major obstacles to a project on any specific lake.

- *History and Case Studies in NYS*

There have been literally thousands of permits issued by the NYSDEC for the use of grass carp since 1991; the vast majority of these are for very small (< 1 acre "farm") ponds with no inlet or outlet and a single landowner. The majority of the stockings appear to be in Finger Lakes region and western New York (nearly 1000 every year), and in the downstate region (nearly 500 per year). The effectiveness of these stockings has not been documented. The grass carp stocking and aquatic plant response of Walton Lake in Orange County, one of the original (experimental) stockings in the state, has been documented by the NYSDEC Division of Fish and Wildlife. Information about other stockings is largely antidotal.

- *Is That All?*

Biological control methods are not well understood. They are relatively new, have not been studied often in the field, and have not been applied to a wide variety of lake conditions. The most significant reason for the lack of understanding about biological controls, however, is in the nature of biological manipulation. Ecosystems are at once dynamic and extremely fragile; a change in one component in the ecosystem can have dramatic effects in other components within the ecosystem. Unlike physical control methods, and, to a lesser extent, chemical techniques, the results from biological manipulation studies either in theory or in the laboratory cannot be easily reproduced in the field, in actual lakes.

Grass carp may offer an excellent vegetation control option for some situations. There is a great deal of interest in using this species for biological control of nuisance aquatic plants rather than chemical and/or mechanical means. Unfortunately, grass carp are not

the instant solution to all aquatic vegetation problems in every lake. Even where they have been effective, there have been undesirable side effects. For many lakes, the potential side effects inherent in grass carp treatments will more than outweigh the benefits.

The experiences in New York State have been somewhat variable. In nearly all cases when stocking rates are high, grass carp effectively remove submergent aquatic plants, such as in Lake Mahopac (southern New York). In other locations, long-term eradication of nearly all plant material has accompanied grass carp introduction, to the detriment of the long-term integrity of the aquatic ecosystem, particularly as habitat for fish spawning and survival. In some cases, this has also resulted in short-term water quality impacts—primarily increasing turbidity and decreasing water clarity.

At lower stocking rates, non-target aquatic plants have often been most heavily controlled, particularly when the target plant is Eurasian watermilfoil, a plant not generally near the top of the menu for grass carp. For example, the initial stocking in Walton Lake (10 fish/vegetative acre) had only limited impact on plant densities, while a higher stocking rate two years later (15-19 fish/vegetative acre), resulted in removal of about 30% of the plants[,] and a selective removal of all but the Eurasian watermilfoil (which increased in some areas). Subsequent higher stocking rates (to 20-27 fish/acre) removed these exotics, resulting in a paucity of plants throughout the lake (although emerging plants generally were much less affected). This did not have any measurable impact on water clarity, but did result in a drop in fish catch rates as plant populations dropped.

Until moose can be harnessed and stocked in lakes, grass carp are the only “biomanipulation” tool that has worked successfully in controlling excessive levels of nuisance aquatic plants.

#### 4. Aquatic Herbicides

- *Principle*

Aquatic herbicides (pesticides) are chemical compounds used to kill undesired macrophytes and restrict further vegetation growth. Herbicides are used primarily to kill specifically-targeted aquatic vegetation species, whether floating, emergent, or submerged. They also provide short-term clearance for recreational areas and navigational channels. As with other in-lake weed management strategies, herbicides address neither the cause nor the source of the problem.,

Herbicides are applied in either liquid or granular form. In most cases, the chemicals are applied to the water directly overlying the problem area. Most granular herbicides are activated through photodegradation of the granular structure, releasing the active chemical. These chemicals either elicit direct toxicity reactions or affect the photosynthetic ability of the target plant. The plants die and degrade within the lake. Some herbicide residuals sink to the lake sediment, providing some additional temporary control of vegetation. For some herbicides, however, once the granules sink to the bottom and out of the **photic zone** (area penetrated by light), photodegradation ceases, and the chemical is no longer effective. .

There are generally two classes of aquatic herbicides. **Contact herbicides** affect only those portions of the plant contacted by the herbicide, usually through (plant) toxicity. **Systemic herbicides** affect metabolic or growing processes within most or all of the plant, often translocating from the leaves to the root system. In general, systemic herbicides tend to take longer to work, but are often more effective at controlling plants for a longer period. Contact herbicides generally work more quickly but have less longevity. However, individual herbicides within these classes have different modes of action for either inhibiting plant growth or destroying the plant itself.

Both classes of herbicides are registered for use in NYS and since many herbicides contain toxic chemicals, only licensed applicators should place herbicides in lakes. Most herbicides can be used in most lakes, but some lakes used for a domestic drinking water source may have restricted uses for certain herbicides.

Correct timing of the chemical application is important, since seeds can germinate and roots can sprout even when the parent plants are killed off. The specific time for the application will depend on the specific target weed, required dosage rate, water temperature, water chemistry characteristics of the lake, weather conditions, water movement and retention time, and recreational use of the lake. Curly-leaf pondweed has a growing season from mid-fall through early summer, while Eurasian watermilfoil usually grows from early spring through the end of the summer. Herbicide applications must consider the timing of the growing season relative to the algae levels (since photodegradation of herbicides may be slower when algae reduces lake clarity), ice cover, and the effect the chemical application will have on the recreational use of the lake. Most herbicides have restrictions on the use of the water body immediately after treatment, lasting up to 30 days, depending on the dose rate or use of the lake.

Follow-up monitoring should track the fate of the applied chemical, and changes in the plant communities, water quality conditions, and impaired uses. The effectiveness for any given herbicide treatment varies with the treatment design, and the conditions of the

#### Case Study- Aquatic Herbicides

**Lake Setting:** Snyders Lake is a 110 acre lake found in the Capital District region of New York State, used primarily by local residents for swimming and boating.

