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Invasive Species Management Plan for Oswego Lake

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Executive Summary

This Invasive Species Management Plan defines an overarching strategy for the Lake Oswego Corporation (LOC) to mitigate threats from invasive species to Oswego Lake. Invasive species pose a direct risk to recreational and aesthetic uses of the lake, critical LOC infrastructure, and ecological communities within the lake. The Plan is particularly concerned with two bivalve mollusks in the genus *Dreissena*: the zebra mussel (*Dreissena polymorpha*) and the quagga

mussel (*Dreissena bugensis*). These mussels grow in dense colonies that damage watercraft and underwater structures as well as displace native species. A recent scientific report found that an intense infestation of mussels in Oswego Lake is unlikely due to the water chemistry, but a low to moderate level of infestation is possible. Any level of infestation could be very serious and warrants proactive preventative measures and response plans should an invasion occur. In addition to the harmful mussels, this Plan identifies preventative and response measures for other species such as hydrilla (*Hydrilla verticillata*) that have the potential to harm Oswego Lake.

Strategies outlined in this Plan are as follows:

- Identification and prioritization of likely potential invasive species
- Identification of vectors of establishment
- Prevention strategies
- Development of monitoring plans
- Rapid response action plans and control measures if an invasion is detected

Prevention is the top management priority for all invasive species as the cost and difficulty of controlling or eradicating an invasion increase significantly as an invasion spreads. This includes active measures to exclude species as well as the ongoing education and involvement of community members. Effective monitoring and rapid response action plans are the next priority to detect and eradicate an exotic species before it establishes and spreads. The integration of these strategies will help the LOC prevent significant deleterious effects from invasive species in Oswego Lake so that the basic operations of the LOC are facilitated and recreational and aesthetic opportunities are preserved.

Introduction

Problem Statement

Oswego Lake is prized by the shareholders of the Lake Oswego Corporation (LOC) for its natural beauty and recreational opportunities. Invasive plant and animal species have the potential to hinder these uses as well as the LOC's central mission to "maintain and improve Oswego Lake and to protect its value and quality". Invasive species are defined as nonindigenous organisms whose intentional or unintentional introduction is likely to cause economic or environmental harm or harm to human health. Natural control mechanisms like predators and disease are not present for many invasive species so their populations grow rapidly. The potential for Oswego Lake to be invaded by aquatic invasive species has been a real threat for over a century and there are presently numerous invasive species in the lake that are problematic. The species that currently cause the greatest nuisance are the aquatic weeds Brazilian elodea (*Egeria densa*) and curlyleaf pondweed (*Potamogeton crispus*). Both of these weeds form dense mats and the LOC uses herbicide applications and mechanical and manual removal to help lessen their impact.

Only recently has this potential for invasion included organisms that can severely impact the day-to-day operations of the LOC. Two members of the family *Dreissenidae*, the zebra mussel (*Dreissena polymorpha*) and the quagga mussel (*Dreissena bugensis*), pose a new level of threat to Oswego Lake and other water bodies in the western United States. Native to Eastern Europe, *Dreissena* mussels appeared in the Great Lakes in the late 1980's. The mussels rapidly spread to other waterbodies and now are found in 25 states and two Canadian provinces. Both mussel species have recently been found in California and Colorado and quagga mussels have additionally been found in Nevada and Arizona. The likely vector of introduction of the mussels to non-connected waterways is recreational watercraft. Though neither species has yet been found in an Oregon waterway to date, the threat clearly exists. In 2007, a vehicle transporting a boat that had passed through Oregon heading to British Columbia was intercepted in Washington State and found to have zebra mussels attached. There have been over 100 other documented interceptions of watercraft transporting *Dreissenidae* in the West in the last 5 years.

Zebra and quagga mussels grow in dense colonies that clog intake pipes and screens, foul boat hulls and motors, and damage underwater structures. They also displace native species and disrupt the food chain. Eradication of these freshwater mussels is nearly impossible once a population is established and control measures are difficult and costly. Water chemistry may limit the size of a mussel infestation in Oswego Lake, but even a small established population could create significant ecological and economic damage.

Aside from the harmful dreissenid mussels, several other invasive species that are not yet present in Oswego Lake, such as hydrilla (*Hydrilla verticillata*) and giant salvinia (*Salvinia molesta*), also pose a significant risk. The state of Washington has spent about one million dollars in an ongoing fifteen-year effort to eradicate and monitor hydrilla in two small (68 total surface acres) connected lakes. This eradication effort appears to be successful, in part due to identifying the invasive plant before it was able to spread extensively and carrying out comprehensive control measures. The cost and effort of controlling such an invasion increases rapidly as an invading species spreads and the most effective and economical control methods involve preventing new species from establishing in the first place (Lodge et al. 2006).

Oswego Lake is vulnerable to threats from invasive species like mussels and weeds because it lies in an urban watershed that has many potential vectors of introduction. Portland State University wrote, and is responsible for implementation of, the Oregon Aquatic Nuisance Species Management Plan. However, that Plan does not provide a comprehensive strategy for specific waterbodies, like Oswego Lake, or management plans for specific species present. This document outlines a management framework for the LOC that focuses on prevention of new invasive species in Oswego Lake and outlines strategies to monitor and respond to new invasions.

Objectives and Strategies

The central objective of this Plan is to establish a comprehensive strategy to address potentially harmful new invasive species and invasive species already established in Oswego Lake. Prevention is the top priority, followed by monitoring and preparation to quickly respond to a detected invasion (see Figure 1). The Plan focuses on species that pose the greatest risk, however it also addresses other less threatening species. The Plan outlines the following strategies:

1) Identification and prioritization of organisms that pose threats to Oswego Lake

Known potential invasive species are prioritized based on their ability to impact Oswego Lake, the proximity of existing populations, and the likelihood of survival if introduced.

2) Identification of potential vectors of species introduction

The specific mechanisms that potential invasive species could use to enter Oswego Lake are defined and prioritized.

3) Prevention as the first line of defense

Prevention is the most cost-effective and environmentally sound management approach. This is the top priority in this plan.

4) Development of a monitoring strategy for Oswego Lake

New strategies are suggested for the LOC to maximize the likelihood that a nascent invasion is detected early so that appropriate response measures can be implemented.

5) Creation of rapid response action plans and control measures

This Plan outlines specific actions to be taken to respond to a diverse set of potential invasion scenarios, including rapid response plans in case of detection of an invasive species in Oswego Lake as well as improved control measures for existing invasive species.

It should be recognized that no strategy could be completely prophylactic in excluding invasive species. The management framework outlined in this Plan gives the LOC a multifaceted approach to prevent and respond to invasion threats. A summary of common stages in an invasion process and corresponding management options is outlined in Figure 1. These strategies, along with the ongoing education and involvement of shareholders, provide the best chance at mitigating threats from unwanted organisms from entering and harming the Owego Lake resource.

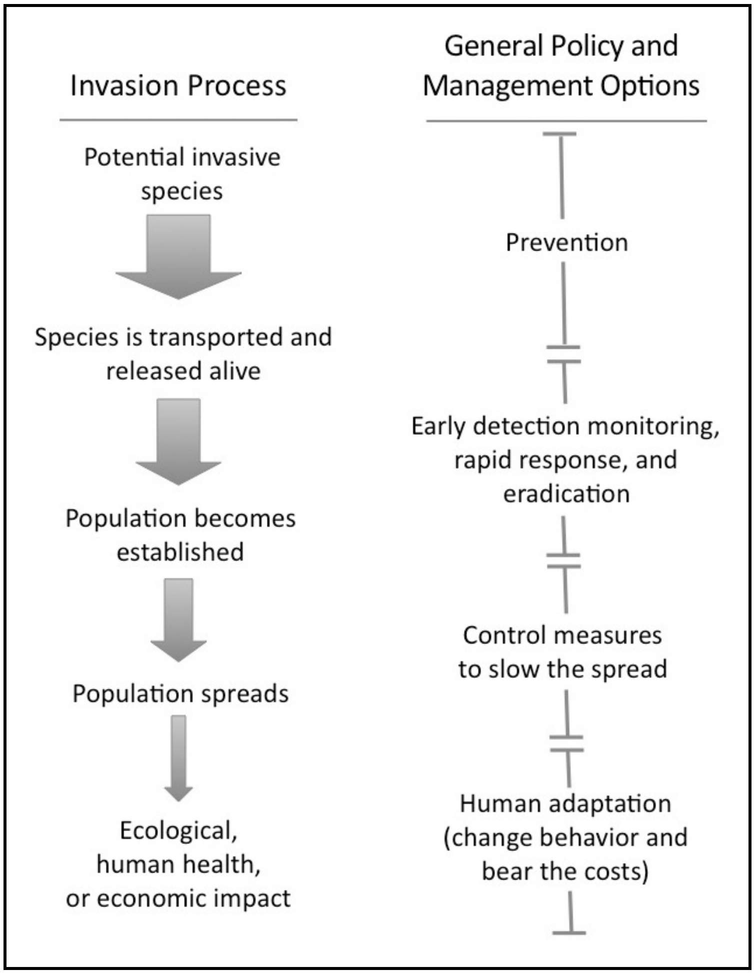

Figure 1. Stages common to all invasions and corresponding policy and management options available. Arrow size corresponds to likelihood of each process stage. Adapted from Lodge et al. 2006.

Likely Potential Invaders

The following is a list and priority ranking of likely potential invaders that threaten Oswego Lake. It is based on information from the Oregon Invasive Species Council, government agencies, scientific literature, and input from local invasive species experts. This list should not be considered completely comprehensive, as that is nearly impossible in today's world of globalization. Nevertheless, identifying the most likely invaders is the first step in risk analysis and will help the LOC prepare and mitigate threats from specific known invaders.

Organisms are divided into three priority classes based on four criteria: (1) their potential to negatively impact Oswego Lake if introduced, (2) proximity of existing populations, (3) the likelihood that the organism would survive in the environmental conditions of Oswego Lake (4) being associated with a high risk vector like boating. A summary of this information is available in Appendix 1.

Priority Class 1 – Highest Threat

These organisms could become a serious nuisance and control measures will likely need to be enacted if they are introduced.

Zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*)
Both of these bivalve mollusk species were introduced from Europe into the Great Lakes in the late 1980's via shipping ballast water. Both species have a high fecundity, early sexual maturation and can be prolific invaders. Hundreds of millions of dollars are spent on control measures in the United States annually. The mussels grow in dense colonies that have the potential to cause significant ecological damage. Other specific impacts to Oswego Lake could include damage to the headgate, watercraft, docks, piping, and the outlet dam and hydropower structure. Some differences exist between the two species such as spatial distribution patterns and water quality requirements, but overall they produce similar impacts and share similar life histories (Heimowitz and Phillips 2008).

