



Restoring British Columbia's
Garry Oak
Ecosystems
 PRINCIPLES AND PRACTICES

Chapter 7
 Ecological Inventory and
 Monitoring

Contents

7.1 Introduction 3
 7.1.1 Guiding Principles for Inventory and Monitoring 4
 7.2 Inventory: Determining What is Present 7
 7.2.1 Design Considerations for Inventory and Monitoring 7
 7.2.2 Characterizing the Site 10
 Case Study 1. Photo-point Monitoring 12
 7.2.3 Ecological Classification 14
 7.2.4 Ecological Description 16
 7.2.4.1 Vegetation 18
 7.2.4.2 Soils, Landforms, and Surficial Geology 22





7.2.4.3 Inventory and Monitoring of Animals.....	25
7.2.4.4 Water (Hydrology).....	33
7.2.4.5 Climate.....	34
7.3 Monitoring: Assessing Success.....	34
7.3.1 What is Monitoring and Why is it Important?.....	35
7.3.2 What Sites Should be Monitored?	36
7.3.3 What Should be Measured?	37
7.3.4 What Methods Should be Used?	37
7.3.5 When, How Often, and for How Long Should Monitoring be Done?	39
7.4 References	41
Appendix 7.1	45
Photo-point Monitoring Protocols and Analysis Methods Used in Restoration Monitoring at Fort Rodd Hill National Historic Site	45





Chapter 7

Ecological Inventory and Monitoring

by Don Eastman and Christian Engelstoff, in collaboration with Brenda Costanzo, Fred Hook, James Miskelly, Todd Golumbia, Richard Hebda, Carrina Maslovat, Robert Maxwell, Dave Polster, and Conan Webb



Biologists Matt Fairbarns and Hans Roemer survey rare plants. Photo: Dave Polster

7.1 Introduction

Inventory and monitoring are key steps in restoring Garry Oak ecosystems (see Chapter 5: Restoration Planning). Without these activities, the success (or failure) of restoration projects cannot be evaluated, nor can the need for intervention be detected in a timely way. This chapter provides guiding principles and approaches for inventory and monitoring stages of Garry Oak restoration and describes commonly used methods. It shows practitioners how to design ecological inventory and monitoring programs that yield information on project outcomes that can be compared readily to data from other studies. Inventory and monitoring activities unique to the social component of restoration are addressed in Chapter 6: Outreach and Public Involvement.



Inventory is the process of collecting information to describe the state of an ecosystem or ecosystem characteristics at a particular point in time.

Inventory is the process of collecting information to describe the state of an ecosystem or ecosystem characteristics at a particular point in time. Inventory is an integral element of a restoration project and corresponds to Stages 2 and 3 of the Restoration Project as presented in Chapter 5: Restoration Planning. An inventory provides information to assess the current status of a site (how badly degraded is the area and does it merit restoration?) and identifies what species are present and their abundance (what kind of restoration is needed?). Inventory helps identify key ecological processes and problems that need attention (e.g., invasive species), and provides the basis for deciding what type of restoration is needed. It also identifies “assets” of the site, such as the number and abundance of native species. Inventory is also the essential first step in the monitoring chain, as inventory data provide the baseline against which future observations will be compared. Without a baseline, change cannot be detected or measured. Finally, inventory is essential

for characterizing reference ecosystems; these are critical for defining restoration targets and assessing progress.

Monitoring is the act of making repeated measurements of a meaningful indicator. It is an integral part of a restoration project, and corresponds to Stage 7 of the restoration project stages (Table 5.1 in Chapter 5). Monitoring is the “Achilles’ heel” of restoration; too often, considerable effort applied at the outset of a restoration project wanes after the initial work is done. This scenario plays out time and again in Garry Oak restoration projects and in many other types of restoration. Failure to monitor is short-sighted because without monitoring there is no objective way to establish success. Why invest time and money in a project without knowing if the goal is achieved? Without monitoring, how can emerging problems be detected? Without monitoring, how can adaptive management be implemented?

Monitoring is the process of making repeated measurements to detect change over time.

7.1.1 Guiding Principles for Inventory and Monitoring

In this publication, four key principles guide ecological inventory and monitoring:

1. Set clear objectives
2. Ensure reliability
3. Match effort with outcomes
4. Adopt an ecosystem-based approach

These principles apply specifically to the ecological aspect of restoration; they also apply to the important “social” dimension of ecological restoration covered in Chapter 6.

1. Setting Clear Objectives

Clear objectives are essential to project success. Unclear objectives often cause disagreements among participants, lead to lost opportunities, require additional expenditure of time or money or both, and can result in overlooking the collection of important data or collecting the wrong kind of data. Developing specific and measurable objectives takes time and careful consideration. For example, it is difficult to evaluate the success of a project for an objective such as “to restore



FOUR KEY PRINCIPLES GUIDE ECOLOGICAL INVENTORY AND MONITORING

1. Set clear objectives
2. Ensure reliability
3. Match effort with outcomes
4. Adopt an ecosystem-based approach

These principles apply specifically to the ecological aspect of restoration; they also apply to the important “social” dimension of ecological restoration covered in Chapter 6.

the native plant community”. It is far easier to evaluate success when objectives are clearly defined, such as, “to reduce the distribution and abundance of Common Snowberry (*Symphoricarpos albus*) by 20% in two years” or “to increase the cover of Western Buttercup (*Ranunculus occidentalis*) by 50% in five years.” In these two examples, it is clear that the inventories should record the distribution and abundance of the two species before restoration starts, and that monitoring should include techniques to measure the plant cover of each species. From the perspective of inventory and monitoring, defining clear objectives before a project begins is important for determining sampling design and methods.

As discussed in Chapters 5 and 6, one way of assessing whether or not objectives are useful is to see if they are “SMART”, that is, are they:

- Specific
- Measurable
- Achievable
- Realistic
- Timed

If project objectives pass the SMART test, they will likely be successful.

2. Ensuring Reliability

Since many decisions are based on inventory and monitoring data, it is important to take steps to help ensure that data are objective and reflect the actual situation “on the ground”. One step that helps ensure reliability is to collect data following standard methods that are applicable to Garry Oak ecosystems. A second step is to have appropriate sampling and experimental designs. However, the requirement to meet statistical goals is sometimes very onerous and may not even be possible because of small site sizes. In these cases, reporting results from all sites to a central clearing site may help at least strengthen “anecdotal” information. Notwithstanding these cases, restoration practitioners should aim for reliability of their data to promote the understanding and sharing the results of restoration projects and to further promote the recognition of restoration as a professional field.

Defining clear objectives before a project begins is important for determining sampling design and methods.



3. Matching Effort with Objectives and Outcomes

Projects vary in the level of detail they require for inventory and monitoring. For example, restoring an urban backyard by removing invasive species requires different levels of monitoring than a project involving re-introduction of a rare species. The scope of inventory and monitoring activities should be driven by the scope and complexity of the project. Applying too much effort is unnecessary and impractical, and it wastes resources. In the first example above, photo-point monitoring might do the trick and show more flowering camas from year to year. In the second case, specific cover measurements in fixed-frame plots with measurements of cover, flowering success, and plant survivorship might be needed. Applying too little effort is short-sighted and can compromise the collection of relevant and reliable data. One method for implementing this principle is to have intensive and extensive sites within an overall restoration project site. At intensive sites, considerable effort is expended on detailed inventory and monitoring. At extensive sites, the level of effort is reduced with the aim of ensuring that the results from the intensive site are evident at other sites (that is, the results are generally applicable over the area of interest).

4. Adopting an Ecological or Ecosystem-Based Approach

In this approach, all ecosystem components on the site, including species and key processes, are evaluated for their significance to the project's objectives. In most restoration projects, only a subset of components (such as the abundance of one or two species) is measured. Nevertheless, it is important to evaluate all major components at the outset in order to select the elements that warrant measurement and ensure that the selected subset of components is representative. In an ecosystem-based approach, sites adjacent to the project are also examined. This approach encourages restoration practitioners to look at several spatial scales, including the landscape in which a restoration project is situated.



