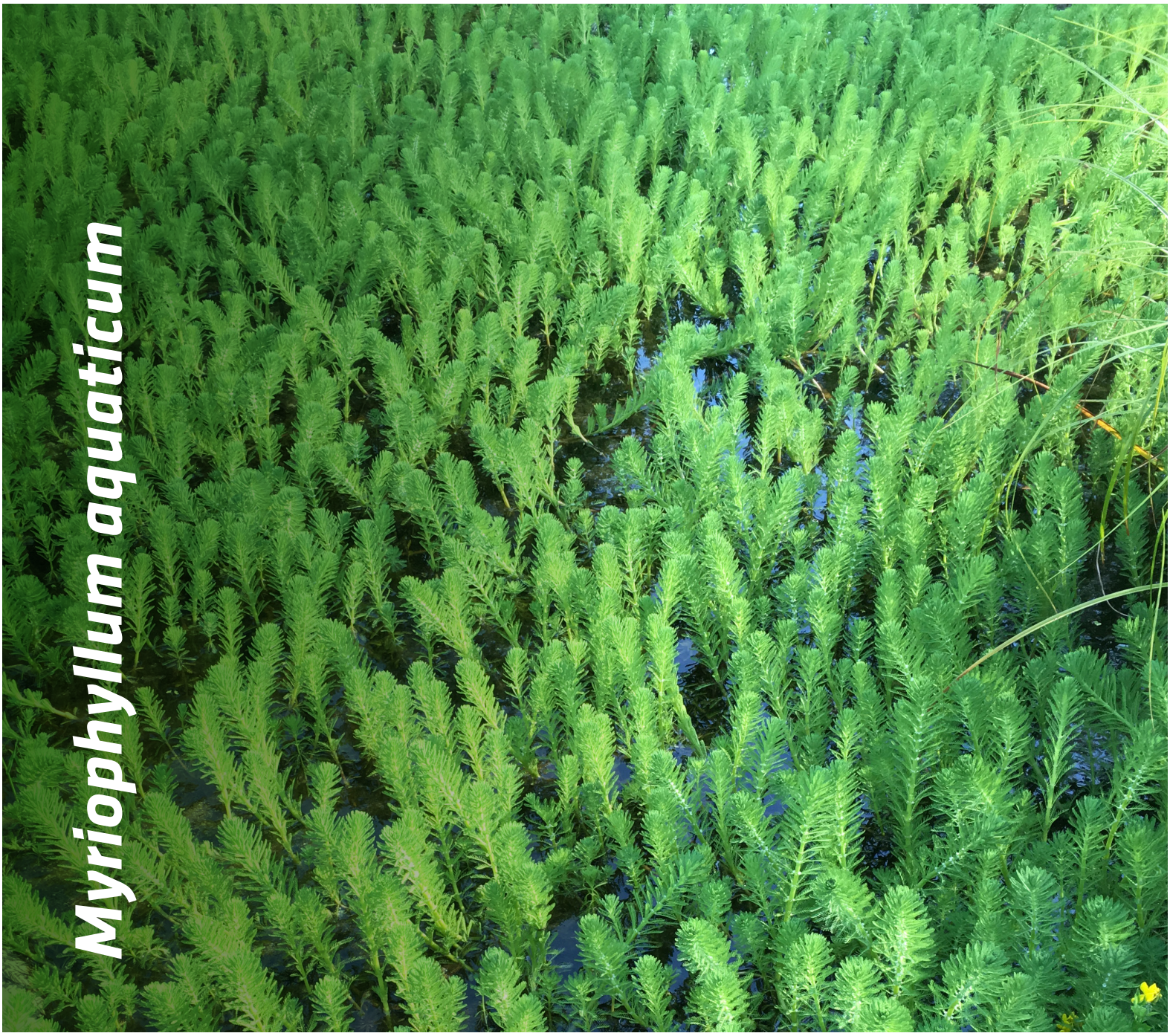

BEST MANAGEMENT PRACTICES FOR

Parrot's Feather

in the Metro Vancouver Region

metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION

ISCMV
INVASIVE SPECIES COUNCIL OF METRO VANCOUVER

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Introduction

The impacts of invasive species on ecological, human, and economic health are of concern in the Metro Vancouver region. Successful control of invasive species requires concerted and targeted efforts by many players. This document – "**Best Management Practices for Parrot's Feather in the Metro Vancouver Region**" – is one of a series of species-specific guides developed for use by practitioners (e.g., local government staff, crews, project managers, contractors, consultants, developers, stewardship groups, and others who have a role in invasive species management) in the region. Together, these best practices provide a compendium of guidance that has been tested locally by many researchers and operational experts.

Parrot's feather is a perennial aquatic plant native to South America. It was introduced to North America as an aquarium and aquatic garden plant (Ontario's Invasive Species Awareness Program, 2016). It grows from the bottom of fresh water bodies through the water column with plant tips emerging above the surface, quickly forming dense mats of vegetation. It is most problematic in small ponds, irrigation channel networks and streams (CABI, 2018).

Academic institutions, government, and non-government organizations continue to study this species in British Columbia. As researchers and practitioners learn more about the biology and control of parrot's feather, it is anticipated that the recommended best management practices will change overtime and this document will be updated. Please check metrovancouver.org regularly to obtain the most recent version of these best management practices.

REGULATORY STATUS

Although parrot's feather is an invasive plant of concern in the Metro Vancouver region, it is not currently regulated anywhere in British Columbia.