Potential to survive in Oswego Lake
Calcium (Ca) concentration and pH are known to be major limiting factors for *Dreissena* mussels. The lower limit of Ca concentration for survival in European lakes was found to be 28 mg L^{-1} (Ramcharan et al. 1992). Zebra mussel populations have been observed at much lower Ca concentrations in North America, some as low as 8 mg L^{-1} (Jones and Ricciardi 2005). Most researchers place the minimum Ca threshold for North American *Dreissena* populations between 12-15 mg L^{-1} (Cohen 2007). Cohen predicts that the populations recorded at lower Ca concentrations "probably represent either misidentification, limited or inaccurate calcium data, or non-reproducing sink populations from populations established upstream in higher Ca waters." Whittier et al. (2008) devised an invasion risk scale based on 3000 stream and river sites in the contiguous United States as follows: very low risk < 12 mg L^{-1}, low risk 12-20 mg L^{-1}, moderate risk 20-28 mg L^{-1}, and high risk > 28 mg L^{-1}. The pH range necessary for growth and reproduction has a lower limit of about 7.3 (Ramcharan et al. 1992, Sprung 1993) and an upper limit of 9.3-9.6 (Bowman and Bailey 1998).

A risk assessment for zebra and quagga mussel survival in Oswego Lake was completed by *Dreissena* expert G.L. Mackie in September 2008. The report determined that the risk of a massive infestation in Oswego Lake is small, largely due to low Ca concentration, but also from seasonal changes in pH and other water quality characteristics. The potential for the mussels to survive in low to moderate densities was, however, deemed possible. The report suggested more extensive Ca measurements be performed to produce a risk assessment with greater accuracy.

Beginning in September 2008 the LOC measured Ca in four regions of the lake as well as locations along the two inlet streams (Figure 2). Ca concentrations were greatest in the Oswego Canal at Bryant, ranging from 18-25 mg L^{-1}. Ca concentrations were lower and generally homogenous in the main lake, West Bay and Lakewood Bay ranging from 10-18 mg L^{-1} with an overall average of about 12.5 mg L^{-1}. Springbrook and Lost Dog Creeks had similar Ca levels ranging from 9-17 mg L^{-1}. These Ca concentrations measured in Oswego Lake reaffirm the potential of zebra and quagga mussels to survive in Oswego Lake. Any size of infestation could be very serious and outright exclusion should be a central focus of LOC management.

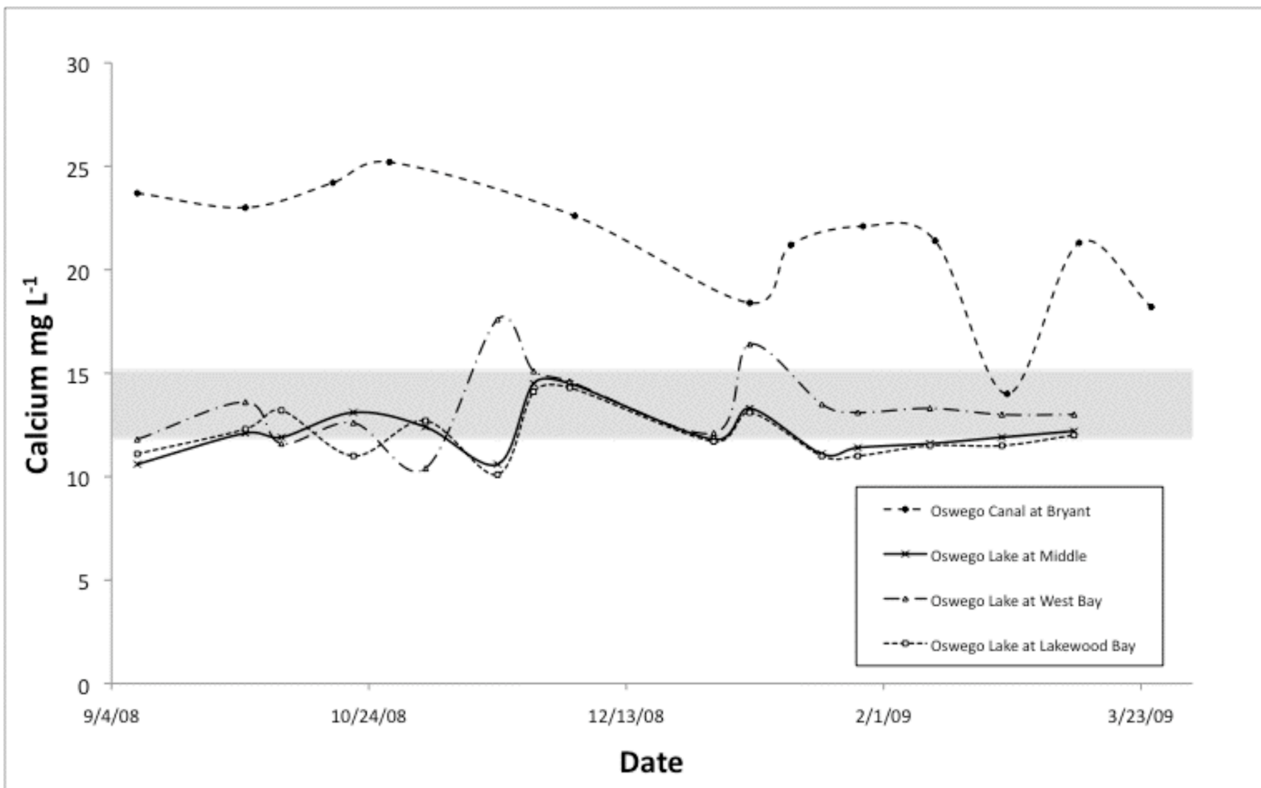

Figure 2. Calcium levels (mg L^{-1}) at four regions of Oswego Lake. West Bay and Lakewood Bay samples taken from 1m, middle taken at 5m, Oswego Canal taken at 0.5m. Grey bar indicates average minimum calcium threshold in North America for zebra and quagga mussel survival, though populations have been found at calcium levels below 12 mg L^{-1}.

Hydrilla (*Hydrilla verticillata*)

Hydrilla is a federally listed noxious weed and one of Oregon Invasive Species Council's 100 most dangerous species to keep out. Native to Asia, hydrilla was sold in the U.S. as an aquarium plant beginning in the 1950s and has since become very problematic, particularly in southern states. It has been dubbed "the perfect aquatic weed" due to its rapid growth and adaptability. Hydrilla competes effectively for sunlight, growing from as deep as 15 m at a rate of up to one inch per day until it forms dense surface mats that can exclude all other submersed vegetation (Langeland 1996). Two forms of the plant exist in the United States. The Dioecious female form of the plant is less cold tolerant and predominate in the South, while most populations north of South Carolina are predominantly monoecious. Two populations of dioecious hydrilla were recently discovered in southwestern Idaho in waterways that are fed by geothermally warmed water. These waterways are of particular concern because they are in the Snake River watershed. It was detected in two small, connected lakes (Pipe and Lucerne Lakes) in King County Washington in 1994. An extensive decade-long eradication effort followed that appears to be successful as no hydrilla plants have been detected in recent years. The fact that hydrilla survived in Washington and in portions of the northeast United States demonstrate that it would likely survive and be a serious threat to Oswego Lake if introduced.

African waterweed (*Lagarosiphon major*)
African waterweed is a rooted perennial plant native to mountainous regions in southern Africa and does not yet occur in the United States. It has become a major problem elsewhere in the world in places like Ireland and New Zealand and is also on the 100 Worst List in Oregon as well as being a federally listed noxious weed. The plant grows to the surface (from as deep as 6.5 meters in clear water) and forms a dense surface canopy that crowds and shades out other plants. It is tolerable of many aquatic conditions (Caffery 2007) and would likely survive if introduced to Oswego Lake. Aside from detrimental impacts to ecology and recreation, African waterweed has significantly impeded hydropower facilities in New Zealand due to clogging intake screens. Dispersal of African waterweed is primarily done from vegetative fragments as the entire population in Ireland is female.

Milfoil and parrot feather (*Myriophyllum spicatum* and *M. aquaticum*)
Milfoil and parrot feather are also rooted perennial aquatic weeds that form dense surface mats. Both plants are already prevalent in Oregon waterways and are class "B" noxious weeds in the state. Milfoil is particularly troublesome in waterways with nutrient loading where it exhibits very rapid growth rates. Milfoil also spreads via plant fragments and this is a particular concern in Oswego Lake given the proximity of exiting populations and the potential for boaters to transport weed fragments inadvertently.

European water chestnut (*Trapa natans*)
Commonly referred to as water chestnut, this weed has become problematic on the East Coast of the United States. Water chestnut is an annual rooted herb with a floating rosette of leaves that form dense surface mats that limit navigation and crowd out other species. The attractive leaves of the plant and ease of cultivation have made it popular in water gardens. The plant produces a woody seed that has four sharp points (hard enough to penetrate shoe leather) that can be up to _ inch long. These seeds collect in the water and on beaches and pose a hazard to swimmers. Over $4.5 million were spent on control efforts in Lake Champlain alone from 1982-2001 (Naylor

2003). Its known range currently does not extend west of Pennsylvania. It is a class "A" noxious weed in Oregon and also on the 100 Worst List.

Giant salvinia (*Salvinia molesta*)
Giant salvinia is a floating, rootless aquatic fern that reproduces easily from vegetative fragments. Salvinia grows very rapidly forming dense surface mats. The plant is federally listed as a noxious weed. It has been observed to double its biomass in ten days under ideal natural conditions. The weed has been very problematic in Texas and other regions of the southern United States, but the USGS predicts that Oswego Lake might be beyond its potential range due to cold winter temperatures. Nevertheless, salvinia is still considered one of Oregon's 100 most dangerous potential invaders.

Water primrose (*Ludwigia hexapetala*)
Water primrose is a perennial herb that produces attractive yellow flowers. It grows in dense thickets at the margins of waterways rooted one meter of water or less. It forms long stems that stand erect up to one meter high and runners that can extend across the bank or open water. Water primrose would be a threat to Oswego Lake in the canals and other riparian areas adjacent to very shallow water. Populations currently exist in Lane, Linn, and Benton counties in Oregon and in southern Washington.

