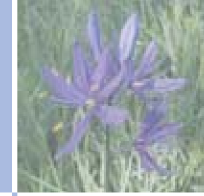


Restoring British Columbia's

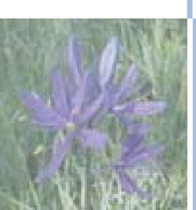
# Garry Oak Ecosystems

PRINCIPLES AND PRACTICES

## Chapter 10
## Species Propagation and Supply

**Contents**





# Chapter 10

# Species Propagation and Supply

by Fred Hook and Brenda Costanzo

Propagation of Common Camas (*Camassia quamash*) at Beacon Hill Park Nursery. Photo: City of Victoria

## 10.1 Introduction

In almost every restoration project, obtaining appropriate native species will be challenging. For example, many of the plant species of interest may not be in commercial production or available in the numbers needed; others will not be available at all. Vertebrate and invertebrate species, such as butterflies, may have to be captive-raised or collected under appropriate conditions, and permits may have to be obtained before those or other endangered species are re-introduced to a site (see Chapter 4: Species and Ecosystems at Risk).

Maintaining the genetic integrity not only of existing source populations but also of the resulting re-introduced populations must also be considered. Maintaining the genetic makeup of the material collected on your restoration site or from a nearby similar site is important for the longevity of the restoration project, especially in view of climate change and other types of environmental change. Additionally, budget concerns, availability of space for on-site propagation, availability of native plant nurseries, and availability of skilled staff can present challenges to restoration projects. Availability of plant material from salvage sites will have to be factored into the decision about whether to collect and propagate the plants yourself or to contract-grow all or part of the supply with commercial nurseries.

The restoration of animal populations through re-introduction or population enhancement requires consideration of similar factors.

Chapter 2: Distribution and Description describes the Restoration Ecosystem Units (REUs) that may be present in your restoration project area, or those that could be sustained on the project site. Refer to Table 2.2 (Chapter 2) and Appendix 4.1 (Chapter 4) to find the species that may have been present in your representative REU but which are currently absent from or present in reduced numbers on the site. Once you have determined your **restoration target** (what your site should look like and how it should function), you can generate a list of native species that you can attempt to re-introduce or enhance. Refer to Chapter 8: Restoration Strategies section 8.4, for further information.

### 10.1.1 Chapter Outline

Most of Chapter 10 deals with plant species but provides some references to other organisms. The overall outline of this chapter is as follows:

**Section 10.1: Introduction**—gives a brief overview of some of the challenges involved in carrying out a restoration project.

**Section 10.2: Basic considerations for plant propagation with respect to restoration** —considers questions regarding the ethical collection of plants and species at risk, and the maintenance of genetic integrity and species diversity.

**Section 10.3: Captive rearing and plant propagation methods**—provides general methods for propagating plants from seed, cuttings, and divisions. Appendix 10.1 indicates which methods are appropriate for species mentioned in this publication.

**Section 10.4: Determining optimum techniques for propagation**—discusses the advantages and disadvantages of different propagation techniques and when those techniques might be appropriate.

**Section 10.5: Seed collection, extraction and cleaning, viability testing, and storage**—provides a general discussion of seed collection, extraction and cleaning, viability testing, and storage methods. Moralea Milne's case study of seed collection at Camas Hill (p. 10–37) provides additional information on these topics.

**Section 10.6: Selection and treatment of plant materials**—discusses the selection of suitable, healthy material to produce vigorous, genetically diverse, but species-true plants for your project.

**Section 10.7: Consideration of timelines**—outlines considerations for planning the initiation of your restoration project, and the propagation, growing, and planting of material for it.

**Section 10.8: Additional Suggestions**

**Section 10.9: References**—lists references cited in this chapter plus those which provide additional information on species-specific propagation techniques.

**Section 10.10: Related Websites**—a compilation of additional information and suggestions for those starting to plan and implement a propagation program for restoration.

**Section 10.11: Related Guides and Handbooks**

In addition, the following case studies highlight propagation programs used in a number of restoration projects:

- Plant Salvage, Section 10.2
- Taylor's Checkerspot Captive Rearing (butterfly re-introduction), Section 10.3
- Fort Rodd Hill Garry Oak Ecosystem Restoration, Section 10.3
- Native Grass Restoration at Gonzales Hill, Section 10.3
- Native Meadow Restoration at Cowichan Garry Oak Preserve, Section 10.3
- Seeds—Collection, Storage, and Germination, Section 10.5
- Contract Growing for Outplanting—Considerations, Section 10.7
- Small Scale Native Plant Nursery Set-up and Operation, Section 10.7

## 10.2 Basic Considerations for Plant Propagation with Respect to Restoration

### 10.2.1 Ethical Guidelines

Various ethical guidelines have been developed for collecting native plant material for propagation. The Garry Oak Ecosystems Recovery Team's Native Plant Propagation Steering Committee has posted guidelines at: www.goert.ca/ethical_collection.

As well, there is the "1-in-20 rule", which refers to collecting no more than one-twentieth (5%) of a plant's parts, of a plant, or from a plant population in a particular site. So before collecting, there should be at least 20 plants within the population, and when collecting propagules, no more than 5% of the plant should be removed, or no more than 5% of the seeds or fruit should be taken.

For further information about considerations when collecting plant materials for propagation, refer to the Genetic Integrity section (10.2.3), and also Source Diversity section (10.6.2).

Salvage of plant materials should not be done unless the site is scheduled to be destroyed. See the following case study on plant salvage.

Salvage of plant materials should not be done unless the site is scheduled to be destroyed. See the following case study on plant salvage.

## Case Study 1. Plant Salvage

by Nathalie Dechaine

Plant salvage tools and equipment ready for harvesting. Photo: Nathalie Dechaine

### Introduction

Ideally, native plants would remain in their natural environment. Typically, native plant salvaging is a last resort to rescue plants that would otherwise be lost to site alteration, such as for housing developments (refer to GOERT's ethical collection guidelines: www.goert.ca/ethical_collection). Preferably, salvaging is conducted by an organized group for an established program rather than as an informal activity. Proper planning ensures that native plant salvage is done in such a way that it protects salvagers, landowners, infrastructure, and ultimately the native plants being salvaged. Native plant rescue is hard but rewarding work if done properly. Salvaging can provide an inexpensive source of locally adapted plants, but it is important to know what will be done with the plants after they are salvaged. Depending on circumstances, they may go directly to a restoration site, a native-plant demonstration garden, or a holding site, or they may be taken by individuals to enhance their own backyards. It is not appropriate to take plants from parks or protected areas. That is considered poaching.

### Planning Prior to Salvaging

#### THE PEOPLE

It is important to consider who will organize and administrate the salvaging and who will help with it. In most cases, native plant rescue is undertaken by volunteers. Fortunately, most areas have local botany, naturalist, or gardening clubs from which the coordinator can recruit volunteers. People with some expertise in gardening and/or native plants can help train other interested but inexperienced volunteers. Preferably, the group can meet beforehand to sign any release of liability forms. Training can be done in a club or classroom setting prior to salvaging, or it can be done in the field. Suggested training topics include ethics, plant identification, salvaging techniques, care and maintenance of salvaged plants, and how to avoid transplanting pests, diseases, and invasive species.

#### THE SITE

Finding potential salvage sites can be made less challenging by considering the following. Each agency has different development approval processes, so it is important to become familiar with local requirements. Some agencies require publication of development applications, or in some states, an intention to clear land. These announcements can be found in local newspapers, on public websites, on signs on the site, or by notifying the local community associations. It is helpful to screen the salvaging potential of the site by speaking with local naturalist groups, neighbours, and the planning department responsible for processing the development application. It is equally important to build a good relationship with the applicant because they are usually responsible for project timelines and granting permission. Generally, supporting native plant salvaging is one way an applicant can help demonstrate their attempt to address environmental and social concerns, and to gain community support, all of which can be requirements for approval.

Once a site has been identified, there are several things to consider prior to salvaging. Permission to salvage must be granted from the appropriate landowner or agency, preferably in writing. The agreement should include terms, conditions, and logistics, such as liability issues (release disclaimer and whether or not insurance is required), how the salvagers will access the site and during which dates and hours, how adjacent property owners will be notified about the salvaging activities, and what will be done with the salvaged plants.

Once permission is granted, it is important to ensure that the area is appropriate. The following conditions should be met prior to salvaging:

- An inventory of the native and invasive plants has been conducted, as thoroughly as possible (seasonally dormant plants may present challenges).
- Legal boundaries are known and marked on-site.
- Underground utilities have been checked, and if present, marked on-site (this may be a legal requirement in some areas).
- Local authorities or naturalist clubs have been contacted for information about any species at risk that may be on-site.
- Any areas that are not appropriate for salvaging (e.g., that are protected for conservation or which pose safety risks) have been identified.

### The Next Step: Opening the Site to Salvagers

Once all the background information has been compiled, a map and written instructions can be used to communicate that information to the salvagers. Email and blogs can be used to organize volunteers and share information, as long as there are measures in place to protect sensitive information. A site orientation is recommended for training volunteers on-site.

#### PLANT SALVAGING

Timing of plant salvaging can be challenging. Ideally, plants should be transplanted when they are dormant, yet dormant perennial plants can be difficult to locate and identify. Annual plants may also be present but not obvious because they can remain ungerminated (dormant) in the soil (a seed bank) until conditions become favourable. Salvaging opportunities are generally the result of the development process, which does not necessarily align with the most opportune time to salvage. It is important to remember that salvaging can be successful at any time of year if the plants are properly cared for.

#### GENERAL TIPS FOR SUCCESSFUL PLANT SALVAGE

- **Protect the roots.** This is key to successful salvage.
- **Smaller is better.** Smaller plants (especially shrubs and trees) adjust to disturbance better than larger, more established plants (with the exception of bulbs).
- **Dig around and under, not through plants.** This method avoids “collateral damage”.
- **Care for the plants immediately after salvaging them.** If possible, transplant plants directly into containers on-site, especially if they are to be stored for a period of time. Plants seem to adjust

better if they rest in containers for a short period of time. In addition, unwanted transplants like weeds or invasive species can be removed, which prevents them from being unintentionally introduced on the new site. Allow for as much time to process and transplant items as it took to dig them up.

- **Keep all plants well watered.** Even though some native plants may be drought tolerant, they will need extra care to help them through the upheaval. For at least the first year of being transplanted, plants should be kept well watered.
- **Salvage components as well as plants.** Salvage other habitat components such as woody debris, rocks, mosses, and soil, which contain mycorrhizal fungi and other beneficial biota.
- **The right plant in the right place.** When replanting the salvaged plant, consider the conditions where it was growing (aspect, drainage, sun or shade, etc.) to ensure conditions in its new spot are appropriate.
- **Dig deep.** Depending on the habitat, some plants, especially bulbs, are quite deep in the soil.

## Tips for Salvaging Specific Types of Plants

### PERENNIALS: BULBS

A transplant spade can wedge up a clump of soil, and bulbs can be pulled from the bottom of the clump. This is easier and protects the bulbs much better than trying to dig them out from the top of the soil. If bulbs are dormant, keep them covered in loose soil and try to bury them as close as possible to the same level as where they were found (to be conservative, bury them a bit deeper than they were found). If the bulbs are flowering, cut off the bloom to preserve the bulb's energy before burying them. Most native bulbs do not do well when left to dry like horticultural bulbs.

### PERENNIALS: ROOT WADS

Dig around root wads carefully. Try to keep the roots as intact as possible. Some native perennials can be divided like horticultural varieties if they appear to be crowded, and may prosper from being separated. Carefully replant the root wads near the soil surface but ensure they are covered with enough soil or mulch to protect them from the elements.

Salvaged plants potted for growing on and re-planting. Photo: Nathalie Dechaine

ANNUALS

Annuals generally do not transplant well but will continue to grow if well cared for. The goal is to keep the plant alive long enough so that it can set seed. Sometimes annuals will appear around other salvaged plants because they came from the seed bank in the soil. It is always recommended to transplant native soil for this and many other reasons (unless there are known diseases or pests present).

SHRUBS

Choose as small a shrub as possible. Get as much root ball as possible, and when necessary, cut roots with a sharp instrument so they heal along clean lines. Prune the top growth so that is it smaller than the underground root ball. More roots than shoots will give the plant enough energy to adjust to being transplanted. Most shrubs are fairly resilient.

TREES

Choose as small a tree as possible. Get as much root ball as possible, and when necessary, cut roots with a sharp instrument so they heal along clean lines . A transplant spade can dig through roots cleanly and can dig deeper than a conventional shovel. Depending on the type of tree, pruning may help or hinder the tree's success. Hardwood trees generally tolerate and in some cases benefit from pruning. Prune the top growth so that it is smaller than the underground root ball. This is generally not recommended for most conifer species. Trees will not survive if their roots dry out, so transplant them immediately and water well.

## Sources

Personal experience, The District of Saanich's Native Plant Salvage program, other experienced salvagers.

## Useful Links

Indiana Native Plant and Wildflower Society—Native Plant Rescue Protocol www.inpaws.org/INPAWS%20Native%20Plant%20Rescue%20Protocol.pdf.

King County Native Plant Salvage Program www.kingcounty.gov/environment/stewardship/volunteer/plant-salvage-program.aspx.

Mason & Grays Harbor Counties – Native Plant Salvage Program http://graysharbor.wsu.edu/NativePlant.

Native Plant Salvage Alliance www.ssstewardship.org.

Native Plant Study Group (Victoria, British Columbia) www.npsg.ca/index.shtml.

Saanich Native Plant Salvage Program www.gov.saanich.bc.ca/resident/environment/salvage.html.

Thurston County – Native Plant Salvage Project http://thurston.wsu.edu/NPS.htm.

**Nathalie Dechaine** *is a member of the Native Plant Study Group in Victoria and formerly worked as Environmental Education Officer for the District of Saaanich.*

### 10.2.2 Species at Risk

If species at risk are going to be restored to a site, permits are required if the species are listed on Schedule 1 of the federal *Species at Risk Act* (SARA) on the SARA registry website.

For provincial Red- and Blue-listed species (listed by the BC Conservation Data Centre) that occur in a Provincial Park or Protected Area, permits must be obtained through the Permit Bureau website.

For information on species at risk and recovery planning, refer to these websites:

- BC Species and Ecosystems Explorer: www.env.gov.bc.ca/atrisk/toolintro.html
- NatureServe: www.natureserve.org
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC): www.cosewic.gc.ca/eng/sct5/index_e.cfm
- Species at Risk Public Registry – Recovery Planning: www.sararegistry.gc.ca/default_e.cfm
- Ministry of Environment – Recovery Planning in British Columbia: www.env.gov.bc.ca/wld/recoveryplans/rcvry1.htm

See also Chapter 4: Species and Ecosystems at Risk, for further guidance on restoration involving species at risk.

### 10.2.3 Genetic Integrity

When selecting plant material for propagation, it is recommended that the ecoregion characteristics of the collection site be considered (e.g., the amount of rainfall, including winter precipitation, and the soil types). As well, plants propagated for outplanting should be field tested to assess the adaptive abilities of each provenance.

If possible, determining the type of breeding system and whether the plants cross-pollinate is also useful to know (genetic composition of the species), but in reality, we know little about our native plant pollinators. Individuals that cross-pollinate produce populations that are genetically different and therefore more adaptable than self-pollinating individuals, which are more genetically homogenous (Jones 2005). Self-pollination can lead to inbreeding and potentially weaken the populations' ability to adapt to different environmental stresses and/or climate change. A plant that is endemic, ephemeral (as are many of the Garry Oak associated species in B.C.), and self-pollinated will have greater genetic variation between populations, whereas a plant that is wide-spread, long-lived, and cross-pollinated will have greater genetic variation within the population and greater ability to adapt to changing conditions.

To preserve the genetic integrity of plant material that will to be restored to a site, it is recommended plants not be used if they are genetically similar to those that were initially (or still) on the site. If seeds are used from plants that were located far from the restoration site, outbreeding depression and swamping could result (Booth and Jones 2001). However, this takes time to assess; therefore, most projects do not have the budget to do field trials and genetic studies. To minimize problems of inbreeding and outbreeding depression, plant material from adjacent or nearby sites can be used for propagation (refer to Species Diversity Section 10.2.4 and Selection and Treatment of Plant Materials, Section 10.6).

If the site where the propagules were collected was already disturbed, the plants will also need resilience and adaptability, which may be found in non-local genotypes (Johnson and Mayeux 1992). The flip-side is that these genotypes may contaminate the local gene pool through hybridization, which is more common in annuals and short-lived perennials (a large number of Garry Oak associated plant species hybridize readily).

### 10.2.4 Species Diversity

Along with the genetic considerations above, appropriate plants need to be chosen according to the microhabitats occurring on the restoration site. If it is not possible to define or use a reference ecosystem you could instead consider the ecological processes that build communities. Refer to the Restoration Ecosystem Units described in Chapter 2: Distribution and Description, Table 2.2, and in particular, the plant species column for plant communities. A target plant community/subcommunity needs to be selected for the restoration site, and an assemblage of plants chosen for propagation. These species assemblages will naturally change and evolve with time, as influenced by climate change, natural succession, and effects of species already present. Depending on how rigorous the restoration target is, there may be a need for ongoing culling and additions to the restoration site.

#### Questions to Ask About Species Diversity

How many individuals are used, which individuals, and collected from where?
How do the species and their numbers relate to community structure and viability?
Will we be able to ensure species diversity in our restoration?

## 10.3 Captive Rearing and Plant Propagation Methods

This chapter deals mainly with plant propagation methods; however, a brief case study on the captive rearing of Taylor's Checkerspot butterfly (*Euphydryas editha taylori*) is also presented. For information on propagating other animal species, GOERT may be able to refer the reader to appropriate experts.

### 10.3.1 Captive Rearing of Vertebrates and Invertebrates

See Case Study following.

CASE STUDY

## Case Study 2. Taylor's Checkerspot Butterfly Captive Rearing

by Brenda Costanzo and Jennifer Heron

Captive rearing of several butterfly species found in Garry Oak ecosystems has been ongoing in the United States. Species reared include Zerene Fritillary (*Speyeria zerene bremnerii*), Fender's Blue (*Icaricia icarioides fenderi*), and Taylor's Checkerspot (*Euphydryas editha taylori*, a.k.a. Edith's Checkerspot var. *taylori*). The most recent captive-rearing research has centred on Taylor's Checkerspot.

Taylor's Checkerspot is listed as Endangered in British Columbia. There are records from southeastern Vancouver Island and the Gulf Islands, and the species' global range extends southward west of the Cascades into Oregon's Willamette Valley. Denman Island currently supports the only known population in B.C.