IMPACTS

Parrot's feather can contribute to a loss of plant and aquatic species diversity by outcompeting and replacing native plant communities (Lastrucci *et al*, 2018). This has a negative impact on overall biodiversity, and can affect habitat quality and food availability for fish, amphibians, waterfowl and other aquatic species (Ontario's Invasive Species Awareness Program, 2016). Studies in Washington State suggest that parrot's feather is highly impactful to slow-water habitats (Kuehen *et al*, 2016). Infestations dramatically reduce the levels of dissolved oxygen in the water column, change invertebrate communities and increase the number of non-native fish species (Kuehne *et al*, 2016). In addition, infestations can trap sediment, causing water levels to rise and slowing water flow. These slow flowing stagnant waters provide optimal breeding grounds for mosquitoes (Pennsylvania Sea Grant, 2013).

Recreationalists and lake shore home owners can be impacted by parrot's feather. Dense infestations in lakes can impede swimming, fishing and boating. Further, decreased recreational and aesthetic values can lead to lower property values (Pennsylvania Sea Grant, 2013).

All levels of government, non-profit organizations and private property owners spend significant resources managing invasive species in the Metro Vancouver region every year. In waterways, irrigation ditches, sloughs and drainage canals, parrot's feather has the potential to inhibit the flow of water, resulting in an increase in maintenance costs. In recent years, agencies represented on Metro Vancouver's Regional Planning Advisory Committee – Invasive Species Subcommittee together spent over $168,000 per year on parrot's feather control efforts. This figure does not include control costs for private landowners across the region, volunteer 'weed pull' hours, or costs associated with education and awareness activities.

REPRODUCTION AND SPREAD

Parrot's feather reproduces vegetatively through plant fragments. In North America, only female plants are present and sexual reproduction by seed does not occur (Raincoast Applied Ecology, 2016). Plant fragments as small as 4 millimetres are capable of establishing a new population (City of Richmond, 2016). In Pitt Meadows, this invader appears to have expanded its range throughout local sloughs and ditches at a rate of approximately 900 metres per year, resulting in a cumulative spread of 12.7 kilometres over 13 years, between 2004 and 2017 (Sloboda, 2019).

Parrot's feather can be spread unintentionally by flooding events and natural dispersal from plant fragments floating downstream (Ontario's Invasive Species Program, 2016). Fragments can travel on birds or animals. It can also be spread by contaminated boats, boat trailers or heavy-duty equipment used for parrot's feather control (Hesketh, 2017).

Most parrot's feather infestations in Metro Vancouver appear to be caused by the accidental or purposeful introduction by homeowners from garden ponds or aquariums (Raincoast Applied Ecology, 2016). Parrot's feather has been an ornamental favourite in fountains, and aquariums due to its blue-green color, feather-like leaves and cascading pattern of growth.

Parrot's feather in the Blind Channel of Katzie Slough
CREDIT: SUSANNE SLOBODA

HABITAT AND DISTRIBUTION

Parrot's feather is native to South America. It was introduced to North America in the early 1900's through the aquaria and nursery trade and is also found in Europe, New Zealand, Australia, and Africa (Wersal *et al*, 2018). It was first collected in British Columbia in 1980 in North Vancouver and was observed in a local slough by Pitt Meadows Public Works in 2004 (Sloboda, 2019) and found again in 2007 in a Garry Point Park drainage ditch in the City of Richmond (Klinkenberg, 2017). It is now widespread in a number of areas in Richmond and there are established populations in Pitt Meadows, Burnaby, Surrey and south Vancouver (Raincoast Applied Ecology, 2016). Abbotsford and Chilliwack also have infestations (Clegg, 2018). This species has also been found in the Capital Regional District on southern Vancouver Island, including the Gulf Islands.

Parrot's feather establishes roots in the bottom sediments of water bodies. It is typically found in nutrient-rich, slow-moving water, such as wetlands, streams, irrigation reservoirs or canals, edges of lakes, ponds, sloughs or backwaters. It is most common in shallow water, but can also be found as a floating plant in nutrient-enriched lakes in depths up to 4.8 metres (Wersal *et al*, 2018).

Parrot's feather prefers habitats where light can penetrate to the bottom of the water column, alkaline conditions (pH range of 6.8-8.0) and water temperatures between 16-23°C. However, it can survive even broader ranges and in saltwater as long as salt concentrations remain below 4 parts per trillion (Wersal *et al*, 2018). Parrot's feather is not usually affected by frost and can survive mild winters in its submersed form (Ontario's Invasive Species Awareness Program, 2016). It usually begins growth when water temperatures reach 7°C (Wersal *et al*, 2018).

CLIMATE ADAPTATION

Climate modellers predict that the Metro Vancouver region will experience warmer temperatures; a decrease in snowpack; longer dry spells in summer months; more precipitation in autumn, winter and spring; more intense extreme events; and an extended growing season. In the past, our region had an average of 252 days in the growing season. In lower elevations 45 days will be added to the growing season by the 2050s, and 56 days by the 2080s, resulting in nearly a year-round growing season of 357 days on average. In higher elevation ecosystems the growing season length will increase by 50% to 325 days by the 2080s (Metro Vancouver, 2016). These changes will stress many sensitive ecosystems, increasing their vulnerability to invasive species.

Parrot's feather is a hardy aquatic plant with broad environmental tolerances (Wersal et al, 2018). It may be able to adapt to our future climate in several ways:

- **Warmer temperatures & extended growing season:** Parrot's feather can tolerate mild frost but it cannot survive extended periods of cold and therefore may benefit from warmer winters (Wersal et al, 2018).
- **Increased precipitation and flooding:** This species is likely to adapt to water level fluctuations resulting from climate change (Wersal et al, 2018).

With these kinds of competitive advantages, this species is more adaptable than native species in a variety of ecosystems, suggesting that it will be able to withstand, and possibly thrive, with changing climate conditions.

Identification

Lifecycle: Perennial aquatic plant that roots in the bottom sediments of water bodies. It produces shoots in spring from overwintering rhizomes. The plant usually dies back to its rhizomes in the autumn with cool weather (Klinkenberg, 2017).