Rock snot (*Didymosphenia geminate*)
Sometimes called didymo, rock snot is a freshwater diatom (a type of single-celled algae) that forms thick benthic mats that resemble brown shag carpet with trailing white wispy tails. Contrary to its name, rock snot feels rough and not slimy to the touch and this characteristic can be used to differentiate it from other native algal species (Spaulding and Elwell 2007). Historically this species only occurred in nutrient-poor waters, but recently its range has expanded to become problematic in nutrient-rich streams and rivers. Rock snot has been shown to survive in lakes, but the only known problematic populations are in rivers and streams. There have been no confirmed sightings in Oregon to date, though there are anecdotal claims that it is already present (Spaulding and Elwell 2007). Populations have been verified in Washington, California, and Idaho. Rock snot is likely transported to unconnected waterways on fishing gear such as waders and felt-soled shoes.

New Zealand mud snail (*Potamopyrgus antipodarum*)
The New Zealand mud snail (NZMS) is a tiny (5-12mm) aquatic snail that is becoming increasingly common in the western United States. It occurs in the littoral zone of lakes and streams and is already established in several rivers in Oregon. Under optimal conditions snail densities can reach up to 300,000 snails/m^2, though environmental tolerances are currently poorly understood. In its natural range, NZMS reproduce sexually and asexually, but in North America all reproduction is parthenogenetic, meaning all individuals are genetically identical females (Alonso 2008). The snails are able to spread via many vectors including passing through the gut of fish and birds alive and from recreational fishing gear.

Yellow floating heart (*Nymphoides peltata)*
This rooted perennial plant produces showy yellow flowers and was an attractive water garden ornamental, but is now listed as an ODA class "A" noxious weed due to its invasive potential.

Yellow floating heart grows in depths from 1-4 meters and creates surface mats of floating heart shaped leaves that shade out other plants and create areas of low oxygen. These mats also impede boating, swimming, and fishing activities. It can regenerate from plant fragments as well as from seeds and root nodes. Single isolated populations were discovered in Oregon in Washington and Lane Counties (in 2004 and 2005 respectively). ODA reports both populations are growing considerably as public opposition to herbicide use in the urban areas where they are currently growing limits control options.

Flowering rush (*Butomus umbellatus*)
Flowering rush was added to the ODA class "A" noxious weed list in 2009. It belongs to the family Butomaceae and is not a true rush. Flowering rush is easy to identify in late summer or early fall when a crown of showy white or pink flowers appear, but is otherwise more difficult when not flowering. The plant grows in dense stands in marshy and shallow riparian areas and achieves a height of 1.5 meters. Flowering rush has numerous reproductive strategies and spreads most easily from root fragments that break off and are distributed by water currents. It had been recorded in the Great Lakes region for over a century, but in the last decade it has spread to Idaho and Montana where it is has become problematic by completely overtaking shallow areas and canals. Control with herbicides used for emergent vegetation is difficult due to its narrow leaves. A small population was recently discovered at the Oregon Garden in Silverton, OR (Vanessa Howard, personal communication). This is the only known population in Oregon or Washington and resource managers are concerned about future spread into the Columbia Basin.

Common reed (*Phragmites australis*)
Common reed is a large perennial grass that can grow to 1-4 meters high. There is both a native subspecies (*americanus*) and a non-native subspecies (*australis*). This latter subspecies is an aggressive invader and a category "A" noxious weed in Oregon. The ODA risk assessment (Jan 2009) lists distinguishing characteristics that can be used to differentiate the subspecies. Morphological differences are subtle and proper identification might take an expert. Common reed grows in marshy areas and shallow water. Stands of the grass can grow so dense that it alters the hydrology and prevents passage to humans, fish, and birds. It would be of particular concern in Oswego Lake in the canals in and Lakewood and West Bays. Reproduction can occur with seeds or via rhizome fragments so effective control methods tend to be labor intensive and tedious. Common reed occurs in numerous places in Oregon, including along the lower Columbia River and at Smith and Bybee Lakes in north Portland. These stands have not yet been identified as to which lineage (native or not) they belong to. Dispersal mechanisms involve water, wind, wildlife, or humans. The most common means is likely water currents and flood events transporting root fragments.

Purple loosestrife (*Lythrum salicaria*)
Purple Loosestrife is an erect (1-2 meters high) perennial herb that produces tall spikes of showy purple flowers. It grows in swampy areas and along the margins of lakes and streams and has the ability to completely choke out shallow areas or form dense stands along the shore. This growth pattern crowds out native plants and can interfere with human uses of the water. Purple loosestrife is very common in northwestern Oregon and currently a class "B" noxious weed in

the state. It would be most problematic in Oswego Lake in very shallow areas or places where populations could limit access from the bank to the water.

Carolina fanwort (*Cabomba caroliniana*)
Native to South America, Carolina fanwort was likely introduced to the United States as an aquarium plant. It survives both rooted and free-floating and produces small (1/2 inch) white, pink, or purple flowers in the summer that float on the surface. The plant propagates from both rhizomes and plant fragments and forms dense mats under suitable conditions. Fanwort is known to occur in side channels of the lower Columbia River and in Cullaby Lake on the northern Oregon coast (Gibbons et al. 1994).

Priority Class 2 – Moderate Threat

These organisms generally become less of a nuisance than the previous group. Nevertheless, they could be problematic in Oswego Lake and control measures would be considered if their populations flourished.

Water hyacinth (*Eichornia crassipes*)
This free-floating aquatic plant has thick, glossy leaves and produces showy lavender flowers. Under ideal conditions, it is reported to be among the fastest growing known plants in the world forming thick mats across waterways. One small population was discovered near Camas, WA in ponds artificially warmed by industrial processes, but it is unclear if it can survive in the relatively cool climate of the Pacific Northwest (WA Dept. Ecology 2009). The plant otherwise occurs predominately in southern regions of the United States with the next closest population occurring in central California. Water hyacinth is still sold locally in many aquatic gardening stores and the utmost caution should be taken to ensure it does not enter other water bodies.

Pond water-starwort (*Callitriche stagnalis*)
Water-starwort is a small rooted aquatic plant that produces oval shaped floating leaves and tiny flowers. It commonly grows in soft sediment along the margins of lakes, canals, and sloughs. Water-starwort is currently distributed in isolated populations throughout northwestern Oregon, though its ability to become a serious nuisance is low.

Bighead and silver carp (*Hypophthalmichthys noblis* and *H. molitrix*)
These Asian carp species escaped into the Mississippi River system from aquaculture activities. Both are filter feeders and commonly achieve weights of over 15 kg in nutrient rich water. Silver carp have a natural reaction to leap as far as 3 meters into the air when spooked which creates a dangerous situation for boaters who are routinely struck by them. Both species are becoming prevalent in the Mississippi and Missouri River drainages but there have also been isolated findings of bighead carp in California and silver carp in Colorado and Arizona. Each are known to be hardy fish but they are thought to only spawn in moving water so it is unclear if they would threaten Oswego Lake if introduced.

Toxic cyanobacteria (*Cylindrospermopsis raciborskii*)
Little is known about this species of blue-green algae. It is thought to be native to tropical regions, but there have been increasing reports of its occurrence in the United States and the OISC has included it on the 100 Worst List. Like some other cyanobacteria, this species is

known to produce toxins that can be harmful to humans (Jones 2005). This species does not form a scum on the water surface like some algal species when in bloom, but it produces a brown tint to the water that is often located in discrete bands below the surface. *C. raciborskii* is very small compared to other algal species as it is 3 - 11 µm long and 2-3 µm wide. Because of this small size they are often missed in plankton tow samples by passing through the mesh.

Golden algae (*Prymnesium parvum*)
This yellow-green algae can be toxic to both humans and fish and is also on the OISC 100 Worst List. It has been responsible for massive fish kills in Texas and elsewhere in the world. Scientific understanding of the range and effects of this species is limited, but it is known to occur in eutrophic, alkaline waters across temperate zones of the world. The closest known populations in the United States are in Colorado, New Mexico, and Arizona. When in bloom, golden algae turns the water a coppery-brown color and may release the toxin prymnesin. The environmental conditions that initiate these blooms are not well understood.

Chinese mystery snail (*Cipangopaludina chinensis*)
Mystery snails are large (up to 65 mm) freshwater snails native to South East Asia. Initially brought to the United States as a food item in the late 1800s, they are commonly sold in the aquarium and water garden industry. They now occur in at least 27 states, including Oregon, California and Washington and are thought to spread via people dumping their aquariums or escaping from water gardens. These snails are a concern because they are a known vector of numerous parasites and diseases that can affect humans their native ranges (including swimmers itch), though these effects have not been well documented in North America.

Priority Class 3 – Lowest Threat

These organisms may become a nuisance or detriment to native wildlife and vegetation, but control measures would likely be impossible or unwarranted.

Watercress (*Nasturtium officinale*)
Watercress is a commonly used as a salad herb by humans but is also can be an aquatic nuisance due to its ability to choke out shallow waterways. It occurs throughout Oregon and is known to be problematic near Eugene.

Asian tapeworm (*Bothriocephalus acheilognathi*)
Asian tapeworm is a harmful parasite that prefers cyprinid fish (carp family). Though it can be detrimental to these species, it is not known to be harmful to humans and likely would not affect the sportfish (largemouth bass, crappie, bluegill) present in Oswego Lake.

Fishhook water flea (*Cercopagis pengoi*) and Spiny water flea (*Bythotrephes cederstroemi*)
Native to Eastern Europe, spiny water flea appeared in the Great Lakes in the 1980s and fishhook water flea later in the late 1990s. Both are successful predators of smaller zooplankton and can outcompete planktivorous fish for this food source. They also have long spiny tails that make them difficult for young fish to eat. Selective grazing pressure by these species is also thought to contribute to harmful algal blooms. Their known range in North America does not extend beyond the Great Lakes region.

Ringed crayfish, Rusty crayfish (*Orconectes rusticus* and *O. neglectus*), Red swamp crayfish (*Procambarus clarkii*), and Marbled crayfish (*Procambarus marmokrebs*)
Ringed and red swamp crayfish are already established in Oregon. All of these species are extremely hardy and can outcompete native crayfish, reduce aquatic vegetation, and cause damage to banks due to burrowing. Red swamp crayfish is a prized food item and grown in aquaculture in parts of the southern United States. Marbled crayfish are unique because it is parthenogenetic; all individuals are female and can reproduce asexually. It was discovered in the aquaria trade and has since been introduced into Europe and Madagascar and thought to be a serious potential pest.

Black carp (*Mylopharyngodon piceus*)
Black carp are native to eastern Asia and were introduced to the United States accidentally from grass carp stocks. They are now used in aquaculture in the southeast United States. Black carp feed on mollusks and have become problematic in several regions of the Mississippi River.

Muskellunge and pike (*Esox* spp.)
Muskellunge and pike are voracious predators and prized gamefish in parts of the United States. They currently do not exist in Oregon and could be detrimental to established fish populations.