Captive rearing of Taylor's Checkerspot has been ongoing since 2003 at the Oregon Zoo in Portland Oregon, in conjunction with butterfly reintroduction projects in Washington State.

The captive-rearing project at the Oregon Zoo involved collecting Taylor's Checkerspot eggs from the wild (eggs are laid from mid-May to early June), collecting wild females for egg production, and using captive-reared females for egg production. The first two methods of egg production have provided the greater percentage of hatched eggs. The larvae are reared in small plastic containers that are lined with paper towels and closed with a clear perforated lid. The lid is then covered with fabric to prevent the larvae from escaping because they tend to crawl to the top of the containers. Leaf material (Ribwort, *Plantago lanceolata*) is placed in the containers to provide the larvae with food. In order to keep the humidity high, the containers are placed on damp towels inside a large open bin. Light is also provided by UV fluorescent tubes above the bins.

Pre-diapause larvae enter diapause anytime from mid-July until mid-February. Once molting is completed, the larvae are placed in clean, small plastic containers. These containers have inverted terra cotta plant pots placed over top of them, and they are moved to an outdoor location that is protected from wind and rain. They are checked weekly, and any larvae that have died are removed. After diapause, the small containers are removed from the plant pots, placed back into large open bins, and again provided with fresh host plants, high humidity, and exposure to light. The larvae may enter the pupal stage by early March, and are then ready for release into the wild.

The Oregon Zoo has had increasing success with their captive-rearing projects. For example, 490 eggs were collected in 2005, and 29 larvae were released in 2006. In 2006–2007, 930 larvae were hatched, and 726 (or approximately 78%) were released into the wild.

### References

Oregon Zoo: www.oregonzoo.org/Conservation/Butterflies/checkerspot.htm.

Linders, M.J. 2007. Development of captive rearing and translocation methods for Taylor's checkerspot (*Euphydryas editha taylori*) in south Puget Sound, Washington: Washington Department of Fish and Wildlife, Wildlife Program, Olympia, Wash. 2006–2007 Annual Report. www.southsoundprairies.org/documents/LindersTCSTransAnnReport07.pdf.

**Brenda Costanzo** *is the Senior Vegetation Specialist with the BC Ministry of Environment.* **Jenny Heron** *is the Invertebrate Specialist with the BC Ministry of Environment and the Chair of GOERT's Invertebrates at Risk RIG.*

## 10.3.2 Plant Propagation Methods

This section details the methods for plant propagation through sexual methods (fertilized seed) and asexual or vegetative methods (plants produced using material from a single parent with no exchange of genetic material). Vegetative methods include herbaceous cuttings, stem cuttings from shrubs, and division. Required supplies, materials, equipment, and techniques are given for successfully starting and growing native plants in the nursery.

Vegetative methods include herbaceous cuttings, stem cuttings from shrubs, and division.

### Supplies, materials, and equipment needed for seed sowing and growing

#### GROWING MEDIA

- mix for starting seed – commercial seed starter
- mix for plug propagation – soilless Sunshine Mix #4
- mix for potting on – sterilized soil:peat moss:perlite mixed at a 2:1:1 ratio and add 30 ml (2 tbsp) of 2-13-0 bonemeal to each 10 litres (2.6 gal) of mix
- mix for growing on – perlite or sawdust:sand:peat mixed at a 1:1:1 ratio.

*Note: Moisten the peat/sawdust before mixing. If using perlite, use a dust-mask and dampen to avoid dust inhalation.*

#### CONTAINERS

*Pots*

- small pots – 2" or 4" (5 or 10 cm)
- plastic cell packs or plugs in trays with drainage; use nursery trays with drainage holes for cells/plugs
- deep boxes 24" x 12" x 4" (60 x 30 x 10 cm) with slats in the bottom for bulbs e.g., Fawn Lilies (*Erythronium oregonum*) or camas lilies (*Camassia* spp.); or, for less time to flowering, use shallow plastic trays with no more than 1" (2.5 cm) of soil. Note: A good watering regime is required and trays must not be allowed to dry out during the growing season.
- open nursery flats with drainage for direct sowing of herbaceous perennials

*Root trainers*

- Hillson root trainers (for larger plants such as rose, Saskatoon (*Amelanchier alnifolia*), Alder (*Alnus* spp.), Common Snowberry (*Symphoricarpos albus*)
- Smaller root trainers for grasses/perennials
- Tinus containers for Garry Oak (*Quercus garryana*) seedlings (these are approximately 1 litre, or .26 gal)

*Note: Root trainers[1] are plastic containers with ribbed sides and an open bottom. The ribs are designed to encourage deep growth rather than circling and the containers are hinged to open so that plants can be removed without root disturbance.*

1 All root trainers are supplied by Spencer-Lemaire Industries Limited, Beaver Plastics Ltd Head Office: 7-26318-TWP RD 531A, Acheson, Alberta, Canada T7X 5A3, phone 1-888-453-5961, Fax: 1 780 962 4640,
E-mail: growerinfo@beaverplastics.com

*Plugs*

Plug trays are generally 11" x 21.5" (28 x 55 cm) with between 36 and 522 cells from 1/2" to 3" (1.3 to 7.5 cm) deep. They are designed to be used with mechanical seeders and must be matched to the specific requirements of each machine. Plugs can be seeded by hand and some large, commercial growers will sow trays on contract.

Garry Oak (*Quercus garryana*) seedlings in a 112 plug styroblock. Photo: City of Victoria

- Plug tray sowing is used where large numbers of plants are required. Plants are usually moved from cells into larger containers after germinating and establishing but some species may be planted out directly as plugs.
- It will be necessary to determine the appropriate number of seeds per cell for each species and the appropriate size and depth of cell. As this information is not generally available for Garry Oak ecosystem restoration species, it may be necessary to acquire extra seed to do trial sowings.
- Individual cells are open at the bottom to allow watering by placing on wick mats, reducing the incidence of seedling damage through overhead watering. Their advantage over open sowing (where seeds are scattered on trays of soil) is that roots don't intertwine with those of other plants in the tray and so little disturbance takes place when they are pricked out and potted on.
- Due to the limited volume of medium in each cell, plants are especially vulnerable to damage through insufficient or excess watering or fertilizing, and accumulation of salts. The number of plants in a small space makes them susceptible to insect attack or fungal growth.
- For species where limited seed is available, the use of root trainers which hold more soil can allow for growing seedlings larger, which may be advantageous.
- Plug trays are usually only used once but can be recycled. Root trainers, if treated carefully, can be re-used for 5 years before recycling.

*Plastic cell packs – 21" x 11" (55 x 28 cm)*

- plastic tray with or without perforations for drainage, and containers that fit inside the tray in range of sizes with various cell sizes
- trays can be re-used; cells will last about two seasons and then can be recycled

*Styro blocks*[2]

- usually for forestry trees but can used for vigorous shrubs and grasses (Case Study 4) and come in a variety of sizes
- common block formats are 200 and 112 plugs; cavity volumes of 2.4–6.6 cu inch (40–108 ml)

2 Supplier: Beaver Plastics Ltd., 7-26318-TWP RD 531A, Acheson, Alta, Canada, T7X 5A3, 1-888-453-5961, techsupport@beaverplastics.com

### Sexual Propagation

Seed dormancy is the mechanism that prevents seeds from germinating until conditions are appropriate. There are two basic types of seed dormancy:

- **Seed coat dormancy** – The seed coat is impermeable to water
- **Embryo dormancy** – The seed embryo must undergo physiological changes, usually under cool, moist conditions. This process, known as stratification, is a method of simulating the natural conditions under which the seed would normally germinate: a period of cool, moist weather for plants that germinate in the spring in our climate; a period of warm, moist weather for those that germinate in summer or early fall.

Seed dormancy is the mechanism that prevents seeds from germinating until conditions are appropriate.

#### METHODS FOR OVERCOMING DORMANCY

- **Seed coat** – The most common way to overcome seed coat dormancy is to scarify the seed coat to allow water to pass through. This can be done mechanically by rubbing the seeds with sandpaper, nicking with a file or knife, or, in a few cases, chemically by acid etching. In any case it must be done in such a way that it does not damage the embryo.
- **Embryo** – Seeds may be sown outside in the fall and overwintered outside, or stratified by placing the seeds between damp paper towels in an airtight plastic container, and storing in the refrigerator at 2–5°C (36–40°F) for 1–3 months. The same result can also be achieved by covering seeds in damp peat moss in plastic bags and storing them in the refrigerator. Time will vary for stratification within the same seed lot and it is possible to do several seed lots for one, two, and three months, starting in January/February so that seeds are ready to be sown outside in spring. Check containers for mold and germination, and remove any seeds that show either. Pot up germinating seeds (see below).

#### SEED SOWING METHODOLOGY

- Refer to the previous section to determine the time and method of sowing for their dormancy type. This information can be found in a variety of places including the propagation guidelines on GOERT's website (www.goert.ca/propagation) and the USDA Fire Effects Information Database.
- Clean your pots/flats just prior to using them by soaking in a solution of 10% household bleach for 20 minutes, and then dry.
- Determine which seeds will be sown at what quantity in what container. Sowing density may need to be determined through trials but some information can be extrapolated from rates for similar species that are in commercial production. See also section 10.4.3 on determining quantities of seeds to be grown.
- Use cleaned seed (see section 10.5 for information on seed collection, cleaning, storage).
- Fill containers with appropriate medium and lightly tamp down. The planting mix should be moderately moist (i.e., not running with water when squeezed).
- Place small seeds on the top of the medium and separate as best as possible; press slightly into the soil medium; lightly cover with dry, clean, washed sand, forestry sand, or crushed granite (crushed granite is an Imasco product sold in agricultural supply stores for use as poultry grit) and bottom water, or gently mist using a watering rose (fine watering roses are sold in some garden supply stores, from specialist greenhouse suppliers, and from outlets like Lee Valley

Tools). You can mix the smaller seeds with fine sand before sowing as this makes it easier to handle the seeds and spread them into the containers by using a salt shaker with appropriate sized holes (this works best for sowing into open flats).

- Very fine seeds and spores can be sown on top of the topping grit. The pots are then set in a tray of water until the medium pulls water up to the surface of the soil. The same capillary action will pull the fine seeds or spores down to the medium's surface.
- Plant larger seeds at a depth of 1–2 times the diameter of the seeds, cover with medium, then pea gravel or clean washed sand (to help with drainage and prevent damping off), and gently water with a fine mist nozzle. Cover and maintain moisture levels as with small seed.
- Label (using a permanent, waterproof, fade-resistant marker (pencil works the best!)) the flat/container with the plant name and date of sowing. Record this information with the amount of seed sown, source of seed, seed treatment, medium type, in nursery records (templates for nursery records are given in the appendices). Cover with a sheet of glass, Plexiglas, or plastic wrap, or layers of moistened newspapers to retain the moisture.
- Place flats outside. If necessary cover with screen door mesh stapled to the edges of the flats to deter insects/pests from removing seeds. Germinating seeds need to be moist and may need to be checked twice a day, or be watered on a timed system.

### POST-GERMINATION CARE

- Move seedlings into semi-shaded location or one with morning sun/dappled sun only.
- Monitor moisture; do not overwater or allow the seedlings to dry out.
- Once the seedlings have their first true leaves, prick or plant them out into a nutrient-rich potting mix. Make your own mix: sterilized soil:peat moss:perlite in a 3:2:1 ratio and add 30 ml (2 Tbsp) of 6-8-6 fertilizer to each 10 litres (2.6 gal) of mix. You can water with a weak liquid form of transplanting fertilizer (4-10-2) weekly, but ensure that the soil is moist before applying any fertilizer.
- Seedlings should be acclimatized in a shade house or lath-covered cold frame for a few weeks until they are set out in longer-term storage areas. Fertilize every 7–14 days from spring until late July.
- In the fall, pot up seedlings that have sufficient root mass into larger pots. Check the size of the root balls to determine the next pot size that should be used (see "Potting On" below). Do not use a pot that is too large or too small.
- Overwinter in a cold frame, sunk in sand, sawdust, or soil in nursery beds (to retain moisture and protect from frost), in a cool greenhouse, or in a place that is protected in some way (such as by using Remay cloth or shade cloth) from fluctuating temperatures and wind.

### POTTING ON

- Moving seedlings to a larger pot size may be required the following spring, which will vary with the species growth rate, but this should be done before the plant is pot-bound.
- Move up one container size (pots are usually in 2" (5 cm), 3" (7.5 cm), 4" (10 cm), 6" (15 cm), 8" (20 cm), 1/2 gallon (2 litres), 1 gallon (4 litres) sizes).
- Put some potting mix in the bottom of the container, place the plant in the centre of the new pot, and make sure it is at the same height as the previous pot.

- Add potting mix around the plant and firm gently around the edges of the pot and next to the stem.
- Water and re-label.
- Record the date of transplanting and numbers of species in nursery records.

## Asexual or Vegetative Propagation

*Herbaceous cuttings are of three types:* ***tip, root,*** *and* **rhizome***. See also stem cuttings below.*

### TIP CUTTINGS

Herbaceous cuttings are of three types: tip, root, and rhizome.

- Tip cuttings are taken from early spring to early summer from herbaceous perennials.
- Choose cuttings from healthy, vigorous plants. Remove the top 3–6" (7–15 cm) with at least two leaf nodes.
- To ensure that there will be enough cutting material, shear back the stock plants repeatedly in the spring/summer, and keep them well fertilized. The stock plants will bush out and there will be a succession of tip cuttings available.
- Take the cuttings on a cloudy, humid day with no wind and have the potting mix and pots ready for insertion of the cuttings.
- Place at least one leaf node or axil well into the potting mix. Remove any leaves that will be below the soil, and pinch out any growing tips and buds.
- For a good potting mix use seed starting mix and coarse perlite at a 2:1 ratio; peat moss and coarse perlite mixed at 1:1 ratio, or a 1:1 mix of sharp sand and perlite.
- Strike cuttings into containers using 16"x 16" x 3" (40 x 40 x 7.5 cm) flats, or 11" x 21" (28 x 55 cm) flats, or plugs.
- Keep air around cuttings humid with a mist system or enclose in a plastic bag using small sticks to keep the bags open, or use the domed plastic lids that fit over standard flats.
- The cuttings should receive only morning light until they are rooted, then should be hardened-off gradually (in the spring) in a cold frame over a 2-week period before placing outdoors.

### ROOT CUTTINGS

**Examples of root types: Small roots: Woolly Sunflower (*Eriophyllum lanatum*) (REU#3, 5), Common Yarrow (*Achillea millefolium*) (REU#1, 3, 5), Shootingstar (*Dodecatheon* spp.) (REU#1)Medium-sized roots: Rough-leaved Aster (*Eurybia radulinus*) (REU#3)**

- Root cuttings can be taken for the propagation of some shrubs and herbaceous perennials.
- Use healthy root pieces in late winter or early spring prior to the start of new growth, but when the roots have a supply of stored foods.
- Wash roots and choose firm, fleshy roots about the thickness of a pencil.
- Choose sections that are as close as possible to the root crown of the plant. Dispose of any weak, damaged, or diseased roots.
- Use sterilized secateurs or knives to cut roots into short sections. Cut the root tip end on an angle, and straight-cut the end nearest the root crown (this will make it obvious which end goes up when striking the cutting).

- Dibble a hole with a pencil approximately 1–2" (2.5–5 cm) deep. Place cuttings vertically or at 45° angle into a soil-less potting mix of coarse sand, a 2:1 mix of sand and peat moss, or a mix of equal parts vermiculite and perlite (use a dust mask) with the root tip end placed down into the pot.
- Cover the medium's surface with fine sand or pea gravel.
- Water the cuttings in gently to ensure good contact with the medium and cover the container with plastic, glass, or Plexiglas.
- Label the containers and enter the name of the plant, its source, the number of cuttings, the date they were collected and the type of medium used in your nursery records (see appendices).
- Place pot in a warm but shaded place. It may take 6–8 weeks before new shoots and roots have developed.
- Cuttings can be potted up when they have 2–3 sets of leaves, or sooner, depending on the size of the container in which they have been started.

### RHIZOME CUTTINGS

**Examples: Perennials: Long-stoloned Sedge (*Carex inops*) (REU#1, 2, 7).**
**Shrubs: Saskatoon (REU#7), Nootka Rose (Rosa *nutkana*) (REU#1, 2, 5), snowberry (REU#1, 2, 3, 5, 7)**

- Divide rhizomes with at least 2–3 buds or nodes in each section.
- Lay the section on the top of soil-less potting mix so that it is in contact with the soil. You may want to anchor the sections with opened up paper clips or some other type of anchor.
- Water and cover with glass or Plexiglas.
- Label the containers and enter the name of the plant, its source, the number of cuttings, the date they were collected and the type of medium used in your nursery records.
- Place in the shade until new shoots have developed.

**Stem cuttings** taken from shrubs are of three types: *softwood, semi-hardwood*, and *hardwood* cuttings. Use potting medium of equal parts sand:peat moss (or peat substitute if peat from a renewable source is not available), perlite:peat, or vermiculite:sand.

Stem cuttings taken from shrubs are of three types: *softwood, semi-hardwood,* and *hardwood* cuttings.

### SOFTWOOD CUTTINGS

**Examples: Dull Oregon-grape (*Mahonia nervosa*) (REU#8), Indian-plum *(Oemleria cerasiformis)* (REU#1, 2), Mock-orange (*Philadelphus lewisii*)**

- Take these in early morning during spring or early summer, using new growth when deciduous shrubs are first leafing out.
- Take the growing tip plus two to three nodes (3" (75 mm) in length).
- Cut beneath a leaf node.
- Trim large leaves to reduce moisture loss.
- Place rooting medium in 4" (10 cm) pot. Press firmly down leaving approximately 3/8" (1 cm) at the top.

- Use a pencil or dowel to make holes in the medium.
- Dip the root ends of cuttings in rooting hormone #1.
- Insert cuttings into the holes in the medium and firmly press media around the edges so cuttings remain upright.
- Gently water and label the containers and in your nursery records enter the name of the plant, its source, the number of cuttings, the date they were collected and the type of medium used.
- Provide mist and bottom heat if it is available. If not, cover the container with clear plastic bags (support bags with small sticks such as chopsticks or bamboo skewers), clear plastic domes (ones that fit over flats), or cut open large, clear pop bottles and use them as domes. Check for condensation build-up and vent the cover.
- Place in a semi-shady location (cuttings will need filtered light such as under deciduous trees) and check for mold and monitor moisture levels.
- Check for rooting in 6–8 weeks by gently tugging on the cuttings. Knock out the cuttings and check the roots, which should be 1/2–3/4" (1.5 to 2.25 cm) long.
- Pot up rooted cuttings in 4" (10 cm) pots and place in a shade house or sink into sand or soil in a cold frame over the winter.