Biologist Carrina Maslovat conducts a vegetation survey using standardized methodology.
Photo: Dave Polster



7.2 Inventory: Determining What is Present

7.2.1 Design Considerations for Inventory and Monitoring

Five key design principles guide ecological inventory and monitoring:

1. Locate and describe reference sites and conditions
2. Establish control or untreated site(s)
3. Replicate sampling
4. Distribution of sample plots
5. Clearly organize information collection into three categories (stages)

1. Locate and Describe Reference Sites

It is critical to define and describe reference conditions for the restoration site—that is, the target ecosystem characteristics (see Chapter 8, Section 8.4). Therefore, the first design consideration is to locate and describe reference sites. The usual objective of restoration projects is to restore an ecosystem so that it resembles what was found historically on the site, or at least to restore it to an undamaged condition (except in the case of novel ecosystems (Hobbs et al. 2006, 2009)). Since degraded sites no longer resemble what was historically present, there is a need to determine what the undisturbed system looked like, i.e., the target ecosystem. Many approaches are used to determine what target ecosystems should look like, however, the standard way is to locate one or more reference sites that are ecologically comparable but not highly degraded. This strategy is not easy to apply, because all Garry Oak ecosystems are degraded. Other sources of information need to be examined to provide reference or target information, such as historical written accounts, old maps, photographs, paintings, and oral histories. For Garry Oak ecosystems, the undamaged state is usually taken to be what existed before settlement by Europeans.

FIVE KEY DESIGN PRINCIPLES FOR ECOLOGICAL INVENTORY AND MONITORING:

1. Locate and describe reference sites and conditions
2. Establish control or untreated site(s)
3. Replicate sampling
4. Distribution of sample plots
5. Clearly organize information collection into three categories (stages)



2. Establish Control or Untreated Site(s)

Control sites provide a reference to compare sites at which intervention occurs. Usually such sites are located in the restoration area and match the treated area in all respects, except for not being treated. A possible exception to this guideline is with projects involving the removal of invasive species. In these cases, control sites may have to be established away from the restoration site to avoid plants from the control site re-invading the restored area (D. Polster, pers. comm. 2010). Controls enable the effects of other factors, such as a very dry spring or an unexpectedly late frost, to be disentangled from the effects of the restoration treatment itself. Year-to-year variation needs to be distinguished from long-term trends if the real progress due to restoration is to be detected.

Controls enable the effects of other factors, such as a very dry spring or an unexpectedly late frost, to be disentangled from the effects of the restoration treatment itself.

3. Replicate Sampling

Replication strengthens confidence in the results. When only one plot or site is inventoried, it is unclear just how well that plot represents the entire site, even if the sample is chosen to be typical of the conditions. Sampling several areas at different locations within the restoration site helps characterize and appreciate variation. Both the size and the variability of a site influence the number of samples that should be taken, and both sample size (the number of plots) and plot size and shape are important considerations.

Sample size: The number of samples that should be taken depends on the variability of a site rather than its size. Large and very homogenous areas can be sampled with a low number of plots because variability is low; but large and very heterogeneous areas require large numbers of samples because of variability and not size. A rule of thumb used by Garry Oak restoration practitioners is to sample 15–30 plots but statistical formulae can be used to determine appropriate sample size.

Plot size and shape: This topic is addressed under each ecological component as it varies with the component being measured.

Garry Oak ecosystems are heterogeneous, creating difficulties in setting up a sampling design that is equally suitable for all component ecosystems (and the components of each ecosystem!). The desirable number of replicates (i.e., replicate samples, or plots) can be calculated by using statistical formulae (Zar 2009). However, one of the difficulties with relying on traditional statistical formulae is the high variability of many sites. Traditionally, accounting for this variability would involve increasing the number of sample plots at a site (i.e., increasing sample size). However, in ecosystems where variation is a natural characteristic of the ecosystem, for example small seepage areas on rock outcrops, using a greater number of small plots will not resolve the issue of high variance. In these cases, it may be more suitable to incorporate the ecosystem's natural variability into the sampling design by using larger plots, instead of more of them. Sample size and plot design are described in more detail in section 7.2.4, however, a full discussion of replication and statistical study design is beyond the scope of this document; restoration practitioners should consult appropriate textbooks (e.g. Zar 2009).



4. Distribution of Sample Plots

Plots are distributed in one of three ways: random, systematic, or representative (Zar 2009). All three designs have been used in Garry Oak restoration projects.

Random distribution of plots is necessary to make inferences with specified levels of precision and confidence. An element of randomness can be incorporated into a sampling design in a variety of ways. A common way of distributing sample plots is to use a table of random numbers, such as those that are found in most statistical textbooks, e.g., Zar (2009), to select the “x” and “y” coordinates shown on a grid superimposed on a map of the site (Note that random sampling method can be stratified to improve efficiency and obtain better results).

In systematic sampling, plots are distributed over a site according to a spacing rule, e.g., every tenth metre on a set of transects evenly spaced 25 metres apart.

Representative sampling requires that observers select site(s) that they think best represent the typical variation in an area. This subjective assessment is commonly used in British Columbia for characterizing ecosystems (BC Ministry of Environment, Lands and Parks; BC Ministry of Forests 1998). It is the basis of the sampling that was conducted to develop the ecological classification of the Province (Biogeoclimatic Ecosystem Classification), and thus has gained wide acceptance within the professional community as an effective sampling design for the diverse ecosystems of B.C. However, data collected from representative sample plots cannot be analyzed statistically.

Selective sampling of uncommon ecosystems or elements can provide an increased level of confidence that these parts of the ecosystem are being effectively monitored.

Whichever of these three methods is selected, it may mis- or under-sample conditions that are rare but important. For example, small ephemeral pools may represent less than 1% of the landscape in a Garry Oak area, and any of the three sampling methods could miss these pools.

Selective sampling of uncommon ecosystems or elements can provide an increased level of confidence that these parts of the ecosystem are being adequately described and effectively monitored.

Whatever sampling system is used, no matter how many replications are sampled, and whatever reference sites are chosen, the same methods must be used during the life of a project, or else comparisons among plots and sites over the life of a project will be invalid.

5. Clearly Organize Information Collection into Three Categories (Stages)

It is vital that information be collected in a systematic way, using standard formats. Among other

Whatever sampling system is used, no matter how many replications are sampled, and whatever reference sites are chosen, the same methods must be used during the life of a project, or else comparisons among plots and sites over the life of a project will be invalid.





Biologist James Miskelly surveys plants at a translocation site for Golden Paintbrush (*Castilleja levisecta*). See Case Study 1, Chapter 4. Photo: Nicole Kroeker

benefits such as reproducibility, this approach avoids duplicating effort (A. Harcombe, pers. comm. 2009). The three parts are:

- Collecting information on the project area or property (Characterizing the site, 7.2.2)
- Defining the ecological units (Ecological classification, 7.2.3)
- Sampling within the ecological units (Ecological description, 7.2.4)

The next three sections describe details of these stages.

7.2.2 Characterizing the Site

Once a decision is made to restore a site, the first step is to inspect it, assuming that legal access to the land has been secured, and that the landowner has agreed to the restoration. The Land Trust Alliance of BC's *Guide to Baseline Inventories* (LTABC 2006) provides detailed procedures for producing a baseline inventory report for conservation properties and may serve as a useful guide for restoration practitioners. On the first field visit, the biophysical and geographical scope of the project area needs to be recorded, using notes and sketches. Often, this initial information helps confirm or revise project objectives and sampling plans. Preliminary samples can be collected, such as specimens of dominant plant species and water for chemical analyses. Since some analyses take many weeks and even months to complete, an early start on sample collection may save time later on.

Efficient and effective data collection requires adequate preparation prior to visiting the site. This implies having a sturdy, waterproof field notebook, preparing and printing data forms, securing maps, and gathering together appropriate equipment and field guides.

Characterizing a site involves recording basic information for the area. The *Field Manual for Describing Terrestrial Ecosystems*, 2nd edition, provides a section on site description that contains a list of relevant information, a description of each feature, and a form called the





Ground Inspection Form, number FS882C1) (www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh25-2.htm). This version builds upon an earlier edition (Province of British Columbia 1998: note that this inventory manual is a revision of a yet earlier version by Luttmerding et al. (1990) which has a greater level of detail (D. Polster, pers. comm. 2009)). Additional information that is often required for restoration projects can be found in Vesely and Tucker (2004) (see below).

Standard attributes on the Ground Inspection Form:

- exact location and boundaries, recorded as latitude and longitude or as UTM coordinates
- elevation or elevational range in metres
- general slope in percent or degrees and meso-slope position (crest, upper, middle, lower, toe)
- predominant aspect and range of aspects in cardinal directions or degrees
- topography at meso- and macro- levels (relative position of the site within the local area), including surface shape—convex, concave, even
- Ecoregion and Biogeoclimatic subzone or variant
- moisture regime
- nutrient regime (general conditions only, no need for detailed soil tests at this point)
- access points
- general climate
- drainage features, especially areas of waterlogging, wetlands, and drainage patterns

Additional information for Garry Oak and associated ecosystem restoration projects (adapted from Vesely and Tucker (2004) and Green and Klinka (1994)):

- land status: public or privately owned, presence of covenants or other legal features, legal boundaries
- land-use history, e.g., roads, trails, logging, mining, farming
- natural features on or in the vicinity of the site, such as cliffs and caves
- contact information for local environmental organizations. These groups often are valuable sources of information and can provide long-term stewardship for restored areas.