Round goby (*Neogobius melanostomus*) and Amur goby (*Rhinogobius brunneus*)
These two small fish species have been shown to displace native species in the Great Lakes region. Two instances of Amur goby have been found in the Columbia River watershed, but the fish have an amphidrominous life history (juveniles go to sea) so they are unlikely to survive in Oswego Lake. Round goby have the positive effect of preying on zebra mussels, but their influence has not been shown to control mussel populations in North America.

Ruffe (*Gymnocephalus cernuus*)
Ruffe is another small fish species that has become problematic in the Great Lakes region. Its effects would be limited to impacting existing fish populations in Oswego Lake.

Snakehead (*Channa* spp.)
Snakeheads are a predatory fish native to Asia that have the unique ability to breathe air for several days if necessary. They have been found in California and several Eastern states. Snakeheads can reach over one meter in length and have been shown to severely disrupt food chains due to their prolific predation. They are able to tolerate a wide range of environmental conditions and are capable of reproducing quickly.

Oriental weather loach (*Misgurnus anguillicaudatus*)
This small eel-like fish already exists in the lower Willamette River. It is sold in the aquarium trade and can displace other fish.

Banded killifish (*Fundulus diaphanous*)
The small (<13 cm) banded killifish is well established in the lower Columbia and Willamette Rivers. It is native to eastern regions of North America.

Mosquitofish (*Gambusia affinis*)
Mosquitofish are small (7 cm long), aggressive fish that is native to the Southern and Eastern regions of the United States. They have been distributed all over the world due to their reputation to prey on mosquito larvae. The actual efficacy of this is debated, but mosquitofish have become a nuisance in many places by having other deleterious effects to desirable fish and insects.

Viral hemorrhagic septicemia virus (VHSv) (*Novirhabdovirus* spp.)
VHSv is a pathogen that causes mortality in fish species. Since 2003, fish kills in the Great Lakes and eastern Canada have been linked to VHSv. The virus is included in the 100 most threatening invaders to Oregon and could impact gamefish in Oswego Lake. There is no evidence that this disease is harmful to humans (CFSPH 2007).

Snapping turtle (*Chelydra serpentina*)
This non-native turtle competes with native turtles and amphibians. Isolated occurrences have been reported throughout Oregon. Snapping turtles can harm humans with their severe bite, though this is usually only a risk if someone attempts to handle one.

Invasive and Nuisance Species Already Established

Brazilian elodea (*Egeria densa*)
This problematic weed may have escaped into the lake from an adjacent water garden. It was first noticed by LOC staff in the summer of 2001. It now occurs in numerous regions of the lake and forms thick mats in the summer. It is controlled with herbicides and handpulling. Of the existing invasive species in Oswego Lake, this one poses the most significant threat. Additional recommendations for control are discussed later.

Curlyleaf pondweed (*Potamogeton crispus*)
Curlyleaf pondweed is another aquatic weed that is a nuisance in Oswego Lake. It is also ubiquitous in shallow areas and controlled by the LOC with herbicides and by mechanical removal.

Yellow flag iris (*Iris pseudacorus*)
This exotic species grows near the bank and produces showy yellow flowers. Yellow flag iris is a class B noxious weed in Oregon and has the potential to take over shoreline areas. The plant occurs in patches in shallow areas across many regions of Oswego Lake. These populations have the potential to become a problem in the canals and at the narrow entrances to West Bay and Lakewood Bay. The LOC currently undertakes no measures to control it.

Fragrant Water Lily (*Nymphaea odorata*)
This water lily has large floating leaves and attractive pink or white flowers. It is native to the eastern United States but is now commonly found throughout the country. The natural beauty of the plant and ease of cultivation make it popular in water gardens and ponds. However, when introduced into larger bodies of water it can dominate shallow areas by forming dense surface mats. Fragrant water lily was first observed in Oswego Lake several years ago (Mark Rosenkranz, personal communication) and now is distributed sporadically across shallow areas of the lake.

Asian clam (*Corbicula fluminea*)
Asian clams are common in the Columbia and Tualatin River systems. Like the zebra mussel, this mollusk can grow in dense colonies that foul infrastructure and pipes. In Lake Tahoe, the clams exist in patchy densities up to 3200 clams/m^2 in water up to 32 meters deep, with the greatest densities occurring between 3 and 10 meters (Wittmann et al. 2008). Observed populations in Oswego Lake are widespread, but have not been reported in these problematic densities. There is a potential that denser populations may exist in deep water in Oswego Lake and have so far gone unnoticed. The upcoming drawdown in 2010 will be a good indicator of this. Large numbers of Asian clams can also increase calcium concentration in the sediment due to the accumulation of dead clam matter (Vermeij 1994), which may indirectly increase the risk for zebra and quagga mussel survival.

Nutria (*Myocastor coypus*)
Nutria are large rodents, sometimes confused for beavers, that can be identified by their orange teeth front teeth and thin tails. They are becoming increasingly common in the Willamette Valley and are destructive to riparian areas due to their burrowing and feeding activities. Nutria can carry diseases and pathogens that are transmittable to humans and pets (Sheffels and Sytsma 2007). They are sporadically seen in Oswego Lake and the LOC or property owners trap them when possible.

Red-eared slider (*Trachemys scripta elegans*)
This exotic turtle is found throughout Oregon and competes with native turtles and amphibians. Red-eared slider's range expansion has been aided by the fact that they are common pets and sometimes released by humans.

Cormorant (*Phalacrocorax auritus*)
Cormorants are native to Oregon, but they are considered a nuisance in Oswego Lake due to their ability to denude trees, dirty property, and consume large amounts of fish. The LOC currently uses harassment tactics to control cormorant populations.

Vectors of Species Introduction

Overview

A wide variety of vectors exist for invasive species to reach Oswego Lake. Aside from the natural 4520-acre watershed, Oswego Lake draws water seasonally from the Tualatin River, which has a watershed approximately one hundred times larger and is fed from the highly-used Henry Hagg Lake. Any aquatic nuisance species occurring in this expanded basin is logically a potential threat to Oswego Lake, though the fish screen on the headgate on the Tualatin River should prevent fish and large plant fragments from directly entering the lake. Additionally, there are known mechanisms that enable species to be transported great distances and across natural barriers so proximity and interconnectedness are not the only risks.

The three most significant vectors of introduction to Oswego Lake are the Tualatin River, water gardens, and recreational boating. The latter of these has the potential to transport organisms (including *Dreissena* mussels) long distances. Zebra mussels have been shown to survive overland journeys of five days or more attached to boats (Ricciardi 1995). They and other organisms would likely survive much longer if contained in water in a ballast tank or livewell. Accidental or intentional species release by people either from private property or one of the points of public access is also a risk that warrants concern.

The following is a list of the known vectors recognized in the scientific literature (Carlton 1993, Johnson 2001, Mackie 2008, US EPA, USDA) that are present in Oswego Lake. They can be broadly grouped into three categories: natural vectors, unintentional anthropogenic vectors, and intentional anthropogenic vectors.

Natural Vectors

- Insects, fish, mammals, or waterfowl

  The headgate at the Tualatin River has a fish screen that prevents the transit of fish. There is no other natural way for fish to enter lake. Birds and other animals can transport macrophytes, algae, zooplankton and other small organisms. The potential of waterfowl to transport zebra or quagga mussels is very low (Johnson and Padilla 1996). It is nearly impossible to prevent birds and other animals from entering the lake, but the LOC should remain aware of invasive species currently in surrounding areas.

- Water currents and connected waterways

  The Tualatin River and connected Henry Hagg Lake are potentially a source of many aquatic invasive species. The fish screen on the headgate should prevent fish and large plant fragments from entering Oswego Lake, but it would not keep out organisms that have a planktonic larval stage (like dreissenid mussels). Two small streams, Springbrook and Lost Dog (with catchment areas of 1253 and 798 respectively) directly feed Oswego Lake and are another potential source of exotic species.

- Wind

The topography and climate around Oswego Lake make waterspouts (wind driven phenomena known to transport planktonic organisms) unlikely. Other species of concern are not likely transported by wind.

Unintentional Anthropogenic Vectors

- Recreational boating

  This is likely the most probable mechanism of introduction for many species of concern, especially *Dreissena* mussels and aquatic plants. Seven specific mechanisms of zebra mussel transport by boaters were recognized in a scientific paper (Johnson et al. 2001). They are: (1) adults attached to exterior hull or motor, (2) adults attached to anchors or material snagged by the anchor, (3) adults attached to aquatic macrophytes entangled on the boat or trailer, (4) larvae in engine cooling water, (5) larvae in bilge water (6) bait buckets, and (7) live wells. Of these, the authors found that transport in live wells and by attaching to entangled macrophytes were the most common means of transport of zebra mussels. Ballast water held in special wakeboarding boats common on Oswego Lake is another mechanism that should be recognized. The potential for Oswego Lake boat owners to travel to regions of the Southwest known to have *Dreissena* mussels makes this threat very significant. The mandatory boat decontamination policy set forth by the LOC should negate this risk if properly implemented.

- Construction / contractors working on lake

  Watercraft used by non-LOC entities for construction or repair purposes can also transport invasive species. The LOC currently requires cleaning of all watercraft prior to working on the lake. Other equipment used in the water such as dredges and backhoes should be cleaned as well.

- Scientific research

  Though inadvertent, there are documented cases of researchers spreading invasive species. This is unlikely on Oswego Lake due to the low frequency of research activities by outside agencies.

- Storm drains

  4250 acres of the surrounding area contains storm drains that discharge directly into Oswego Lake. Any organism entering a storm drain could enter the lake.

- Water gardens

  Private water gardens commonly contain exotic plants and/or fish that can be discharged to surrounding waterways during storm events or transported by birds and animals. This is a particular concern for lakeside property owners. Regulations about the sale of prohibited plant species are poorly enforced and the public can easily purchase (many times unknowingly) highly invasive or prohibited plants. The LOC preformed a survey of water gardens surrounding the lake in 2001. This survey is now out of data and it should be repeated.
- Fishing activities

Recreational fisherman releasing bait or using fouled gear is a known vector. Parasites and disease can enter the lake from fish stocking, though the LOC does not stock fish normally. Neither the Oregon Department of Fish and Wildlife nor the LOC currently enforce fishing state fishing regulations on Oswego Lake. The LOC has no stated regulations beyond those of the State of Oregon. This Plan later suggests that the LOC should monitor fishing activities and enforce regulations set by the State of Oregon.

- Diving gear

  Diving gear can get fouled by aquatic invaders and poses a risk if divers travel from one body of water to Oswego Lake without cleaning their gear and/or allowing it fully desiccate. The LOC should require all divers (either recreational or professional) to clean their gear before entering Oswego Lake.