### SEMI-HARDWOOD CUTTINGS

**Examples: Saskatoon (REU#7), Tall Oregon-grape (*Mahonia aquifolium*) (REU#1, 3, 5, 7), Western Trumpet Honeysuckle (*Lonicera ciliosa*) (REU#1, 2)**

- Take these cuttings in early morning in mid to late summer (early June to August).
- Use the current year's growth, approximately 4-6" (100–150 mm) in length including the softer top growth and the slightly hardened older growth.
- Remove any developing buds or blooms.
- Use steps iv–xiii in Softwood cuttings, except use rooting hormone #2.
- Use a mist system and bottom heat, if available.

### HARDWOOD CUTTINGS

**Examples: Oceanspray (*Holodiscus disolor*) (REU#1, 2, 3, 7), Indian-plum (*Oemleria cerasiformis*) (REU# 1, 2), Nootka Rose (REU#1, 2, 5)**

- Take these in mid-winter, usually from deciduous trees and shrubs once their leaves have dropped.
- Use previous season's growth—about the thickness of a pencil.
- Take long lengths, about 12" (0.3 m), bundle together with elastic bands or string, and dip the root ends in liquid hormone #3.
- Place the bundles in boxes filled with damp peat moss or sharp sand and plunge up to ¾ of their length into the medium.
- Cover bundles with Garry Oak leaves, burlap, or Remay cloth, and store over the winter (2–3 months) in cold frames while the callus forms.
- Plant the rooted cuttings out in nursery beds in spring, or pot them up into the rooting medium. Remember to label the containers and enter the name of the plant, its source, the

number of cuttings, the date they were collected and the type of medium used in your nursery records.

## Division

### DIVISION OF HERBACEOUS PERENNIALS AND SHRUBS

**Examples of herbaceous perennials: Yarrow (*Achillea millefolium*) (REU#1, 3, 5), Thrift (*Armeria maritima*) (REU#6), Rough-leaved Aster (*Eurybia radulinus*) (REU#3?), Pearly Everlasting (*Anaphalis margaritacea*) (REU#5?)**

- Divisions can be made of fibrous-rooted herbaceous perennials, fleshy crowned perennials, and some multi-branched woody shrubs, which form dormant buds at the base of the stems.
- Cuttings are best done when the plant is dormant in early winter or late fall.
- Ensure the plant material is moist before dividing.
- Prepare either a transplanting bed or pots with soil mix.
- Divide the crown by cutting around the perimeter of the perennial or shrub with a sharp shovel.
- Split the crown of herbaceous perennials by slicing with a sharp transplanting shovel or a knife into pie-shaped wedges (about 2–3 only), ensuring there is sufficient root material attached to the crown. Remove any dead material from the centre of the plant.
- For shrubs, cut back the tops of the shrub and slice off the outer sections with adequate roots at the base of the stems (e.g., Nootka Rose (REU#1, 2, 5), Oceanspray (REU #1, 2, 3, 7)).
- Keep the material moist while the sections are out of the ground, and water in once transplanted or potted up.
- Perennials that are kept as stock plants should be divided every 2–3 years following the guidelines for dividing in the fall for spring/summer bloomers, and dividing in the spring for late summer/fall bloomers.

### DIVISION OF BULBOUS PERENNIALS

For more information, please see "Propagating Flowering Bulbs, Corms, and Rhizomes: Some shortcuts from the Beacon Hill Nursery Experience", Appendix 10.1.

**Examples of bulbous perennials: Bulbs: Nodding Onion (*Allium cernum*) (REU#7), Hooker's Onion (*A. acuminatum*) (REU#5), camas spp. (REU#1, 3, 4, 5), Chocolate Lily (*Fritillaria affinis*) (REU#4)**
**Corms: Harvest Brodiaea (*Brodiaea coronaria*) (REU#4), Fawn Lily (REU# 1, 2), Fool's Onion (*Triteleia hyacinthina*, White Triteleia) (REU#4)**

- Using stock plants, lift and divide bulbs.
- Bulblets can be removed from the edges of the basal plate (camas spp.) or at the leaf bases (onion spp.).
- Divide stock plants every 3–4 years in the fall by lifting and separating bulblets.
- Pot the bulblets up into flats or pots, water in, and label.
- Corms can be divided in the fall by removing the old inner corm and separating the outer smaller cormels from the base of the new corm.

- Place the dry new corms and smaller cormels in a paper bag or box in a cool area that will not freeze.
- Plant these in pots, flats, or nursery beds in the spring.

### SUCKERS

**Examples of plants that produce suckers: Saskatoon (REU#7), Nootka Rose (REU#2), Mock-orange (*Philadelphus lewisii*), Common Snowberry (REU#1, 2, 3, 5, 7)**

- Take side shoots from shrubs that arise from below the ground.
- Make cuttings when the shrub is dormant.
- Dig out the suckering shoots with roots intact and separate from parent plant.
- Pot up or transplant the rooted suckers into nursery bed.

### LEAF PETIOLE CUTTINGS

**Examples: Broad-leaved Stonecrop (*Sedum spathulifolium*) (REU#3,7).**

- Leaves can be used to propagate perennials vegetatively.
- Take leaf cuttings in spring when the leaves are plump, but prior to flowering, or in early fall.
- Using a sharp knife, remove the leaf near the base of the plant.
- Insert the leaf base into the rooting medium; water and label the containers and enter the name in your nursery records of the plant, its source, the number of cuttings, the date they were collected and the type of medium used.
- Place the pot in a warm place with diffused light.
- Repot into individual pots after about four months.

## Case Study 3. Fort Rodd Hill Garry Oak Ecosystem Restoration—Parks Canada Agency

by Conan Webb

The objectives of this project at Fort Rodd Hill (FRH) were to:

a. test the efficacy of cutting out mature Orchard-grass (*Dactylis glomerata*) by removing only the root crown

b. test the feasibility of removing Orchard-grass by hand on a small scale (four 6 m x 6 m deep-soil plots (7.17 sq. yds.) and two shallow soil plots on rocky slope areas: one approximately 10 m x 10 m (10.95 sq. yds.); the other 10 m x 20 m (10.94 yds. x 20.87 yds.)

c. test the feasibility of removing Orchard-grass by hand on a medium scale (1.3 ha rock outcrop (3.21 acres))

d. investigate the feasibility of converting an herb layer dominated by Orchard-grass into one dominated by native grasses by removing mature Orchard-grass and planting native grasses at both a small (0.04 ha (0.098 acre)) and medium (0.5 ha (1/24 acres)) scale.

The study site is located in Victoria, on the west side of Esquimalt Harbour, and is in the Nanaimo Lowlands Ecosection and the Coastal Douglas-fir biogeoclimatic zone. Most of the area is underlain by Wark gneiss, a coarse to medium-grained metamorphic rock that outcrops extensively. Glacial deposits overlay bedrock throughout much of the study area, and deep-soil pockets occur within many bedrock exposures. Due the large number of deer present on the site, a fence was installed prior to planting. The study site is on the slopes and toe of a wooded (Garry Oak and Douglas-fir, *Pseudotsuga menziesii)* rock outcrop. The outcrop has been surrounded by a deer fence 2.1 m high and 400 m long (2.29 yds. x 437.45 yds.), which encloses approximately 1.3 ha (3.21 acres).

The grass species that were outplanted were selected based a number of factors:

a. common native species found growing in similar habitats around the Orchard-grass field

b. common native species found growing in similar less-invaded habitats at FRH

c. how robust native species were, which was presumed to correlate with their ability to compete with Orchard-grass

d. ease of growing

e. availability of local seed sources (at FRH)

As well, the native Blue Wildrye (*Elymus glaucus*), Alaska Brome (*Bromus sitchensis*), Columbia Brome (*Bromus vulgaris*), and Alaska Oniongrass (*Melica subulata*) were selected as species to plant in the study site. The study site already contained individuals of all of these species.

The wildflower species selection was based on the same criteria as those for grasses, except for criterion (a). Wildflower species planted were Spring Gold (*Lomatium utriculatum*), Harvest Brodiaea (*Brodiaea coronaria*), and Fool's Onion (*Triteleia hyacinthina*, White Triteleia).

Seed was collected on-site within the 54 ha (133.43 acres) of land managed by Parks Canada Agency. Seed was collected by University of Victoria co-op students who had been hired annually as part of the larger Garry Oak restoration project at this site. When grass seed was naturally dispersing, it was collected by using the thumb and forefinger to pinch the stem firmly below the inflorescence, then drawing the hand down the inflorescence to collect the seed in the palm of the hand. Collecting sites were visited weekly over the seed-ripening period, and plants were tested to determine when most of the seeds from any given inflorescence would detach easily. Regular visits ensured that a site was not left so long that no mature seeds were left on the plants.

The amount of time needed to collect seed was highly dependent on:

a. the overall plant density and number of inflorescences per plant: low plant density (or few inflorescences per plant) increases the time to search for and travel between plants
b. the number of seeds collected per plant (this is also affected by seed readiness: if too early, few seeds can be collected from each plant)

It took approximately 50 hours to collect 1.1 kg (2.43 lbs.) of seeds from the species at FRH, and more time if species identifications had to be confirmed. Grass seed generally was ready for harvesting from mid-June to mid-July; however, there were also yearly variations of approximately two weeks. To obtain a broad genetic mix, seed should be collected from tall, medium, and short plants in equal amounts, as well as from plants growing in different microhabitats. Because seed at different sites ripens at different times, collections have to be made over a number of days.

The collected seed was sent to Yellow Point Propagation[1] for cleaning. Airflow was used to blow away the chaff and unfilled florets. Only a few hours were required to clean the 1.1 kg (2.43 lbs.) of grass seed.

Seed storage was not necessary as grass plugs could be sown and outplanted in the same year, and seeds could also be broadcast in the fall. The seeds underwent a simple germination test prior to sowing: seeds were counted out; placed on a moist paper towel and sealed in a jar; the jar was placed on a windowsill; and the number of germinates were counted over a set period of time (two weeks) to estimate percent germination.

Seeds that were to be grown as plugs were sent to the nursery shortly after being collected and sown in early August. Seed to be broadcast was kept in a dry place until early fall when it was scattered after the fall rains began.

Seed was sown in 310 styro block at the beginning of August (310 Beaver Styro blocks have 160 cells, each holding 60 ml (2.03 oz.) and are about 10 cm deep (4")). Originally, 410 styro blocks (112 cells each holding 80ml (2.70 oz.) and are 10 cm deep (4")) were used; however, the smaller 310 size allowed the roots to fill the cavity quicker and were also easier to plant. The number of seeds planted per cavity was generally 3, but this may well vary based on the results of standard germination tests conducted in a growth chamber, the state of the seed, and the growing time (plugs can be ready sooner if more seeds are sown).

Some species exhibited dormancy while others did not. No dormancy was found in Blue Wildrye, Alaska Brome, or Columbia Brome. It was found that Alaska Oniongrass needed a cold stratification

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1 Yellow Point Propagation, 13735 Quennell Road, Ladysmith, B.C. V9G 1G5 Phone: 250-245-4635. Email: ypprop@shaw.ca

period prior to germination. The seeds at FRH were stratified naturally over the winter by leaving them in mild weather in the unheated greenhouse (with the polyethylene walls removed). If colder weather or snow was in the forecast, the greenhouse walls were put on. This needs to be considered during the planning stage as it can drastically affect the sowing time, or the seeds will require artificial stratification.

The growing medium was peat-based with other components: vermiculite, perlite, and bark mulch to a ratio of 2:1 (peat:other components). This ratio gives a porous mixture that drains quickly and allows for frequent misting without over-watering. A slow release 14-14-14 fertilizer was used in the mix (100 day release) along with the other soil amendments of: 2 kg (4.40 lbs.) of lime and 500 grams (17.64 oz.) micronutrients in approximately 1 1/2 yd. mix. Dolomite lime was added to adjust the pH to approximately 6.

The greenhouses were kept at 15° to 25°C (59°F to 77°F) until the seeds germinated, and then the temperature was allowed to drop to 10°C (50 °F) at night. During the day, the greenhouse vents opened automatically at 20°C (68 °F), and were closed at night.

After the plants germinated, a 20-8-20 forestry water-soluble fertilizer was applied at a rate of 150 ppm of nitrogen at each watering. During the rapid period of growth the plants were given a water-soluble fertilizer at each watering.

A block weight difference between dry and wet weight was used to determine when to water. The difference from saturation to dry was approximately 2 kg (4.40 lbs.) and depending on the temperature and growth, it would take from a few days to over a week between fertilization.

The grass plants were allowed to reach approximately 25 cm (10") in height and then cut back to 15 cm (6"). This procedure produced a bushy plant with a good root for transplanting. The best plugs resulted from two shearings before outplanting, and shearing done in the spring. A good plug from spring planting would take about 8 weeks, whereas in the fall it would take about 11 weeks.

The plugs are ready when they can be removed from the styroblock cell cavity and have a good tight bundle of roots. Care must be taken that the plants are not grown too long or they will become root-bound. At this time, the seedlings were extracted from the styroblocks, bundled, and then placed in boxes for shipping. The plugs are able to stay in the boxes for 7–10 days if kept in a cool, shady place. If they are to be held for a longer period of time, the boxes need to be opened and watered. Outplanting can begin soon after the first soaking fall rain, usually around mid-October, and can continue throughout winter and early spring.

The site must be prepared prior to planting. This was initially done in September, however, preparing in June prior to Orchard-grass seed set proved to be better. No new weeds will germinate after this time due to the summer drought conditions. Preparation entails removing Orchard-grass by cutting out the root crown with a hooked knife (e.g., carpet knife). This method was chosen because it created minimal soil loss and disturbance compared to pulling out the entire root system. It took two people approximately a week to clear 444 metres$^2$ (531 sq. yds.), and the grass had covered 100% of the area.

Since 2005, 4000-5000 plugs have been planted into the study site annually. Grass plugs are trimmed to about 10 cm (4") in height before planting. A planting hole is created by cutting into the soil with a tool and the plant is inserted with the top of the plug being level with the soil that is then packed back around the plug. This method is quicker and creates less soil disturbance than digging does. All species were planted 25 cm to 30 cm apart (10" to 12") (~ 13 plugs metre$^2$ (1.2 yds.$^2$)). No aftercare is generally needed if the plugs are planted in the fall after the first heavy rains. The first year planting was done using inexperienced staff and took 7 days for two people. In subsequent years a professional planter was contracted and planted approximately 4000 plugs in two days.

Two methods of monitoring have been used for this project: 1) recording percent cover of all species in the planting sites before and after treatment and annually since, and 2) photo monitoring of the sites (see Chapter 7, Case Study 1 and Appendix 7.1 for photo monitoring techniques). Orchard-grass has declined from an average of 16-30% percent cover in 2005 to less than 5% in 2008. Percent cover for Blue Wildrye has increased from less than 5% to 31-50% cover. No change was detected for California Brome, which was not detected in pre-treatment surveys, but is now at less than 5% cover. Columbia Brome was planted in one area, and has now increased to 6-15% cover. Alaska Oniongrass was a minor component planted in each area: its cover has not changed since the study began in 2005, and the study is ongoing.

Costs were highly variable and depended largely on how much of the work was contracted, however the main steps and their costs are:

a. Collecting the seed (a few hours to a couple of days of work) was done by staff. Cost per square metre is negligible.
b. Seed-cleaning cost is negligible compared to the other costs. If care is taken in collecting seeds using the method described, you may not have to clean the seed further.
c. Nursery cost has proven to be the most variable: from $0.15 per plug up to $0.75 per grass plug.
d. Planting the plugs generally costs around 4 cents per plug or around $5.59 per square metre at our planting density of about 13.7 per square metre (16.4 yd$^2$)

**Conan Webb** *is a Species at Risk Recovery Planner for Parks Canada Agency at Fort Rodd Hill National Historic Site.*

CASE STUDY

## Case Study 4. Native Grass Restoration at Gonzales Hill

by Tara Todesco

The objectives of the restoration at Gonzales Hill Park were to remove non-native species from two fairly highly disturbed areas and replant with native grasses, grown by local community members from seed harvested within the park. TLC The Land Conservancy of B.C., along with other partners, has been working to restore the Garry Oak ecosystem in the park. The goals of the project were to improve the ecological integrity of Gonzales Hill Regional Park, to use an adaptive management strategy in the restoration plan for the park, and to encourage community participation.

Gonzales Hill Regional Park is located on Denison Road just off Beach Road in Victoria. Gonzales Observatory, built on the summit of the hill in 1914, was a weather station for 75 years, and the building is a heritage building. The 1.8 ha (4.45 acre) park was established in 1992 and is a small fragment of Garry Oak habitat located within a residential area. Due to its location, the site is subjected to a high degree of recreational use. Soil compaction, site disturbance, and lack of active management have resulted in the establishment of a high proportion of non-native invasive species.

The elevation at the summit of the park is 67 m (220 ft.). The site is ridged, with elongated hillocks of metamorphic rock (Wark Gneiss) that run in an east/west direction with pockets of soil in the rock indentations and in low-lying areas. In the five areas surveyed, there was a top layer of organic material 2–10 cm (3/4"–4") deep. The aspect of the soil pockets is approximately westward with a slope between 0 and 15°. Water is from precipitation, and the site drains rapidly. Surrounding vegetation includes patches of Douglas-fir (*Pseudotsuga menziesii*) and Shore Pine (*Pinus contorta* var. *contorta*).

Native grass plantings were carried out in two main areas near the observatory on sites that had been impacted by both the construction of the building and the development of a small, ornamental garden during the 1950s and ’60s. Both areas were covered primarily with non-native grasses, cotoneaster (*Cotoneaster* sp.), and English Ivy (*Hedera helix*). Both sites, except for a few rocky sections, had deeper soils than most of the rest of the park, probably due to past gardening activities and the subsequent decomposition of ivy leaves.

With the help of biologist James Miskelly (CRD Parks), two grass species were identified for propagation and replanting in the park: Blue Wildrye (*Elymus glaucus*) and California Brome (*Bromus carinatus*). These two species were chosen because they are both native and common within the park. Collections were made when grass seeds could easily be pulled by hand from the heads during a period of relatively dry weather (late July). No cleaning was required. Seed collection took less than 1 hour in each season, and both harvests in 2007 and 2008 took place in late July.

Seeds were counted and packed by hand for distribution to volunteers within a few weeks of harvesting. Seeds were then stored in paper envelopes in a dark, dry place. Volunteers were given seeds and supplies and looked after sowing and growing-on of grass plugs, which took a few hours each season. The volunteers grew the grass plugs at their homes.