Stem: Stems grow 2–5 metres long (Ontario's Invasives Species Awareness Program, 2016). Submersed shoots creep along the water surface with extensive branching from nodes and vertical growth of emergent stems that can extend up to 30 centimetres above the water surface (Wersal *et al*, 2018). In heavily infested water bodies, the emergent portions can be so dense that the water is not visible, and it appears as if you could walk on top of the plant (Murray, 2018).

Leaves: Leaves are feather-like and resemble small fir trees. They are whorled with 20 or more segments per leaf. The leaves are heterophyllous existing both above water (emergent) and below water (submerged). Emergent leaves have whorls of 4–6 leaves per node, are 2 to 5 centimeters long and appear bright green with a waxy surface (Dickinson & Royer, 2014). Submerged leaves are 1.5–3.5 centimetres long, have whorls of 3–6 leaves per node, and are more feathery and reddish in colour (Ontario's Invasives Species Awareness Program, 2016; Penn State Sea Grant, 2013 and DiTomaso and Kyser, 2013).

Flowers: Flowers are small (1.6 millimetres long) and inconspicuous with white spikes at the tips of emergent shoots (Wersal *et al*, 2018). Flowers usually appear in spring or summer but sometimes in fall (Wersal *et al*. 2018).

Fruits: North American plants are all female and do not produce fruit (Dickinson & Royer, 2014).

The following photos show parrot's feather plant parts.

Emergent leaves

CREDIT: GRAVES LOVELL, ALABAMA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES, BUGWOOD.ORG

Portions of submerged stems

CREDIT: CITY OF RICHMOND

CREDIT: VILSESKOGEN VIA FLICKR

SIMILAR SPECIES

Several aquatic plants resemble parrot's feather in form and habitat, but they all lack upright stems above the surface water. Ten species of *Myriophyllum*, including parrot's feather, have been found in the Pacific Northwest (Williams *et al*, 2018) as outlined below.

NATIVE *MYRIOPHYLLUM*

1. Cut-leaf water-milfoil (*Myriophyllum pinnatum*) – dark green stems and foliage; whorls of 3 to 5 leaves per node; winter buds are absent.

2. Farwell's water-milfoil (*Myriophyllum farwellii*) – often over looked as it grows deep at the bottom of lakes; whorls of 3 to 6 leaves per node; winter buds are absent.

3. Western water-milfoil (*Myriophyllum hippuroides*) – appears deep green in color; whorls of 4 to 6 leaves per node, with some additional alternate leaves scattered outside the whorls.

4. Siberian water-milfoil (*Myriophyllum sibiricum*) – whitish stems; whorls of 3 or 4 leaves per node, mostly 1 centimetre or more apart; well-developed winter buds are present.

5. Ussurian water-milfoil (*Myriophyllum ussuriens*) – emergent leaves are opposite or in whorls of 3; threadlike winter buds are present on leaf axis.

6. Whorl-Leaf water-milfoil (*Myriophyllum verticillatum*) – whorls of 4 or 5 leaves per node; leaves usually have myriophylloid glands at the base of the lower segments; winter buds are present.

NON NATIVE *MYRIOPHYLLUM*

7. Eurasian water milfoil (*Myriophyllum spicatum*) – plant is reddish-brown in color; whorls of 3 to 5 leaves per node, mostly 1 centimetre apart or more on stem; 14–21 leaflet pairs per leaf, which is more than Parrot's feather and native milfoils; winter buds are absent. This species is also highly invasive in British Columbia.

8. Variable leaf water-milfoil (*Myriophyllum heterophyllum*) – whitish stems; whorls of 4–6 leaves per node.

9. Andean water-milfoil (*Myriophyllum quitense*) – lower leaves are reduced to bract-like structures; strong whitish roots; winter buds are absent.

Parrot's feather may also be confused with Brazilian elodea (*Egeria densa*), which is native to South America and also invasive in British Columbia. It has been confirmed in two water bodies in British Columbia – a City of Richmond drainage waterway and Glen Lake in Langford. Brazilian elodea is recognized by the provincial government as an Early Detection Rapid Response (EDRR) candidate species (IMISWG, n.d.). It can be distinguished from parrot's feather by its finely serrated, bright green leaves arranged in whorls of 4 leaves per node. Its leaves are spaced by short internodes giving a 'leafy' appearance. Brazilian elodea is usually submerged, but can form dense mats on the surface of water. In the spring and summer, Brazilian elodea blooms with small, white, three-petal flowers that float on top of the water or slightly above (City of Richmond, 2018; IMISWG, n.d.).

Eurasian water milfoil (*Myriophyllum spicatum*)
CREDIT: ALISON FOX, UNIVERSITY OF FLORIDA, BUGWOOD.ORG

Parrot's feather may also be confused with the many *Potamogeton* (pondweed) species that grow in British Columbia, that have entirely submersed leaves.

Brazilian elodea (*Egeria densa*)
CREDIT: ROBERT VIDÉKI, DORONICUM KFT., BUGWOOD.ORG

Tracking

The Provincial government maintains the Invasive Alien Plant Program (IAPP) application (British Columbia Ministry of Forests, Lands and Natural Resource Operations and Rural Development, 2017), which houses information pertaining to invasive plant surveys, treatments, and monitoring. Many agencies, including local governments, have their own internal invasive species inventory and mapping protocols that are used by staff, contractors and, in some cases, the public. Agencies in British Columbia that do not enter data into IAPP are encouraged to check it regularly because it contains public reports and data from other agencies and it is important to consider as much data as possible when making management decisions. The Map Display module of IAPP is publicly accessible.

When carrying out parrot's feather inventory, it is useful to record the following information as it will later inform treatment plans (adapted from Raincoast Applied Ecology, 2016):

- Geographic location,
- Size and density of infestation,
- Photo of the infestation,
- Location in relation to nearby areas and water bodies that may be at risk to new invasions, and
- Location of wetlands connected to infested sites by public access routes and boat launch sites.