- Seaplanes

  Seaplanes can transport small organisms in water trapped in pontoons or transport macrophytes attached externally. Seaplanes very infrequently land on Oswego Lake so this threat is minimal.

- Aquaculture

  Escape or inadvertent release of fish or plants from aquaculture projects is a minimal threat to Oswego Lake due to the lack of proximity of any aquaculture activities.

Intentional Anthropogenic Vectors

- Released for sport

  This is a primary concern for exotic fish species. Largemouth bass and other warmwater fish species may have entered Oswego Lake via this vector, though they also could have entered from the Tualatin River before the fish screen was present.

- Released for food

  Though some invasive species (watercress, mitten crab, crayfish) are used as a food item, the probability of an intentional release in Oswego Lake is low.

- Aquarium / pet release

  This is a common problem across all waterways and is difficult to prevent. Common species released are turtles, fish, and crayfish. Education of community members about the dangers of releasing pets and aquariums is key to minimizing this threat.

- Biocontrol

  Biocontrol agents are organisms that are released to control other organisms. Sometimes the biocontrol agents themselves pose a problem. This is unlikely a concern as the LOC does not employ any biocontrol and biocontrol agents used by outside agencies nearby are not known to be problematic. The potential release of biocontrols by private citizens is a concern that can be addressed through education.

- Religious or cultural practices
  Certain cultural traditions involve releasing live organisms into the environment. This is generally an unlikely vector.

- Sabotage
  This is highly unlikely in any waterbody, but the unique status of Oswego Lake being a limited access waterbody, located in a generally affluent community might increase this risk.

Prevention Strategies

Outright exclusion of new invasive species is by far the most cost-effective management approach. It is also the most environmentally sensible because it prevents additional stress to desirable organisms and does not require harsh chemicals or disruptive physical control methods. Successful prevention requires an integrated approach that focuses on known vectors and promotes public outreach and education. The following recommendations will help the LOC direct their prevention efforts to maximize efficiency and resources.

Specific Recommendations for Prevention

Ensure proper boat cleaning

Recreational boating is one of the highest risks for invasive species introduction. The LOC has developed a boat cleaning protocol that reflects the best management practices to prevent aquatic invasive species being from transported by boat (Appendix 2). It is imperative that this protocol be followed exactly with each boat that is launched on Oswego Lake that was previously on another waterbody. There is currently no system in place to monitor if boats are properly cleaned. The LOC could explore using a carbon copy receipt with a checklist completed by the boat washer of each required point to help ensure that this is done. Additionally, staff of the LOC and third party contractors that wash the boats could seek specialized training from the Oregon State Marine Board in boat washing techniques.

A recent scientific paper (Morse 2009) found that hot-water spraying might be less effective at killing zebra mussels attached to watercraft than previously thought. This study found that continuous spraying with water at ≥ 60°C for ten seconds or ≥ 80°C for five seconds is needed to achieve 100% mortality. With a one second wash at 80°C, 97% of the mussels survived in the study. The study found that 99% mortality could be achieved with a five second spray at 69.1°C (156.2 °F). The LOC boat cleaning protocol recommends spraying with water heated up to 82°C (180°F). The findings of this study corroborate that the current policy could be effective in killing attached mussels with sufficient (≤ 5 seconds) contact time with hot water.

The use of chlorine as originally recommended in the decontamination protocol is not being practiced by the boat washing contractor due to feared damage to watercraft. The Center for Lakes and Reservoirs at PSU currently uses a 1% iodine solution to flush the engine cooling system and bilge of their sampling boats (Steve Wells, personal communication). Flushing with chlorine or iodine is the most effective way to ensure that any organism being transported within the boat is killed. However, thorough flushing with water alone may be sufficient and has no risk of damaging the watercraft. Flushing with hot water is more effective than unheated water.

Enforce fishing regulations

Numerous invasive species are directly associated with recreational fishing. The Oregon Department of Fish and Wildlife does not monitor activity on Oswego Lake, though the regulations they set still apply. The LOC should be aware of state fishing regulations and their importance in preventing the introduction of invasive species. Some of the key regulations designed to prevent invasive species are:

- No live fish or crayfish can be used as bait. Amphibians will likely also be illegal to use in years to come.
- No unauthorized fish stocking. This will be up to a Class C felony in Oregon starting in 2010.

  > ORS 498.222 "No person shall: (a) Transport any live fish unless the person has first obtained a permit therefore from the State Fish and Wildlife Commission. (b) Release or attempt to release into any body of water any live fish that was not taken from that body of water, unless the person has first obtained a permit therefore from the commission."

Update survey of water gardens along lake and retailers in the vicinity

Some properties along the lake have decorative water gardens. Heavy rains and birds and wildlife can transport these plants into Oswego Lake. Many plants used in these water gardens can become a serious nuisance if they establish in the lake. Brazilian elodea was likely introduced into Oswego Lake by this vector. The LOC did a survey of water gardens surrounding the lake in 2001, but that information is now out of date. It would be advantageous for the LOC to repeat this survey. This would also provide an additional platform for outreach to shareholders about the dangers and vectors of invasive species introduction. The LOC could additionally survey garden retailers in the vicinity to ensure they are not selling invasive aquatic weeds. This would also enable the LOC to make recommendations to shareholders about where to purchase non-invasive plants for their water gardens.

Educate staff about invasive species and corresponding LOC policy

All levels of staff at the LOC should have a basic knowledge of the risks and vectors of invasive species. Employees that work at the marina who interact with shareholders should be able to respond to questions and comments regarding invasive species risks and corresponding LOC policy. Staff working on the water should be on the constant lookout for new exotic species or changes in abundance of existing ones. All LOC staff should be vigilant for situations and activities which could lead to the introduction of invasive species (e.g. unauthorized boat launches, aquarium dumping, etc).

Educate shareholders about invasive species

Successful prevention and mitigation of invasive species in Oswego Lake cannot be achieved by the LOC's effort alone. The shareholders that use and enjoy the lake should be educated about ways they can help prevent the introduction of exotic species and monitor for their presence. The LOC should continue to expand opportunities for outreach and education. This could be achieved by visible signage at the marina and easements, brochures, newsletters, and presentations at shareholder meetings. Education topics could include:

- Rationale for boat cleaning process
- Ways lake users could accidentally introduce invasive species
- Key species to look out for
- How to report a sighting

Monitoring Strategies

Though outright exclusion is the cornerstone of this Invasive Species Management Plan, some exotic species may evade prevention efforts. There is commonly a lag time between when an exotic species is introduced and when it becomes a pest. This lag time provides resource managers a key window to eradicate an invading species when the population is still small (Lodge 2006). However, there in an inverse relationship between sampling effort and population size. Limited sampling ability and small population numbers make monitoring for insipient invasive species difficult (Welk 2004). Monitoring efforts should thus be as comprehensive and efficient as possible to maximize the likelihood of successfully identifying new organisms. The following specific recommendations would help the LOC improve their monitoring efforts.

Zebra/Quagga Mussels

Deploy artificial substrates

The Center for Lakes and Reservoirs (CLR) at PSU makes low cost artificial substrates that can detect juvenile and adult mussels. The LOC used to deploy these but has stopped in recent years. The simple substrates consist of a section of perforated PVC pipe that is suspended below a dock or buoy. These are then pulled up slowly and visually checked every month for attached mussels. Newly settled mussels can be very small (<1 mm) and a magnifying glass can help identify them. The person monitoring should also feel the substrate for a gritty texture. Numerous other things can cause this gritty texture as well and if that is found, contents of the surface should be scraped into a plastic bag, along with a cotton ball soaked in rubbing alcohol, and sent to the CLR for further analysis. The LOC marina is an obvious location to place the substrates, but several could be deployed across Oswego Lake and the canals to increase the likelihood of detection.

A database of the locations of deployed substrates in the broader region is maintained by the CLR to assist with inter-agency coordination and to identify gaps in monitoring. Every additional substrate deployed increases the monitoring power of the area. Artificial substrates are currently deployed in Henry Hagg Lake, upstream of Oswego Lake on the Tualatin River.

Monitor existing substrates

Zebra and quagga mussels prefer to grow on hard substrates like rocks, gravel, bulkheads, and dock pilings. Visual surveys of suitable habitat should be done routinely by LOC staff, especially when water levels are low. Surveys with snorkeling and diving gear or underwater cameras do not necessitate lower water levels, but are more difficult and expensive. Particular attention should be made to the headgate structure and hydropower plant, as those are places mussels could colonize first if originating from the surrounding watershed.

Veliger monitoring

Veligers are the larval form of zebra and quagga mussels. They are free swimming and likely to be the life stage that colonizes a new area due their ability to be transported by water currents or humans. Veligers are more difficult and expensive to detect than adults. Nevertheless, monitoring for this stage is the most effective way to discover an incipient population and provide an opportunity for effective rapid response. Lake Granby Colorado is an example of this detection method working. Quagga mussel veligers were discovered in the lake in July 2008.

Surveys to look for adult populations that must have produced these veligers have so far come up negative.

The CLR at PSU currently has a draft Workplan (Sytsma and Wells, in progress) that extensively covers veliger-monitoring protocol. The method suggested in the Workplan utilizes a plankton tow net, like the ones the LOC already uses for their routine plankton surveys, and special microscopy methods for identification. The LOC could adjust their current plankton tow procedures to additionally monitor for zebra/quagga mussels if the person analyzing the water samples was properly trained. PSU could also provide this analysis for a fee.

Key points of the PSU Veliger Monitoring Workplan (draft) include:
- Plankton tow nets should have 63 micron mesh
- Samples should be collected by boat
- As many tows as possible should be done at each site and combined into one container that is preserved with 70% ETOH
- More samples increase likelihood of detection
- Plankton tows should be done in several areas across the lake, focusing on boat launches, dams, intakes, outflows, and down wind areas
- The optimal time to sample is when water temperatures are between 16° and 19°C
- Polarized light microscopy and training in veliger identification are needed to analyze water samples

Other Species / General Monitoring

Systematic Macrophyte Surveying
Regular systematic macrophyte surveys would help the LOC monitor the curlyleaf pondweed and Brazilian elodea currently in the lake as well as detect new species that may establish. Ideally, surveys would be done twice in the year, once in June and again in August. Survey locations should cover both random points around the lake as well as known problematic locations. If a new species is detected and thought to be problematic, additional surveys with SCUBA divers could give a more accurate picture of the invasion. The following techniques will maximize the utility of macrophyte surveys:
- Use a stratified random sampling design
- Sample a wide variety of locations, substrate types, and depths
- Identify all plants to the species level
- Do extra sampling in high risk areas (e.g. boat launch, canal to Tualatin)
- Record frequency of occurrence for each species
- Record spatial data to track historical trends and particularly note problematic areas
- Sample the entire depth range of possible growth and establish maximum depth of colonization

Benthic Grab Samples
Sampling sediment could help the LOC detect New Zealand mud snail, zebra and quagga mussels, Asian clam, and Asian mystery snail. Benthic sampling devices (e.g., Eckman and Ponar dredges) are widely commercially available. Sediment samples should be filtered with a

500 µm mesh sieve and samples can be preserved in formalin for later analysis if needed. Larger sieve sizes can be used, but would not effectively capture mud snails. As with zebra mussel veliger monitoring, the more samples collected increases the detection power.