**The Problem:** While more than 20% bottom coverage of rooted aquatic plants had been reported in the lake from the time of the biological surveys of the 1930s through at least the late 1980s, water quality issues, particularly winter and spring blooms of the red alga *Oscillatoria rubescens* and complaints of turbidity by nearby development had dominated discussions about the management of the lake. Weeds had not been sufficiently dense to warrant active management until the late 1990s, but at that time, dense aquatic plant beds were dominated by Eurasian watermilfoil throughout the littoral zone.

**Response:** After significant public debate about the need for management and the available alternatives, the Lake Association of Snyders Lake voted to apply fluridone to the entirety of the lake in the spring of 1998. A combination of private funds and state local assistance grants were used to offset the appx. \$25,000 cost for the treatment.

Fluridone was applied at a rate of approximately 13-18 (parts per billion, or ppb), and was tracked by the lake association at several locations and depths for about 5 months. Fluridone residuals remained above 6ppb for at least 55 days, above 4ppb for more than 115 days, and were still above 2ppb for at least 155 days. The greater-than-expected longevity was due to a combination of factors, including a dry spring and summer resulting in little outflow (through a small sand-bagged outlet), a slow drop of the thermocline, and a lower rate of photodegradation.

**Results:** By the end of the summer in the year of treatment, there was no evidence of any submergent aquatic plants in the lake. Scattered submergent plant growth returned the following summer, although this was limited primarily to macroalgae (*Chara* spp.) and isolated single stems of Eurasian watermilfoil, mostly in thin sediments. In 2000 and 2001, however, extensive billowing beds of brittle naiad (*Najas minor*) were found in the areas where sediment was thick and organic, and small quantities of other native plants (large-leaf pondweed, leafy pondweed, macroalgae) were found in isolation throughout the littoral zone. Eurasian watermilfoil was still largely limited to small patches, mostly in the thinner sediments. Maps showing aquatic plants in the lake prior to treatment and in 2000 look very similar, with the brittle naiad replacing the milfoil. However, while the brittle naiad grew very bushy below the surface, unlike the milfoil, it did not form dense canopies at the surface.

lake and treatment site listed above (Westerdahl and Getsinger, 1988). In general, for contact herbicides the effectiveness of an herbicide treatment will last anywhere from several weeks to several months, usually corresponding to a single growing season. Since seeds and roots frequently are not affected by treatment, once the chemicals have degraded or washed out of the system, plant growth will resume, and reapplication may be necessary. Effectiveness rarely carries over to the next growing season. For systemic herbicides, treatment effectiveness is often not observed for at least three to four weeks (and often up to six to eight weeks), although plant control with these herbicides have been observed to last for several years.

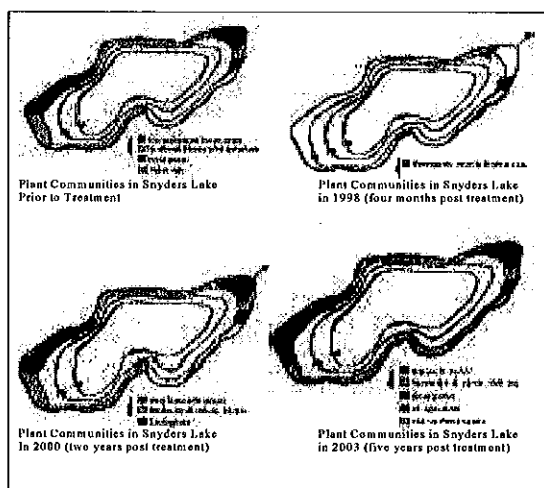
#### • *Target Plants and Non-Target Plants*

At the dosage rates allowed in New York State lakes, most aquatic herbicides are not selective. If applied when plants are actively growing, at concentrations allowed by the label, most plants within the treatment zone will be removed by these herbicides. Selectivity can be increased by timing the applications to when the target plants are preferentially growing. To a lesser extent lower dosage rates appear to exert some selectivity.

#### Case Study- Aquatic Herbicides (cont)

**Results (cont):** After 2001, milfoil recolonized large patches of the littoral zone, although it was still much less dominant than prior to treatment, due to the well-established brittle naiad beds. The milfoil spread to some areas not previously occupied by any macrophytes. The coverage and density of the milfoil/brittle naiad beds were significant enough to trigger a spot treatment with endothal in the summer of 2004 in the areas of the lake with the highest macrophytes coverage (and, perhaps not coincidentally, the highest sedimentation rate).

Most antidotal information from lake residents and visitors indicate a general satisfaction with the results of the initial treatment, with few reported complaints from anglers about the lack of a fishing edge or loss of any year-classes. Water quality conditions were relatively stable throughout the treatment and subsequent response period, and reports of blue-green algal blooms or other water quality complaints were less common than in most previous five-year periods, despite the potential available of nutrients not taken up by the rooted plants. However, this may have been more a function of more favorable weather conditions.



**Lessons Learned:** Aquatic plants appear to recover (or get re-introduced) after a long

**Source:** Kishbaugh, S.A. 2002. Assessment of Eurasian watermilfoil control with Sonar at Snyder's Lake, NY: 1998-2001. Presentation to the NEAPMS annual conference, Suffern, NY.

In New York State, the most frequently used aquatic herbicides are diquat, 2,4-D, endothol, glyphosate, and fluridone.