The use of photo-point monitoring is strongly recommended for conducting both inventory and monitoring.

As well as recording the above features, the project area should be photographed from different perspectives. One method is to take photographs in the four cardinal directions from the centre of an ecosystem polygon, as in the study of Anniversary Island in the Gulf Islands National Park Reserve (Parks Canada Western and Northern Service Centre 2008a). As well, a diversity of photographs should be taken each time the site is visited as these will be useful for presentations on the restoration project. The use of photo-point monitoring is strongly recommended for conducting both inventory and monitoring. Photographs from fixed points provide a visual record of baseline conditions and can be used as a monitoring tool to document changes over time. Hall (2002) provides detailed field procedures, concepts, and analysis methods. Also, Chapter 6 of the Grassland Conservation Council of British Columbia's grassland monitoring manual describes a photo-point monitoring procedure that could be adapted to Garry Oak ecosystems (Delesalle et al. 2009). (Download *Grassland monitoring manual for BC* at www.bcgrasslands.org/publications.htm.)



Case Study 1. Photo-point Monitoring

by Conan Webb

Photographs are perhaps the easiest method of creating a record of site conditions. When taken over a time interval, photographs can record vegetation changes over time—it is for this reason that photo-point monitoring is widely used in documenting changes.

Photos can be used for qualitative reference or for quantitative analysis; quantitative analysis, however, requires attention to repeatable protocols. Even if you don't plan on performing quantitative analysis, following a few simple protocols will make qualitative comparisons easier. In addition, following some simple protocols will make quantitative analysis possible if someone chooses to take this on at a later date.

Photo-point monitoring requires that each photo in the series be taken from exactly the same point (establish a permanent marker!) and precisely framed to encompass the same area of the site (try to include an immovable object such as a rock outcrop to assist with framing). Including a vertical, brightly-painted pole of a known length within the frame allows viewers to estimate heights of ground vegetation layers (this pole should be a known distance from the camera). Make sure that you take each photo at the same time every year so that the series shows long-term vegetation trends, not seasonal changes in foliage. Keep good notes about your photo sessions; it is all too easy to end up with just a pile of photos, and photos alone are useless if you don't know some basic details about where and when they were taken. Notes about the landscape might be important as well: while the identity of that yellow flower may have been obvious when you took the photo, it may not be identifiable a couple of years later from the photograph alone.



“Before” photo: The initial baseline photo taken in July 2002 prior to broom removal and deer fence installation. Note that this photo was taken at a different time of year and is not directly comparable to the May 2007 photo. The protocol for this site calls for both late- and early-season photos to be taken each year. The late-season photos such as this one capture late season flora such as grasses and, in general, can be directly compared only to other photos from the same season. However, invasive Scotch Broom (*Cytisus scoparius*), which is a perennial shrub and the primary species of interest, is obviously lacking from the May 2007 photo following.





“After” photo: A monitoring photo taken in May 2007 after six years of broom removal and two years after a deer fence was installed. This photo shows the early-season bloom of camas which is not evident in late-season photos. This is also a good time of year to capture Scotch Broom when it is in bloom and shows up well in photos. Note that the protocol has been updated to include a photo identification number and date on a chalkboard in the image. This keeps such information with the photo.

The preceding paragraph touches on only some of the considerations for photo-point monitoring. *The Photo Point Monitoring Handbook: Field Procedures* (Hall 2002) covers photo monitoring in much more detail. These protocols have been adapted for use in photo-point monitoring of Garry Oak ecosystems at Fort Rodd Hill National Historic Site and are included in Appendix 7.1.

The advantage of photos is that they are relatively quick to take; however analyzing the photographs still takes time and it is easy to end up with a backlog of photographs waiting for analysis. If analysis is planned time must be set aside for it. *The Photo Point Monitoring Handbook: Part B: Concepts and Analysis* (Hall 2002) goes over photo analysis in detail. While Hall’s method is based on prints, this method has been adapted to a completely digital workflow for use at Fort Rodd Hill National Historic Site. This digital workflow uses free software and is outlined in Appendix 7.1.

While photographs are a widely used method, they do have limitations and the usefulness of photo-point monitoring must be assessed in light of project objectives. Photos are best for measuring changes in shrubs and trees, while some easily recognizable forbs can be monitored using photo-point monitoring, not all species can be easily identified in a photo.

References

- Hall, F. C. 2002. Photo point monitoring handbook, Forest Service, U.S. Dept. Agriculture. www.treeresearchfs.fed.us/pubs/3255. (Accessed 2010).
- Carere, D., K. Harding, E. Rafuse, and R. Underhill. 2010. Species and ecosystems at risk: Fort Rodd Hill and Fisguard Lighthouse National Historic Sites of Canada: Summer 2009. Unpublished report prepared for Parks Canada Agency, Government of Canada, Victoria, B.C.
- Conan Webb** is a Species at Risk Recovery Planner with Parks Canada Agency, Victoria, B.C.

7.2.3 Ecological Classification

Classifying a site into its component ecosystems is important because different ecosystems:

- may have different restoration challenges
- often require different treatments
- may respond to treatments in different ways
- vary in their suitability for various native species, and
- provide a reference framework for comparison and may indicate reference conditions.

The appropriate level of ecological classification depends on the restoration objectives and the complexity of the area to be restored. Typically, small areas are generally uniform, so their ecological classification is straightforward. However, most Garry Oak ecosystems are ecologically complex, consisting of at least several different ecological units.

Classification involves subdividing the restoration area into component ecosystems that are generally uniform (i.e., have similar ecological attributes) within themselves but differ from others. Identifying ecosystems present on a site is often straightforward because the differences among them are obvious, even to the “untrained” eye. For example, a shallow soil ecosystem can be separated easily from a deep soil ecosystem by the plant community.

The different ecosystems are mapped as individual “polygons” on a study area map. Aerial photographs are a valuable source of information for delineating ecosystems. Generally, the most recent colour photographs at a scale of 1:5,000 or 1:10,000 are suitable for most restoration projects in Garry Oak ecosystems. Coverage of this sort is available for most of the range of Garry Oak ecosystems on Vancouver Island. Also, aerial photographs can be obtained from the provincial government at <http://archive.ilmb.gov.bc.ca/crgb/airphoto/index.htm>. Aerial photographs can be viewed at the Map Library at the MacPherson Library at University of Victoria. Individuals with a University Library card can also check out photographs and borrow stereoscopes (calling ahead to 250-721-8230 will help ensure that library staff are available to help). Viewing aerial photographs stereoscopically is even more helpful in delineating ecosystems because slopes, aspects, and vegetation heights are discernable.

The CRD Regional Community Atlas is a very useful tool for sites in the Capital Regional District (www.crdatlasc.ca). It has relatively recent colour orthographic aerial photographs, on which you can make measurements, and with the capability of displaying contour intervals. In most cases, individual trees are easily recognizable and identifiable.

Ecological classification can also be completed using satellite imagery combined with Geographic Information Systems to create three-dimensional images. Other imaging technologies, such as LIDAR (Light Detection and Ranging), can also be used to facilitate ecological classification.

Several terrestrial ecological classification systems are used in British Columbia, and at least three have been used for Garry Oak ecosystems (Blackwell 2007, Erickson and Meidinger 2007, Green and Klinka 1994). For the purposes of this publication, the Restoration Ecosystem Units

Classification involves subdividing the restoration area into component ecosystems that are generally uniform within themselves but differ from others.



Figure 7.1 A preliminary attempt, for illustration purposes, at applying the Restoration Ecosystem Units (REU) classification system to the vegetation of Fort Rodd Hill National Historic Site of Canada.

(REU) system proposed in Chapter 2 is recommended. The REU classification is ecologically sound because it is based upon previous studies of Garry Oak ecosystems by qualified ecologists (Erickson and Meidinger 2007). As well, the REU classification system is compatible with the two other ecological classification systems that are widely used in British Columbia—the biogeoclimatic system (Meidinger and Pojar 1991) and the ecoregional system (Demarchi 1995). REUs are of special importance to restoration practitioners because they also function as treatment units, i.e., all polygons of a particular type of REU should respond similarly to a restoration treatment.

The CRD Regional Community Atlas is a very useful tool for sites in the Capital Regional District (www.crdatlas.ca). It has relatively recent colour orthographic aerial photographs, on which you can make measurements, and with the capability of displaying contour intervals. In most cases, individual trees are easily recognized and identified.