A propagating plan was designed to allow the planting-out of the grass plugs in late September or early October to take advantage of the start of the fall rains. During the first two weeks of August,

Outplanting of grass plugs at Gonzales Hill Regional Park. Photos: Tara Todesco and Kathryn Martell


volunteers sowed the seeds into plastic planting trays that each contained 50 cells (54 cm x 27 cm (22" x 10"). Four seeds were sown in each cell, and moist peat was used as the planting medium. Seed trays were placed in a sunny location and kept moist until germination occurred. The trays were then moved to a semi-shaded location and were watered as required (i.e., not allowing the plants to be flooded or dry out completely). No fertilizer was added.

The grasses remained in the trays for an average of eight weeks. Planting-out of the plugs, using approximately 5 cm (2") of space between plugs, was carried out in late September and early October. A full day each year was required for two volunteers to complete the planting. The plugs were watered for the first two weeks after planting, or until consistent rainfall occurred.

During the growing period, the two target sites were cleared of all non-native grasses and any remaining roots. Removal techniques were based on best practices outlined on the GOERT website at www.goert.ca/invasive, and clearing was carried out by volunteers. There was no over-digging of the soil, and planting was carried out in the resulting open soil. This was to minimize opportunities for re-invasion by non-native species.

The grass growing project attracted a different set of volunteers to The Land Conservancy. These volunteers were interested in growing plants for the park's restoration but were not necessarily interested in other types of volunteering. To attract volunteers, local advertisements were placed through Volunteer Victoria, The Fairfield Community Organization, and the Garry Oak Ecosystems Recovery Team. In addition, volunteers were recruited from TLC's on-call volunteers. Each volunteer came in ahead of time to discuss the project and fill out volunteer application forms. As well, volunteers were encouraged to come by individually to take a look at the park and to review the growing instructions when they picked up their seeds and supplies.

Volunteers were used whenever possible in all stages of the project in order to develop a core of local community members with a sense of stewardship for the park. Ongoing communication with volunteers, including asking for follow-up phone calls and emails to track when the grasses were sown and how growth progressed, was important for keeping the volunteers' interest and commitment.

The costs involved with the restoration of the park were minimal: they covered the costs of planting trays and peat. In-kind costs included the staff hours from TLC and CRD staff, including the transport of the debris from the site by CRD Parks.

## References

Bonenfant, N., L. Kwasnicia, and A. Smith. 2007. Gonzales Hill Regional Park: study site—restoration of Garry Oak ecosystem. University of Victoria, Restoration of Natural Systems Program, Student Technical Series No. STS0710-311.

**Tara Todesco** *formerly worked at Gonzales Hill for TLC The Land Conservancy as Volunteer Management Coordinator.*

English Ivy (*Hedera helix*) growing at Gonzales Hill Regional Park before clearing, September 24, 2007 (left) and ivy partially cleared at Gonzales Hill Regional Park, September 27, 2007 (right). Photos: Tara Todesco

## Case Study 5. Native Meadow Restoration at Cowichan Garry Oak Preserve—Nature Conservancy of Canada

by Irvin Banman and Tim Ennis

The main objective of the restoration conducted at the Cowichan Garry Oak Preserve (CGOP) by the Nature Conservancy of Canada (NCC) is to restore the native deep-soil Garry Oak ecosystem grasses and camas on a site that was formerly dominated by introduced agronomic grasses. A second objective is to establish a native Garry Oak nursery comprised of grasses for the purposes of seed harvesting.

Sedges (*Carex* spp.) and camas growing in old farm fields at the Cowichan Garry Oak Preserve. Photo: Irvin Banman

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Native grass seedlings planted out in an old hayfield at the Cowichan Garry Oak Preserve. Photo: Irvin Banman

The non-native grasses that dominated the site are well-established forage and hay grasses, mainly Meadow Foxtail (*Alopecurus pratensis*) and Timothy (*Phleum pratense*). The rich dark topsoil extends to a depth of 1 m (3 feet) (an average depth of .4-.6 m or 1-2 feet), under which lies layer of heavy clay, then bedrock and shale. Historically, CGOP may have been a Qggc plant association – Garry Oak – Great Camas (*Camassia leichtlinii*) – Blue Wildrye (*Elymus glaucus*), according to the Erickson and Meidinger Classification Guide of 2007 (www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr040.htm).

The site is part of the extensive deep-soil camas meadows that were maintained by the Cowichan First Nations in the lower Cowichan River watershed before European settlement. The field in which the study is being conducted still contains the historical Garry Oak ecosystem deep soil savannah structure with very large old Garry Oak (*Quercus garryana*) trees spaced far apart (anywhere from 50 m (55 yds) to distances of hundreds of metres). The terrain slopes very gently to the west. The field is moderately wet during the winter months and retains moisture until late May to early June depending on the amount of winter and spring precipitation, after which time the ground becomes very dry until the arrival of the fall rains.

The species planted were Blue Wildrye (*Elymus glaucus*), California Brome (*Bromus carinatus*), California Oatgrass (*Danthonia californica*), Junegrass (*Koeleria macrantha*), Roemer's Fescue

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Junegrass (*Koeleria macrantha)* and California Oatgrass (*Danthonia californica*) seed stock plantings at Cowichan Garry Oak Preserve. Photo: Irvin Banman

Propagation frames at the Cowichan Garry Oak Preserve. Photo: City of Victoria

(*Festuca roemeri*), and Great Camas (*Camassia leichtlinii*). Seed was collected at the Cowichan Garry Oak Preserve and several other local areas with permission and under permit where required, and ethical seed collection guidelines were followed. These species were chosen partially to serve as a supply of native seed for further restoration. As well, they were chosen in order to observe which native grasses would perform the best in competition with each other and the non-native species, the seed of which is still in the seed bank. It is expected that the tall stature grasses, Blue Wildrye and California Brome, will out-compete the other grasses over time.

The site for the nursery is situated along a main access road into the preserve. The area chosen was in very poor condition, having been heavily disturbed and dominated by introduced grasses, Oxeye Daisy (*Leucanthemum vulgare*), Scotch Broom (*Cytisus scoparius*), and thistles (*Cirsium* spp.) The site is exposed to full sun and was enclosed with fencing to keep out deer and rabbits. Water is supplied by garden hose from the house on-site which is 200 m (218 yards) upslope from the nursery. A frame was constructed over the nursery for the installation of shade cloth in the spring until September.

The nursery has 20 cold frames, 2.5 metres x 1.5 metres (8 feet x 4 feet), for starting grasses and forbs. Some of these accommodate pots and trays; others are filled with soil and hold plants grown from seed. Three cold frames have been filled with salvaged camas, and there is open ground covered with landscape fabric for more mature plants, as well as trees and shrubs. Raised tables were constructed outside of the fenced area to accommodate additional potted plants when more space was needed. There is also a small greenhouse, which is being used on a trial basis for growing grass plugs. Mixed ready-to-use soil is stored under tarps next to the nursery.

Currently, two staff are employed at the site. Volunteers assist mainly during the winter months when youth programs are up and running and when community members are available. Volunteers contributed 500–600 hours to the nursery and out-planting program from October 2009 to April 2010. In addition, casual volunteers put in approximately 50 hours assisting with weeding and watering during the summer months.

All seed is locally collected in the Cowichan Valley area. Care is taken to collect no more than 5% of seed in any given population, and only up to this amount if the species are common and abundant throughout the region.

All plants for the restoration are propagated at the nursery except for salvaged plants like Common Camas (*Camassia quamash*), Spring Gold (*Lomatium utriculatum*), and Broad-leaved Shootingstar (*Dodecatheon hendersonii*). Trees and shrubs are salvaged from construction sites in the immediate vicinity, usually within a couple of kilometres of CGOP.

Seed collection occurs between the beginning of June and the end of September. Timing depends on the species collected and when the seed is ripened. Collection takes place during a warm and dry portion of the day, never after a rain or heavy dew, so that the seed is as dry as possible when going into storage. Most (95%) of the seed is collected on-site at CGOP. Some common forb and grass seed is collected at Mt. Tzuhalem Ecological Reserve under a permit issued by BC Parks for the purposes of Garry Oak ecosystems restoration. Seed collection is done mainly by NCC staff, and occasionally by volunteers.

The seed collection method is basic. Seed is collected by hand and several plastic yogurt containers wired together are used so that seed from numerous species can be collected at once. Seed is always transferred to breathable paper bags for storage so that it can continue to dry if there is any moisture left.

Seed collection from the grass nursery is carried out by cutting the grass stalks and taking them in bundles to the work shed. The stalks are spread out on the floor of the shed and the seed is separated by either shaking the seed off the stalk or combing it into plastic tubs. The time spent on grass seed collecting is approximately 80 hours per year. The amount of seed that can be collected from the grass nursery is far greater than what can be collected from the field in the same amount of time.

Seed cleaning, if necessary, is done by hand by rolling the seed to remove the husks and/or by winnowing (blowing off the chaff). Berries from shrubs and tree species like Saskatoon

Weeding in the propagation area at Cowichan Garry Oak Preserve. Photo: Irvin Banman

Grass seedbed at Cowichan Garry Oak Preserve after seed harvest. Photo: Irvin Banman

Grass plugs growing in root-trainers at Cowichan Garry Oak Preserve. Photo: Irvin Banman

Potted seedlings growing in frames at Cowichan Garry Oak Preserve. Photo: City of Victoria

(*Amelanchier alnifolia*) are macerated, washed, hand-rubbed over screens and then air-dried. Visual inspections are done to ensure that non-native seeds do not contaminate the mix. In total, 16 hours are spent annually cleaning seed at CGOP by NCC staff.

All seed is stored in the uninsulated work shed, which allows it to undergo natural temperature fluctuations and humidity levels until it is planted in the nursery. So far, no seed has been lost to mold or rot. This may be due in part to the fact that seed is not stored for very long periods (it is generally used within a year).

The standard soil blend used for all species grown in pots and trays is:

- 45% native soil (from what was once a hay field and is now cultivated to make way for native grasses)
- 45% sterilized fish compost*
- 5% Garry Oak soil (to inoculate the mix)
- 5% perlite

For most of the 45 species grown at the CGOP nursery, planting is initiated in the fall and continues into early- or mid-winter. Grasses are sown into plug trays; bulbous species (e.g., camas) and longer rooted species (e.g., Spring Gold) are sown in longer open trays. Tree and shrub species are sown in one-gallon pots. On average, 3–6 seeds per cell or pot are sown to ensure that each container has one plant in it. If more than one seed germinates, plants are separated into their own containers unless the roots are too intertwined. Almost all of the seedlings are subsequently replanted into larger containers for further development.

All plants remain exposed to the elements, and since the growing environment is not controlled, there is no need to harden-off the plants prior to outplanting in the field. No fertilizer is used, and watering is done only when required, which depends on the weather.

*certified organic fish and forest fines with neutral pH, heat treated to eliminated weeds; made on Vancouver Island and obtained from a local nursery.

Grasses started early in summer that have had sufficient warm weather to develop adequately go into the field 2 months after sowing. If the grasses are sown in the fall, they go into the field up to 8 months later. Some grass plugs are replanted first into one-gallon pots to grow larger because they not only survive better but also will then produce seed in the field in the first season. Bulb and perennial species are planted out after a minimum of 3 years in the nursery; trees and shrubs, anywhere from 2 to 3 years. Almost all species stand a much better chance of surviving if they have well developed deep root systems, which enable them to draw enough water to make it through the summer drought.

A variety of preparation techniques is used on planting sites. For grass species, the location is either on tilled ground or ground that is plant-free after having been covered with ground fabric for a couple of seasons (study plot). When grasses are planted out in ecologically sensitive areas at CGOP, they are placed into holes left from the removal of introduced species. In general, outplanting for all species takes place during the fall and winter months when soil moisture levels are high so that plants do not suffer from lack of water. On sites that are easy to water, outplanting is done at any time of year. Camas bulb planting is usually done in the fall and winter, but this is not absolutely necessary as the bulbs are very resilient, even when planted in spring and summer (as long as they are at least 2 cm (3/4") in diameter).

During the course of a year, 6000 grass plugs are started. It takes approximately 7-person hours to outplant 1000 grass plugs, not including preparation time and moving the plugs and supplies to the site. If plugs are planted into untilled areas, it may take 14–20 hours to plant 1000 plugs.

## Suggestions/Pit-falls

- Frost may sometimes push plugs up and out of the ground if planted in bare cultivated soil, so care must be taken to plant the plugs as deep as possible.
- Sometimes too many plugs were grown and there was insufficient time to plant them all out.
- Herbivory is an issue and deer had a significant impact in the study plot on species they favour; they browsed heavily on California Oatgrass and Great Camas in particular.
- Fencing has been installed to keep out the native Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*) and non-native Eastern Cottontail (*Silvilagus floricans*) rabbits that have impacted the plantings. Additional 300 cm (9 feet) high exclosures have been installed around the outplantings to minimize losses.
- Ensure that plants are well-watered at all stages of growth and when they are re-potted, and that enough time is budgeted for weeding.
- If at all possible, allow plants to develop good root systems by keeping them in the nursery for as long as possible before outplanting, otherwise they may easily be overwhelmed by competition or die from lack of moisture.

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**Tim Ennis** *is the Director of Land Stewardship for NCC (B.C. Region).*

## 10.4 Determining Optimum Techniques for Propagation

### 10.4.1 Direct Seed Sowing vs. Container Seed Sowing

Direct seed sowing generally requires more work than container seed sowing because the site has to be prepared ahead of time and any germinating weed seeds have to be removed. In addition, seeds that are direct sown may not find the appropriate germination site if they are scattered, and/or they may be eaten by animals or insects.

It is easier to control the growing environment and track seed germination and rooting of any type of cuttings if they are in containers (e.g., you can control watering/media during the growth/fertilization schedule). Seeds started in plugs or containers will be able to obtain sufficient root development before outplanting. The exception will be when using whip cuttings, such as those used in bioengineering projects (Polster 2009). Starting seedlings in containers will give them a competitive advantage over other plants, especially weeds.

Container seed sowing also enables development to be monitored and provides consistent growing conditions, especially during the vulnerable seedling stage. Record keeping is easier with this method of sowing (e.g., you can determine the known number of propagules to outplant), as is the automatic application of water and fertilizer. A greater number of propagules will also reach maturity and therefore will be available for outplanting.

### 10.4.2 Nursery Bed vs. Containers for Vegetative Propagation

Deciding on using either nursery beds or containers for vegetative propagation depends on the growth type of the species to be propagated. Nursery beds are traditionally used for shrubs and trees, but they can also be used for perennials and grasses.

It is easier to control the growing environment and track seed germination and rooting of any type of cuttings if they are in containers.

Some advantages of using nursery beds are as follows:

- They are less costly than containers.
- Less water is used (containers can dry out faster).
- There is greater root development for larger shrubs and trees; however, you may need to ball or burlap them for transportation which will require equipment to lift the plants, supplies, and the correct timing to be arranged for this process.
- Using nursery beds may allow the plants to stay in the beds longer than if in containers since they will not need to be repotted, as their roots are not constrained by a container. Beds may be used for trials, and plants can be maintained for future stock production (e.g., shrubs can be cut back to generate long stems to use as whip cuttings for bioengineering).
- Perennial plant materials in beds can be used for division and for taking root cuttings.

Some disadvantages of using nursery beds are as follows:

- Plants in nursery beds are hard to move around in the nursery and containers also facilitate taking plants directly to the outplanting site.

- The need to weed the nursery beds, which will have more ground surface area for weeds to grow in than containers.
- When the plant material develops through rhizomes, it is possible that the material will become too large and difficult to divide.
- Nursery beds require an initial investment to prepare the soil, which is costly.

### 10.4.3 Number of Propagules Needed (Estimation of Numbers for Outplanting)

When estimating the numbers of plant materials required for outplanting at a specific site consider the following:

- spacing (width and height considerations of the mature plant)
- percentage germination for species (each collection of seeds will differ)
- the plant composition (matrix) of the landscape microsite (refer to Table 2.2 in Chapter 2) that you want to restore to
- guidelines for spacing and numbers per species (e.g., one bunchgrass per $m^2$ for woodland and up to $5/m^2$; 4-8 herbaceous perennials/$m^2$; one shrub every 5 $m^2$; one tree every 50 $m^2$).

## 10.5 Seed Collection, Extraction and Cleaning, Viability Testing, and Storage

### 10.5.1 Seed Collection

When collecting seeds for native plant propagation, ethical collection guidelines should be followed. The GOERT website provides an example of such guidelines (www.goert.ca/ethical_collection). Additional guidelines can be found at the florabank website (www.florabank.org.au).

When collecting seeds for native plant propagation, ethical collection guidelines should be followed.

Seeds must be collected when they are ripe, which depends on the type of seed. For example, capsules must be dry and papery, and the seeds usually become brown to black when ripe. Berries or drupes normally turn red to dark purple when ripe. Banerjee et al. (1998) provide collection guidelines for woody plant seeds.

Collection methods for fruits vary depending on the type of fruit and the volume needed. Methods include simple hand-picking, removing entire fruit clusters, raking naturally fallen fruit from the ground, or flailing branches to cause fruit to fall onto tarps.

Collect only what you need for your project, and be prepared to properly store the cleaned and dried seeds for future use.

Record-keeping is extremely important in the propagation of native plants (refer to Section 10.7.3 and appendices); records can be referred to in subsequent years for guidance. The types of information that should be recorded are: species name, collection site, site description, date of collection, elevation, aspect, etc. You may want to use a specific code and a unique number for each record (see Appendix 10.2 for a seed collection record template).

### 10.5.2 Considerations for Collecting in Adjacent Sites

Before collecting seed from sites adjacent to the restoration site, a microhabitat assessment of these sites (refer to Table 2.2 in Chapter 2) should be completed to improve compatibility of propagated plants with the restoration site. This will increase the chance that the gene pool is maintained for those species collected.

When considering whether or not to collect from a site adjacent to the restoration site, determine if the species are the same (by identifying them correctly to species, variety, or subspecies), and if the genetic diversity of the resulting restoration planting will be increased by collecting at this site. It is also important to obtain written permission from the landowner to access the land, and to have the appropriate liability insurance (see Case Study 1). You should also ensure that there is minimal damage to the site and propagule sources.

## Case Study 6. Seeds – Collection, Cleaning, Storage, and Germination

by Moralea Milne

One of the most enjoyable aspects of restoration is the collection of propagules for your project. After you have surveyed your site and reference sites, and determined which species are most likely to have been present and which species you will spend your efforts on replanting, you have the opportunity to search for these species.