- Diquat is a contact herbicide used to control emergent species such as cattail; floating species such as duckweed; and submerged species such as coontail, milfoil, nitella; and some varieties of pondweed. It is often used with chelated copper sulfate for algae control.
- 2,4-D is a systemic herbicide used for controlling a wide variety of emergent, floating, and submerged species, primarily Eurasian milfoil, coontail, and water hyacinth. Like diquat, it remains in the sediment for several months.



- Endothol is a contact herbicide used primarily for control of coontail and most pondweeds, including curly-leafed pondweed. It stays in the water column longer than either diquat or 2,4-D.
- Glyphosate is a contact herbicide used almost exclusively on emergent and floating plants, especially cattail and waterlily.
- Fluridone is a systemic herbicide used extensively in recent years for the control of Eurasian watermilfoil and curly-leafed pondweed. It has been used at low dosage rates to attempt to manage target plants while preserving non-target plants.

The table below indicates the susceptibility of common New York State submergent, floating, or emergent plants to these herbicides.

- *Advantages*

Unlike many other in-lake management techniques, aquatic herbicides can be applied directly to the problem plants, although many of the herbicides registered in New York State are so water soluble that they do move somewhat out of the treated areas. Aquatic herbicides are available for immediate or long-term control of nuisance plants, and some of these herbicides have been shown to be somewhat selective if applied at the right time (usually very early or very late in the growing season, corresponding to when target plants, such as invasive exotic weeds, are preferentially growing) and at the right dosage rate.

Aquatic herbicides have been effective at providing at least temporary control of Eurasian watermilfoil in some New York State lakes. This pernicious exotic weed has not been consistently (or at least somewhat selectively) controlled by any of the other whole-lake treatment strategies. While generally cost-prohibitive for treatments of very large areas or very large lakes, aquatic herbicides are often less expensive than other large-scale plant control methods.

- *Disadvantages*

Chemically-treated lakes may experience some significant side effects. Because herbicides kill plants primarily through toxic response, the toxicity of the herbicide to non-target plants and animals can be of great concern. Short-term impacts of aquatic herbicides have been fairly well studied for most of the inhabitants of lakes and the surrounding environment, and have been deemed to be an "acceptable risk" if applied in the appropriate manner. In general, humans and most animals have high tolerance to the toxic effects of herbicides presently approved for use in lakes. This is especially true of the newer generation herbicides that have been formulated to impact metabolic processes specific to chlorophyll-producing plants. However, the long-term impact of herbicides on humans and other plants and animals in the environment continues to be poorly studied. High herbicide dosages can elicit toxic response for the applicator and protective gear must be worn.

Non-target plants may not be resistant to the herbicide. If a wide variety of plant species are eradicated by herbicide treatment, the fast-growing ("opportunistic") exotic species that were the original target plants may recolonize the treatment area and grow to levels greater than before treatment. There are only very limited data on the effect of specific herbicides on plant species in New York State lakes. It is not clear if the target plant

species listed on the herbicide labels can be completely controlled without adversely affecting non- target species at any given lake.

**Impact of NYS Registered Herbicides on Common Nuisance Aquatic Plants**

<b>Susceptibility to Herbicide</b>					
<b>Aquatic Plant</b>	<b>Diquat</b>	<b>2,4-D</b>	<b>Endothal</b>	<b>Glyphosate</b>	<b>Fluridone</b>
<b>Emergent Species</b>					
<i>Lythrum salicaria</i> (purple loosestrife)	low	low	low	high	low
<i>Phragmites</i> spp (reed grass)	low	low	medium	high	low
<i>Pontederia cordata</i> (pickerelweed)	low	medium	low	medium	low
<i>Sagittaria</i> spp (arrowhead)	low	high	low	high	low
<i>Scirpus</i> spp (water bulrush)	medium	high	low	high	low
<i>Typha</i> spp (cattails)	medium	medium	low	high	medium
<b>Floating Leaf Species</b>					
<i>Brasenia schreberi</i> (water shield)	medium	medium	medium	low	medium
<i>Lemna</i> spp. (duckweed)	high	medium	medium	low	high
<i>Nuphar</i> spp (yellow water lily)	low	medium	medium	high	medium
<i>Nymphaea</i> spp (white water lily)	low	medium	medium	high	medium
<i>Trapa natans</i> (water chestnut)	low	medium	low	low	low
<b>Submergent Species</b>					
<i>Ceratophyllum demersum</i> (coontail)	high	medium	high	low	high
<i>Cabomba caroliniana</i> (fanwort)	medium	medium	high	low	high
<i>Chara</i> spp. (muskgrass)	low	low	low	low	low
<i>Elodea canadensis</i> (common waterweed)	high	medium	low	low	high
<i>Heteranthera dubia</i> (water stargrass)	high	high	medium	low	medium
<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)	high	high	high	low	high
<i>Najas flexilis</i> (bushy pondweed)	high	medium	high	low	medium
<i>Potamogeton amplifolius</i> (largeleaf pondweed)	low	low	medium	low	medium
<i>Potamogeton crispus</i> (curly-leafed pondweed)	high	low	high	low	high
<i>Potamogeton robbinsii</i> (Robbins pondweed)	low	low	medium	low	high
<i>Stuckenia pectinatus</i> (Sago pondweed)	high	low	medium	low	medium
<i>Utricularia</i> spp (bladderwort)	high	medium	low	low	high
<i>Vallisneria spiralis</i> (eelgrass)	low	low	medium	low	medium

\*- adapted from Holdren et al., 2001 and others

When herbicides are applied in a lake environment, the affected plants drop to the bottom of the lake, die, and decompose. The resulting depletion of dissolved oxygen and release

### Case Study- Aquatic Herbicides

**Lake Setting:** Waneta Lake is an 800 acre lake in the western Finger Lakes region that is part of a two-lake chain with Lamoka Lake (downstream to the south); the Waneta-Lamoka Lakes Association was formed in 1938 to address a variety of lake management issues. The lake is also a valued local fishery for largemouth- and smallmouth-bass and a secondary source for muskellunge brood stock throughout the state, and thus the lake fisheries have enjoyed a high level of protection.