The Restoration Ecosystem Units (REU) system proposed in Chapter 2 of this publication was developed to create functional treatment units for restoration practitioners. It is based on previous studies of Garry Oak ecosystems and is compatible with other ecological classification systems used in B.C.

Typically, delineated REU polygons will contain small areas of other ecosystems. Following protocols used in Terrestrial Ecosystem Mapping (BC Ministry of Forests and Range 2007), these inclusions are usually not mapped if they comprise <10% of a polygon's area. However, it is important to note their occurrence and to estimate the proportion of the polygon they comprise because it may be the complex of ecosystems that is important. For example, a species of bird may nest in a small ecosystem that is situated within the polygon of a large ecosystem, and forage in the larger ecosystem. In this case, both ecosystems are important for supporting the species.

Also, these inclusions may provide important habitat for species at risk, in which case a finer ecological resolution may be needed, such as identifying small vernal pools containing the Endangered Fragrant Popcorn-flower (*Plagiobothrys figuratus* ssp. *figuratus*). Study objectives should indicate the need for this level of classification.

Whatever classification system is used, the key point is to define and map the area's ecosystems accurately. If the classification is poor or the ecological polygons are poorly defined, or the maps produced have low resolution or poor spatial representation, the restoration plan will be built on a poor framework that could jeopardize the success of restoration efforts (A. Harcombe, pers. comm. 2009).

7.2.4 Ecological Description

Each restoration ecosystem unit or REU needs to be described ecologically. For the purposes of this publication, ecosystems or REUs consist of the following five components:

- Plants (vascular plants, non-vascular plants and lichens)
- Animals (vertebrate and invertebrate)
- Soils, landform, and surficial geology
- Water (hydrology)
- Climate

Restoration practitioners need to decide which components require an inventory and what level of detail is required for each component. These choices are determined primarily by project scope, project objectives, and available resources. For example, mycorrhizal fungi may be important in the successful establishment of some woody plants, and therefore it may be important to inventory these fungi. Notwithstanding the need to consider all ecosystem components, for practical reasons and because of the availability of expertise, most Garry Oak restoration projects focus on vascular plants, soils, vertebrates and “showy” invertebrates like butterflies.

The Restoration Ecosystem Units (REU) system proposed in Chapter 2 of this publication was developed to create functional treatment units for restoration practitioners. It is based on previous studies of Garry Oak ecosystems and is compatible with other ecological classification systems used in B.C.

Chapter 7 Ecological Inventory and Monitoring



Typically, choosing appropriate methods for conducting inventories is a daunting task because each ecosystem component can be described by many different methods. Two considerations help narrow the choices: First, the methods must produce data that relate clearly to the objectives. For example, if an objective is to decrease the cover of exotic grasses, then a technique that measures the cover of these grasses is vital. Second, methods should be selected from recognized methodologies because they yield reliable data which enable comparisons to be made with information from other projects. In cases where there are no established methods, subject-area experts can help to develop suitable approaches. The following table may help select appropriate methods (Table 7.1).

Two key considerations will help to choose appropriate inventory methods. The methods must produce data that relate clearly to the objectives, and follow recognized methodologies.

In British Columbia, established methods for inventory of ecosystem components are well documented in the series published by the British Columbia Resources Inventory Standards Committee (www.ilmb.gov.bc.ca/risc/pubs/index.html), and the reader is referred to this source for additional information on inventory methods.

Table 7.1 Levels of inventory for restoration of Garry Oak ecosystems

Level of detail	Cost and degree of effort	Sampling system (how information is collected)	Rigor, reliability and utility	Ecosystem components examined (scope and depth of detail)
I	Low	Whole area surveys; no replication	Subjective; low rigor; applies only to site; often used for reconnaissance	Most conventional components covered but not in depth; overall picture recorded; qualitative, lists of species for example
II	Medium	Representative sampling; some plot-based sampling; little or no replication	Subjective or without estimate of error; improved reliability	Vascular plants; conspicuous animals, mostly vertebrates; general soil features such as texture and depth; some invertebrates; hydrology; quantitative
III	High	Systematic or random; plot-based with replication	Improved reliability and utility; results may be publishable in technical journals	Vascular and non-vascular plants; vertebrates and many invertebrates; increased attention to soils and hydrology; quantitative; basic statistical analyses





Emily Gonzales conducts a vegetation survey in a Garry Oak meadow. Photo: Rebecca Best

7.2.4.1 Vegetation

Vegetation inventory documents the distribution and abundance of plants in an area slated for restoration or in a reference site. Many methods are available for collecting this information (see Table 7.3), and the final choice is based on restoration objectives, the scope and complexity of the restoration area and time available. Whatever methods are selected, the aim is always to collect data that can document the success or failure of the restoration.

Whatever methods are used, reliable vegetation inventories have several features in common. They:

- Collect voucher specimens. Ideally, this should be done for all species, but certainly for unidentifiable plants, according to methods described by Brayshaw (1996). Rare species should not be collected but photographed instead.
- Make multiple visits to a site (Hebda 2007). Limiting factors or essential ecosystem characteristics are often not evident if only a single visit is made during a pleasant time of the year. Also, some plant species, including some rare ones, are visible only early in the growing season. Hence, they would not be detected during a summer or autumn survey. Thus, a plant survey at the wrong time of the year may not provide the information needed to carry out a successful restoration, or worse, the restoration activities might destroy an endangered or threatened species. It is also important to visit a site after extreme events or conditions, e.g., heavy rainfall, snow, drought.
- Note plant vigour. Lack of vigour may indicate nutrient shortages or toxicities. Special attention needs to be given to plants that have narrow ecological tolerances.

SMALL AND UNIFORM SITES

For small and uniform project sites with simple restoration objectives, vegetation inventory may consist of a walk over the area to record the distribution and relative abundance (e.g., common, less common, rare) of vascular plants present (tree seedlings, shrubs, ferns, herbaceous plants, and grasses) in the understorey. Mosses and lichens should also be recorded. Of course, special





attention should be paid to recording rare, desirable, keystone and invasive species. If the area occupied by these types of species is important, a GPS unit can be used to define the area's perimeter. Observations on the distribution and abundance of dead trees and fallen limbs and logs, commonly referred to as coarse woody debris (CWD), should also be made as these elements are crucial habitat materials for many wildlife species.

Also, in the small and uniform areas typical of some Garry Oak meadow plant communities (vernal pools for example), it is often possible to count, map, and measure all trees in the overstorey. All trees, including damaged and dead ones (snags), should be measured for their height, diameter at breast height (DBH), and crown diameter. Tree height is most easily measured by using a “tree measuring stick” or Biltmore stick or by using a clinometer, tape measure, and simple geometry. Tree diameter is measured at a standard height of 1.3 m (4.5 ft) from the ground (Diameter at Breast Height or DBH). This measurement can be made using a Biltmore stick or a diameter tape that measures diameters directly. Snags are measured using the same techniques. Crown diameter, or the width of the tree crown, is estimated by measuring the longest axis of the crown and then the longest axis at a right angle to the first axis, and taking the average of these two measurements. Note any signs of disease, such as scarring (and possible causes, e.g., fire, lightning, machinery), dead tops, broken off branches, bracket fungi, and discoloured foliage. Plant species, including mosses and lichens, growing on trees should not be overlooked: unknown species can be photographed and submitted afterwards to experts. Also, note any evidence of use by wildlife, such as browsing, cavities, and bark damage. Ages of trees can be obtained by using an increment borer to extract a core from the trunk at 1.3 m above ground level which can then be aged by counting annual rings. Taking an increment core from a Garry Oak (*Quercus garryana*) tree can be difficult as oak wood is very hard. Note that the age based on cores taken at 1.3 m is the age of a tree *above that height*, referred to as breast height age. To determine the actual age of the tree, the breast height age has to be corrected for the estimated number of years it takes trees to reach 1.3 m: unfortunately, this correction factor has not been developed for Garry Oak. Alternatively, age can sometimes be determined by counting annual rings in a section of a recently downed log.

REGENERATION SURVEYS

If the regeneration of Garry Oak is an important component of a restoration project, a regeneration survey can estimate the number of young oaks on a site. This information can then be used to determine if plantings are needed to meet a desired stocking level, i.e. a specified number of young oaks per hectare. A survey methodology for British Columbia's Garry Oak ecosystems has not yet been developed, but a modification of the method described by Vesely and Tucker (2004) for Oregon could probably be used until an acceptable method is developed. These authors suggest distributing circular plots systematically over the area of interest, and counting seedlings (DBH <5 cm) and saplings (5–10 cm) in each plot. A plot radius of 5.63 m yields a plot area of 0.01 ha, so that multiplying plot counts (either for individual plots or for the mean of all plots) by 100 converts readily to a “per hectare” basis. Regarding the number of plots to be used, Vesey and Tucker (2004) noted that survey accuracy generally increases with increases in survey intensity, that is, the percentage of the survey area that is included within measurement plots. The calculation is: survey area multiplied by survey intensity divided by plot area: the result of this calculation is the number of plots required for a survey. Typically, suitable survey intensities range from 5%–10%.