Vigilance by LOC Staff

All members of the LOC staff that spend time on the water should have a basic understanding of the status of existing aquatic nuisance species and be on the constant lookout for new exotic species or changes in the distribution of existing species. Marina staff should ensure that all boats entering the water have been decontaminated according to established LOC protocol.

Volunteer Monitoring by LOC Shareholders

Shareholders spend the vast majority of time on Oswego Lake and can take an active role in invasive species monitoring with a little training and encouragement. The LOC should encourage them to report any suspicious organisms or changes in weed growth they observe. If shareholders are participating and thinking about monitoring they might also be less prone to actions that result in exotic species introduction (e.g. dumping aquariums into the lake). They can also help by participating with the zebra mussel artificial substrate program.

Response Plans and Control Methods

Rapid response measures are essential for the LOC to implement if an exotic species is discovered that has the potential to become a nuisance. Effective control and eradication is most feasible and economical early in the invasion process. Rapid response measures additionally can help contain an invasion and prevent spread to other unaffected waterways. Though the specific response actions taken will differ depending on the situation, the same basic strategies should be followed to initially respond and develop appropriate control measures.

Steps in Rapid Response for Oswego Lake

(1) Confirm identity of exotic species

If LOC staff is unsure about the identity of the species, expert staff at PSU's Center for Lakes and Reservoirs should be consulted. A picture with something for size reference (coin, or key) could be sent or the sample could be preserved in alcohol and transported to the center directly for analysis.

(2) Inform relevant agencies if necessary

Depending on the species, other state agencies may be required to be involved with the response. The first step is to call the Oregon Invasive Species Hotline: 1-866-INVADER (1-866-468-2337). This call will be taken by the Oregon Invasive Species Council and other agencies will be notified if needed.

(3) Determine scope of invasion

Surveys should be done in the area of detection and elsewhere in the lake to characterize the distribution and density of the exotic species. This could be aided with SCUBA divers if appropriate.

(4) Prevent further spread and contain invasion

All possible efforts to contain the invasion and prevent spread to other waterways should be enacted. This step can be done simultaneously with step three. This may involve not drawing water from the Tualatin River or releasing water to the Willamette River. If the invasion is localized, aquatic curtains could be deployed to contain the invasion. This method has been utilized by the Washington Department of Ecology and is discussed later in this section. Additionally, appropriate measures should be enacted to ensure boats leaving the lake are not transporting the organism.

(5) Formulate and implement response strategy

Appropriate control strategies should be developed and implemented with the primary goal to eradicate the invasive species if possible. Specific control measures are outlined in the next section of this report.

(6) Monitor efficacy

Depending on the nature of the invasion, control may take weeks, months, or even years to be successful. It is imperative that the LOC regularly monitor the efficacy of any response plan that is enacted.

(7) Adjust response if necessary and continue to monitor

Response measures should never be viewed as static. Adjustments to control strategies should be enacted if the method is unsuccessful, or changes in population densities warrant another tactic. Monitoring should continue after any response adjustments and these steps should be looped until the species is eradicated.

Overview of Control Methods

This section outlines control measures and their suitability for high priority invasive species. New methods are continually being established and evaluated and regulations governing their use are prone to change. This section is designed to provide an overview of applicable methods and should not be considered comprehensive. References to more detailed and specific response plans are noted when appropriate.

Zebra/Quagga Mussels and other Invertebrates

Chemical Treatment

A variety of chemical compounds and application methods are effective in killing zebra and quagga mussels. The only documented example of a complete extermination in a water body is a 12-acre quarry pond in Virginia that was injected with a potassium chloride solution. The chemical was injected over a three week period, with concentrations reaching about 100 mg/L (well below the limit that causes human or other environmental harm). The operation was successful, but had the distinct advantage of the pond being small and not connected to other waterways. It also carried a price tag of $365,000, making it financially unfeasible in larger waterways.

Currently, most chemical treatments are used in closed systems and piping where lethal concentrations are easier to achieve and collateral environmental damage is minimal. There are numerous effective chemicals and molluscicides in use. Many are chlorine based, a compound that is safe for humans and other organisms and does not bioaccumulate. Research is currently being done on the efficacy of endothall, a common herbicide. Use of endothall could have collateral effects by harming aquatic plants and other organisms as well, and research of its suitability would need to be done prior to application.

Mackie (1995) tested the efficacy of alum in removing zebra mussel veligers from raw water supplies. The LOC already uses alum throughout the lake to treat excessive phosphorus levels that sometimes develop. The tested concentrations of alum were not sufficient to be acutely toxic to the larvae, however the physical flocculation process did remove a percentage of the veligers from the water column. Alum is thus not a reliable control method, but it not counter productive.

Curtains or Barriers

Barriers can be made around a population of mussels to deliver a localized chemical application without impacting the surrounding water. It has been attempted for other species (aquatic plants in Washington State) but its efficacy for zebra mussels is unknown. This approach would be most effective for an isolated concentrated population of mussels or the removal of mussels from a high priority area. The 2008 Lake Pueblo Zebra Mussel Response plan predicts costs and logistical considerations would be high for this method.

Physical Removal

Removal by hand has shown to be an effective method in removing zebra mussels from Lake George, New York, where divers removed 19,000 mussels in 2000. Follow up removal efforts yielded less than 2000 mussels per year, showing hand-removal alone was successful in significantly decreasing the population. Concurrent use of suction machines can aide in removing harvested mussels, though they usually are not powerful enough to remove the mussels alone. Hand harvesting can be expensive, but it has minimal collateral damage to other organisms.

Drawdown

This might be one of the most effective and cost efficient methods to control an established population of mussels in Oswego Lake. The LOC is able to manipulate water levels on Oswego Lake and a drawdown of 20 or more feet is possible. Ricciardi (1995) tested various desiccation scenarios and found logically that mussels died out faster in warmer and less humid environments. More than 50% of large mussels (21-28 mm) died after 5 days of exposure at 20 ˚C and 95% relative humidity. At the same temperature, mortality increased to 83% in 50% humidity and 100% in 10% humidity. At 30˚C all mussels died in 5 days regardless of humidity. Payne (1992) also demonstrated that exposure to cold can be lethal to zebra mussels. In that experiment, 100% mortality was achieved after 48 hours of continuous exposure at 0˚C. These results suggest that a drawdown in the warm summer months or during a cold spell in winter could be successful at greatly reducing mussel densities. Exposed mussels can additionally be removed from surfaces by blasting with high-pressure water, sand, or carbon dioxide pellets. There have been no known examples of drawdown alone completely eliminating mussels.

Biocontrol

Numerous biocontrol agents are being tested for efficacy in controlling dreissenid mussels. These agents would likely not have a dramatic short-term effect in mussel populations nor be suitable in Oswego Lake at this time.

Anti-fouling Paints

Several commercially available anti-fouling paints are available and can be applied to specific surfaces where mussel colonization is not desired. These compounds are expensive and have non-target effects, but could be useful in places like the trash screen covering the outlet to the flume line or on the headgate intake structure.

Heat

Exposure to hot water is lethal to zebra mussels. The heat required to achieve 100% lethality of submersed mussels depends on the temperature the mussels are acclimated to. McMahon (1995) estimated that zebra mussels acclimated to 20˚C could be completely killed if instantly exposed to water at 38˚C. Other aquatic species such as the seaweed *Undaria pinnatifida* have been controlled effectively by this method. Heating open water can be achieved by numerous methods, including heating elements, modified cutting torches, and directly applying superheated steam or water. Commercial solutions for heating piped systems are available and have proven effective in controlling mussels.

Hot water can also be used to kill emersed mussels like those attached to a trailered boat. A recent scientific paper (Morse 2009) tested the temperature and exposure time needed to achieve lethality. The paper reports that continuous spraying with water at ≥ 60°C for ten seconds or ≥ 80°C for five seconds is needed to achieve 100% mortality. Spraying with water at 69.1°C for five seconds was found to achieve 99% mortality. In contrast, spraying with 80°C water for only one second had minimal (3%) mortality. The paper suggests that hot water is effective in killing mussels if there is sufficient contact time(5-10 seconds), but is ineffective with short (<5 seconds) contact time.

Benthic Mats

Researchers in Lake Saratoga, New York, covered zebra mussel populations with four m^2 plastic mats and achieved over 99% mortality after nine weeks of covering. This technique shows promise to be a low-cost method with minimal side effects for controlling isolated populations of mussels.

Bury

Mussel populations can be buried with uninfested sediment using dredges. This method could create significant turbidity and release of nutrients and be difficult to implement in Oswego Lake.

Electrical and Acoustic Energy

Numerous technologies have been explored using low-voltage electrical fields and acoustic energy. Eight volt A-C current was shown to prevent mussels from settling, though it does not appear to affect veligers. Electrical currents that span two points can kill juveniles and also prevent mussel settlement, but it again was ineffective in affecting veligers (Smythe and Cooper 2003). Sound treatment, cavitation (acoustic energy that forms and collapses microbubbles), and vibration have lethal effects on all life stages of mussels, but could impact other organisms and pose structural risks (vibration) to man-made objects. All of these technologies show promise, but are too nascent to be implemented by the LOC at this time.

Control For Piped Systems

Effective strategies have been developed for preventing mussel settlement and damage to piped systems and water control structures. These strategies usually involve a combination of individual control elements like: mechanical filtration, anti-fouling coating, thermal treatment, mechanical cleaning, and chemical treatment. The headgate structure, outlet structure, and hydroelectric power plant would be particularly susceptible to damage from a zebra or quagga mussel invasion. If one were to occur, the LOC should immediately and routinely monitor each of these structures and implement appropriate control measures to maintain their functionality.