Reporting

Please report parrot's feather occurrences to:

- The Provincial Report Invasives program (via smart phone app www.gov.bc.ca/invasive-species).
- The Invasive Species Council of Metro Vancouver: 1-604-880-8358 or www.iscmv.ca.
- The municipality where the parrot's feather was found.
- The landowner directly – If the landowner is unknown, the Invasive Species Council of Metro Vancouver can provide support to identify the appropriate authority.

Reports submitted through these channels are reviewed by invasive species specialists who coordinate follow-up activities when necessary with the appropriate local authorities.

Prevention and Control Strategies

Effective invasive plant management may include a variety of control techniques ranging from prevention, chemical, manual, mechanical, biological and/or cultural methods. Each method is described below in order of effectiveness.

Since parrot's feather has the ability to reproduce vegetatively through root and stem tissues, management options must be carefully evaluated on a site by site basis to avoid further spread and complications. Eradication of this plant typically requires a dedicated, multi-year, planned approach. Follow-up monitoring and treatment will be required for several years regardless of the treatment technique.

STRATEGY COLOUR LEGEND

GREEN: RECOMMENDED

ORANGE: CAUTION

RED: NOT RECOMMENDED OR NOT AVAILABLE

PREVENTION: IMPERATIVE

Prevention is the most economical and effective way to reduce the spread of parrot's feather over the long term. Below are some simple actions that can be carried out to prevent the introduction and spread of parrot's feather.

- Parrot's feather should not be purchased, traded or grown. Instead, use non-invasive plants that are naturally adapted to the local environment. Grow Me Instead and the Restoration section provide recommendations for non-invasive species to use in aquariums and water gardens.
- It is illegal to release plants and animals into the wild, or dump aquarium or water garden debris into rivers, streams, lakes or storm sewers. See the Disposal section of this document for appropriate disposal locations or inquire with staff at the location where the parrot's feather was purchased.
- Plants, plant parts and mud should be cleaned from boats and fishing gear. Any items that can hold water (e.g. buckets, wells, bilge and ballast) should be drained onto dry land. All items should be completely dried before use at another water body or site. All machinery or equipment that is used for parrot's feather management or used in areas infested with parrot's feather should also be cleaned. See Cleaning and Disinfection section below.
- Special care should be taken when controlling parrot's feather to prevent the movement of plant parts downstream.

Excavation of parrot's feather in ditches in Richmond

CREDIT: CITY OF RICHMOND

MECHANICAL/MANUAL: RECOMMENDED

Manual control should be carried out with extreme caution due to the likelihood of spread through root and stem fragments. Mechanical control is a time-consuming treatment option that will require dedication to frequent removals over numerous years. Treated sites should be surveyed in spring (March), summer (June), and early fall (October) to identify re-occurring infestations. Any necessary in-water work permits should be acquired from the appropriate authorizing organizations.

APPLYING MANUAL/MECHANICAL CONTROL METHODS IN RIPARIAN AREAS

Schedule removal works during a period of least risk to fish species, outside of the fish window. Adhere to Provincial and Federal riparian regulations. It is recommended to consult with a qualified environmental professional when working around water bodies.

Care should be taken to restrict the downstream movement of stem fragments that will result from cutting operations as regrowth is rapid from this type of propagule. Containment of plant parts during manual/mechanical treatments is critical, particularly during excavation (Ministry of Environment and Climate Change Strategy, 2018; Raincoast Applied Ecology, 2016). The following **containment procedures** are recommended. A qualified environmental professional should oversee and monitor this work if there is risk of amphibians, fish or other species getting trapped in the contained area.

- For small infestations (i.e., ditches or canals), a hardware cloth screen (1/4" mesh) should be installed at the upstream and downstream ends of the treatment area. The screen must be left in place for 1 to 5 days following completion of the work and cleaned following management activities (see Cleaning and Disinfection section below). These procedures may require use of a boat.
- For larger watercourses, a flexible floating net with lead-line should be used to contain the treatment area. In most cases, the net should be installed at the downstream end of the site. The net must be cleaned following excavation and left it in place for 1 to 5 days (if possible).
- During management activities, visual searches of the area should be conducted and any fragments hand-picked or netted. This may require use of a boat. Note that emergent fragments have higher regeneration capacity, so capture of these fragments is more important than submerged fragments (Xie *et al*, 2018).

Chances of success will improve if several of the following manual/mechanical techniques are used in combination. The City of Richmond has been carrying out parrot's feather management trials since 2011 using various methods including frost treatments, excavation, shade treatments and benthic barriers (geotextile) (Tillyer, 2018). From these trials, the treatment methods that showed the most promise for control of parrot's feather were excavation followed by overhead shading, or benthic barrier placement over the infested substrate (Hesketh, 2017).

Bucket with a thumb

Side-cast compost of parrot's feather onto the bank of No. 3 Road Slough, Chilliwack

CREDIT: DAVID BLAIR, CITY OF CHILLIWACK

EXCAVATION/DREDGING

The removal of stems, roots, and contaminated sediments from the bottom of lakes, rivers, harbours, and other water bodies is possible using an excavator. Excavation should happen in March when overwintering stems are visible as surface mats, with follow up treatment in June or July during full growth (Raincoast Applied Ecology, 2016). It is best to use a standard cleaning bucket thumb on the excavator. The excavator operator should be clearly briefed to understand the purpose of the work and to ensure that fragmentation is avoided. It is advisable to have an expert onsite supervising the work. Water levels must be < 0.5 metres deep during excavation so may require drawing down water (see Cultural Control section below). Remove at least 15–25 centimetres of the infested sediment to eliminate regrowth (DiTomaso *et al*, 2013).