### Plant Identification and Locating Plants in the Field

If you are in any doubt as to plant identification, it is best to locate promising populations with the help of an expert, preferably during the flowering season because many vascular plants are easier to identify when they are in bloom. *You will need to receive permission to hike in and collect from these areas.* Identify the healthiest and most vigorous plants; they will likely produce the highest quality seeds. Mark their exact locations so when you return you can identify the plants in their new, less obvious stage as seed containers. The best way to record their locations is with a GPS device, but a little brightly coloured tape (that is removed later) can also be used to narrow down the location to the last few metres. It is also useful to collect or photograph representative seedheads and mount them so they can be used as a learning/identification tool.

Step lightly through these Garry Oak and associated ecosystems; disturbances, especially in sensitive rocky bluffs, can facilitate the spread of invasive species. It is best to collect seeds on dry days so that you do not have to worry about wet seed heads and subsequent mold problems.

It is most important to collect propagules from within your restoration site or from the nearest populations. Researchers are discovering new information on species every day. Some species that have been identified as a single species are in fact separate species with different ecological preferences.

### Seed Collection

Refer to GOERT's ethical guidelines (www.goert.ca/ethical_collection) on the number of propagules that you should collect from species, populations, and locations. As well, consult with local knowledgeable sources as to the appropriate time to collect seeds.

Many factors can influence when seeds are ripe and the quantity of seeds you might find: early and late seasonal changes, moisture and drought, browsing by predators, elevation and geographic variations, disturbance regimes, the plants' own individual requirements, and other vagaries of which we have no or incomplete knowledge. For example, Garry Oaks are mast-fruiters—plants that produce acorns in abundance only irregularly—but the acorns are predated by Band-tailed Pigeons (*Columba fasciata*), Steller's Jays (*Cyanocitta stelleri*), and Eastern Grey Squirrels (*Sciurus carolinensis*), and are vulnerable to infestations by various weevils.

Consider when you are harvesting in lean years that you are decreasing the quantity of seeds available for natural reproduction and for food for some native species. Also, a population might have been decimated already; therefore, find and mark more sites than you think you will need.

Seed collection supplies include paper and plastic (Ziploc) bags, or small plastic storage containers; a small, waterproof booklet and additional waterproof paper; indelible writing implements; a GPS unit; and field guides for identification. Use paper bags when collecting dry seeds to reduce the possibility of mold. Soft-bodied seeds, such as berries, are better collected in plastic bags or plastic storage containers.

On each seed container, record the date, plant name, location, and any other relevant information (e.g., plant colour and vigour, associated plant species, recent weather conditions (dry year, wet year), a note to try collecting two weeks earlier, later, etc.). You may want to use a code for each collection and record the code and its corresponding information in a field notebook (see also Section 10.7.3 and appendices).

### Directions for Cleaning Dry Seeds

by Heather Koni-Pass (from Jan 2007 NPSG News: www.npsg.ca)

FLUFFY SEED HEADS (e.g., Yarrow (*Achillea millefolium*), Oceanspray (*Holodiscus discolor*)): You will need sturdy gardening gloves, a sieve that will allow seeds to pass through, an ice cream bucket, newspaper, small plastic bags, and labels. With gloves on, take small handfuls of seedheads and rub them between your hands over a newspaper to separate the seeds and chaff. Place the broken seedheads into the sieve and sift. Save and label the seeds after discarding the chaff.

CAPSULES and PODS (e.g., Nodding Onion (*Allium cernuum*), camas spp., shootingstar spp.): You will need sturdy gardening gloves, a rolling pin, a large screen with mesh that will let seeds pass through, newspaper, small plastic bags, and labels. With gloves on, put a handful of capsules or pods on the newspaper. GENTLY crush the capsules or pods with the rolling pin. Take the resulting mixture and place it over a small mesh screen to separate out the chaff. Save and label the seeds; discard the chaff. Many pods curl open when dry; therefore, it is just as easy to flick the seeds out with your fingers or a thin probe.

CONES (for Grand Fir (*Abies grandis*)): You will need a face mask, paper grocery bag, blank newsprint, and a sieve that will allow the seeds to pass through. Put the cones in the paper bag and shake vigorously. Pour the contents into the sieve and sift the seeds through. Dry the seeds on the blank newsprint.

WINNOWING (e.g., grasses, sedges, and rushes): Winnowing is best for separating heavier seeds from the chaff. This is easiest done by working at a large table. You will need a broom, a dust pan, a large plastic sheet, newspaper, a fan, two deep buckets of the same height, and an ice cream bucket. Cover the table with the plastic sheet and cover the plastic with newspaper. Place one deep bucket at the end of the table, upside down, and stand a fan on the bucket with its head in a fixed position, facing down the length of the table. Turn the fan on low speed. Hold your hand in front of the fan so you can judge where the airflow is not too strong. Position the second deep bucket, right-side up, at this point in front of the fan.

Put the seeds and chaff into the ice cream bucket and hold that bucket above the second bucket that is in front of the fan, slowly pouring a little of the contents into the second bucket. If positioning is correct, the heavier seeds will fall into the deep bucket and the chaff will blow onto the table. If the air current is too strong and everything blows onto the table, simply scoop up the mixture, move the deep bucket a little further away from the fan and try again. With some experience, it becomes easy to judge the distance from the fan.

NUTS (e.g., Garry Oak (*Quercus garryana*)): You will need seeds, a bucket of water, two screens of the same size with two pieces of black landscape cloth to match the screens, and weights or clamps to hold the screens together. For acorn sowing: use 1-gallon pots full of leafy compost.

Put all seeds in the bucket of water and soak overnight. Seeds that sink are viable; discard any ones that float.

PLANTING OAK SEEDS: Place a layer of landscape cloth on a screen, spread the acorns over the cloth, and cover with a second layer of landscape cloth. Place the second screen on top and weigh or clamp all together. This is to ensure that rodents or birds do not eat the seeds. Place this package on a table in a greenhouse or in a shady spot outdoors, and water 3–4 times a day. As the acorns sprout, transfer them individually to deep, narrow pots containing good leafy compost that has been gently tamped down. Water in and continue to water regularly. Seedlings should remain in this pot until sold or ready to plant out. Take care not to damage the long root.

If you have only a handful of acorns, sprouting can be done in a canning jar with a screen on top. The cupboard under the kitchen sink is a good, dark, warm spot for sprouting the acorns.

### Directions for Cleaning Soft-Berried Seeds

by Heather Koni-Pass (from May 2006 NPSG News: www.npsg.ca)

EXAMPLES: Saskatoon (*Amelanchier alnifolia*), Salal (*Gaultheria shallon*), honeysuckle (*Lonicera* spp.), Oregon-grape (*Mahonia* spp.), Indian-plum (*Oemleria cerasiformis*), Nootka Rose (*Rosa nutkana*), Common Snowberry (*Symphoricarpos albus*)

EQUIPMENT: Waterproof apron, water source at work table, several buckets, food processor, duct tape, large sieve, clean stir stick, several cleaning rags, fine-meshed screens, clean newspaper, fan, small plastic flower pots.

- Put one or two layers of duct tape on the blades of the food processor—one layer for small seeds (e.g. *Rubus*-raspberries), two for larger seeds (e.g. Indian-plum).
- Put a small number of berries in the food processor; fill with cool water.
- Holding your hand over the spout, pulse several times until a slurry forms.
- Fill a bucket 1/2 full of cool water. Pour the slurry into the bucket of water and swirl around. Unviable seeds and berry mush will float to the surface. Viable seeds will sink to the bottom of the bucket. Set the sieve over another bucket.
- Slowly pour swirling water through the sieve, stopping before the clean seeds are poured out of the first bucket. If cleaning fine seeds, line a screen with clean newspaper. Omit newspaper for large seeds. Retrieve clean seeds from the first bucket and spread on the screen.
- Examine the remains that are left in the sieve. If you feel there are enough seeds remaining in the slurry dregs, repeat processing.
- Repeat this process until all fruits are seeded.

When you have completed the screening process, put the screens of cleaned seeds in a well-ventilated space to dry. Stand a flower pot under each corner of the screens to ensure good ventilation. Cover with a second screen so the seeds are not eaten by rodents. Stir gently several times a day while drying, or gently run a fan in this area to help the drying process. If seeds stick together while drying, simply rub them through your hands occasionally to separate. When sufficiently dry, the seeds can be sown, or stored in the refrigerator.

## Seed Storage

from: www.jvk.net/pdf/drk_seed_storage_and_handling.pdf

Check the Garry Oak Ecosystems Recovery Team's (and other) propagation guidelines (www.goert.ca/propagation) for information on seed storage times. Some species will keep for decades. Others will keep for only months or a few years, with decreasing germination success as time goes by.

Generally, seeds should be dried to 5–8% relative humidity (RH) and then stored at 5°C (41oF) to retain optimum seed quality. Seed quality will be affected when moisture content falls below 5% RH (vigour declines) or above 8% RH (seeds deteriorate); above 12% RH, fungi can grow. Refrigerators are the right temperature for seed storage but have approximately 40% RH. To ensure proper drying, seal the seeds in a jar (wide mouth canning jars work well) with a desiccant such as silica gel.[4] The amount of silica gel placed in the jar should equal the weight of the seeds. Storing the seeds for 7–8 days in a tightly sealed container along with the silica gel should bring the seeds down to approximately 8% RH. Once this is done, remove the seeds, repackage/label, and store in an airtight container. Seeds should be stored in a cool, dark, dry place such as an unheated basement room or the refrigerator.

If silica gel is not available, powdered milk or cornmeal, tied in a small breathable fabric such as cheesecloth, can be used. Small seeds will dry sufficiently overnight; larger seeds may take several days. If dried seed packets are opened and left unsealed for several hours, the seeds' moisture content will increase rapidly. They will have to be dried again to ensure continued vigour and viability.

Some seeds have short lifespans and can be stored only a short while. Garry Oak acorns should be planted almost immediately. They should be kept cool and moist until planting because they will not tolerate being dried out.

## Seed Scarification

In order to propagate plants at our convenience, it is sometime necessary to artificially induce germination. One technique for doing so is seed scarification (see page 10–17). It is used on many tree and shrub species that have developed hard seed coats for protection. In their natural environment, the seeds might sit for one, two, or more seasons until their seed coats have deteriorated enough to allow moisture and air to access to the embryo and initiate the germination process. Hairy Manzanita (*Arctostaphylos columbiana*) and Kinnikinnick (*Arctostaphylos uva-ursi*) are two species that can be forced into an earlier germination by using various means of seed scarification. Mechanical treatments involve gently rubbing the seeds with sandpaper or a nail file, nicking them with a sharp implement, or cracking them with a hammer. Chemical treatments include immersing the seeds in vinegar for periods of time, or covering them with boiling water and leaving them to sit until the water has cooled. Whichever method is used, it is important to open the seed coat without harming the embryonic plant. Scarified seeds do not store well and should be planted as soon as possible.

4 Silica gel can be purchased at scientific supply stores. It comes as a coloured product. A pink or red colour means the product is still working; blue means it has ceased to be useful. The gel can be reinvigorated by heating to 110–180°C.

## Seed Stratification

Many seeds need stratification. This involves manipulating the seeds' environment by providing moisture and alternating cold and warm temperatures, which simulates seasonal changes. For example, Saskatoon seeds will germinate after a cool, moist stratification period. This can be done by placing cleaned seeds in a sealable plastic bag along with some slightly moistened peat moss, and keeping the bag in the refrigerator for approximately three months. After this time, the seeds can be sown. Alternatively, the seeds can be planted directly into their container and left outdoors for the winter. Common Snowberry seeds are more particular; they first require a warm, moist, 60-day period of stratification followed by 180 days of cool, moist storage before planting. The seeds should be checked regularly as they stratify to monitor for signs of mold or dryness.

Some seeds need both scarification and stratification to germinate. Check propagation guidelines for individual species' requirements.

Whether for large-scale production or your own satisfaction, proper seed collection, storage, and germination technique is an important consideration in any project. Enjoy the process!

**Moralea Milne** *is a graduate of the Restoration of Natural Systems Program at the University of Victoria, and a member of GOERT's Native Plant Propagation and Invasive Species Steering Committees.*

### 10.5.3 Seed Extraction and Cleaning

Cleaning and extracting seeds can be done on a small scale, as described below. See also Case Study 6, and Young and Young (1986).

Dry, dehiscent capsules (fruits which spontaneously open to release the seeds within) can be placed upside down, while still attached to the main flowering stem, into large paper bags and allowed to dry until the seeds are released (e.g., camas spp., shootingstar spp., Small-flowered Alumroot (*Heuchera micrantha*), Chocolate Lily, Fawn Lily). Note that not all seeds will mature in the capsules if collected while still immature. This method is mainly for capsules that have maturing seeds but are not quite open yet.

Dry, indehiscent fruit (fruits which don't spontaneously release their seeds) should be separated from the stalk or capitulum of the plant; e.g., Western Buttercup (*Ranunculus occidentalis*), *Lomatium* spp., Woolly Sunflower, *Aster* species. It may take some time to hand-remove the seeds from the stem.

Fleshy fruits can be hand-mashed or lightly macerated in a blender with water. The remaining pulp is floated off, and the filled seeds (ones that sink to the bottom of the container) are then laid out to dry on newsprint or paper towels.

For record keeping purposes, record the genus and species, date of collection, source of seed, approximate numbers or weight of seed, method of cleaning, seed production per kilogram of initial fruit collected, and any associated costs. Refer to Section 10.7.3 and record-keeping templates Appendices 10.2–10.4.

### 10.5.4 Seed Viability Testing

Seed germination testing is performed to generate an estimate of the viability of the seed lot. A sample of 100 seeds per seed lot is used to determine the percent germination under a controlled experiment (e.g., germination in a growth chamber). Appropriate temperature and light conditions are employed over a set time period. The standard is 15/20°C (59/68°F) alternating for 16 hours in the light and 8 hours in the dark (Baskin and Baskin 1998). This method requires some controlled environment conditions and a replication of samples.

It is also possible to X-ray seeds (using a subset of the seedlot) to see if the embryos are filled, but this requires access to a seed testing lab. Another standard viability test is the tetrazolium test, which is performed on a subset of the seed lot (Baskin and Baskin 1998). The embryo can also be excised from a subset of the seed lot, and should be white and firm (Baskin and Baskin 1998).

All of these methods will provide an indication of how many seeds are needed to be sown in order to produce the required number of propagules for the project.

### 10.5.5 Seed Storage

Seed viability depends on the general health, age, and maturity of the seed, and on preventing deterioration while in storage. The latter depends on providing the optimal temperature and humidity conditions for the seeds when they are in storage.

In general, the smaller the seed, the less time it remains viable in storage; therefore, some species are best sown as soon as they are ripe. Garry Oak acorns are recalcitrant, meaning they are meant to germinate soon after ripening, and therefore do not store well. Seeds that have embryo dormancy can be stored for only 2–5 years (grasses); seeds with seed coat dormancy could remain viable for 15–20 years under optimal storage conditions.

#### Storage Conditions

- Dry seeds to 4–6% moisture content. This is the most important factor in determining the viability of stored seed.
- Seal in paper packets in moisture-proof containers.
- Add a silica desiccant or a twist of cornmeal in wax paper to maintain low moisture content while in storage.
- Maintain an ideal storage temperature of 3–5ºC (37–41ºF).
- Maintain an ideal relative humidity of 20–25%.

## 10.6 Selection and Treatment of Plant Materials

### 10.6.1 Stock Plants *in situ*

Plant material must be collected properly, the species identified correctly, and complete records kept.

Propagules can be collected from the restoration site and then grown in a nursery setting for outplanting in one to two seasons' time. However, it is important not to inadvertently select the propagule in a way that will potentially decrease the genetic diversity of the resulting plant material and its adaptability to the restoration site (see Reichard 2001; Dunwiddie and Delvin 2006). For genetic considerations, refer to Basic Considerations for Plant Propagation with Respect to Restoration, Section 10.2. Also, refer to Determining Optimum Techniques for Propagation, Section 10.4, and to Case Studies 3 and 5 for more examples.

Plant material must be collected properly, the species identified correctly, and complete records kept. Seeds and cuttings should always be kept in separate containers and labelled with the scientific name, collection date, and collection site (provenance), using a code, if necessary. Seeds and cuttings that have been collected from different microsites but are of the same species should also be kept separate and labelled. Following the ethical collection guidelines of GOERT (www.goert.ca/ethical_collection) will increase the chances that a wide variety of propagules are collected which contain genotypic and phenotypic diversity.

If stock plants are continually grown on a nursery site for propagule collection, they may hybridize with wild species and other native species (particularly grasses). Therefore, it is recommended that multiple generations of propagules not be produced from nursery stock plants. Instead, the nursery stock plants should be renewed frequently from appropriate local sources (Dunwiddie and Delvin 2006).

### 10.6.2 Source Diversity

As mentioned above, collecting from a wide variety of parent stock material on the site will increase the likelihood that broad genetic diversity is represented within the propagules, and thus also in the restored population. One way this can be ensured is to collect propagules from the site to be restored as well as at adjacent sites (see Section 10.4).

Additionally, plants that are close to one another at the collection site will likely have a similar genetic make-up (Millar and Libby 1989; Rogers 2004). Therefore, material should be collected from plants that are farther apart, and the 1-in-20 rule should be used (see Section 10.2). Also, since there may be genetic variation in germination, growth patterns, and development, the best seedlings or the first to root should not be the only ones selected. It is essential to have a broad window of time for germination and growth in order to allow a variety of propagules with a full range of characteristics to develop (Campbell and Sorensen 1984; Meyer and Monsen 1993). In this way, the selection of resulting materials for restoration will have included consideration of the geographic, genetic, and adaptation diversity of those materials (Jones 2005).

For further information on retaining a broader source diversity including genetic composition, refer to the section on stock plants *in situ* 10.6.1, and the genetic integrity section 10.2.3. As well, following the ethical collection guidelines (www.goert.ca/ethical_collection) provided on the GOERT website will also provide a wider variety of parent stock for the restoration site.

### 10.6.3 Monitoring Program

To monitor outplanting success, it is essential that accurate and complete records are maintained during the production stages (see Section 10.7). As well, monitoring the outplanting success of each species relative to its source (provenance) data will provide useful information for future restoration projects. Additionally, the number of propagules that survive at the restoration site over a certain time period should be measured. This may aid in evaluating whether or not the species becomes a self-sustaining population. Refer to Chapter 7: Inventory and Monitoring for full details on monitoring a restoration site.

## 10.7 Consideration of Timelines

### 10.7.1 Production Schedules (Planning Ahead for Outplanting)

In order to develop production schedules for the species, type, and number of propagules to be used in restoration, the time-frame for outplanting must be known. The production schedule is then based on the length of time required for the seedlings and cuttings to develop, and is planned backwards from the outplanting time.