**The Problem:** Waneta Lake has a long history of recreational use impacts associated with both nuisance algae and nuisance weed growth. The latter has been exacerbated by the introduction and spread of Eurasian watermilfoil throughout both Waneta and Lamoka Lakes since at least the mid-1980s. By the late 1990s, Eurasian watermilfoil comprised just over 50% of the biomass of aquatic plants in Waneta Lake. Mechanical weed harvesting was conducted during the mid-1980s, with funds provided through the Aquatic Vegetation Control Program (AVCP, the predecessor to the Finger Lakes-Lake Ontario Watershed Protection Alliance). This was marginally successful, but the funds for this activity dissipated over time.

**Response:** The lake association proposed the use of fluridone to reduce the coverage and density of Eurasian watermilfoil while maintaining sufficient cover of native plants to protect the valuable fisheries resource in both Waneta and Lamoka Lakes. After much discussion and "negotiation", the NYSDEC issued a permit for the whole-lake application of fluridone only in Waneta Lake at an initial concentration of 12-14 ppb in the summer of 2003, with provisions for a bump application as needed to restore fluridone residuals back to 6ppb within 60 days. Due to very low dilution (probably due to relatively low inflow and low photodegradation), however, fluridone residuals remained above 6ppb, without supplemental applications, for more than 60 days, and remained above 3ppb for nearly 175 days.

Performance standards were devised to evaluate herbicidal impacts to Waneta Lake and proposals for follow-up treatments in Lamoka Lake. Native and exotic plant recovery were monitored as part of an extensive survey program conducted by Cornell University, and results were evaluated by the lake consultant and NYSDEC to determine if "sufficient" recovery existed to maintain cover and refuge in the event of a downstream (Lamoka Lake) treatment. This corresponded to < 25% loss of native plant cover and overall aquatic plant biomass, and > 90% milfoil removal, within the year of treatment, and return to pre-treatment plant densities the following year.

**Results:** As a result of the herbicide treatment, Eurasian watermilfoil disappeared from the lake, and there was no evidence of milfoil anywhere in the lake through at least the summer of 2004. Traces of native plants were found in 54 of the 91 sites with some evidence of plant growth prior to treatment in 2003, and in 50 sites in 2004, with native plant biomass reduced to about 5% of the pre-treatment native biomass. No significant water quality changes or fisheries impacts were reported (or attributable to the herbicide treatment), and it is expected that native plant recovery will accelerate beginning in 2005, as was found in other lakes with similar initial recovery patterns. Due to delays in the plant recovery in Waneta Lake, however, large-scale treatment of Lamoka Lake was not approved. It is anticipated that the strategies used to evaluate the Waneta Lake treatment will be utilized in assessing the impacts (positive and negative) of other herbicide treatments throughout the state.

of nutrients could have detrimental effects on the health or survival of fish and other aquatic life as well as stimulating new plant growth.

The effectiveness of systemic herbicides is often delayed. Given that the most effective treatment windows correspond to periods bounded by the onset of thermal stratification in the beginning of the year (to avoid treating the entire lake rather than the upper warmer waters where plants tend to grow) and by the onset of fish spawning and native plant uptake (when surface waters warm to > 50°F), plant dieoff may often not occur until early to mid summer. This means that plant control from systemic herbicides might not be "enjoyed" by lake residents until much of the recreational season has passed.

#### • *Costs*

Herbicide costs will vary with the chemical brand and form (liquid or granular), required dose rate, applicator fees, and frequency of application. Typical costs for using herbicides are approximately \$200-400 per acre of treated area per treatment, with the majority of these costs associated with the raw materials.

#### • *Regulatory Issues*

Herbicide use in New York State requires a permit from the DEC regional environmental permits office, in compliance with the Environmental Conservation Law. If all or part of the lake contains a regulated wetland, an additional wetland permit may be required. For those lakes for which the generic Environmental Impact Statement (EIS) prepared by the manufacturers of these herbicides is deemed insufficient to address the myriad of permitting issues that might be appropriate in the

lake, a site-specific EIS may be required to issue these permits. The Adirondack Park Agency will require a separate permit for herbicide use within the boundaries of the park.

**Case Study- Aquatic Herbicides: Waneta Lake (cont)**

**Lesson Learned:** The controversies over the proposed treatment in Waneta Lake are a microcosm of the issues surrounding the use of aquatic herbicides in New York State, and it is unlikely that all parties involved will agree that the process and the results were adequate. However, the dialogue accompanying the application process was insightful and open, and the compromise reached by the advocates for, the opponents of, and the mediators in the permitting and evaluation process may serve as a template for future contentious aquatic plant management proposals. It is also hoped that the results from the well-designed monitoring plan will provide sorely needed answers to continuing questions about the use of aquatic herbicides in New York State lakes.

**Sources:** Lord, P.H., R.L. Johnson, and K. Wagner. 2005. *Effective aquatic plant monitoring: data and issues from Waneta Lake*. Presentation at the NEAPMS annual conference, Saratoga Springs, NY.

Lord, P.H., R.L. Johnson and M.E. Miller. 2004. *Waneta Lake 2003 and 2004 plant community structure research subsequent to 2003 fluridone treatment for control of Eurasian watermilfoil*. Cornell University report. Ithaca, NY.