This management technique may be more successful if used after another manual removal method or followed by overhead shading placed over the infested substrate (see Cultural Control section below) (Hesketh, 2017).

Excavation is expensive and is best suited for large infestations and projects. It may alter water body characteristics, by increasing turbidity or generating plant fragments that may regrow or disperse downstream. It is critical to follow the containment procedures outlined above, as a targeted activity or in conjunction with regular maintenance operations (e.g., ditch maintenance) (Raincoast Applied Ecology, 2016).

While using these methods, the excavated material should be examined for the presence of aquatic organisms (such as salamanders), which should be released back into the site.

The City of Chilliwack saw good success after excavation of parrot's feather at the No. 3 Road Slough (Blair, 2019). Excavated plant material was side-cast in a manner to prevent its re-release into the channel (see photo on previous page) and allowed to compost. Thorough collection and disposal of all floating plant fragments was undertaken downstream of the excavation. Excavated plant material was subjected to sub-zero temperatures in the evenings (Blair, 2019). After 6 weeks, the project yielded a decrease in parrot's feather and improved habitat conditions for waterfowl. The site will continue to be monitored (Blair, 2019).

HAND PULLING

Pulling by hand can be effective for small areas; however, it is labour intensive and care must be taken to remove entire plants including emergent shoots, submersed shoots, roots and rhizomes, as well as all fragments, or regrowth will occur. This method may not be possible at sites where the entire water column is not accessible.

HARVESTING

Harvesting is carried out with a floating harvester machine that contains a cutting mechanism and hydraulic lifts for raising and lowering the cutting depth. Once the weeds are cut, a steel conveyor mesh carries the weeds on board to a holding area beneath the operator's platform. A conveyor in the rear of the vessel off-loads the collected plant matter on-shore where it is left to dewater and then be loaded and trucked away (SOLitude Lake Management, 2017). Harvesting can be effective for larger sites, however, it can be expensive and care must be taken to remove the entire plant including emergent shoots, submersed shoots, roots and rhizomes, as well as all fragments or regrowth will occur. Harvesting has not been used as a treatment method in British Columbia for parrot's feather. However, it has been used in the Okanagan for "cosmetic control" of Eurasian milfoil in large lakes, although it is not the most effective method used for that species (Okanagan Basin Water Board, 2018).

Harvester used to remove aquatic plants from the surface of Burnaby Lake

CREDIT: I. LAU

CULTURAL: CAUTION

SHADING

The shading method is effective for narrow and shallow water courses that can be easily covered. Wersal (2010) found that parrot's feather biomass can be reduced in 70% shade. Growth can be suppressed by placing a permeable shade cloth or other synthetic barrier to light (e.g., plastic or Tac150) over the infestation. Covering materials can be installed as surface layers, on frames over actively growing plants or following excavation to prevent regrowth (Raincoast Applied Ecology, 2016). The shading technique was tested in the City of Richmond along drainage ditches in 2015 and has reduced the parrot's feather biomass significantly. However, construction and installation of shading structures is expensive and time consuming and is therefore unsuitable for large infestations.

Shading trial over parrot's feather infested ditches in the City of Richmond

CREDIT: CITY OF RICHMOND

BENTHIC BARRIER

A benthic barrier (also known as benthic mat/weed mat/bottom screen) is a mat that can be placed at the bottom of a body of water to prevent or inhibit the growth of plants through shading and smothering. It consists of a dark fabric/material that blocks sunlight and is held against the bottom by weights.

Benthic barrier material must be gas permeable to remain anchored (Wayne County, 2018). For example, plastic or Tac150 can be secured with 10' sections of 3/8" rebar. Other suitable bottom screen materials include densely woven synthetics, landscaping fabric, geotextiles, plastics and nylon tarp. The City of Richmond uses the product 'Nilex 4553' (Tillyer, 2018). It is important to ensure that the entire area, including channel banks, is covered by the material since parrot's feather often persists along the margin of treatment areas and colonizes open water above the fabric (Raincoast Applied Ecology, 2016). Where possible, use a single continuous piece of textile to avoid seams, as areas of overlap can be exploited by parrot's feather rhizomes (Tillyer, 2018). If multiple pieces are required, use extra-large areas of overlap and an accordion fold system to make seams as impermeable as possible (Tillyer, 2018).

Although this method is effective and relatively inexpensive, it is not suitable for large water bodies and it may impact non-target sediment-dependent species, including native aquatic plants and bottom dwelling organisms (Wayne County, 2018).

RIPARIAN REFORESTATION

Re-planting riparian areas with non-invasive species can create shade and reduce parrot's feather growth. Optimal parrot's feather growth occurs in intermediate light intensities, particularly 30% shade. This method typically takes 5 to 10 years of growth to be effective (Raincoast Applied Ecology, 2016).

The City of Pitt Meadows undertook a riparian planting project along Katzie Slough in October 2018 (including willow live-staking) where parrot's feather is prolific (Sloboda, 2019). One of the objectives of the project is to shade out parrot's feather; the site will be monitored in subsequent years to determine success of this method (Sloboda, 2019).

CASE STUDY: SERPENTINE WILDLIFE MANAGEMENT AREA

Around 2012, parrot's feather was first observed by Ducks Unlimited Canada (DUC) staff at the Serpentine Wildlife Management Area (WMA) in Surrey. By 2014, the invasive aquatic plant had begun to dominate one segment of this wetland complex. The Serpentine WMA was agricultural land that has been restored to a series of wetland compartments that can be isolated and their water levels managed through a series of drainage ditches, water control structures and a pump, which draws fresh water from the landward side of the Serpentine Sea Dam.

Beginning in 2014, DUC staff began turning off the pump that feeds water into the segment in which parrot's feather had begun to dominate. The segment dried out naturally during summer months and rainfall refilled it during fall, winter and spring. This new hydrological regime, mimicking a natural coastal ephemeral wetland, resulted in a dramatic decline in parrot's feather at the Serpentine WMA. However, in deeper ditches and shaded areas where the soil moisture remained, the plant has maintained its stronghold.