COMPREHENSIVE VEGETATION INVENTORY

Larger and ecologically more complex areas need a more comprehensive vegetation inventory than the simple surveys described above. For these inventories, some form of sampling is required because it is not possible or feasible to count everything. There are three important considerations in designing more detailed surveys:

- plot size and shape (square, rectangle, circle, plotless)
- plot distribution (representative, systematic, or random)
- sample size (number of plots)

Selecting the most suitable combination of these three variables can be determined by considering project objectives, available resources, and desired reliability of the resulting data. Consult a biostatistician for advice. Fortunately, previous workers in Garry Oak ecosystems have developed several approaches that restoration practitioners can use.

Provincially, the most commonly used method of vegetation inventory in forested ecosystems is described by BC Ministry of Environment, Lands and Parks and BC Ministry of Forests (1998). In this approach, 20 x 20 m plots (400 m²) are located at sites judged by the investigator to be representative of the ecosystem unit under study. Thus, in the forest ecosystems of southern Vancouver Island, 400 m² plots are considered adequate. *Note: for relatively uniform Garry Oak ecosystems, 100 m² may be an appropriate plot size (D. Polster, pers. comm. 2009).*

LARGER SAMPLE PLOTS

Where the ecosystems being sampled are very heterogeneous, e.g., rocky slopes with pockets of deeper soil and ephemeral pools and seepage zones, a larger sample plot may be more suitable to represent the variability of the site. In these situations, instead of using the sample plot sizes described above, size can be determined using the minimal area concept described by Oosting (1956). Basically, this method entails establishing plots of increasing size, doubling the size of the plot each time, until no (or very few) new species are found. The plot size at this point is considered the minimal area (some ecologists then double this area for their surveys). For example, an initial plot of 0.5 m² might be used. The number of species recorded in that plot is totalled. The plot size is then doubled to 1 m² and the number of species is counted. The plot size is again doubled to 2 m² and the number of species is again recorded. If no more species were recorded in the 2 m² plot, then this would be the minimal plot size.

Regardless of plot area and shape, vegetation is divided conventionally into four layers (Table 7.2), and the cover of each species is estimated for each layer as a percentage of the surface area of the plot, to the nearest whole number. Defining layers and estimating percent cover takes a lot of practice, and training with an experienced surveyor is desirable. For specific information on defining layers and estimating cover, refer to Section 3 in the *Field Manual for Describing Terrestrial Ecosystems* (www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh25-2.htm). Note that some low-growing shrub species (e.g., Kinnikinnick (*Arctostaphylos uva-ursi*)) have been assigned to the herb layer. Consult Table 3.1 in the above Field Manual for a list of these species. Also, record species seen in the area but not recorded in the plot, as well noting species not seen but expected in the area.

All trees in the overstorey, or A layer, are identified and measured for DBH, height, and crown area, using methods noted previously.



Table 7.2 Vegetation layers commonly used in inventory of Garry Oak ecosystems (after BC Ministry of Environment, Lands and Parks and BC Ministry of Forests (1998))

Layer	Vegetation	Description
A	Tree layer	Includes all woody plants greater than 10 metres tall
B ₁	Tall shrubs	Includes all shrubs and regenerating trees between 2 and 10 m
B ₂	Low shrubs	Includes all shrubs and regenerating trees less than 2 m tall
C	Herbs	Includes all non-woody plants such as ferns, grasses, grass-like plants, forbs, saprophytes, some low-growing, woody species, and species of “doubtful” life form
D	Ground layer	Includes tree seedlings less than 2 years old and mosses, lichens, and liverworts

MEASURING COARSE WOODY DEBRIS

Coarse woody debris can be measured by using two 24 metre transects that are centered on the plot centre. The bearing of the first transect is randomly selected and the second transect is placed at right angles to the first. The following characteristics are measured for each piece of CWD intercepted by these transects:

- diameter
- decay class, based on the entire piece, by using the table of decay class indicators (in www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh25.htm)
- tilt angle of each piece
- length of each piece, measured or estimated

Consult the following website for additional details:
www.ilmb.gov.bc.ca/risc/pubs/teecolo/fmdte/cwd.htm.

SMALL PLOT SURVEYS

Instead of using one large plot, another approach involves using a set of small plots. In this method, plant cover is estimated for each understorey vegetation layer. Typically, the herb and ground layers (C and D in Table 7.2) are assessed using either 1 m² plots that are square, circular, or rectangular, or a 20- x 50 cm quadrat (Gayton 2003), called the Daubenmire frame after an American plant ecologist who pioneered this approach. The shrub layer (B) is assessed using a larger plot, usually 2 m² or 3 m² in size. Plots are either clustered together around a plot centre in a grid pattern, or spaced along one or more transects. For systematic layouts, sample plots are usually placed along transects that are oriented across the slope of the site to maximize the amount of variability within a transect. Note that an element of randomness is preferred if statistical inferences are planned, and a biostatistician can advise how best to do this.

In these small plot surveys, plant cover is usually estimated visually for each plot, either to the nearest percent or by cover classes (see BC Ministry of Forests and Range and BC Ministry of



Environment (2010) for a guide to cover classes). Estimating cover to the nearest percent may seem to be the best choice, but percent cover is difficult to estimate consistently among observers. Using cover classes helps overcome this problem. For example, individuals are more likely to agree on a cover class rating that spans 5–20% than they are to agree on a cover estimate of 15%. Two commonly used plant cover scales are the Daubenmire method, with six cover classes, and the Braun-Blanquet system which features ten cover classes (Mueller-Dombois and Ellenberg 1974).

POINT AND LINE INTERCEPT METHODS

Although visual estimation of plant cover in small plots is the most commonly used technique in Garry Oak ecosystems, some workers have used point and line intercept methods, e.g., on Anniversary and Eagle Islands in the Gulf Islands National Park Reserve (Gulf Islands National Park Reserve 2008a, 2008b). An example of the point intercept method was on Anniversary Island, where plant species occurring at 50 and 130 cm above the ground at 50 cm intervals along a transect (a tape measure stretched between two end points) were recorded. In a variation on this method, forb and grass intercepts were recorded on a 10 cm spaced grid in a 1 x 1 m quadrat. With line intercept, the length of the transect intercepted by each plant species is recorded.

There is a group of methods that do not require laying out plots. Known as “plotless” methods, they rely on measuring distances between plot centres and individual plants and/or distances between individual plants. These methods do not appear to have been used in Garry Oak inventories, and so are not covered in this chapter. If readers wish more information on these methods, they should contact a plant ecologist or consult a plant ecology text.

7.2.4.2 Soils, Landforms, and Surficial Geology

Soil inventories can reveal potential management problems such as predisposition to erosion or compaction, and can help guide the selection of plant species for re-vegetation. Similar to vegetation inventory, soils can be inventoried at various levels of detail. Whatever level of detail is selected, it is useful to bear in mind that soils have three major components—physical, chemical, and biological—and that all soil information can be organized under these three headings.

The first step for soils inventory is to collect information from existing soil survey reports for the site and the surrounding area. Consult Day et al. (1959), Jungen (1985), and Muller (1980) for soils information for southeastern Vancouver Island. This step provides a preliminary information base, but a field-based inventory is also needed to: a) relate soils of the study area to those described in the soils reports, and b) collect information specific to the area.

The second step is to subdivide or stratify the project area into meaningful soil units. Usually, the restoration ecosystem units (REUs) defined in Chapter 2 serve this purpose, just as they do for vegetation. However, it is helpful to confirm this stratification with a soil scientist to ensure its accuracy.

The third step is to characterize the soil in each REU polygon. This calls for digging several test holes (soil pits) in each major REU and at reference sites. Test holes should extend through the root zone, usually 50–60 cm deep, but may be shallower if the basic parent material is reached. Soil inventories should be conducted in June, when soils can be dug easily. This approach was used in surveying Garry Oak Restoration Project (GORP) sites in Saanich municipality (Giasson and Maxwell 2002).