ENSR International. 2001. *Draft supplemental environmental impact statement for the control of Eurasian watermilfoil in Lamoka and Waneta Lakes with fluridone*. Document No. 8734-352-03. Willington, CT.

Nearly all of the aquatic herbicides registered for use in New York State carry at least one water use restriction, ranging from 24 hour restrictions on bathing to 30 day prohibition of the use of the lake water for irrigation of established row crops. These restrictions are clearly identified on the label governing the use of each of product formulations registered in New York State

Herbicide applicators must also be licensed by New York State. A list of licensed applicators is available from the NYSDEC Bureau of Pesticides in Albany. Applicators may also need to carry an insurance policy.

Permits have been issued for aquatic herbicides in nearly every part of New York State. In fact, upwards of 500

permits are issued annually, not including purchase permits for small farm ponds. However, in some regions of the state, such as the Adirondacks no aquatic herbicide permits are being issued. The myriad of reasons include overlapping regulatory authority (the NYSDEC and the Adirondack Park Agency), strong sentiments about the use of herbicides, the presence of and concern for protecting rare and endangered species, and the lack of historical precedent in the use of many aquatic plant control strategies (due in part to the historical lack of problems with invasive plants). . A paucity of permits is also the case for lakes in other regions of the state used for potable water intake or encompassing wetland areas, since the permitting rigor is often more significant in these waterbodies. On the other hand, many lakes in the downstate region have been treated with aquatic herbicides.

Copper-based herbicides (for rooted plant control) have been registered for use in New York State, but since they can kill some fish species at the label application rate, these require extensive review and environmental assessment by the NYSDEC.

- *History and Case Studies in NYS*

Aquatic herbicides have been used in New York State for many years. Federal regulation began by at least the early 1900s, although the "modern" pesticides regulations largely stem from the passage of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1947. However, federal and state attention to pesticides, including aquatic herbicides, was significantly heightened by the publication of *Silent Spring* by Rachael Carson in 1962. Since then the aquatic herbicides used in lakes have been subject to more stringent testing and regulations, resulting in amendments to FIFRA starting in 1972.

However, most of the lakes treated with aquatic herbicides have not been closely studied either before or after treatment. The most closely monitored lakes include Waneta Lake in Schuyler County and Snyders Lake in Rensselaer County.

- *Is That All?*

Perhaps no other lake-related issue causes as much heated discussion as chemical controls. At many lake association meeting, large or small, there will likely be two factions, both convinced that the other could ruin the lake. One faction may claim that there are absolutely no conditions or situations that call for chemical treatments. The other group may insist that if herbicides are not applied immediately, weeds will take over the entire lake, destroying recreational use and slicing property values. And neither group is likely to listen to the other.

There have been few, if any, documented cases of an herbicide treatment gone completely awry. Any health problems associated with contact with herbicide-treated lakes may be perceived and based on an expected threat. While toxicological studies indicate that short-term human health effects or impacts to non-targeted organisms in the lake ecosystem are probably very small when herbicides are applied according to the permitted label, long-term monitoring of ecological or human health has not occurred. An herbicide treatment may also be ineffective due to poorly timed applications, unusual weather conditions, eradication of non-target plants, reinfestation by exotic species, or by simply using the wrong herbicide to control a particular species. Even when successful, treatments will have to be repeated at least every growing season, as is the case with nearly all symptom-based vegetation control techniques. These limitations and concerns need to be balanced against the ecological damage that may occur when invasive plants spread through a lake ecosystem, creating "biological pollution" and drastically altering the ecological balance.

Although herbicide use requires a permit in New York State, the decision whether to use chemical treatment usually rests with the lake association, residents, or lake management team. As much information as possible should be obtained about the particular species of nuisance plant, proposed herbicide, existing water chemistry conditions on the lake, and the benefits and drawbacks of using this particular herbicide on this particular lake to control this particular plant. It is important to use discretion when extrapolating information from a different lake to the conditions at your lake. Differing weather conditions, recreational uses, water chemistry characteristics, and vegetation types could yield dramatically different results from one lake to another. The DEC regional office may be able to provide some assistance in obtaining information about the lake and proposed herbicide.

## **5. Shading**

- *Principle*

Shading involves the use of chemical dyes to inhibit light penetration to the lake bottom, ultimately controlling the growth of nuisance aquatic vegetation in areas greater than two to four feet deep. These non-toxic vegetable dyes work by reducing light penetration in the water ("shading"), and by the absorption of wavelengths within the photosynthetically

active region of light. Absorbing these wavelengths prevents the plants from photosynthesizing and growing.

The dyes treat the entire waterbody and are usually not used on large lakes due to cost limitations. Dyes are most effective in small waterbodies with little or no flow where the appropriate concentration can be maintained. The duration for treatment for either large or small lakes is a function of water retention time. Dyes will be significantly and quickly diluted or washed downstream in lakes with inflow and outflow.

The use of shading dye is prohibited in potable water supplies; however, there are no use restrictions associated with the use of water treated with shading dye immediately after the application

The most common chemical dye used in shading is Aquashade®, an inert blue liquid vegetable dye made primarily of food colors. However, in recent years, many other products that perform the same function have been advertised as “landscaping tools”, “colorants” or to improve the “aesthetic quality” of the water, thus avoiding claims of any herbicidal impacts that require permits and compliance with regulatory restrictions outlined in FIFRA. Some of the products, particularly those registered as having herbicidal impacts, are often combined with copper formulations to enhance control of algae.