Each subsequent year of drawdown has further reduced the extent of parrot's feather, even in areas where moisture remains. Maintaining the lowest possible water levels during winter freezing (December/January) has also been attempted as a part of control efforts but it is hard to determine whether this has significantly contributed to the reduction achieved to date. The next steps will be to continue monitoring annual reductions and to introduce either mechanical removal and/or the benthic barrier approach. The drying out of the wetland seasonally has had co-benefits of managing invasive bullfrogs as well as increasing the abundance of native smartweed (Polygonum spp.), a waterfowl superfood.

Parrot's feather in the Serpentine Wildlife Management Area in October 2014

CREDIT: DUCKS UNLIMITED CANADA

October 2016 after two summers of allowing the wetland to dry out

CREDIT: DUCKS UNLIMITED CANADA

WATER DRAWDOWN

This method involves controlling the water table at the infested site, thereby exposing sediments and plant roots to prolonged drying or freezing. A qualified environmental professional should oversee and monitor this work if there are amphibians, fish or other species present at the site.

- **Water Drawdown via Drying**: Low water levels will expose the plants to desiccation and can ultimately affect plant vascular structure, rendering the plant incapable of nutrient transport and function. When the water level is again raised, these previously anchored plant structures will often float downstream, or they can be hand-removed (New Hampshire Department of Environmental Services, 2010). A drawdown lasting more than 3 months, or consecutive drawdown events, may result in complete control of parrot's feather, if the sediments remain completely dry (Wersal, 2010).

  At sites where drawdown is possible by controlling water levels, it is a relatively inexpensive control method. However, it is also unpredictable, and may cause some undesirable species to increase in abundance. Parrot's feather is well adapted to drawdown and flooding events and success of this method depends on the site, exact water depth and length of drawdown operation (Wersal & Madsen, 2011). Further, drawdown is non-selective and will result in the removal/death of aquatic invertebrates and fish, and the loss of use of the water body for the duration of the drawdown. To mitigate potential losses of submersed plants, fish, and invertebrates, a partial drawdown may be used to expose parrot's feather growing along the shoreline of a water body (Wersal, 2010).

- **Water Drawdown via Freezing**: Freezing temperatures and lake sediments can damage the structure and integrity of the vegetative material. Scouring action of ice moving over the exposed water body bed will force tubers and rooting systems from the substrate. While this method can impact parrot's feather survival, it is considered a passive method as it is unpredictable and uncontrollable.

TARGETED GRAZING

Although cattle and waterfowl may graze the shoots of parrot's feather, placing livestock in waterbodies has significant logistical challenges and negative consequences on water quality and aquatic habitat, and therefore parrot's feather is unsuitable for control by targeted grazing (Miller, Tarasoff & Salmon, 2021).

FLOODING

Although parrot's feather is adaptable to flooding events, it will not thrive in sustained deep flood conditions, as without the emergent vegetation it cannot photosynthesize well (Wersal & Madsen, 2011). It is unclear what kind of flooding event is most conducive to parrot's feather management. Understanding that parrot's feather growth is limited in deeper water may be more useful as a predictor for where this species will grow, rather than as a management technique (Wersal & Madsen, 2011).

CONVERSION TO VEGETATED MARSH

Parrot's feather prefers open, sunny habitats and does not compete well with taller vegetation such as cattails and trees. Decreasing the water depth to 30 centimetres (summer depth) will encourage growth of taller emergent species that may eventually outcompete parrot's feather (Raincoast Applied Ecology, 2016). This method may reduce open water and habitat for fish and other aquatic species, and may also reduce flow (Raincoast Applied Ecology, 2016). This conversion method has not been tested in Metro Vancouver and is probably not a suitable management strategy for many parrot's feather infestations in this region.

CHEMICAL: NOT RECOMMENDED

When alternative methods to prevent or control invasive plants are unsuccessful, professionals often turn to herbicides, however, **herbicide application for parrot's feather is not recommended due to poor absorption and the potential risks to fish, amphibians, and other aquatic species**. It may also impact local water sources intended for human consumption (Raincoast Applied Ecology, 2016). The following section provides more details about the regulations and complexity of using this control method.

With the exception of substances listed on Schedule 2 of the Integrated Pest Management Regulation, the use of herbicides is highly regulated in British Columbia. Site characteristics, goals, objectives and legal requirements must be considered when prescribing a herbicide. This summary of the *Integrated Pest Management Act* provides an overview of the provincial legislation.

In Canada, there is one registered herbicide labeled for parrot's feather control in water bodies. It is a restricted herbicide which means it can only be used under certain circumstances by specially trained individuals and it is not available to the general public (most pesticides intended for aquatic application are designated "Restricted" under the federal classification system). In British Columbia, Section 14(1)(b) of the *Integrated Pest Management Act* requires anyone using a restricted class product to hold a certificate issued. In British Columbia, it requires either approval or a permit depending on the status of the waterbody.

Herbicide could be used in combination with the drawdown method. After drawdown, the parrot's feather would likely be active for the first few days and herbicide treatment with a glyphosate product (approved for terrestrial use) would be effective (Ralph, 2019). The drawdown would need to remain in place long enough to ensure maximum translocation of the herbicide to the root tips (Ralph, 2019). This period of time would depend on a number of factors including weather (Ralph, 2019). This method also requires a special permit due to the proximity of herbicide use near water (see below).

PESTICIDE LICENCE AND CERTIFICATION

A valid pesticide license is required to:

- offer a service to apply most pesticides;
- apply most pesticides on public land including local government lands1; water bodies;

Pesticides (e.g., herbicides, insecticides, fungicides) are regulated by the federal and provincial government, and municipal governments often have pesticide bylaws.