Chapter 7 Ecological Inventory and Monitoring



TABLE 7.3 Methods used to sample vegetation in selected projects in Garry Oak ecosystems

Source/ study area	Sampling system and aim	Sampling design	Plot size and shape for layers sampled	Layers sampled	Sampling frequency	Sampling intensity
Anniversary Island – monitoring for Polygon B	Line intercept for percent cover	8 parallel transects, 10 m apart, oriented perpendicular to the slope	Species intercepted every 50 cm at 50 cm and 130 cm above ground	Understorey and low shrub layers		
Anniversary Island – monitoring for Polygon A		2 transects 2m apart, oriented parallel to the long axis of the treatment area	As for Polygon B			
Eagle Island effective- ness monitoring	Point intercept	Randomly distributed quadrats	1 x 1 m, permanently marked with steel	Forbs and grasses: 120 x 120 cm frame with a nylon grid spaced every 10 cm – all species recorded as well as ground cover Shrub layer: 2 x 2 m frames centred over the 1 x 1 m forb /grass plots–percent cover estimated for two vertical strata: low shrubs <2 m, and tall shrubs from 2–10 m	April and late June –early July	50 plots for 1.4 ha open coniferous forest, rock outcrops, shrubland, open canopy Garry Oak
Mill Hill (Maslovat 2008)			3 x 3m, corners marked with rebar and spray painted orange with metal tag on SW corner indicating plot number (GPS coordinates recorded)	Percent cover of tree canopy and shrub canopy, calculated as foliar cover; mosses on rock and wood not included		
Somenos Garry Oak Protected Area	Transects with Daubenmire plots	Uniformly spaced along transect	1 m ² with ¼ m ² smaller plots nested in corner	All layers	Conducted annually	8 transects with 10 plots each





Chapter 7 Ecological Inventory and Monitoring

The following properties can be gathered from soil test holes (Green and Klinka 1994):

- general depth of soil, i.e., depth to the parent material
- presence and average thickness of accumulated humus (Ah horizon) and other visible layers
- proportion of coarse fragments (rocks > 2 mm) of soil volume
- texture in the rooting zone. Texture is estimated in the field by a simple technique that indicates the relative proportions of sand, silt, and clay in the soil (see Appendix 4 in Green and Klinka (1994) or Steinfeld et al. (2007:52))
- presence of mottling or gleying that indicates temporary or fluctuating water tables
- humus form (see pages 15-16 in Soils section of BC Ministry of Forests and Range and BC Ministry of Environment (2010))
- root restricting layer, if present, and type of restriction, e.g., bedrock, cemented layer
- surficial materials, e.g., lacustrine, glacial till, alluvium, colluvium.
- description of organic material and thickness
- presence of earthworms and other biota
- relative moisture regime (see Appendix 5 in Green and Klinka (1994))
- relative nutrient regime (see Appendix 6 in Green and Klinka (1994))

In addition to these features, chemical attributes such as pH can be assessed using field kits, e.g., Hach kits or the LaMotte waterproof pH meter.

All of these soil features can impact restoration treatments. For example, depth to an impervious layer, texture, extreme rockiness, proneness to compaction, erosion susceptibility, burning history, and drainage can all affect the selection of plants to be used for restoration. Soil samples should be collected and pictures taken of the soil profile if unusual situations are encountered, e.g., suspected contamination.

In some situations, a more detailed level of soil inventory is required. This entails digging soil pits and describing a wide variety of soil attributes (e.g., colour, texture) for each soil layer or horizon. If even more complex analyses are warranted, e.g., if trace element deficiencies are suspected, soil samples can be sent to an analytical laboratory. Most soils laboratories specify the method for collecting soil samples for analyses. Usually, soil samples are collected from at least six sites to a depth of 15 cm, and then mixed thoroughly. Of course, if the project area has obviously different soils (e.g., a wet low-lying area versus an exposed shallow soil area) each type needs to be sampled separately.

Detailed inventory of soil biota is best left to experts. Inventories and identification of soil organisms usually requires specialized knowledge and equipment. The need for this level of detail in a restoration project can be judged by referring to project objectives and by consulting a soil scientist.





7.2.4.3 Inventory and Monitoring of Animals

GENERAL CONSIDERATIONS

Inventory and monitoring of animals faces many challenges. Animals are:

- mobile (so it is often difficult to see them clearly and to know how much time they actually spend in an area)
- cryptic (so they are difficult to see)
- night-active (which makes detection difficult)
- often silent for most of the year (so using auditory clues is not always possible)
- widely variable in their behaviour and ecology, necessitating inventory methods that are “customized” to take advantage of their particular attributes. For example, some bat calls are beyond human hearing ability and so specialized equipment is needed for their detection.

Thus, collecting animal data on an ecological unit basis can be tricky. Detected individuals may be from a broader area, and the animal may freely roam around many units. Observers may displace animals from their typical habitat, complicating an understanding of species-habitat relationships.

Three types of vertebrate inventory are possible: present/not detected, relative abundance, and absolute abundance (Caughley 1977). The choice of type of inventory depends on project objectives, but estimates of absolute abundance are not often undertaken because they are expensive, time-consuming, and usually unnecessary. The basic level of inventory involves recording *animal presence*. Not seeing an animal *is not* conclusive proof that it is absent, even after many surveys. The most that can be said is that the species was not detected. *Relative abundance* involves using methods that detect changes in numbers, but do not yield the actual numbers of animals present nor the actual change in numbers. *Absolute abundance* uses methods that estimate the actual numbers of individuals present. This is almost always estimated by sampling as it is virtually impossible to make accurate direct total counts of animals.

For all three types of inventory, many methods are available. The reader is advised to consult standard textbooks, such as Krebs (1999), for further information, or consult species experts. Another invaluable source of information for British Columbia is the provincial government’s Resource Inventory Standards Committee (RISC) website which contains standard methods for most vertebrate and some invertebrate species (<http://archive.ilmb.gov.bc.ca/risc/pubs/tebiodiv/index.htm>).

Any inventory that involves handling or marking vertebrates requires permits as specified by legislation (e.g., Wildlife Act, *Species At Risk Act*), and by permitting policies of municipal, regional, provincial, and federal governments. All necessary permits must be obtained before field work begins.

Special mention must be made for studies of amphibians, especially for surveys where several ponds are visited. It is essential to follow the Standard Operating Procedure: Hygiene Protocols for Amphibian Fieldwork. Also, consult the Amphibian Disease page on the BC Frogwatch Program’s website (www.naturewatch.ca/english/frogwatch/bc) to avoid spreading diseases such as the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) and ranavirus. In short, thoroughly disinfect boats, boots, and equipment between survey sites.





Chapter 7 Ecological Inventory and Monitoring

A useful first step in animal inventory is to create a list of species expected at the site. Such a list can be based on check lists, relevant references, and the expertise and experience of competent local biologists and naturalists.

In the field, all species seen or heard should be recorded, noting the date, time of day, weather conditions, and the habitat(s) or REUs in which animals are sighted. For unknown animals, photographs and detailed notes (e.g., colour, size, prominent features) will aid in identification. Because many animals are difficult to find, signs such as tracks, scats, burrows, or dens are often the only evidence of a species' presence.

AMPHIBIANS

Identification of amphibians found in Garry Oak ecosystems can be facilitated by field guides and the pamphlet published by BC Ministry of Environment (see BC Frogwatch Program). These sources help determine the species to be expected at study sites and also aid in the identification of adults, larvae, and egg masses of amphibians. Data collected on frogs can be entered in the BC Frogwatch Program website (www.naturewatch.ca/english/frogwatch/bc). Note that all frog species found in B.C.'s Garry Oak ecosystems are pond breeders. Of the six salamanders that occur here, three species do not require standing water. General information on inventory methods is presented below, and the reader is directed to the following website (<http://archive.ilmb.gov.bc.ca/risc/pubs/tebiodiv/index.htm>) for detailed descriptions of standard survey methods for pond-breeding amphibians and terrestrial salamanders.

Present/not detected surveys

Amphibian surveys are either aquatic or terrestrial, and involve searching for egg masses, larvae, and adults.

One aquatic approach is to listen for vocal species that can be detected and recorded by call at the appropriate times of year during optimum weather conditions, such as warm calm evenings. Silent species and surveys at the wrong season or in sub-optimal weather conditions will yield incomplete information. For example, Pacific Chorus Frogs (*Pseudacris regilla*) call from late March to May; Northern Red-legged Frogs (*Rana aurora*) call under water in February and can only be heard using a hydrophone; Bullfrogs (*Lithobates castesbeianus*) bellow their characteristic call in July.

A second aquatic method is to search ponds for adult frogs, salamanders, and toads by sitting or walking quietly along pond edges, especially at the north-eastern corner of ponds where amphibians often aggregate. Binoculars and dip nets are two important pieces of equipment for these surveys.

A third aquatic method focuses on larvae and egg masses. Tadpoles and salamander larvae can be captured using a dip net while wading along shallow parts of a wetland or from a boat, canoe, or kayak. Minnow traps work well, but traps must be partly in air as trapped animals must have access to air. Identification of tadpoles and larvae can be tricky, and is best done by an experienced herpetologist.