- *Target Plants and Non-Target Plants*

Shading dyes have been shown to be somewhat effective for several nuisance plants including *Elodea* (common waterweed), *Potamogeton* (pondweed), *Najas* (naiad), *Myriophyllum* (milfoil) and some filamentous algae. However, shading dyes are usually

#### Case Study- Shading to Grass Carp: Adirondack Lake

**Lake Setting:** Adirondack Lake is a 200 acre lake in the town of Indian Lake in the middle of the Adirondack Park. It was formed by a stone dam originally built in 1910 (to create a recreational lake) and rebuilt by the Civilian Conservation Corps in the 1930s. The lake is characterized by a group of floating peat bogs, which have been managed by a variety of strategies over time, presently corralled by a log boom.

**The Problem:** Rooted aquatic plant growth has been the subject of complaints since the late 1960s to early 1970s. By the late 1970s, the aquatic plant populations in the lake were dominated by beds of large-leaved pondweed, although other native species were well represented.

The Adirondack Lake Association utilized a number of lake management tools, from water level drawdown (from 3 to 9 feet), mechanical harvesting, and aquatic herbicides (2,4-D), during the late 1970s and early 1980s.

**Response and Results:** In 1984, Aquashade, an inert vegetable dye, was applied at a rate of 1 part per million (500 gallons), in combination with a relatively deep lake drawdown. As a result, 90% of the aquatic plant beds (large-leaf pondweed beds comprised 95% of the biomass) were cleared from the lake for two years, with aquatic plant growth limited to shallow water by early 1986. However, by later that year, the APA estimated aquatic plant growth to be “moderate” to “abundant”. By the following year, after a deep winter drawdown, Aquashade was applied again to control primarily large-leaved pondweed beds covering 80% of the shoreline to a depth of 7 feet. This resulted in a shift in the aquatic plant communities from large-leaved pondweed to brittle naiads (*Najas minor*) and common waterweed (*Elodea canadensis*) by the following year, although, after a year of no control, the large-leaved pondweed returned to abundance. As aquatic plant growth increased, Aquashade was applied a third time in 1991, again after a (lower) winter drawdown, and a fourth time in 1994, at a total cost (for the four treatments) of about \$54,000.

By 1996, the lake association shifted the agent of control from Aquashade to grass carp, in part due to the lower costs (an expected cost of \$35,000 for 10 year grass carp control versus about \$54,000 for 10 years of shading agents). The effectiveness of the carp have been evaluated through aquatic plant surveys conducted on the lake since 1999. It appears that the plant communities have shifted from dominated by large-leaf pondweed (*Potamogeton amplifolius*) to a mixed community with a brittle naiad and a multitude of native milfoils and other submergent and floating-leaf plants. Overall plant coverage and densities have decreased slightly over the last several years.

**Lessons Learned:** It was believed that the repeated Aquashade treatments reduced plant populations in the deeper water, but had less impact in the shallow water, although the extent of the impact, and whether the shift from one dominant plant to another was acceptable, is not clear. The grass carp were generally effective at reducing the population of a plant (large-leaf pondweed) that is often considered to be a nuisance, although it is not known if the overall reduction in plant biomass adversely affected the fisheries or overall lake ecology.

**Source:** Grim, J. 1996. Supplement to Adirondack EAF: Environmental Impacts of Stocking Triploid Grass Carp. Unpublished report, Rhinebeck, NY.

Kishbaugh, S. 2004. Aquatic plant survey of Adirondack Lake. Unpublished report submitted to the Hamilton County SWCD. Albany, NY.

generalist agents. Since dyes reduce the transmission of light into a lake, all submergent plants tend to get affected by this process. Specific weed beds or sections of a lake cannot be isolated for treatment unless flow between this area and the rest of the lake can be restricted

- *Advantages*

Lake dyes are non-toxic to humans and most aquatic organisms, including the invertebrate species likely to be exposed to the dye during treatment. They are relatively inexpensive for small lake and pond applications, although these costs may become prohibitive for larger-scale treatments.

- *Disadvantages*

Since the field research on the dyes has been rather sparse, it is not clear which aquatic plant species, including algae, are affected by the treatments. Some shallow water or light-insensitive plants, such as the opportunistic Eurasian watermilfoil, may actually be selected for with this technique. Since the dyes are so soluble, they tend to migrate throughout the lake, minimizing opportunities for control in selected areas of the lake. Non-target plants may be adversely affected by the dyes, including some providing fish habitat.

These dyes can frequently and rapidly wash out of a lake, so repeated applications may be required in lakes with very low residence times (high flushing rates) or during periods of rapid water movement into and out of a lake, such as major storm events.

- *Costs*

The cost of the chemical dyes is about \$50 per gallon, which is sufficient to treat four acre-feet of water at the recommended concentration of 1 ppm (one acre-foot equals one acre of surface area treated to a depth of one foot).

- *Regulatory Issues*

Chemical dyes require a pesticides permit from the NYSDEC and the APA if the label on the dye promotes plant control (acts as an herbicide), since the use of herbicidal agents is governed under FIFRA (see the section on the use of Aquatic Herbicides in this chapter). For those products that provide "landscaping" or "colorant" to lakes or ponds, permits are not required.

- *History and Case Studies in NYS*

There is little historical information on the use of shading agents in New York State lakes, although they have been commonly used on ponds, particularly golf course and ornamental ponds, for many years. The only large-lake experiment with the use of lake dyes was in Adirondack Lake in the late 1980s.

- *Is That All?*

There have been few attempts to use chemical dyes in New York State. Although chemical dyes use physical light inhibition and not toxicity as the mode of action, pesticide permits are required (from the regional DEC office and the APA) to apply the dye to a lake. The public may perceive the technique to be another herbicide with the potential of eliciting toxic reactions in non-target organisms. The dyes also impart a

somewhat unnatural color to the lake water. Despite the efforts by the manufacturers to mimic the coloring of the lake environment (if not the actual water color), some lake residents will not comfortably swim or bathe in the colored water.