- Health Canada evaluates and approves chemical pest control products as per the *Pest Control Products Act*.
- The *Integrated Pest Management Act* sets out the requirements for the use and sale of pesticides in British Columbia. This Act is administered by the Ministry of Environment and Climate Change Strategy'.
- Several municipalities have adopted bylaws which prohibit the use of certain pesticides.

Everyone who uses pesticides must be familiar with all relevant laws.

1 on up to 50 ha/year by a single organization. Organizations looking to treat over 50 hectares of land per year are also required to submit a Pest Management Plan and obtain a Pesticide Use Notice confirmation.

HERBICIDE APPLICATION IN AQUATIC SYSTEMS IN BRITISH COLUMBIA

In British Columbia, application of pesticides in water for invasive plants management may require an authorization under the *Integrated Pest Management Act*. Most applications to bodies of water require a pesticide use permit (PUP). Since bodies of water are owned by the province, all decisions regarding potential pesticide use must be made by a responsible member of the provincial government (or delegate). "Self-contained" filtration ponds and ditches may or may not be considered bodies of water (Mullan, 2018). The term is results-based and considers the likelihood that pesticide-treated water can reach rivers, streams or aquifers.

Proponents looking to apply herbicide in water should first contact Integrated Pest Management Program Telephone: (250) 387-9537 or Email: bc.ipm@gov.bc.ca. If the provincial government deems a permit is required, the proponent (owner/land manager) must apply for a PUP and the application fee of $1,000. Proponents must also conduct public and First Nation consultation. Once all parties have been satisfactorily consulted and all requirements of the permit have been met, the province may issue a PUP for a maximum of 3 years. Issuance is a legal decision, but can be appealed. ONLY companies or practitioners with a valid Pesticide License and staff who are certified applicators (or trained assistant applicators working under a certified applicator) may apply the herbicide.

HERBICIDE LABELS

Prior to each use, herbicide labels must be reviewed thoroughly to ensure precautions, application rates, all use directions, site characteristics are known and application directions strictly followed. Other label information includes trade or product name, formulation, class, purpose, registration number, precautionary symbols and what to do in order to protect the health and safety of both the applicator and public. (British Columbia Ministry of Environment and Climate Change Strategy, 2011).

Under the Federal *Pest Control Products Act* and the Provincial Integrated Pest Management Regulation, **persons are legally required to use pesticides (including herbicides) only for the use described on the label and in accordance with the instructions on that label**. Failure to follow label directions could cause damage to the environment, poor control results, or danger to health. Contravention of laws and regulations may lead to cancellation or suspension of a license or certification, requirement to obtain a qualified monitor to assess work, additional reporting requirements, a stop work order, or prohibition from acquiring authorization in the future. A conviction of an offence under legislation may also carry a fine or imprisonment.

Labels are also available from the Pest Management Regulatory Agency's online pesticide label search or mobile application as a separate document. These label documents may include booklets or material safety data sheets (MSDS) that provide additional information about a pesticide product. Restrictions on site conditions, soil types, and proximity to water may be listed. If the herbicide label is more restrictive than provincial legislation, the label must be followed.

HERBICIDE OPTIONS

Only diquat (e.g. Reward© Aquatic Herbicide), is registered in Canada for general aquatic use, with parrot's feather identified as a target species. It is a contact herbicide that will kill the vegetation it comes in contact with, but significant regrowth is common. **It is a restricted herbicide and in British Columbia it requires either approval or a permit depending on the status of the water body.**

In British Columbia, other aquatic herbicides are currently only permitted under "emergency registration" from Health Canada. Recent emergency registrations have been granted to glyphosate and imazapyr (R.D. Breckels, B.W. Kilgour, 2018). However, glyphosate is generally not recommended for parrot's feather control, as this herbicide only kills emergent shoots and plants often regrow in

greater densities. The use of imazapyr has been evaluated on small infestations with excellent and moderate results (Wersal, 2010). In the United States there are formulations of glyphosate and imazapyr registered for use in aquatic systems, but no formulations are currently registered for aquatic use in Canada.

BIOLOGICAL: NOT AVAILABLE

At present, there are no approved biological control measures for parrot's feather in British Columbia (Wersal, 2010); however, a number of biological agents have been evaluated outside of Canada for parrot's feather management. These include *Lysathia* species and *Listronotus marginicollis*, leaf-feeding insects that reduce emergent shoot biomass in the plant's native range and *Pithium carolinianum*, a fungal pathogen that causes root and stem rot and decrease overall plant integrity (DiTomaso *et al*, 2013; Raincoast Applied Ecology, 2016).

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CONTROL SUMMARY

The following table provides a summary and comparison of control methods for parrot's feather.

CONTROL STRATEGY	TECHNIQUES	APPLICABLE SITE TYPE	PROS	CONS
Mechanical	**Excavation/ dredging**	Large scale infestations	Moderate control, particularly after manual removal	Expensive; may alter characteristics of water body; disturbance creates fragments spreading; can be successful if used in combination with other methods
Manual	**Hand Pulling**	Small scale infestations	Inexpensive	Labor intensive; disturbance creates fragments
	Harvesting	Small infestations	Moderate control	Expensive; requires specialized equipment; may alter characteristics of water body; disturbance creates fragments
Cultural	**Shading**	Small infestations	Offers moderate control	Need 70% or more shade to reduce biomass; construction of the shading structures is expensive and time consuming
	Benthic Barrier	Small to moderate scale infestations	Effective; inexpensive	Non-selective; can affect other species, including aquatic invertebrates
	Riparian Reforestation	Large scale infestations	Inexpensive	Reduces open water and habitat for other species, may reduce flow; takes a long time for adequate growth to shade water body/infestation
	Water Drawdown	Large scale infestations	Inexpensive	Must be dry; parrot's feather may tolerate drawdowns lasting 9+ months if sediment remains moist; non-selective and can affect other species; not possible for all sites
	Flooding	Large scale infestations	Inexpensive	Non-selective and can affect other species; not possible for all sites
	Conversion to Vegetative Marsh	Large scale infestations	Inexpensive	Reduces open water and habitat for other species; may reduce flow; takes a long time for adequate growth to shade water body/infestation