Surveys for egg masses require exploration of pond edges by walking or by canoe, rowboat, or kayak. Egg masses are gelatinous blobs with dark centres, often attached to underwater vegetation or submerged branches. Detecting and identifying egg masses requires practice, so



field guides and local herpetologists are important resources. Because not all species lay their eggs at the same time, surveys must be conducted at the optimum time for the target species.

Terrestrial surveys are also used to detect amphibians. Most amphibians found in Garry Oak ecosystems can be found in the terrestrial environment at some time during a year. Some of these species will travel a considerable distance from water, such as Rough-skinned Newt (*Taricha granulosa*) and Western Toad (*Anaxyrus boreas*). Some of the salamanders found in Garry Oak ecosystems, such as Ensatina (*Ensatina eschscholtzii*), Western Redback Salamander (*Plethodon vehiculum*), and Wandering Salamander (*Aneides vagrans*), do not require standing water to breed and are found in the terrestrial environment all year round.

The best way to locate these species in daylight is to look under woody debris, vegetation, and other cover objects where the animals hide (taking care not to destroy their habitat in the search!). During the spring, amphibians like colder and wetter weather, and might come out of hiding so they are more easily detected. During wet nights, amphibians can be detected on the forest floor or on the roads in the survey area. For night surveys, strong flashlights or flood lights are required and for safety reasons, work in teams of at least two people. The terrestrial salamanders are often easiest to find using cover boards (see the appropriate RISC manual for details).

Relative abundance

Relative abundance can be obtained by standardizing the above mentioned searches for amphibians. For example, the relative abundance for vocalizing frogs can be determined by listening for a set number of minutes at predetermined spots in wetlands. At each spot, estimate how many frogs can be heard and what species are calling. Sometimes it is not feasible to count individual frogs when many are calling, such as the Pacific Chorus Frog. In these situations, number categories (0, 1-5, 6-20, >20) or categories of relative calling intensity can be created, such as those recommended by Frogwatch (www.naturewatch.ca/english/frogwatch/bc/steps.html).

For example:

T (trace) – no frogs or toads heard

L (low) – individuals can be counted; calls not overlapping

M (medium) – some individuals can be counted; other calls overlapping

H (high) – full chorus; calls continuous and overlapping; individuals not distinguishable

Aquatic spotting surveys can be standardized by establishing survey points, duration, time of day, and weather conditions, and repeating surveys under these conditions, as much as possible. Even with rigorous standardization, it is important to keep in mind that observer bias influences detection of adults and eggs masses. Since observers are likely to vary from survey to survey and year to year, it may be preferable to rely on trapping because it has the least observer bias.

To obtain relative abundance of terrestrial salamanders, the best method is to conduct cover board surveys under standardized conditions. However, for some species, mark-recapture techniques can be used to establish relative abundance. The latest marking method uses coloured elastomers or passive interrogation tags (PIT): both methods require injecting the marker under the animal's skin. To prevent injuring the animals, both of these methods



require involvement by professionals with relevant experience in injecting markers. In lieu of professionals, proper training is essential and is likely to be a mandatory condition of a permit.

Absolute abundance

Short of draining a pond and counting what is present (not logistically feasible nor acceptable), the method of choice is mark-recapture. This technique is labour intensive and is usually not necessary unless changes in numbers of amphibians is a project objective. Moreover, there is currently no RISC manual available to determine absolute abundance of terrestrial salamanders.

REPTILES

Snakes and Lizards

Four snake species and two lizard species occur in B.C.'s Garry Oak ecosystems. The most abundant snake is the Northwestern Garter Snake (*Thamnophis ordinoides*), and the two less common species are the Common Garter Snake (*T. sirtalis*) and the Western Terrestrial Garter Snake (*T. elegans*). The Endangered Sharp-tailed Snake (*Contia tenuis*) is the rarest species. The two lizard species are the native Northern Alligator Lizard (*Elgaria coerulea principis*), which is relatively common and widespread, and the introduced European Wall Lizard (*Podacris muralis*) which is mainly found in parts of the Capital Region District (Durrance Road, south of Brentwood Bay in Saanichton) and in Duncan (Bertram 2004).

Identification of reptiles found in areas with Garry Oak ecosystems can be facilitated by field guides or the pamphlet published by the Ministry of Environment (see BC Frogwatch Program website). The BC Frogwatch Program website also allows data to be entered and helps determine what species occur in the area.

Present/not detected surveys

Surveys for the presence of reptiles can entail sight surveys, trapping, or use of artificial cover objects (ACOs). The procedure for sight surveys calls for walking quietly around the study



Herpetologist Christian Engelstoff creates a monitoring station by placing an asphalt cover object in potential Sharp-tailed Snake (*Contia tenuis*) habitat. This method avoids disturbance of natural habitat features like rotten logs, rock piles, and forest litter. Landowners contribute to the research by checking for snakes under the artificial cover objects. Photo: Todd Carnahan



area on warm sunny days in the spring, or along roads during summer nights, and searching for animals.

A more intensive survey method involves trapping. Most snakes and lizards can be trapped in funnel traps outfitted with drift fences that lead the animals into the traps. The Sharp-tailed Snake is a special case and the best way to detect this species is by distributing up to 20 ACOs (small pieces of asphalt roofing materials approximately 30 x 60 cm) every 5–10 metres along meandering transects in suitable micro-habitat, i.e., south-facing rocky slopes with CWD or litter or duff. The ACOs are then checked approximately weekly to see if snakes are underneath. Because the Sharp-tailed Snake can be found in areas with rare plants it is important not to cover any of these plants with ACOs. As with amphibian inventory, it is critical to ensure that all applicable permits have been obtained before handling reptiles.

Relative abundance

As with amphibians, relative abundance can be assessed by standardizing presence surveys. Another approach is to use time-constrained, quadrat or transect searches (See RISC Manual 38: www.ilmb.gov.bc.ca/risc/pubs/tebiodiv/snakes/assets/snake.pdf) under standardized conditions. For example, search a defined area for 15 minutes in the summer under sunny and warm conditions. When the same area is to be searched several or more times, it is important to minimize damage to the habitat, for example by dividing an area into subunits and searching different subunits on different surveys. Weekly surveys of ACOs in spring and fall and bi-weekly in summer can be used, but these surveys are very labour-intensive and their effectiveness is untested.

Absolute abundance

Direct counts for determining total numbers is not possible for reptiles, so some type of mark-recapture study is necessary to estimate absolute abundance. Unless a restoration project is directed at the recovery of an endangered reptile, this level of intensity is not necessary.

Turtles

The two most common turtles found in B.C.'s Garry Oak ecosystems are the Endangered Western Painted Turtle (*Chrysemys picta belii*) and the introduced Red-eared Slider (*Trachemys scripta*). Several other introduced species can be found throughout the region.

Present/not detected surveys

Determining the presence of these species requires a land-based vantage point or a floating platform, such as rowboat, canoe, or kayak, from which the shoreline can be scanned. Surveys need to take place on sunny days in the spring (March, April, and May) when basking is at its peak. Up to 3–5 surveys may be necessary to confirm presence or likely absence of turtles.

Relative abundance

Relative abundance can be estimated by conducting visual surveys that are standardized either by time or survey locations or both. Relative abundance can also be obtained by mark and recapture methods, but before engaging in capturing and handling turtles, practitioners need to take training and obtain the appropriate permits, as both species are protected by the BC Wildlife Act.



To capture turtles, basking traps and baited hoop traps are tried-and-true methods, and both might be needed as there appears to be seasonal variation in the success of these traps. From mark and recapture methods, population estimates can be derived if individual turtles can be identified. A marking method is described in RISC manual 37, and the shell notching approach is recommended as it is the least invasive method. There are no RISC methods to determine absolute population estimates of turtles.

BIRDS

Present/not detected surveys

The simplest method is to record all birds seen and heard in the area, preferably over the course of a year to pick up resident, breeding, and migrating species (Many field guides are available, e.g., Dunn and Alderfer (2006), and the novice can consider improving their bird identification skills by participating in birding field trips offered by local naturalist clubs.) Many birds are most likely to be detected at dawn during breeding season, but Gross (1995) conducted winter surveys. The presence of owls can be detected, especially during the breeding season, by listening, calling, or playing calls plugged into a loud speaker. As well, all signs of bird activity, such as tree cavities or old nests, should be recorded. If it is only possible to sample one time, then spring is best as it will most likely pick up birds breeding in the area, although migrants will be missed. Field data can often be augmented by reference to local bird checklists and by contacting local naturalists.