Nonetheless, this control strategy is less expensive than many other strategies, and may result in some limited success in controlling nuisance vegetation with only minor side effects. Lake associations or lake managers attempting to use chemical dyes are advised to enlist public support prior to application in lake waters used for recreational purposes. Depending on the wash-out rate for the lake, these dyes may persist through much of the recreational season.

### **Other Methods and Why They Don't Warrant Even a Few Paragraphs...**

#### **1. Plant Pathogens**

Plant pathogens, such as fungi, have been researched for many years, including studies looking at the impact of these pathogens on populations of Eurasian watermilfoil. However, this has not evolved into a viable plant management technique, or at least a technique that can be utilized by lake managers and has any history of utilization within New York State.

#### **2. Surface Covers**

Surface covers are usually constructed from the same material as benthic barriers (opaque plastic or equivalent), and also operate as light-inhibiting agents, but they float on the water instead of being anchored on the plants. Since these frequently interfere with recreation and can be aesthetically displeasing, they have not regularly been used in New York State lakes.

#### **3. Copper**

Copper is a common algacide, and is discussed in greater detail in the algae control section of this book. It may be applicable in those rare instances in which a macroalgae, such as *Chara* (a weakly rooted alga that superficially resembles larger aquatic plants), inhibits lake use. However, the dosage rate required to control most of these true weeds (**macrophytes**) is much higher than would normally be allowed for algae control.



## References

- Baker, J.P., H. Olem, C.S. Creager, M.D. Marcus, and B.R. Parkhurst. 1993. Fish and Fisheries Management in Lakes and Reservoirs. EPA 841-R-93-002. Terrene Inst. U.S. Environ. Prot. Agency, Washington, DC.
- Conesus Lake Association, 2002. The Conesus Lake dockside/near shore lake weed and algae treatment guide. Lakeville, NY.
- Cooke, G.D., et al. 1993. Restoration and Management of Lakes and Reservoirs. Lewis Publishers, Boca Raton, FL.
- Cooke, G. D. and R. H. Kennedy. 1989. Water quality management for reservoirs and tailwaters. Report I. In-lake reservoir water quality management techniques. Tech. Rep. E-89-I. U.S. Army Corps Eng., Vicksburg, MS.
- Creed, R. 1998. A biogeographic perspective on Eurasian watermilfoil declines: Additional evidence for the role of herbivorous insects in promoting declines? J. Aquat. Plant Manage. 36: 16-22.
- Crowe, G.E. and C.B. Hellquist. 2000. Aquatic and wetland plants of northeastern North America: a revised and enlarged edition of Norman C. Fassett's A manual of aquatic plants. University of Wisconsin press.
- Darrin Freshwater Institute. 1991. Hand harvesting Eurasian watermilfoil in Lake George. DFWI Rep. 91-7. Rensselaer Polytechnic Institute, Troy, NY.
- Eichler, L.W. et al. 1995. Recolonization of the littoral zone by macrophytes following the removal of benthic barrier material. J Aquat Plant Manage. 33: 51-54
- Engel, S. 1984. Evaluating stationary blankets and removable screens for macrophyte control in lakes. J. Aquat. Plant Manage. 22:43-48.
- Holdren, C., W. Jones, and J. Taggart. 2001. Managing Lakes and Reservoirs. N. Am. Lake Manage. Soc. and Terrene Inst., in coop. With Off. Water Assess. Watershed Prot. Div. U.S. Environ. Prot. Agency, Madison, WI.
- Johnson, R. 2002. Personal communications. Ithaca, NY.
- Lord, P.H., R. L. Johnson and K. Wagner. 2005. Effective aquatic plant monitoring: data and issues from Waneta Lake. Presentation at the Northeast Aquatic Plant Management Society annual meeting, Saratoga Springs, NY
- McComas, S. 1993. Lake Smarts: The First Lake Management Handbook. Terrene Inst., U.S. Environ. Prot. Agency, Washington D.C.
- Newroth, P. and R. Soar. 1986. Eurasian watermilfoil management using newly developed technologies. Lake Reserv. Manage. 2: 252-57
- NYSDEC, 2002. New York State Water Quality 2002. Albany, NY.

Perkins, M.A., H.L. Boston, and E.F. Curren. 1980. The use of fiberglass screens for control of Eurasian watermilfoil. J. Aquat. Plant Manage. 18:13-19

Sheldon, S. and L. O'Bryan. 1996. The life history of the weevil, *Euhrychiopsis lecontei*, a potential biological control agent of Eurasian watermilfoil. Entomolog. News 107: 16-22.

Solarz, S. and R. Newman. 1996. Oviposition specificity and behavior of the watermilfoil specialist *Euhrychiopsis lecontei*. Oecologia 106: 337-44.

Westerdahl, H.E. and K.D. Getsinger, eds. 1998. Aquatic plant identification and herbicide use guide. Vol. 2. Aquatic plants and susceptibility to herbicides. Waterways Experiment Station. U.S. Army Corps Eng., Vicksburg, MS.

## **Definitions**

**Emergent plants** grow primarily above the water surface, although the plant may be rooted in the water. Cattails, purple loosestrife, and phragmites are examples of emergent plants

**Exotic species**- not native to a lake, and usually not native to a larger geographic region (the Adirondacks, New York, North America....), at the time of European settlement. Usually refers to plants or animals accidentally or purposefully introduced to an area outside of its historic range. Also referred to as non-native, alien, or introduced species.