Macrophytes

General Control Methods

A multitude of techniques are available to control undesirable aquatic weed growth. Lake managers can use physical, mechanical, chemical, and biological methods, each with their own distinct strengths and weaknesses. Effective and responsible control for a given situation requires an approach that integrates the management objective, the target species, and possible collateral effects from the action. A ‘no control’ option should be considered as well when available control methods would have a net negative impact. The total "cost" of a weed infestation is difficult to quantify and goes beyond the scope of this Plan. An invasion of a plant like hydrilla would have state-wide implications and require larger scale consideration. Information on the management strategies in this section is drawn from the Blue Lake Integrated Aquatic Vegetation Management Plan (Pfauth and Sytsma 2004), the Guide for Developing Integrated Aquatic Vegetation Management Plans in Oregon (Gibbons et al. 1999), and best management practices for aquatic plant management as defined by the Aquatic Ecosystem Restoration Foundation (2005).

<u>Physical Controls</u>

Physical control methods include dredging, lake drawdown, bottom barriers, raking, and hand pulling and cutting (Table 1). Dredging is an expensive endeavor, but could be appropriate in the canals and shallow bays of Oswego Lake. The effects on weed growth would be temporary, but these sections would become deeper and more navigable. Drawdown can expose weeds leading to desiccation in warm weather or freezing in cold weather. It also can be combined with hand pulling for greater efficacy. This method is achievable and desirable Oswego Lake as regular (every three to four year) drawdowns are a part of LOC operations. A major drawdown of 22 feet is planned starting in September 2010 and this opportunity should be capitalized on as this will expose macrophyte beds not normally exposed by other drawdowns. Manual removal of Brazilian elodea and curlyleaf pondweed should take place as early as possible in that drawdown when the plants are still fully formed and easy to identify.

Bottom barriers are an effective way of limiting all plant growth in a small area, particularly around docks. Numerous homeowners have implemented bottom barriers with varying success. Bottom barriers need to be properly installed and to be effective. Hand pulling and raking is another inexpensive and effective way to clear around docks or swimming areas. This can also be done by shareholders themselves. Harvesting can also be done by SCUBA divers to clear areas in deep water or target specific species, although this method is costly and only feasible on a small scale.

Table 1. Summary of physical control options for aquatic weeds in Oswego Lake.

Method	Advantages	Disadvantages	Suitability
Dredging/Sediment removal	• Creates deeper water • Long-term results if water is deep enough	• Expensive • Releases nutrients • Must dispose of sediment	• Could be applicable in canals and shallow bays

Drawdown	• Inexpensive • Can be coupled with herbicide or hand pulling	• Reduces recreation opportunities and aesthetics	• LOC is already performs regular drawdowns • A major drawdown is scheduled for 2010 that should be capitalized on
Bottom barrier	• Site specific • Inexpensive • Available to individual homeowners	• Not species specific • Labor intensive • Barriers can interfere with recreation	• Should be installed in spring before growing season • Appropriate around docks and other high priority areas
Hand pulling / Raking	• Effective in small shallow areas • Can be done by individuals • Harvested plants can be composted	• Not effective for large areas	• Appropriate around docks and other high priority areas • Shareholders could perform themselves if desired
Diver harvesting	• Immediate effect • Permit not needed • Species specific • Can remove entire plant	• Difficult for large areas • Expensive • Additional suction dredge sometimes needed	• Could be used to control specific problem species if the need arises

Mechanical

Mechanical control involves techniques that utilize machinery to cut the weed or disturb the sediment so that it is unable to grow. Each of these methods can be effective, but they all can cause plant or root fragmentation which actually can promote the spread of some unwanted species. They also have a high initial cost and additionally might need permits to operate. The LOC owns and operates a mechanical weed harvester to reduce nuisance areas of curlyleaf pondweed and native elodea. This has the immediate effect of clearing the upper portion of the water column from the weed.

Table 2. Summary of mechanical control options for aquatic weeds in Oswego Lake.

Method	Advantages	Disadvantages	Suitability
Mechanical harvesting	• Immediate effect • Permit not needed • Minimum bottom disturbance	• Large, unsightly machinery • Plant fragmentation • Disposal cost	• LOC owns and uses weed harvester
Rotovation/ Cultivation	• Removes root structures	• Additional machinery needed • Creates turbidity and releases nutrients • Permit may be needed • Plant fragmentation	• Not appropriate due to possible nutrient release, target species, and difficulty in operating machinery in Oswego Lake
Sediment agitation	• Minimal effort once installed • Effective over time	• Permit may be needed • Expensive • Plant fragmentation	• Useful around private docks

Chemical

Herbicides can be less expensive than other plant control methods, but strict national and state regulations dictate their use. Herbicides can affect swimming, fishing, irrigation and other water use and chemical levels in the water need to be monitored after herbicides are applied. Public opinion can be strong regarding chemical usage and court cases have been known to affect the way herbicides are permitted to be used. The LOC currently has a permit from Oregon DEQ to apply fluridone and diquat and uses these with moderate success to control nuisance weeds currently in the lake. This permit will have to be renewed in 2010 if herbicide use will continue. Common chemicals used to control aquatic weeds are summarized in Table 3.

Curtains or other barriers can enable herbicide applications to a localized area to limit non-target effects. The Washington State Department of Ecology has utilized several different techniques to deliver isolated herbicide applications. In Lake Shoecraft (Snohomish County, Washington), two large patches of Eurasian water milfoil were growing in the lake. Silt curtains were deployed to completely isolate the areas milfoil and a treatment of fluridone was released inside the curtains. The curtains successfully contained the herbicide and the milfoil was completely eradicated inside the curtains (Kathy Hamel, personal communication). Further details about the operation are available on the Snohomish County website[1]. In Mason Lake, (Mason County, Washington) lake residents helped build small plastic ‘tents’ out of plastic sheeting and PVC pipes. These ‘tents’ were lowered on top of small Eurasian water milfoil patches with the aid of divers and the herbicide triclopyr was injected into the tent via a flap in the top. This method also worked and details of the operation are available on the Washington Department of Ecology Website[2].

Table 3. Summary of chemical control options for aquatic weeds in Oswego Lake.

Chemical	Advantages	Disadvantages	Suitability
Fluridone	• Sytematic - kills entire plant • Effective for underwater plants • Low doses needed • Minimal non-target effects	• Long contact time needed • Needs little water movement to be effective	• Already Used
Diquat	• Short contact time required	• Does not affect root structures • Non-target species affected • Short-term efficacy	• Already Used
Glyphosate	• Sytematic – kills entire plant • Effective for floating-leaved plants • No label restrictions on swimming and fishing	• Non-selective for species • Does not work for underwater plants like milfoil or hydrilla	• Not recommended at this time due to lack of appropriate target species
Imazypyr	• Effective for floating and emergent plants • Low toxicity to other organisms	• Restrictions on irrigation use post-treatment	• Not necessary for current problem species
Endothall	• Short contact time	• Does not affect root	• Has proven effective

[1]http://www1.co.snohomish.wa.us/Departments/Public_Works/Divisions/SWM/Work_Areas/Water_Quality/Lakes/Lake_Shoecraft_Milfoil_Control_Project.htm

[2] http://www.ecy.wa.gov/Programs/wq/plants/management/MasonLakeProject.html

	• Effective for some species • Low toxicity to fish • Can be used in small areas with pellets	structures • Potential use restrictions • Short-term efficacy • Should not be used with copper compounds	for Brazilian elodea
2,4-D	• Sytematic and selective • Effective broad-leaved species like milfoil • Fast acting • Low toxicity to fish	• Toxic to sediment dwelling organisms	• Not recommended at this time • Effective for milfoil, which is not present on Oswego Lake
Triclopyr	• Systematic– kills entire plant • Effective for broadleaved plants • No label restrictions for swimming and fishing	• Swimming restrictions needed after application • Not effective for curlyleaf pondweed	• Not recommended due to potential human impacts and lack of effect for target species
Copper compounds	• Inexpensive • Short contact time	• Accumulates in sediments • Can be toxic to mollusks and fish	• Not recommended due to potential non-target risks (including humans)

<u>Biocontrol</u>
Biocontrol involves using one organism to control another one. Biocontrol agents can be broken down into two groups: host-specific and generalists. Host-specific agents only feed on one target species and when that target species becomes unavailable or too sparse, the biocontrol agent dies. This type of biocontrol is ideal, but is unfortunately limited for submersed aquatic plants. Insects have been identified that have specificity to milfoil (*Acentria ephemerella* and *Euhrychiopsis lecontei*), hydrilla (*Bagous* spp. and *Hydrellia* spp.), and purple loosestrife (*Galerucela* spp.), but these invasive species do not exist in Oswego Lake at this time. Efficacy and potential adverse effects from these host-specific biocontrol agents and others are still relatively unknown and are not recommended for use in Oswego Lake at this time.

Generalist biocontrol agents are ones that feed on aquatic weeds indiscriminately. Sterile, triploid grass carp (*Ctenopharyngodon idella* Val.) are a commonly used as they will eat many aquatic weeds, though they usually exhibit a feeding preference depending on the mixture of plants available. The Oregon Department of Fish and Wildlife has strict regulations regarding the introduction of grass carp (particularly in regards to lake size and connectivity to other waterways) and it is unlikely the LOC would attain a permit to release them. Intermediate levels of control with grass carp are not feasible and consideration of their use is thought of as all or nothing. This is exemplified in Devils Lake, Oregon where they were introduced in 1986. Eight years later, the grass carp had consumed all macrophytes in the lake, which proved detrimental to the warmwater fishery there (Buckman and Daily 1999). Removing all the aquatic vegetation with grass carp could have other detrimental effects in Oswego Lake like increasing nutrient levels and turbidity and is not consistent with management goals.

Strategies and Case Studies for High Priority Species

Brazilian elodea (*Egeria densa*)

This species can be controlled effectively with the herbicide diquat. Parsons (2007) applied diquat to Battleground Lake in Clark County, WA in June 2003 achieving a maximum concentration of less than 90 ppb four hours after treatment. Brazilian elodea biomass was reduced more than 98% when checked again in August 2003 and was even less in May 2004. Two years after treatment in June 2005, biomass was still at less than 6% of the pretreatment levels. This treatment had minimal effects on other native macrophytes in the lake. The state of California has achieved effective control using copper compounds and fluridone. If fluridone is used, it should be applied in the spring to coincide with growth cycle of the plant. Mechanical harvesting is effective to clear surface mats and create open water for a limited time, but is generally not recommended because it spreads fragments of the plant which leads to additional spread. Additionally, summer drawdown was proven effective for this species in New Zealand reservoirs (Chapman 1972).