Garry Oak species should be planted in the late fall to late winter when the ground is already moist.

Garry Oak species should be planted in the late fall to late winter when the ground is already moist. Early spring may also be an optimal time if there are spring rains in late May to early June; however, with climate change, this may not necessarily be a reliable time for outplanting unless irrigation is used on site.

Timelines need to be determined for collecting cuttings, sowing seeds, potting-up cuttings, and potting-on seedlings/plugs. As well, time for acclimation will also be necessary, and will require the use of a shade or lathe house, or a cold frame to overwinter and/or harden plant material off before planting out the following spring. Other temporal considerations will depend on the species and the growth habit. For example, there may be a need to pot-on larger shrubs that are slower growing and require a longer (2–3 years) period to mature before being outplanted.

When planning the production schedule, also consider the following:

- Determine which species are going to be propagated.
- Determine the numbers of species required.
- Determine what locality the species will be collected from.
- Maintain records of the provenance of the propagules for all species.
- Determine how these species will be propagated (vegetatively or by seed) and how much stock material or what volume of seed is required.
- Determine the size of the propagated material required to ensure optimal outplanting survival (this will vary with the species and propagation method).
- Determine the date by which the site should be prepared so it is ready to receive the materials. Coordinate this date with the delivery of the materials.
- Ensure adequate numbers of staff are available to organize and load the materials for delivery.
- Create an outplanting schedule that is somewhat flexible to ensure the weather is appropriate for outplanting (preferably a non-windy, overcast morning).

### 10.7.2 Contracting-out Growing for Restoration Projects

If the materials are to be grown by a wholesale nursery, then the considerations listed in Section 10.7.1 have to be coordinated with the grower. As well, a budget has to be developed for the grower's costs. These include costs for labour; materials and supplies such as containers, soil media, water, and fertilizers; collection of seeds and cuttings and preparation of propagules; and maintaining the resulting seedlings and cuttings as well as the plants and stock plants. (See Case Study 7 following.)

CASE STUDY

## Case Study 7. Contract Growing for Outplanting—Considerations

by Siriol Paquet, Sylvan Vale Nursery

Sylvan Vale Nursery Ltd. is a located in Black Creek on Vancouver Island, B.C. The nursery was established in 1980, has 200,000 sq feet (18,580 sq metres) of growing space, and remains a family-run business. It maintains a custom program, and currently grows forest seedlings, Christmas tree seedlings, native plants, ornamentals, berry plants, and grasses, as well as plants for restoration, agroforestry, hedging, and many other applications. Services include on-site seed stratification, cold storage, and delivery. Over the years, modern techniques and automation have been incorporated along with many new buildings and equipment.

The number of propagules per species that are required to meet plant orders is based on historical data of the number of recoveries (successfully germinated and grown plants) per container type. The length of time to produce each species is also determined by historical data, and is species-dependent. For example, grasses tend to have fairly high recovery per block; approximately 80–90% of plants per container are grown to shipping size. Bulbs tend to be more problematic because consistent production of a set amount of shippable plants per container is not possible; therefore, more seed is needed.

Facilities include greenhouses, cold frames, mist bench/heated benches for rooting, and nursery fields. The different facilities' use is determined by the species to be propagated and the needs of clients. Seed storage is a minor consideration at the nursery and does not normally factor into pricing. Supplies needed are based on the volumes of each container type and include soil and other media, potting supplies (pots, flats, labels, cells, plugs, fertilizers, and/or growth hormone). Other costs factors include labour, energy, packing supplies, and sometimes shipping. Staffing is required in the greenhouses and office throughout the year and 24-hour computer monitoring of greenhouse environmental conditions is also used. A seasonal crew is employed for sowing, harvesting, etc.

Scheduling seeding, division, and growing-on to ensure that plants are ready for the project is determined by the client's requested delivery date. Scheduling is also determined by the overall production demands at the facility, seed availability, and stratification times.

Large-scale production is more economical for the nursery; however, small numbers of plant species can be produced, with the smallest amount being 100 plants. Price is determined by volume of plants required. Plants are held up to two years from sowing. After that time, the maintenance cost far outweighs the price received for the plant. The ideal production time in a business context is from four months to one year.

The nursery tries to use a seed source that is located near the project planting site, and seed is collected from a variety of plants to maintain genetic diversity. Planning is necessary, and timing is dependent on when the seed is ready for collection, when it is viable, and whether or not there is an accessible seed source location. As well, it may be determined that it is not economical to collect seed. Instead, seed may be purchased from a reputable seed dealer.

For some of the most commonly ordered plant species, the nursery maintains stool beds, which are nursery beds of plants for cutting stock. Where possible, vegetative material (twigs, roots, and divisions) is also collected or purchased for production of plant material.

Once the plant material is deemed to be extractable from the container, shipping can be done on very short notice; however, the usual required notice is 48 hours. When shipping, consideration as to the time of year and seasonal weather patterns is necessary to ensure optimal survival of plant material.

One challenge for nursery growing of native plants is obtaining enough information about producing plant material. There is a limited amount of knowledge on the species-specific methods of seed stratification, length of time to produce plant material, scheduling production of materials, seed availability, and budget considerations. Another problem for growers is that the market is currently depressed, so it is not economical to retain a large volume of plant material on hand. As well, for some requests, the time it takes to produce material may not meet clients' needs.

## References

GOERT (Garry Oak Ecosystems Recovery Team) Native Plant Propagation Guidelines: www.goert.ca/propagation.

U.S. Department of Agriculture Forest Service Fire Effects Information database: www.fs.fed.us/database/feis/plants/index.html.

Native Plant Network Propagation Protocol database: www.nativeplantnetwork.org/network .

**Siriol Paquet** *is co-owner of Sylvan Vale Nursery, Ltd., in Black Creek, B.C.*

### 10.7.3 Post-propagation Records

Record-keeping is essential to monitor the progress of the restoration project and to find efficiencies in techniques, methodology, and budgets. All stages should be documented, from the initial collection stage through all growing phases to outplanting. The success of the restoration project should also be monitored. By compiling this knowledge through the use of templates, the restoration practitioner will be able to fine-tune or adapt certain techniques or budgets for the next project. This body of knowledge will also allow the sharing of information for other restoration projects during the planning phase.

Examples of post-propagation records include:

- dates and numbers/species by provenance for pricking-out of seedlings
- date and numbers/species by provenance of seedlings or cuttings potted up
- number of seeds or cuttings required to produce required amount of material for outplanting
- overall timeline of when seedlings or cuttings are ready for outplanting relative to method of propagation
- final production characteristics (e.g., size, age, height, pot size)
- costs of labour, equipment, materials, and supplies to produce each species
- final destination of the plants produced
- survival numbers after one, two, three, and five years at the site

Record-keeping is essential to monitor the progress of the restoration project and to find efficiencies in techniques, methodology, and budgets.

See record-keeping templates Appendices 10.2–10.4 and Chapter 7: Inventory and Monitoring for more information.

## 10.8 Additional Suggestions

A compilation of additional information for those starting to plan and implement a propagation program for restoration.

1. Track species, seed source (provenance) and performance (monitor on a yearly basis) including outplantings, and any nursery trials.
2. Maintain detailed and complete records (label materials using a code if necessary to help with tracking).
3. Confirm the taxonomic identification of difficult species (e.g., grasses, sedges, rushes) for all seed lots, and check after they mature.
4. Determine the amount and type of materials needed (e.g., start planning 1–3 years ahead of outplanting).
5. Schedule propagation to correspond with outplanting deadlines so that the appropriate numbers of propagules are produced and are ready to leave the nursery.
6. Collect species from on-site and adjacent to the site, but not too far away.

7. Use your records to continue to learn about each species and methods of propagation (i.e., use adaptive management).
8. Have a goal even if you cannot rely on a reference ecosystem for the site, and inventory and classify the site (refer to Table 2.2 in Chapter 2 on Restoration Ecosystem Units).
9. Try to avoid decreasing the gene pool for the species (e.g., avoid inbreeding or repeatedly using the same stock material for different outplanting sites).
10. Publicize both the failures and successes of your project (i.e., share your information!).
11. Publicize the work that will be done ahead of time (before collecting propagules) in order to engage the neighbours, naturalist groups, environmental non-governmental organizations, and other stakeholders.
12. Recognize both the ecological and cultural significance of the site to be restored and plant appropriate species.

CASE STUDY

## Case Study 8. Small-scale Native Plant Nursery Set-up and Operation

by Carrina Maslovat

Small-scale nurseries can provide stock to individual areas, which ensures there is a supply of plants grown from local genetic stock material. Most nurseries will collect from material close at hand, and very few projects are able to request contract-grown local plant material. However, because land costs are extremely high, particularly in urban areas, it may be cost-prohibitive to purchase land for a nursery. Efficiency of scale is also a consideration for nurseries. A small nursery, such as one that is less than 0.4 ha (1 acre), can be maintained by hand rather than with equipment. Larger-scale nurseries are more efficient but require a greater land base.

Choice of nursery location is related to the site-specific requirements of the plants that will be grown (e.g., level ground, sun exposure, soil quality unless growing strictly in containers, access roads, quality and cost of water). Each site will naturally be better for growing some species rather than others—for example, hot dry sites are potentially better for growing Garry Oak ecosystem species.

Determining which species to grow for restoration purposes is difficult unless the nursery grows for a specific project. It is almost impossible to determine what the demand will be for restoration and to have the right plants in the quantity and size required for a project. Large restoration projects generally happen sporadically and require large volumes of plants. As plants continue to outgrow their pots, they have to be potted up into larger pots; however, larger sizes of some species are not desired for some restoration projects. Some restoration practitioners prefer to purchase local stock from a supplier that they know will provide healthy material. This will ensure a higher success rate of survival in the long term, rather than requesting specific species that have not been field-tested and therefore may not perform as well.

The initial budget for set-up of a small nursery is usually for infrastructure, such as cold frames and an irrigation system, plus the cost of supplies such as containers, hoses, soil media, etc. For Garry Oak species, a heated greenhouse is not necessary, but a cold frame to protect small and newly rooted plants from the wind is essential. As well, a mist bench with a heating coil is essential for propagation by rooting. A small bar fridge can be adequate for seed storage. Soil and associated amendments are also essential. Storage areas may include simple open-ended, 3-sided cinder block containers. A shade/lathe house or shade cloth in part of the nursery is useful especially for protecting plants during more sensitive stages of development.

Staffing for a small nursery is mainly seasonal, with additional staff required in early spring and fall for propagation, pricking-out, and potting-on. Summertime labour is needed mainly for maintenance, watering, and pruning. Seeding can be done outdoors in the fall, so stratifying the seed ahead of time in refrigerators is not necessary. Hardwood cuttings can be taken in the fall; softwood cuttings can be taken in the spring. Using nursery field plots instead of containers to grow plant material will be impractical unless the soil is amenable; using nursery field plots can be costly, and for a small nursery, not possible due to size constraints. Seed collecting following ethical guidelines can also be done by nursery staff in the summer and fall.

**Carrina Maslovat** *is a consulting biologist, Salt Spring Island, B.C.*

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## 10.10 Related Websites

Florabank www.florabank.org.au.

GOERT (Garry Oak Ecosystems Recovery Team): Native Plant Propagation Guidelines www.goert.ca/propagation.

King Co., Washington State: Native Plant Guide: http://green.kingcounty.gov/GoNative/Index.aspx.

Lady Bird Johnston Wildflower Center: www.wildflower.org/about (see plants database).

Native Seed Network (U.S.) www.nativeseednetwork.org.

Native Plants Journal http://nativeplants.for.uidaho.edu/journal.

Portland Bureau of Environmental Services: Native Plant Selection Guide www.portlandonline.com/bes/index.cfm?a=eahdc&c=dcbec.

Saanich Municipality: Native Plant Salvage Program www.saanich.ca/resident/environment/salvage.html.

University of Victoria Restoration of Natural Systems (ER338): Selection and Propagation of Native Plants for Ecosystem Restoration (Spring 2002) www.for.gov.bc.ca/hfd/library/FIA/2002/FIA2002MR022.pdf.

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Washington State Master Gardeners: Gardening in Western Washington http://gardening.wsu.edu/nwnative (see gardening, propagating, and growing section).

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# Appendix 10.1

## Propagating Flower Bulbs, Corms, and Rhizomes: Some Shortcuts from the Beacon Hill Nursery Experience

The staff of the City of Victoria Nursery at Beacon Hill Park have grown native bulbs and perennials for use in the park for several years. The following observations come from that experience.

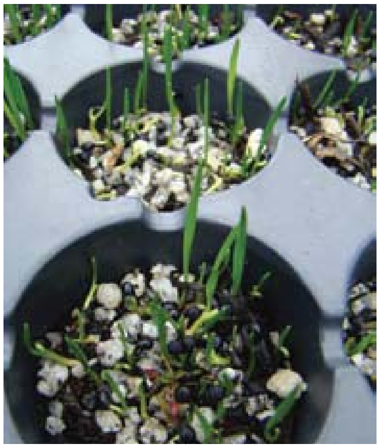
With an understanding of native species' adaptations to environmental patterns, growers can use knowledge of plant characteristics to take shortcuts in producing plants. The Garry Oak ecosystems of southern Vancouver Island share a relatively common pattern of long, dry summers and warm, wet winters. The response of many plants to that pattern is to go into some form of resting state in the hottest, driest part of the year. Seeds rest on the soil and many of them germinate in fall as rains begin and while temperatures are still warm enough for growth. Bulbs, corms, and rhizomes rest below the surface, insulated from the heat by a blanket of soil, until fall rain spurs them into new root growth. Some bulbs move themselves down into the soil to a point where temperature and moisture levels remain relatively constant.

Extending the pre-drought growing season, adding nutrients, and keeping roots cool can help to produce blooming size perennial plants earlier than by following natural growth patterns. The tendency of some bulbs to work their way down through the soil to a level where they remain cool and slightly moist can be exploited by growing in shallow containers to produce larger bulbs sooner.

For some other plants exploiting their natural tendency to multiply can be used to produce moderate numbers of useable size plants faster than growing from seed.

### Camas – Greater and Common (*Camassia leichtlinii* & *C. quamash*)

In nature, camas is reported to take 5 to 7 years to flower from seed. This time can be shortened to between 2 and 4 years by taking advantage of their natural growing patterns.



Left: Camas seed germinating in plug trays. Photo: City of Victoria

Right: Blooming size camas in open flats. Photo: City of Victoria

Much of the time from seed to flower for camas in relatively deep soil sites in our region is the time it takes for the bulb to find its proper level in the soil—anywhere from 15 to 30 cm (6" to 12") below soil surface. In nature camas seeds germinate in the fall and begin to put a root down. In the next spring they put up a leaf and begin to form a bulb during the brief growing season before the summer drought sets in. The next fall roots begin to grow again and the small, new bulb elongates down into the soil, reaching for the depth that stays cool through the summer. It may extend as much as 2 cm (3/4") each year and the energy needed for that limits the increase in the size of the bulb until the appropriate depth is reached.

In the nursery it is possible to grow camas in shallow flats, reducing the energy loss from the bulbs working down through the soil. Both Great Camas and Common Camas benefit from being sown thickly. Fill normal 25 x 50 cm (10" x 20") plastic plant trays that have some drainage holes with a sterile mixture of sharp sand and horticultural peat or sterile potting soil to a depth of approximately 4 cm (1 1/2"). Sprinkle freshly collected seeds in late summer over the surface at the density that would be appropriate for grass seed: a coverage of about 1 seed per centimeter (per 1/2"). If seeding must be done later in the season and the seeds are no longer round and smooth, they can be moistened by spreading on moist paper towels until they plump. In either case, cover them thinly enough with medium grit or forestry sand to still be able to see the seed through the cover. Place the flats in a cool, shaded area until rains begin in the fall. Once the rain begins and the air cools, germination will begin. Place the flats where they will be exposed to the weather and in the sun. Put them on a surface such as large crushed rock or a mesh top bench. If the trays are placed on soil or on a flat surface, the camas roots will move out through the drainage holes and bulbs will form under the flats. An air gap is essential during the growing season to prevent this. The germination rate of camas sown in this way will be very high (close to 100%).

As soon as leaves begin to show in the following spring, begin to fertilize the camas with a balanced, liquid fertilizer (any soluble plant fertilizer with a number like 20-20-20 will do) at approximately 1/2 the rate recommended on the label at each watering. Water and fertilize, being careful not to overwater, through the summer, moving the flats into partial shade when temperatures are at their hottest. The leaves will die down on their own, some weeks later than those growing in the wild, and at that time stop watering and put the flats aside in a cool spot to wait for the fall rains begin again and restart growth. Repeat the treatment.

In the summer of the second year, after the leaves have died down and before the rains begin, screen the bulbs out of the sand/peat/soil mixture. Some will be the size of grains of rice and some the size of peas. Screen or sort the larger bulbs from the rest and plant them into a flat of the same mix as before: put a 2 cm (3/4") deep layer of the mix in the bottom of the same kind of plant tray and spread the larger bulbs over the surface, about 2 cm apart (3/4"). Cover with another 2 cm of sand/peat/soil mix and then with a thin layer of grit. Do the same with the smaller bulbs but at about 1 cm (1/2") spacing. Once again put them in a cool spot until fall and then continue to fertilize and water. Some will bloom in the third summer and most will do so by the fourth.

Bulbs can be left in the flats for several years as long as they are watered and fertilized during the growing season. They should be screened out of their flats during their summer dormancy for planting in the following fall. Plant out as soon as the soil is moist more than a few centimetres (~1") down but be sure to plant at least 15 cm (6") down—if not you'll wait a few years before you see a bloom as the bulb spends energy finding its preferred depth.

### Onions (*Allium acuminatum* & *A. cernuum*)

The onions take 2 to 3 years from seed collected in the summer and sown that fall. Like camas, they like to be crowded in their pots and their growing season can be extended by watering and fertilizing through the dry part of early summer. Sow them in the same way as camas, thickly in shallow flats, and screen and thin them in their second summer.

If you take the largest bulbs in the second year and pot them into 10 cm (4") pots in a good potting soil in clusters of 5 or 6, they will begin to divide and multiply on their own, giving you a good pot-full after another growing season.

Nodding Onion (*Allium cernuum*) seedlings from a 10 cm pot. Photo: City of Victoria

### Harvest Brodiaea (*Brodiaea coronaria*)

Harvest Brodiaea take 2 to 3 years to flower from fresh seed planted in the fall immediately after collection. They, too, can be sown thickly in flats but aren't as sensitive as camas to soil depth—corms will stay relatively near the top of the pot.