**Floating plants** may or may not be rooted underwater, but the majority of the plant is associated with a floating leaf. Water lilies, watershield, duckweed, and watermeal are examples of floating plants

**Invasive Species**- plants or animals that rapidly reproduce and displace native species. Also referred to as noxious species.

**Macrophytes**- large plants (macro meaning large, and phyte meaning plant)- most of the aquatic plants found in New York State can be referred to as macrophytes

**Meristems**- the growing tips of aquatic plants- these are preyed on by herbivorous insects, and are often the most conspicuous part of an underwater plant

**Monoculture**- a single, homogeneous culture without diversity, such as a plant bed comprised solely of a single aquatic plant

**Native Species**- native or indigenous to a region at the time of European settlement

**Naturalized**- introduced from another region and persisting without cultivation; for example, aquatic plants or animals that might not be truly native but were long ago introduced and have adapted to a lake environment

**Nuisance Species**- plants or animals interferes with human activities. Also referred to as weeds.

**Submergent plants** grow primarily underwater, although small floating leaves or fruiting structures may sit on or above the lake surface. Water milfoil, pondweeds, coontail, and bladderwort are examples of submergent plants.

**Veligers**- a larval stage of a mollusk, such as a zebra mussel

## Appendix A: Elements of an Aquatic Plant Management Plan

- Problem Statement
  - **Map(s) Indicating Areas of Plant Growth**
  - **Identification of Aquatic Plants on the Map, Including Invasive/Target Species** (indicate how target species identification was verified- professional? Applicator? Part of monitoring program?....)
  - **History of Invasive Weed Growth-** include year of introduction if known, indicate if invasive weed populations are increasing, stable, or decreasing
  - **Uses Impaired-** identify only major uses affected by weeds and whether these are designated lake uses, including impact of target plants/ exotics on native plants and lake ecology (aquatic life impacts)
  - **Known Occurrences of Rare/Endangered Species of Concern?-** list (reference NYS Protected Plant list as needed)
- Management History
  - **Description of Previous Management Efforts** (one paragraph per control strategy used).
  - **Evaluation of Successes and Failures-** did previous management successfully control problem?
  - **Lessons Learned-** did it work?, use of specific control methods, whether limitations existing on the use of particular techniques at this lake
  - **Does Overall Lake Management Plan Exist?** (does it address plant control?)
  - **Context of Aquatic Plant Management versus other lake management objectives** (is aquatic plant control compatible with other lake management objectives, such as swimming, potable water intake, irrigation water, etc.?)
  - **Description of Public Involvement in Management Efforts-** Lake Association? Local Government? Adoption of Prior Management Plans?
- Management Objectives
  - **Extent of Preferred Management-** summarize in one paragraph
    - Partial vs. whole lake management
    - Seasonal (short-term) vs. year-round
    - Immediate vs. long-term or persistent
    - Selective control vs. removing all plants in targeted area
  - **Expected Use Benefits-** one paragraph summary
  - **Critical Areas to Protect** (re: fisheries, wetlands, water intake)
- Management Alternatives- include information on “practical” use of these alternatives at this lake (what factors affect choice of preferred management alternatives- including bathymetry, flushing rate, outflow/groundwater seepage)- In other words, identify why each management alternative is (or is not) appropriate
  - **Local Control-** hand harvesting, benthic mats, herbicides- one paragraph for all methods

- **Lakewide Control**
  - Physical/Mechanical control- drawdown, mechanical harvesting, shading- one paragraph for all methods
  - Biological control- grass carp, herbivorous insects- one paragraph for all methods
  - Chemical control- herbicides- one paragraph for all methods
- **No Action Alternative-** one paragraph summary
- **Preferred Alternative(s)-** one paragraph summary
- **Integrated Management-** one paragraph summary of whether integrated approach (multiple techniques) is appropriate
- Pre-, During- and Post Treatment Actions Planned
  - **Monitoring-**
    - **Aquatic plant-** describe on-going and future monitoring to support aquatic plant management plan
      - Method (rake toss? point intercept? transects?)
      - Frequency of monitoring? (monthly, annually,...?)
      - Conducted by? (professional or volunteer)?
      - Results reported by maps? Data tables? Presence/absence?
    - **Water Quality-** describe on-going and future monitoring to support aquatic plant management plan
      - Water clarity and/or chlorophyll to evaluate shift from macrophyte-dominated to algae-dominated?
      - Dissolved oxygen measurements to evaluate potential for fish kills during and after treatment?
      - Frequency of monitoring?
      - Professional or volunteer?
  - **Early Response-** describe planned activities- one paragraph each:
    - Hand pulling or benthic mats as individual plants or small beds of reinfested target species
      - Frequency/schedule?
      - Prompted by?
        - Identifications through monitoring program?
        - Reports from lake residents?
    - Educational program re: exotics and vectors of transport
  - **Source Management-** describe planned activities- one paragraph
    - Signage/pamphlets at local launches
    - Boat/prop inspections
    - Strategies for reducing sediment/fertilizer load to lake (list and brief description of proposed strategies)- if not, indicate why this would not be efficient use of resources/effort (not contributing to invasive plant problem, etc)- will the lake resident try to identify sources of pollutants to the lake and start to address this loading
  - **Evaluation of Efficacy (Did it work?)-** brief (one paragraph summary)- timeframes; will this information will be reported to the DEC?
    - Did it control the target plants?
    - Will fisheries impacts be evaluated and how?
    - User surveys planned? (did people think it was successful)

## **Appendix D**

### **Responses to public comments**

No comments were received during the public comment period.