Specific Recommendation for Brazilian elodea:

Of the existing species currently present in Oswego Lake, Brazilian elodea has the greatest potential to become a serious nuisance. Brazilian elodea was surveyed in 2005 when the lake was drawn down and found to occur near the canals at the southwestern end of the lake and in the Lost Dog Creek delta. The plants found in the Lost Dog Creek delta were pulled by hand during the drawdown. In years since, hand pulling has continued as well as applications of the herbicide diquat (Mark Rosenkranz, personal communication). These control strategies have slowed its spread, but they have not been sufficient to eradicate the species. The likelihood of successful eradication diminishes each year and the LOC should increase its control efforts before the plant spreads to more regions of the lake. Updated surveys to characterize its distribution will additionally help focus control efforts in problem areas. Targeted herbicide applications should be directed at all known populations. Removal with the aid of SCUBA divers equipped with a suction dredge should be considered if populations are found in deeper water. The upcoming lake drawdown starting September 2010 will provide an excellent opportunity to control the weed with extensive hand pulling. Hand pulling and surveying should continue at each subsequent lake drawdown (approximately every three years) until no more *Egeria* is found.

Curlyleaf pondweed (*Potamogeton crispus*)

The Massachusetts Department of Conservation and Recreation has developed an extensive response plan (2005) for curlyleaf pondweed. Depending on the size of infestation, it recommends a wide variety of physical and mechanical control methods, as well as use of diquat, endothall or fluridone. Curlyleaf primarily reproduces by forming turions that break off and germinate a new plant. Research on curlyleaf pondweed in nearby Blue Lake (Wells 2009) suggests a two-stage management approach would be most effective to combat turion production. The first treatment should be applied in the late-winter or spring when bottom water temperatures are near 10ºC. This targets growing vegetation before turion formation has peaked. The next treatment should be applied when water temperatures are between 15ºC and 17ºC to target the plants that survived the earlier treatment.

African waterweed (*Lagarosiphon major*)

Control of African Waterweed has proven problematic. One of the most effective control programs took place in Lake Wanaka, New Zealand and is assessed by Clayton (2006). This program utilized hand pulling, suction, dredging, and application of diquat. The combination of these methods proved effective in the control areas, they were however labor intensive and expensive. Mechanical harvesting is effective in the short term, but plant populations quickly re-grow and sometimes spread even more due to plant fragmentation.

Milfoil (*Myriophyllum* spp.)

Milfoil responds well to several chemical herbicides. The State of Washington has used fluridone to successfully eradicate it from several lakes. In Shoecraft for example, milfoil was growing in two large areas at each end of the lake. Two large silt curtains (one about 2500 feet, the other 900 feet) sectioned off the milfoil patches and fluridone was applied every two weeks from June through mid-September 2000. The treatment worked and twice yearly diving surveys subsequently found no milfoil. (Kathy Hamel personal communication). Other agencies also report efficacy with the selective herbicides 2,4-D and triclopyr. The Integreated Aquatic Vegetation Management Plan for Blue Lake, Oregon (Pfauth and Sytsma 2004) addresses milfoil extensively and recommends a comprehensive approach combining physical, mechanical, and chemical methods. As with other aquatic invasive plants, special care must be taken to ensure plant fragmentation is minimized.

European water chestnut (*Trapa natans*)

Water Chestnut has been particularly problematic on the East Coast of the United States and several agencies there have detailed management plans for its control. The Maryland Department of Natural Resources developed a Regional Management Plan (Naylor 2003) that outlines effective strategies in use there. Successful control in the Bird and Sassafras Rivers between 1999 and 2002 was achieved with a combination of mechanical and hand removal and chemical herbicides were not needed. This plan utilized extensive help of volunteers (up to 80 per year). Repeated harvesting makes control generally effective because *T. natans* is an annual plant. If herbicides are needed, the report identifies 2,4-D to be effective.

Giant salvinia (*Salvinia molesta*)

The Australian government released a comprehensive guide on giant salvinia control and management in 2006. This control manual identifies diquat and glyphosate as appropriate and effective herbicides to combat salvinia. Because salvinia is a floating plant, booms can also be deployed to contain an invasion, though another control method would have to be initiated to kill the salvinia contained in the boom. Weed harvesters that collect plant fragments (like the LOC's) are also effective to clear surface mats that have developed.

Hydrilla (*Hydrilla verticillata*)

Oregon has a hydrilla management plan (Sytsma and Perkins 1995) that is in the process of being updated. The Washington State Department of Ecology provides an excellent case study in hydrilla management with the fifteen-year long response after the discovery of hydrilla in Pipe and Lucerne Lakes in 1994. Liquid and pellet forms of Sonar® (fluridone) were applied by a private contractor from 1995 to 2000. Application of the herbicide was forced to stop in 2000 due to a court decision citing that a National Pollutant Discharge Elimination System (NPDES) permit was needed. Hand pulling by divers was performed in 2001 and 2002, but healthy plants were still found in both lakes in the fall of 2002. Herbicide treatment resumed in 2003 and continued through 2007, focusing on existing populations in the latter years. SCUBA and snorkel surveys last observed hydrilla in Lucerne Lake in 2004 and Pipe Lake in 2006. Monitoring efforts have continued through 2008 and the eradication effort appears to be successful. Endothall and diquat can additionally be effective to control hydrilla (Langeland 1996).

Common reed (*Phragmites australis*)
Teal and Peterson (2005) reported on a Delaware Bay marsh that was heavily impacted by common reed. Glyphosate was known to be an effective control measure, but public concern over herbicide use led land managers to test mowing, rhizome ripping, surface scarification, grazing, as well as Glyphosate use. None of the physical or mechanical methods were effective when not combined with herbicide application. The January 2009 Oregon Department of Agriculture Risk Assessment states that hand digging can be effective for small areas, but is labor intensive an requires that all rhizome fragments need to be removed to prevent spread. This document additionally recommends the herbicide Imazapyr early in the growing season (June).

Flowering rush (*Butomus umbrellatus*)
The February 2009 ODA risk assessment for flowering rush indicates that herbicides used for emergent vegetation are not very effective due to the narrow growth structure of the plant. Glyphosate can be effective in very shallow water or if the plant is exposed due to low water. Cutting below the water level will not kill the plant and stands grow back quickly. Hand digging with removal of root fragments is effective, but labor intensive and only feasible in small areas. Raking is not recommended due to the potential to spread root fragments to uninfected areas (Minnesota Sea Grant 2009).

Yellow floating heart (*Nymphoides peltata*)
The floating portions of the leaves (the petioles) can be cut by hand or with the aid of machinery to clear the surface of the lake. This method does not kill the plant and may be required several times a season to maintain open water. To completely eradicate the plant, all rhizome fragments in the sediment must be removed or killed with an herbicide like glyphosate (WA Department of Ecology 2009).

Rock snot (*Didymosphenia geminate*)
Effective control methods for rock snot are not well known at this time. Trials in New Zealand established that chealated copper compounds, drying, freezing, or exposure to hot water are all possibilities for control (Kilroy et al. 2007).

Purple loosestrife (*Lythrum salicaria*)
Application of a 1-1.5% solution of glyphosate is the most often used herbicide to combat purple loosestrife (CA Dept. Food and Agriculture). Other broadleaf herbicides like 2,4-D can also be used. Hand pulling is effective for small infestations and the root structure needs to be removed as well to prevent re-growth. Two beetle species (*Galerucella* spp.) and a weevil (*Nanophyes marmoratus*) have been shown to selectively feed on and damage purple loosestrife.

Fish and Crayfish

Many control techniques for fish and crayfish involve whole lake applications of piscicides (e.g. rotenone) or other biocides. These methods have significant collateral impacts and are not recommended in Oswego Lake except under the most severe circumstances. Preliminary research has shown that electrical barriers across a narrow waterway will prevent transit of bighead and silver carp. This method is currently being tested in the Chicago Ship Canal in an attempt to exclude the invasive fish from the Great Lakes (US EPA 2008). Other research has demonstrated that species-specific pheromones can deter both species of Asian carp by triggering an alarm response (Little and Calfee 2006). Lake drawdown is an additional is method can be effective to reduce populations of both carp and other fish species (Verrill and Berry 1995).

Other Species

Nutria (*Myocastor coypus*)

The LOC occasionally traps and terminates nutria in and around Osewgo Lake. The CLR at PSU released an overview of Nutria Management guidelines (Scheffels and Sytsma 2007). Effective control methods involve trapping, poisoning and shooting. Shooting is obviously not an option in Oswego Lake, and poisoning is not appropriate due to the proximity of people and pets. Thus, continued trapping is likely the best management option.

Related Agencies and Contacts

United States Fish and Wildlife Service (USFWS)
www.fws.gov
- Guides national policy on invasive species management in the context of fish and wildlife management.
- Contact: Paul Heimowitz [paul_heimowitz@fws.gov], Aquatic Nuisance Species Coordinator, Pacific Region

Oregon Department of Fish and Wildlife (ODFW)
www.dfw.state.or.us
- Manages laws and regulations of possession and transport of fish and wildlife species
- Establishes state-wide conservation strategy to combat invasive species
  Contact: Rick Boatner [rick.j.boatner@state.or.us], ODFW Invasive Species Coordinator

Oregon Department of Agriculture (ODA)
www.oregon.gov/ODA
- Defines noxious weeds
- Establishes weed control strategy
- Implements quarantines, eradication / control projects
- Contact: Tim Butler [tbutler@oda.state.or.us], Noxious Weed Control Program Manager

Oregon Department of Environmental Quality (ODEQ)
www.oregon.gov/DEQ
- Regulatory agency responsible for protecting Oregon's water and air quality
- Enforces environmental laws

United States Environmental Protection Agency (US EPA)
www.epa.gov
- Establishes regulations for water use (e.g. Clean Water Act)
- Manages national herbicide permitting (NPDES)

Oregon State Police
www.oregon.gov/OSP
- Can enforce wildlife laws
- Can stop a vehicle pulling a boat with attached weeds or other organisms.

Oregon Invasive Species Council
www.oregon.gov/OISC
- Manages invasive species reporting
- Promotes public awareness of invasive species
- Contact: Mark Sytsma [sytsmam@pdx.edu], Ex-officio council member

Oregon State Marine Board
http://www.boatoregon.com

- Provides boat cleaning training
- Contact: Glenn Dolphin [glenn.dolphin@state.or.us], Clean Marina Program Coordinator

100th Meridian Initiative
100thmeridian.org

- Zebra/quagga mussel information
- Provides resources on boat cleaning
- Contact: Stephen Phillips [stephen_phillips@psmfc.org], Pacific States Marine Fisheries Commission

Center for Lakes and Reservoirs – Portland State University
www.clr.pdx.edu

- Aquatic Nuisance Species Management Plan for Oregon
- Resources for ANS management
- Contact: Mark Sytsma [sytsmam@pdx.edu], Director

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