CONTROL STRATEGY	TECHNIQUES	APPLICABLE SITE TYPE	PROS	CONS
Chemical	**Herbicide Application (diquat)**	New growth	Offers moderate control	Restricted herbicide, requires either approval or permit; unintended environmental/health impact, high public concern, requires trained staff and special permits; may observe re-growth; subsurface application may result in fragmentation; may not kill submerged vegetation or rhizomes
Biological	**No biological control agents are currently available in British Columbia**			

CONTROL SUMMARY COLOUR LEGEND

GREEN: RECOMMENDED

ORANGE: CAUTION

RED: NOT RECOMMENDED OR NOT AVAILABLE

Disposal

ON SITE DISPOSAL

Since parrot's feather does not spread from seeds or colonize terrestrial areas, it can be composted. Biomass can also be disposed on-site (dumped within grassy areas or other locations at least 5 metres from watercourses and outside of wet soils) (Raincoast Applied Ecology, 2016). Ensure that plant material cannot be washed back into a water body during rain.

OFF SITE DISPOSAL

When disposing off site, transport plant parts on tarps or in thick plastic bags to an appropriate disposal or compost facility. In the Metro Vancouver region, several facilities accept parrot's feather plants and/or infested sediments. Please consult this disposal facility list for current details.

PLEASE CONTACT ALL FACILITIES BEFOREHAND TO CONFIRM THEY CAN PROPERLY HANDLE THE MATERIAL.

CLEANING AND DISINFECTION[2]

Before leaving a site, all visible plant parts and soil from vehicles, equipment, and gear should be removed and rinsed if possible. When back at a works yard or wash station, vehicles should be cleaned and disinfected using the following steps:

- Wash with 180 °F water at 6 gpm, 2000 psi*, with a contact time of ≥ 10 seconds on all surfaces to remove dirt and organic matter such as vegetation parts or seeds. Pay special attention to undercarriages, chassis, wheel-wells, radiators, grills, tracks, buckets, chip-boxes, blades, and flail-mowing chains.

2 Adapted from Metro Vancouver 2017 Water Services Equipment Cleaning Procedures and Inspection Protocols.

- Use compressed air to remove vegetation from grills and radiators.
- Sweep/vacuum interior of vehicles paying special attention to floor mats, pedals, and seats.
- Steam clean poor access areas (e.g., inside trailer tubes) – 200 psi @ 300 °F.
- Fully rinse detergent residue from equipment prior to leaving facility.

* Appropriate self-serve and mobile hot power-wash companies in the Metro Vancouver area include: Omega Power Washing, Eco Klean Truck Wash, RG Truck Wash, Ravens Mobile Pressure Washing, Hydrotech Powerwashing, Platinum Pressure Washing Inc, and Alblaster Pressure Washing. Water bodies neighboring wash stations should be monitored regularly for Parrot's feather growth.

Follow-up Monitoring

Whatever control method is used, follow-up monitoring and maintenance treatments are components of an integrated management plan or approach. Parrot's feather infestations should be monitored to track treatment success. This should include location (GPS coordinates), patch size or segment length (square meters), treatment history (dates and methods), and site photos (upstream and downstream views) (Raincoast Applied Ecology, 2016).

Restoration

Restoration is recommended to create competition, control parrot's feather regrowth and replace lost habitat. River pump sand should be used to restore the ditch elevation following excavation. Use of shade or bottom fabric is not recommended after a treatment regime because it does not provide full coverage of ditch margins and culvert inlets, conflicts with future channel maintenance, and is expensive to purchase and install. This strategy requires regular monitoring and repeated excavation by hand and machine (Raincoast Applied Ecology, 2016).

Species must be prescribed based on the ecology of the site and should be determined by a qualified environmental professional who has experience working in aquatic ecosystems. Local biologists, environmental professionals, native and domestic forage specialists, and plant nurseries are all good sources for localized recommendations for regional native species and regionally adapted domestic species, based on site usage. There are several science-based resources available to guide restoration efforts, such as the South Coast Conservation Program's Diversity by Design restoration planning toolkit.

Examples of competitive aquatic species that may be planted at parrot's feather restoration sites are listed below.

AQUATIC PLANTS		
Bull rush	Cattail	Floating-leaved pondweed
Yellow pond lily	White water-buttercup	Robbin's pondweed

Parrot's feather sites are often found in areas with existing, or potential, wildlife populations (e.g. deer, beaver, muskrat, vole, etc.) that can damage restoration plantings. Therefore, any revegetation plan must consider impacts from wildlife and utilize appropriate mitigation measures to protect the restoration and existing native plantings (tree wrapping, exclusion caging/fencing, vole guards, etc.).

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Additional Resources

For more information please refer to the following resources.

- British Columbia Ministry of Forests, Lands, Natural Resources Operations and Rural Development, Invasive Alien Plant Program (IAPP). www.gov.bc.ca/invasive-species
- E-Flora BC, an Electronic Atlas of the Plants of British Columbia. www.eflora.bc.ca/
- GrowGreen Guide. www.growgreenguide.ca
- Grow Me Instead. http://bcinvasives.ca/resources/programs/plant-wise/
- Invasive Species Council of British Columbia Parrot's Feather Factsheet. https://bcinvasives.ca/wp-content/uploads/2021/01/Parrots-Feather_Factsheet_04_22_2019.pdf
- Pesticides and Pest Management. Province of British Columbia https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management

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