Pot them on 2 or 3 to a 10 cm (4") pot but not in a clump—separate them and they will spread to fill the space.

### Chocolate Lily (*Fritillaria affinis*)

Chocolate Lily (Southern Rice-root) will bloom from seed in 3 to 4 years from fresh seed, sown in the fall of the year in which it is collected. Sow thickly but not so thick that the flat, papery seeds overlap, on the surface of a good, sterile potting soil mixed with about half the volume with sharp sand and just cover with a very thin layer of the same mix. Water and fertilize as long as the leaves remain green in the spring and summer after sowing and leave them untouched in the flat until some begin to flower.

Left: Chocolate Lily (*Fritillaria affinis*) seeds germinating in a plug tray. Photo: City of Victoria

Right: Chocolate Lilies blooming in propagation flats. Photo: City of Victoria

In the driest part of the summer during flowering, very carefully lift the bulbs out of the mix. The largest will have already begun to produce the rice-grain-like bulb scales that give them the name 'rice-root'. They are very easily knocked off at this stage. Collect any that have been knocked off and replant them in the flat with the smaller, non-flowering bulbs for harvest in the following years. Most will have reached flowering size by their fourth growing season.

A slightly quicker way to grow Chocolate Lily is to harvest the rice-grain bulb scales from large, mature plants. Take a Chocolate Lily that is several years old out of its pot and it will have a large number of bulb scales around a central bulb. Harvest those scales and sow them like seeds into flats of potting soil, just covering them with more soil, and they will reach blooming size at least one year ahead of those grown from seed. They can be left in crowded flats for 4 to 5 years but will then begin to self-thin—the smallest will die off.

### White Fawn Lily (*Erythronium oregonum*)

Fawn Lilies in nature take 4 to 5 years to bloom from seed. Sown in shallow flats, in an equal parts sharp sand/peat/soil mixture, and watered and fertilized to extend their growing season, they will bloom in 2 to 3 years.

They should be treated in the same way as camas seed but care should be taken to provide them with some shade and to grow them in the coolest spot possible.

Like camas, they will mature at different rates but, unlike camas, they cannot be left for more than 3 to 4 years in crowded flats. As soon as some plants begin to grow large and produce multiple leaves they will crowd each other out and many of the smaller plants will die.

Fawn Lily (*Erythronium oregonum*) seeds germinating in a plug tray. Photo: City of Victoria

Fawn Lily bulbs are more fragile than camas and so it is necessary to be gentle in the screening process. The bulbs are starchy and so attractive to slugs and other creatures in the soil. Care must be taken to prevent them from entering through the drainage holes in the flats. Fine screening is a useful preventative measure.

### Satinflower *(Olsynium douglasii)*

Satinflower is fast-growing from seed, flowering often in its second year, but the seed is difficult to collect as it is flung out from the capsules as soon as it ripens. It won't germinate well unless the seed is ripe and so collecting the pods early requires sacrificing a part of the stem to ensure that there is enough energy for the seeds to ripen.

Satinflower is in the iris family and, like most members of this family, it produces rhizomes that are easy to divide. Each grassy stem in a clump can be divided off as a separate plant. The division needs to be done while the satinflower is in active growth as the tiny, spider-like rhizomes are very hard to find in the soil after they plant goes dormant in early spring. Just after flowering is a good time to work on them. Wash the soil off the roots of the clump and tease the individuals apart. Pot them into individual 10 cm (4") pots in any good potting mix. Fertilize well through the following spring, keeping them as cool as possible to extend the season. There should be a new crop of divisions by the next season.

### Broad-leaved Shootingstar (*Dodecatheon hendersonii*)

The shootingstars are relatively quick from seed—2 to 3 years from fresh seed sown in the fall of the year it is collected.

Seed is the fastest way to propagate shootingstars but if there is some reason to propagate a specific plant—for instance if its colour, form, or leaf is exceptional—it can be propagated successfully from divisions. Shootingstars are in the primrose family and, like most of the family, root divisions with a bud attached will grow well. A mature plant that is growing in rich soil or is fertilized well will often divide on its own, producing extra leaf crowns in its second year and more in subsequent years. Separating those from the main plant will produce good plants. More can be produced by carefully slicing roots with crown buds from around the edge of the original plant.

## Appendix 10.2 Seed Collection Record Template

**SEED COLLECTION FORM**

| **Basic Information** | **Collection Number:** |
|---|---|
| Genus and species | |
| English name | |
| Date collected | |
| Collection site name | |
| Number of seeds | |
| | |
| **Extended data** | |
| Subspecies or variety | |
| Number of plants | |
| Seed maturity | |
| Weather at harvest | |
| Street address/site description | |
| GIS/Lat.&Long. coordinates | |
| Slope/Position | |
| Aspect | |
| Soil texture | |
| Soil moisture | |
| Sun/Shade | |
| Notes: (Plant community, tree cover/species, # of plants sampled, seed state, etc.) | |

## Appendix 10.3 Nursery RecordTemplate (full)

**NURSERY SOWING RECORD** **SEED COLLECTION NUMBER:**

Genus & Species:

English Name:

Seed Collection Site:

Seed Year:

**Germination Data**

Number of Seeds:

Chill Germ %:

No Chill Germ %:

Purity %:

Seed Weight:

Store Moist %:

Total Germinants:

**NURSERY SOWING RECORD** **SEED COLLECTION NUMBER:**

Genus & Species:

Total Germinants:

**Stratification Data**

Date Received:

Soak Date:

Hours Soaked:

Chill Date:

Days Chilled:

Dry Date:

Seed Treatment (scarify, nick, etc.):

Problem/Comment:

(i)

## Nursery Record Template

**Sowing Data**

Sowing Date:

Container:

Medium:

Sowing method (scatter, place, etc.):

Density:

Cover material:

Cover depth:

Number sown:

**Seed Grow Location**

Greenhouse/Frame/Outside:

Exposure/Protection:

Light/Shade:

Temperature Range:

Moisture Regime:

Fertilizer (type, concentration):

**Post Germination**

Pot up/Re-pot Date:

Seedling Stage:

Container:

Medium:

Number of Seedlings:

Mulch:

(ii)

# Appendix 10.4 Nursery Record Template (brief)

**NURSERY SOWING RECORD** **SEED COLLECTION NUMBER:**

Genus & Species:

**Seedling Grow Location**

Greenhouse/Frame/Outside:

Exposure/Protection:

Light/Shade:

Temperature Range:

Moisture Regime:

Fertilizer (type, concentration):

**NURSERY SOWING RECORD** **SEED COLLECTION NUMBER:**

Genus & Species:

| **Growing Record** | | | | | |
|---|---|---|---|---|---|
| Year | | | | | |
| Potting Date | | | | | |
| Pot Size | | | | | |
| Medium | | | | | |
| Grow Location | | | | | |
| Quantity | | | | | |
| Notes: | | | | | |

## Appendix 10.5

### List of Garry Oak ecosystem plants and animals used in this publication, with REU and propagation method information

by Brenda Costanzo, with contributions from lead authors

1. "*" means the species is an invasive alien species; propagation is inappropriate (X)
2. Propagation methods are for **plant species only**, and are only for the native species that are not federally (SARA) listed as Endangered, Threatened, or Special Concern.

| English Name | Scientific Name | Restoration Ecosystem Unit[1] | Propagation Method[2] |
|---|---|---|---|
| **Trees** | | | |
| Arbutus | *Arbutus menziesii* | 1; 3 | 1 |
| Douglas-fir | *Pseudotsuga menziesii* | 1; 2; 3; 5; 8 | 1 |
| English Holly* | *Ilex aquifolium** | -- | X |
| European Elm* | *Ulmus spp.** | -- | X |
| Garry Oak | *Quercus garryana* | 1; 2; 3; 5; 7 | 1 |
| Grand Fir | *Abies grandis* | 7; 8 | 1; 2.2.3 |
| Oregon Ash | *Fraxinus latifolia* | 2 | 1; 2.2.3 |
| Seaside Juniper | *Juniperus maritima* | 7 | 1; 2.2.2; 2.2.3 |
| Shore Pine | *Pinus contorta var. contorta* | 3; 7 | 1; 2.2.3 |
| Western Hemlock | *Tsuga heterophylla* | 8 | 1 |
| Western Redcedar | *Thuja plicata* | 8 | 1; 2.2.3 |
| **Shrubs/Vines** | | | |
| Common Hawthorn* | *Crataegus monogyna** | -- | X |
| Common Snowberry | *Symphoricarpos albus* | 1; 2; 3; 5; 7 | 1; 2.1.3; 2.2.1; 2.2.2; 2.2.3; 3; 5.1 |
| Cotoneaster* | *Cotoneaster spp.** | -- | X |
| Dull Oregon-grape | *Mahonia nervosa* | 8 | 1; 2.1.2; 2.2.1; 2.2.3; 3 |
| English Ivy* | *Hedera helix** | -- | X |
| Gorse* | *Ulex europeaus* | -- | X |
| Hairy Honeysuckle | *Lonicera hispidula* | 1;3 | 1 |
| Hairy Manzanita | *Arctostaphylos columbiana* | 3 | 1; 2.2 |
| Himalayan Blackberry* | *Rubus armeniacus** | -- | X |
| Indian-plum | *Oemleria cerasiformis* | 1; 2 | 1; 2.2.1; 2.2.2; 2.2.3; 3; 5.1 |
| Kinnikinnick | *Arctostaphylos uva-ursi* | 3; 7 | 1; 2.2 |
| Mock-orange | *Philadelphus lewisii* | | 1;2.2.1;2.2.3; 5.1 |
| Nootka Rose | *Rosa nutkana* | 1; 2; 5 | 1; 2.1.3; 2.2.3; 5.1 |
| Oceanspray | *Holodiscus discolor* | 1; 2; 3; 7 | 1; 2.2.2; 2.2.3; 3; 5.1 |

| | | | |
|---|---|---|---|
| Poison Oak | *Toxicodendron diversilobum* | 3 | 1; 2.2.1; 2.2.3 (wear protective clothing and face masks) |
| Red Huckleberry | *Vaccinium parvifolium* | 8 | 1; 2.2.3 |
| Salal | *Gaultheria shallon* | 8 | 1; 2.2.2 |
| Saskatoon | *Amelanchier alnifolia* | 7; 8 | 1; 2.1.2; 2.1.3; 2.2.1; 2.2.2; 3; 5.1 |
| Scotch Broom* | *Cytisus scoparius** | -- | X |
| Spurge-laurel* | *Daphne laureola** | -- | X |
| Tall Oregon-grape | *Mahonia aquifolium* | 1; 3; 5; 7 | 1; 2.1.2; 2.2.1; 2.2.2; 2.2.3; 5.1 |
| Trailing Blackberry | *Rubus ursinus* | 3; 5 | 1 |
| Tree Lupine* | *Lupinus arboreus** | -- | X |
| Western Trumpet | *Lonicera ciliosa* | 1; 2 | 2.2.2 |
| **Forbs** | | | |
| American Vetch | *Vicia americana* | 2 | 1 |
| Barestem Desert-parsley | *Lomatium nudicaule* | 5 | 1 |
| Bearded Owl-clover | *Triphysaria versicolor* ssp. *versicolor* | 5; 6 | N/A |
| Bear's-foot Sanicle | *Sanicula arctopoides* | 1; 3 | N/A |
| Blinks | *Montia fontana* | 4; 6 | 1 |
| Bog Bird's-foot Trefoil | *Lotus pinnatus* | 6 | N/A |
| Bracken Fern | *Pteridium aquilinum* | 5; 8 | 3 |
| Broad-leaved Shootingstar | *Dodecatheon hendersonii* | 1 | 1; 2.1.2 |
| Broad-leaved Stonecrop | *Sedum spathulifolium* | 3; 7 | 1; 5.2 |
| Brook Spike-primrose | *Epilobium torreyi* | 5; 6 | N/A |
| Bull Thistle* | *Cirsium vulgare** | -- | X |
| Bur Chervil* | *Anthriscus caucalis** | -- | X |
| California Buttercup | *Ranunculus californicus* | 5 | N/A |
| California Hedge-parsley | *Yabea microcarpa* | 3; 4 | N/A |
| California-tea | *Rupertia physodes* | 3 | 1 |
| Camas | *Camassia* spp. | 1 | 1; 4 |
| Canada Thistle* | *Cirsium arvense** | -- | X |
| Carpet Burweed* | *Soliva sessilis** | 1 | X |
| Chickweed Monkey Flower | *Mimulus alsinoides* | 4 | 1 |
| Chocolate Lily | *Fritillaria affinis* | 2; 4; 5 | 1; 4 |
| Cleavers | *Galium aparine* | 1; 2; 3; 5 | 1 |
| Coast Microseris | *Microseris bigelovii* | 6; 7 | N/A |
| Coastal Scouler's Catchfly | *Silene scouleri* ssp. *grandis* | 5 | N/A |
| Coastal Wood Fern | *Dryopteris arguta* | 7; 8 | N/A |
| Common Bluecup | *Githopsis specularioides* | 4 | 1 |
| Common Camas | *Camassia quamash* | 1; 3; 4; 5 | 1; 4 |
| Common Chickweed* | *Stellaria media** | 1 | X |

| | | | |
|---|---|---|---|
| Common Vetch* | *Vicia sativa** | 1 | X |
| Common Yarrow | *Achillea millefolium* | 1; 3; 5 | 1; 2.1.2; 3 |
| Creeping Buttercup* | *Ranunculus repens** | -- | X |
| Cup Clover | *Trifolium cyathiferum* | 6 | 1 |
| Death-camas | *Zigadenus venenosus* | 1; 5; 7 | 1; 4 |
| Deltoid Balsamroot | *Balsamorhiza deltoidea* | 1; 3; 5 | N/A |
| Dense-flowered Lupine | *Lupinus densiflorus* var. *densiflorus* | 5 | N/A |
| Dense Spike-primrose | *Epilobium densiflorum* | 2; 5; 6 | N/A |
| Dwarf Owl-clover | *Triphysaria pusilla* | 6 | 1 |
| Dwarf Sandwort | *Minuartia pusilla* | 6 | N/A |
| Elegant Rein Orchid | *Piperia elegans* | 5 | 1 |
| English Daisy* | *Bellis perennis** | 1 | X |
| Erect Pygmyweed | *Crassula connata* var. *connata* | 5 | N/A |
| Farewell-to-spring | *Clarkia amoena* var. *lindleyi* | 5 | 1 |
| Fern-leaved Desert-parsley | *Lomatium dissectum* var. *dissectum* | 3; 5 | N/A |
| Field Chickweed | *Cerastium arvense* | 5 | 1 |
| Fool's Onion | *Triteleia hyacinthina* | 4 | 1; 4 |
| Fragrant Popcornflower | *Plagiobothrys figuratus* | 5; 6; 7 | N/A |
| Geyer's Onion | *Allium geyeri* var. *tenerum* | 5 | 1; 4 |
| Goldback Fern | *Pentagramma triangularis* | 1; 3 | spores |
| Golden Paintbrush | *Castilleja levisecta* | 5 | N/A |
| Grass Peavine* | *Lathyrus sphaericus** | -- | X |
| Grassland Saxifrage | *Saxifraga integrifolia* | 4 | 1 |
| Gray's Desert-parsley | *Lomatium grayi* | 3 | N/A |
| Great Camas | *Camassia leichtlinii* | 2 | 1; 4 |
| Hairy Cat's-ear* | *Hypochaeris radicata** | 1 | X |
| Hairy Hawk-bit* | *Leontodon taraxacoides** | 1 | X |
| Harvest Brodiaea | *Brodiaea coronaria* | 1; 4 | 1; 4 |
| Hawksbeard* | *Crepis* spp.* | 1 | X |
| Heterocodon | *Heterocodon rariflorum* | 4; 5 | 1 |
| Hooded Ladies' Tresses | *Spiranthes romanzoffiana* | 6 | 1; 2.1.2 |
| Hooker's Onion | *Allium acuminatum* | 5 | 1; 4 |
| Howell's Triteleia | *Triteleia howellii* | 5 | N/A |
| Howell's Violet | *Viola howellii* | 5 | 1; 3; 5.2 |
| Jeffrey's Shootingstar | *Dodecatheon jeffreyi* | 2; 5; 7 | 1;2.1.2 |
| Lace Fern | *Cheilanthes gracillima* | 3 | spores |
| Large-flowered Blue-eyed Mary | *Collinsia grandiflora* | 3; 4 | 1 |
| Licorice Fern | *Polypodium glycyrrhiza* | 1; 2 | 3 |
| Lindley's Microseris | *Microseris lindleyi* | 3 | N/A |
| Little Chickweed* | *Cerastium glomeratum** | -- | X |
| Little Hop-clover* | *Trifolium dubium** | 1 | X |
| Lobb's Water-buttercup | *Ranunculus lobbii* | 6 | N/A |
| Long-spurred Plectritis | *Plectritis macrocera* | 6 | 1 |

| | | | |
|---|---|---|---|
| Lowland Cudweed | *Gnaphalium palustre* | 5; 6 | 1 |
| Macoun's Groundsel | *Senecio macounii* | 3 | 1 |
| Macoun's Meadowfoam | *Limnanthes macounii* | 6 | N/A |
| Macrae's Clover | *Trifolium dichotomum* | 7 | 1 |
| Manroot | *Marah oreganus* | 7; 8 | N/A |
| Menzies' Larkspur | *Delphinium menziesii* | 1; 7 | 1 |
| Miner's Lettuce | *Claytonia perfoliata* | 1 | 1 |
| Mountain Sneezeweed | *Helenium autumnale* var. *grandiflorum* | 5 | 1; 3 |
| Muhlenberg's Centaury | *Centaurium muehlenbergii* | 5; 6 | N/A |
| Narrow-leaved Montia | *Montia linearis* | 4 | 1 |
| Needle-leaved Navarretia | *Navarretia intertexta* | 5 & 6 | 1 |
| Nodding Onion | *Allium cernuum* | 7 | 1; 4 |
| Nuttall's Quillwort | *Isoetes nuttallii* | 6 | N/A |
| Olympic Onion | *Allium crenulatum* | 3 | 1; 4 |
| Oregon Lupine | *Lupinus oreganus* var. *kincaidii* | 5 | N/A |
| Oxeye Daisy* | *Leucanthemum vulgare** | 1 | X |
| Pacific Sanicle | *Sanicula crassicaulis* | 5; 7 | 1 |
| Pearly Everlasting | *Anaphalis margaritacea* | 5 | 1; 3 |
| Pine Broomrape | *Orobanche pinorum* | 3 | 1 |
| Poverty Clover | *Trifolium depauperatum* var. *depauperatum* | 5 | 1 |
| Prairie Lupine | *Lupinus lepidus* var. *lepidus* | 3 | N/A |
| Pretty Shootingstar | *Dodecatheon pulchellum* | 5 | 1; 2.1.2 |
| Puget Sound Gumweed | *Grindelia stricta* | 5; 6; 7 | 1 |
| Purple Sanicle | *Sanicula bipinnatifida* | 5 | N/A |
| Pygmyweed | *Crassula aquatica* | 6 | 5.2 |
| Ribwort Plantain* | *Plantago lanceolata** | -- | X |
| Rosy Owl-clover | *Orthocarpus bracteosus* | 6 | N/A |
| Rough-leaved Aster | *Eurybia radulina (Aster radulinus)* | 3 | 1; 2.1.2; 3 |
| Satinflower | *Olysinium douglasii* | 3 | 1; 3 |
| Scalepod | *Idahoa scapigera* | 5 | 1 |
| Scouler's Popcornflower | *Plagiobothrys scouleri* | 6 | 1 |
| Sea Blush | *Plectritis congesta* | 1; 3; 7 | 1 |
| Seaside Birds-foot Lotus | *Lotus formosissimus* | 5 | N/A |
| Slender Popcornflower | *Plagiobothrys tenellus* | 5 | N/A |
| Slender Woolly-heads | *Psilocarphus tenellus* var. *tenellus* | 6 | N/A |
| Slimleaf Onion | *Allium amplectens* | 5 | 1; 4 |
| Small-flowered Alumroot | *Heuchera micrantha* | 7 | 1; 3 |
| Small-flowered Birds-foot Trefoil | *Lotus micranthus* | 3 | 1 |
| Small-flowered Blue-eyed Mary | *Collinsia parviflora* | 3 | 1 |

| | | | |
|---|---|---|---|
| Small-flowered Catchfly* | *Silene gallica** | -- | X |
| Small-flowered Godetia | *Clarkia purpurea* ssp. *quadrivulnera* | 5 | 1 |
| Small-flowered Tonella | *Tonella tenella* | 3 | N/A |
| Small-fruited Parsley-piert* | *Aphanes occidentalis** | -- | X |
| Small-leaved Montia | *Montia parvifolia* | 4 | 1 |
| Small-headed Tarweed | *Madia minima* | 3 | 1 |
| Small-headed Clover | *Trifolium microcephalum* | 1 | 1 |
| Smooth Fringecup | *Lithophragma glabrum* | 4 | 1 |
| Smooth Goldfields | *Lasthenia glaberrima* | 6 | N/A |
| Spanish-clover | *Lotus unifoliolatus* var. *unifoliolatus* | 5 | 1 |
| Spring Gold | *Lomatium utriculatum* | 1 | 1 |
| Sword Fern | *Polystichum munitum* | 8 | 3 |
| Stonecrop | *Sedum* spp. | 3; 7 | 1; 2.1.1; 5.2 |
| Strawberry | *Fragaria* spp. | 5; 7 | 1; 3 |
| Tall Woolly-heads | *Psilocarphus elatior* | 3; 6 | N/A |
| Texas Toadflax | *Nuttallanthus texanus* | 3; 5 | 1 |
| Thistle* | *Cirsium* spp.* | -- | X |
| Thrift | *Armeria maritima* | 6 | 3 |
| Tiny Mousetail | *Myosurus minimus* | 6 | 1 |
| Tiny Vetch* | *Vicia hirsuta** | -- | X |
| Tomcat Clover | *Trifolium willdenowii* | 4 | 1 |
| Victoria's Owl-clover | *Castilleja victoriae* (old name: *C. ambigua* ssp. *ambigua*) | 6 | N/A |
| Wall Speedwell* | *Veronica arvensis** | -- | X |
| Wallace's Selaginella | *Selaginella wallacei* | 3; 7 | 2.1.1; 4 |
| Water-starwort | *Callitriche* spp. | 5; 6 | 1 |
| Water-plantain Buttercup | *Ranunculus alismifolius* var. *alismifolius* | 6 | N/A |
| Western Buttercup | *Ranunculus occidentalis* | 1 | 1; 2.1.2; 3 |
| White Fawn Lily | *Erythronium oregonum* | 1; 2 | 1; 4 |
| White Meconella | *Meconella oregana* | 5 | N/A |
| White-lip Rein Orchid | *Piperia candida* | 1; 8 | 1 |
| White-tipped Clover | *Trifolium variegatum* | 5; 6 | 1 |
| White-top Aster | *Sericocarpus rigidus* (old name: *Aster curtus*) | 2; 3 | N/A |
| Wild Strawberry | *Fragaria virginiana* | 5; 7 | 3 |
| Woolly Sunflower | *Eriophyllum lanatum* | 3; 5 | 1; 2.1.1; 2.1.2 |
| Winged Water-starwort | *Callitriche marginata* | 5; 6 | N/A |
| Yellow Monkey-flower | *Mimulus guttatus* | 6 | 1; 2.1.1 |
| Yellow Montane Violet | *Viola praemorsa* ssp. *praemorsa* | 5 | N/A |

| | | | |
|---|---|---|---|
| **Graminoids/Sedges/Rushes** | | | |
| Alaska Oniongrass | *Melica subulata* | *1; 8* | *1; 3* |
| Alaska Brome | *Bromus sitchensis* | *7* | *1; 3* |
| Barren Brome* | *Bromus sterilis** | -- | *X* |
| Barren Fescue* | *Vulpia bromoides** | -- | *X* |
| Blue Wildrye | *Elymus glaucus* | *1; 2; 3; 5* | *1; 3* |
| California Brome | *Bromus carinatus* | *1; 2; 3* | *1* |
| California Oatgrass | *Danthonia californica* | *1; 5* | *1* |
| Canada Bluegrass* | *Poa compressa** | -- | *X* |
| Carolina Meadow-foxtail | *Alopecurus carolinianus* | *5* | *1* |
| Creeping Bentgrass* | *Agrostis stolonifera** | -- | *X* |
| Cheatgrass* | *Bromus tectorum** | -- | *X* |
| Colonial Bentgrass* | *Agrostis capillaris** | -- | *X* |
| Columbia Brome | *Bromus vulgaris* | *1* | *1; 3* |
| Common Timothy* | *Phleum pratense** | *1; 2; 5; 7* | *X* |
| Common Velvet-grass* | *Holcus lanatus** | -- | *X* |
| Densetuft Hairsedge | *Bulbostylis capillaris* | *4* | *1* |
| Dune Bentgrass | *Agrostis pallens* | *5* | *1* |
| Early Hairgrass* | *Aira praecox* | -- | *X* |
| Foothill Sedge | *Carex tumulicola* | *5* | *N/A* |
| Green-sheathed Sedge | *Carex feta* | *5; 6* | *1* |
| Hedgehog Dogtail* | *Cynosurus echinatus** | -- | *X* |
| Junegrass | *Koeleria macrantha* | *1* | *1; 3* |
| Kellogg's Rush | *Juncus kelloggii* | *5; 6* | *N/A* |
| Kentucky Bluegrass* | *Poa pratensis** | -- | *X* |
| Long-stoloned Sedge | *Carex inops ssp. inops* | *1; 2; 7* | *1; 2.1.3; 3* |
| Many-flowered Wood-rush | *Luzula multiflora* | *1; 3* | *1* |
| Meadow Foxtail* | *Alopecurus pratensis* | *1; 2; 5; 7* | *X* |
| Orchard-grass* | *Dactylis glomerata** | -- | *X* |
| Pacific Woodrush | *Luzula comosa* | *5* | *1; 3* |
| Perennial Ryegrass* | *Lolium perenne** | -- | *X* |
| Red Fescue[3] | *Festuca rubra* | *5; 7* | *1; 3* |
| Poverty Oatgrass | *Danthonia spicata* | *3;* | *1; 3* |
| Ripgut Brome* | *Bromus rigidus** | -- | *X* |
| Roemer's Fescue | *Festuca roemeri* | *1; 3; 7* | *1; 3* |
| Sharp-pod Peppergrass | *Lepidium oxycarpum* | 2(?); 5 (?); 6 | *1* |
| Silver Hairgrass* | *Aira caryophyllea** | -- | *X* |
| Soft Brome* | *Bromus hordeaceus** | -- | *X* |
| Sweet Vernalgrass* | *Anthoxanthum odoratum** | -- | *X* |
| Toad Rush | *Juncus bufonius* | *6* | *1* |
| Tufted Hairgrass | *Deschampsia cespitosa* | *5* | *1; 3* |
| Western Rush | *Juncus occidentalis* | *5; 6* | *1* |

| | | | |
|---|---|---|---|
| **Mosses** | | | |
| Red Bryum | *Bryum miniatum* | 4 | N/A |
| Banded Cord-moss | *Entosthodon fascicularis* | 3 | N/A |
| Broom Moss | *Dicranum scoparium* | 3; 7 | ? |
| Electrified Cat's-tail Moss | *Rhytidiadelphus triquetris* | 2; 8 | ? |
| Flat Moss | *Plagiothecium undulatum* | 8 | |
| Grey Rock-moss | *Racomitrium* spp. | 1; 3; 4 | ? |
| Juniper Hairy-cap Moss | *Polytrichum juniperum* | 1; 3 | ? |
| | *Polytrichum piliferum* | 3 (?) | ? |
| Lanky Moss | *Rhytidiadelphus loreus* | 8 | ? |
| Oregon Beaked Moss | *Kindbergia oregana* | 8 | ? |
| Rigid Apple Moss | *Bartramia stricta* | 3 | N/A |
| Small Flat Moss | *Pseudotaxiphyllum elegans* | 8 | ? |
| Step Moss | *Hylocomium splendens* | 8 | ? |
| Twisted Oak Moss | *Syntrichia laevipila (old name: Tortula laevipila)* | 1; 2 | N/A |
| | *Syntrichia ruralis (old name: Tortula ruralis)* | 1; 2 | ? |
| **FUNGI** | | | |
| **Ascomycota** | | | N/A |
| None | *Coccomyces arbutifolius* | Unknown | N/A |
| None | *Coccomyces quadratus* | Unknown | N/A |
| None | *Cytospora* spp. | Unknown | N/A |
| None | *Diplodia maculata* | Unknown | N/A |
| None | *Erysiphe graminis* | Unknown | N/A |
| None | *Fusicoccum arbuti* | Unknown | N/A |
| None | *Hyponectria lonicerae* | Unknown | N/A |
| None | *Lophodermium cladophylum* | Unknown | N/A |
| None | *Microsphaera berberidis* | Unknown | N/A |
| None | *Microsphaera penicillata* | Unknown | N/A |
| Oak Leaf Curl | *Taphrina caerulescens* | Unknown | N/A |
| **Basidiomycota** | | | |
| Armillaria Root Disease | *Armillaria gallica* | Unknown | N/A |
| None | *Ganoderma* spp. | Unknown | N/A |
| None | *Hericium erinaceus* | Unknown | N/A |
| None | *Hymenochaete tabacina* | Unknown | N/A |
| None | *Inonotus dryadeus* | Unknown | N/A |
| None | *Laetiporus gilbertsonii* | Unknown | N/A |
| None | *Phellinus ferreus* | Unknown | N/A |
| None | *Phragmidium fusiforme* | Unknown | N/A |
| None | *Phragmidium rosae-californicae* | Unknown | N/A |
| None | *Puccinia crandellii* | Unknown | N/A |
| None | *Puccinia recondita* | Unknown | N/A |

| | | | |
|---|---|---|---|
| None | *Puccinia striiformis* | *Unknown* | N/A |
| None | *Puccinia symphoricarpi* | *Unknown* | N/A |
| None | *Pucciniastrum goeppertianum* | *Unknown* | N/A |
| None | *Pucciniastrum sparsum* | *Unknown* | N/A |
| None | *Urocystis colchici* | *Unknown* | N/A |
| None | *Uromyces heterodermus* | *Unknown* | N/A |
| None | *Ustilago heufleuri* | *Unknown* | N/A |
| **Birds** | | | |
| Band-tailed Pigeon | *Columba fasciata (Patagioenas fasciata)* | *8* | N/A |
| Barn Owl | *Tyto alba* | *1; 2* | N/A |
| Great Blue Heron, *fannini* subspecies | *Ardea herodias fannini* | *1; 5* | N/A |
| Horned Lark, *strigata* subspecies | *Eremophila alpestris strigata* | *5* | N/A |
| Lewis's Woodpecker (Georgia Depression population) | *Melanerpes lewis* pop. 1 | *1; 2; 3; 5; 7; 8* | N/A |
| Northern Pygmy Owl, *swarthi* subspecies | *Glaucidium gnoma swarthy* | *1; 2; 3; 5; 7; 8* | N/A |
| Peregrine Falcon, *anatum* subspecies | *Falco peregrinus anatum* | *7* | N/A |
| Purple Martin | *Progne subis* | *Unknown* | N/A |
| Short-eared Owl | *Asio flammeus* | *1* | N/A |
| Vesper Sparrow, *affinis* subspecies | *Pooecetes gramineus affinis* | *3* | N/A |
| Western Bluebird, Georgia Depression population | *Sialia mexicana* pop. 1 | *1; 2; 3; 5; 7* | N/A |
| Western Screech Owl, *kennicottii* subspecies | *Megascops kennicottii kennicottii (Otus kennicottii kennicottii)* | *8* | N/A |
| Yellow-billed Cuckoo | *Coccyzus americanus* | *Extirpated species* | N/A |
| **Insects (non butterfly)** | | | |
| Blue Dasher | *Pachydiplax longipennis* | *Unknown* | N/A |
| Black Slug* | *Arion ater** | | |
| Blue-grey Taildropper | *Prophysaon coeruleum* | *3* | N/A |
| Jumping Gall Wasp* | *Neuroterous saltitrius** | *--* | X |
| (leaf bug) | *Ceratocapsus downesi* | *Unknown* | N/A |
| Oak Leaf Phylloxera* | *Phylloxera glabra** | *--* | X |
| (plant bug) | *Clivenema fusca* | *Unknown* | N/A |
| (robber fly) | *Nicocles rufus* | *1; 2; 5; 8???* | N/A |
| (robber fly) | *Scleropogon bradleyi* | *3* | N/A |

| | | | |
|---|---|---|---|
| (scentless plant bug) | *Harmostes dorsalis* | *Unknown* | *N/A* |
| (seed bug) | *Scolopostethus tropicus* | *Unknown* | *N/A* |
| (shield-backed bug) | *Camirus porosus* | *Unknown* | *N/A* |
| Western Pondhawk | *Erythemis collocata* | *Unknown* | *N/A* |
| **Butterflies** | | | |
| Autumn Meadowhawk | *Sympetrum vicinum* | *Unknown* | *N/A* |
| Boisduval's Blue, *blackmorei* subspecies | *Icaricia icariodes blackmorei (Plebejus icarioides blackmorei)* | *4?* | *N/A* |
| Cabbage White* | *Pieris rapae** | -- | *X* |
| Common Ringlet, *insulana* subspecies | *Coenonympha california insulana (Coenonympha tullia insulana)* | *5; 7* | *N/A* |
| Common Woodnymph, *incana* subspecies | *Cercyonis pegala incana* | *5; 7* | *N/A* |
| Dun Skipper | *Euphyes vestris* | *4?; 6?* | *N/A* |
| European Skipper* | *Thymelicus lineola** | -- | *X* |
| Great Arctic | *Oeneis nevadensis* | *3* | *N/A* |
| Gypsy Moth* | *Lymantria dispar** | -- | *X* |
| Island Blue | *Plebejus saepiolus insulanus* | *4?; 6?* | *N/A* |
| Island Marble, *insulanus* subspecies | *Euchloe ausonides insulanus* | *1; 2* | *N/A* |
| Large Yellow Underwing* | *Noctua pronuba** | -- | *X* |
| Lesser Yellow Underwing* | *Noctua comes** | -- | *X* |
| Moss' Elfin, mossii subspecies | *Incisalia mossii mossii (Callophrys mossii mossii)* | *3* | *N/A* |
| Propertius Duskywing | *Erynnis propertius* | *1; 2; 3; 5; 7* | *N/A* |
| Taylor's Checkerspot | *Euphydryas editha taylori* | *5* | *N/A* |
| Western Branded Skipper, *oregonia* subspecies | *Hesperia colorado oregonia* | *5; 7* | *N/A* |
| Western Meadowlark, Georgia Depression population | *Sturnella neglecta* pop. 1 | *1* | *N/A* |
| Western Sulphur | *Colias occidentalis* | *3* | *N/A* |
| Winter Moth* | *Operophtera brumata** | -- | *X* |
| Zerene Fritillary, *bremnerii* subspecies | *Speyeria zerene bremnerii* | *3* | *N/A* |
| **Mammals** | | | |
| Columbian Black-tailed Deer | *Odocoileus hemionus columbianus* | *1; 2; 3; 4; 5; 6; 7; 8* | *N/A* |
| Eastern Cottontail* | *Sylvilagus floridanus** | *5* | *X* |
| Eastern Grey Squirrel* | *Sciurus carolinensis* | *1; 2; 3; 5; 7* | *X* |
| Ermine, *anguinae* subspecies | *Mustela erminea anguinae* | *8?* | *N/A* |
| European Rabbit* | *Oryctolagus cuniculus* | -- | *X* |

| | | | |
|---|---|---|---|
| Roosevelt Elk | *Cervus canadensis roosevelti* | *1; 2; 8?* | *N/A* |
| Townsend's Big-eared Bat | *Corynorhinus townsendii* | *1; 3* | *N/A* |
| **Reptiles** | | | |
| Gopher Snake, *catenifer* subspecies | *Pituophis catenifer catenifer* | *Extirpated species* | *N/A* |
| Sharp-tailed Snake | *Contia tenuis* | *1; 2; 3; 5; 7; 8* | *N/A* |

1 Refer to list of Restoration Ecosystem Units in Table 2.2 in Chapter 2: Distribution and Description
2 For vascular plants, refer to "Key to Propagation Methods" below
3 There are both native and introduced forms of Red Fescue.

## Key to Propagation Methods

1. Seed
2. Vegetative Propagation
    - 2.1 Herbaceous cuttings – tip, root and rhizomes
        - 2.1.1 Tip cuttings
        - 2.1.2 Root cuttings
        - 2.1.3 Rhizome cuttings
    - 2.2 Stem cuttings – softwood, semi-ripe and hardwood cuttings
        - 2.2.1 Softwood cuttings
        - 2.2.2 Semi hardwood cuttings
        - 2.2.3 Hardwood cuttings
3. Division of herbaceous perennials and shrubs
4. Division of bulbous perennials
5. Other methods
    - 5.1 Suckers
    - 5.2 Leaf petiole cuttings

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