Relative abundance

Relative abundance can be estimated in a variety of ways, but whatever methods are used, surveys should be conducted within two hours either side of sunrise when birds are most active. One common and straightforward way to get a sense of estimating relative numbers is to use the subjective scale of abundance, often found in bird checklists. Most owls are an obvious exception

to this method: owls are usually surveyed at night and the rate of calling under standard conditions can indicate approximate changes in abundance.

More detailed information can be gathered by recording birds seen along transects. In this method, the observer walks along transects at a steady pace and records all birds seen or heard within a pre-determined strip centered on the transect, over a specified time period. One variation on this method is to record the distance and angle of birds seen from the transect. When transects are surveyed repeatedly, temporal patterns can be detected.

The most detailed method for estimating relative abundance is spot counts. In this method, a series of stations are set out along transects that are distributed across the study area. The observer records all birds seen or heard at each station during a fixed time period, usually 5–20 minutes. Transects and stations need to be placed far enough apart to minimize duplicate counting.

Absolute abundance

As with other vertebrates, absolute abundance can be estimated with mark-recapture studies, but these require significant effort.



MAMMALS

Present/not detected surveys

As with birds, record all mammals seen, plus all signs of activity, such as tracks, scats, and dens.

Relative abundance

Inventory methods for mammals vary according to the type of mammal being counted. Live-trapping is usually used to inventory small mammals like rodents because they are unlikely to be seen. Traps are baited and placed along transects that cover the entire study area. Pitfall traps have been used for shrews but they are problematic because the trapped animals often die.

Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*) are the most common large mammal found in Garry Oak ecosystems, and they are often a consideration in restoration because they can damage plantings. For most Garry Oak restoration projects, estimating the relative abundance of deer is the most practical type of inventory. Relative abundance is commonly based on pellet group counts, and for details on conducting pellet group surveys consult <http://archive.ilmb.gov.bc.ca/risc/pubs/tebiodiv/index.htm> (Manual 33).

A local example of a pellet group survey is that designed by Mercer (2006) for use in the Gulf Island National Park Reserve. Pellet counts involve regular counting and clearing of pellet groups in 10 m² circular plots that are spaced at 40 m intervals along sampling transects. The plot area is defined by placing the end loop of a 1.78 m plot cord over the centre point (e.g., nail) of the plot and extending the cord to its full length, to establish the plot radius. Moving the plot cord in a clockwise or counter-clockwise direction 360° around the plot defines the full plot. Any pellet group that is 50% or more within the plot area and (a) consists of 10 or more pellets, 10 cm or more away from the next closest pellet group, or (b) is distinguishable (“newer” or “older”) from the next closest pellet group, is counted. After all groups are counted, the plot cord is rotated in the opposite direction and groups are counted a second time to verify the initial count. The plot is cleared of pellet groups when the count is completed to the satisfaction of the sampling team, so that subsequent sampling will detect pellet groups deposited since the previous sampling date. To detect seasonal changes, plots can be cleared and counted in the fall and thereafter in early spring and late fall. Additional surveys can be conducted in mid-summer (late June to early July).

Results of pellet group surveys must be interpreted with caution. Increased pellet group densities could indicate an increase in numbers, but they could also indicate increased use of the survey area, or a combination of both.

Absolute abundance

Determining absolute abundance for vertebrates is a costly and time-consuming enterprise, and should not be undertaken without the advice and guidance of a vertebrate ecologist. Normally, this level of measurement is not required in Garry Oak restoration, except for threatened and endangered species, in which case estimates of absolute numbers may be necessary.



INVERTEBRATES

Present/not detected surveys

Certain large invertebrates, like butterflies, can be detected by searching for them systematically during appropriate times of day and weather conditions. All potential habitats should be searched. Time of year is important. In the case of butterflies, a site should be re-surveyed every two to three weeks from early spring through the summer to account for different flight seasons among the different species.

Species that are under-represented in visual searches may be detected more easily with a variety of passive trapping approaches. For example, spiders are usually sampled using pitfall traps. Other groups may be better sampled using pan or malaise traps. These are generally lethal methods, but may be the best way to confirm the presence of certain taxa. Some groups may be sampled non-lethally using artificial cover objects.

Relative abundance

Relative abundance can be determined by using the same methods as for presence/absence status but standardizing and repeating the sample. For example, the usual way to determine relative abundance in butterflies is to walk a fixed-width transect at a fixed rate of travel during standardized weather conditions and times of day (Pollard 1977). Only those butterflies that are seen within a certain distance from the observer are counted.

In other parts of North America, native bees are being surveyed through timed observation of a single variety of sunflower (LeBuhn 2010). A similar approach could be developed using native flowers, or a site-specific plan could use a fixed transect where all flowers are checked at a fixed rate.

In the case of species that are best detected using traps or artificial cover objects, relative abundance could be determined through repeat sampling of objects or traps that are set in fixed locations, representative of the whole site, and checked after set periods of time.

Absolute abundance

Absolute abundance can really only be determined through mark/recapture studies. It is important to note that these studies can have significant negative impacts on invertebrates (Murphy 1988). Determining absolute abundance is of questionable value for invertebrates, especially for rare species. Many invertebrates have short life cycles (often one year) and population numbers are highly responsive to variables, such as weather conditions and relationships with predators and parasites. Absolute abundance is likely to vary greatly from one year to the next. With rare species or small populations, mark/recapture studies will result in estimates with very low certainty (Murphy 1988). Moreover, the population is the more meaningful conservation unit in these cases anyway, and relative abundance is likely to be a better tool for measuring changes.

For butterflies, transects can be set up and then monitored regularly. It is important to be consistent and to account for factors such as weather (e.g., monitor only under optimal conditions for butterfly flight, which are generally warm, sunny weather during the warmer period of the day).



For other insects, regular observations can be made of pollinators. Transects can be set up to make regular observations of the presence and abundance of insects in foliage.

Gastropods

An emerging topic is the distribution and species composition of gastropods in Garry Oak ecosystems, partly because of the increasing number of listed species and the occurrence of invasive species. Examples are the Endangered Blue-grey Tailed slug (*Prophysaon coeruleum*), the Red-listed Threaded Vertigo snail (*Nearctula* spp), the Blue-listed Pacific Sideband snail (*Monadenia fidelis*) and the Blue-listed Scarletback Tailed slug (*Prophysaon vanatta*). Forsyth's (2004) *Land Snails of British Columbia* is a helpful reference.

For larger species in the study area, present/not detected surveys can be done by searching leaf litter, downed woody debris, tree trunks, vegetation, and similar objects. Placing and monitoring artificial cover objects made of corrugated cardboard (30 x 30 cm, 3 layers deep) is another approach often used to determine the presence of gastropods, e.g. Ovaska and Sopuck (2010). For smaller species (less than 5 mm), samples of the litter layer are dried and then sifted with three sifts, each with progressively smaller holes.

Relative abundance can be determined by conducting searches that are limited in the size of the search area or in their duration (often referred to as time and/or area constrained searches) or by quadrat searches. Standardized searches of artificial cover objects can also be used to estimate relative abundance. Absolute abundance is not possible to determine with current methods. See Duncan et al. (2003) for a full discussion of survey methods for gastropods.

7.2.4.4 Water (Hydrology)

Inventory of water primarily involves observations of drainage patterns. Maps and field surveys in the wet season are needed to locate low lying areas, seeps, and vernal pools. Indicator plants (see Klinka et al. 1989) are often helpful in determining damp places.

It is also important to assess adjacent areas for the risk of topographic alternations that could affect the restoration area's hydrology. If there is funding, and the restoration area is large, then hiring a hydrologist for a day or two is helpful. However, this is probably not necessary for small projects unless there will be major construction or development adjacent to the site, with an increased potential for changes in water flow on the restoration site.

Attention should be directed to investigating historical changes to hydrology. For example, a restoration site's hydrology could have been altered already by underground drainage pipes and ditching or the redirection of drainage courses, as was carried out historically above the Garry Oak woodland at Government House in Victoria. Such historical impacts could change habitats for some rare plants (B. Costanzo, pers. comm. 2010).

The location and extent of all streams, lakes, and wetlands need to be carefully delineated, as all activities in the adjacent riparian zones are regulated by the provincial government's Riparian Areas Regulation (www.env.gov.bc.ca/habitat/fish_protection_act/riparian/riparian_areas.html). Note that ephemeral or winter streams are included in this regulation, so it is important to survey project areas in winter to identify these streams: they may not be apparent in the summer when they have dried up.

A useful strategy is to visit a restoration site in the late winter after a heavy rainfall and note



where there are pools of standing water and drainage trackways and what their limits are. Noting the elevation limits of high water in ponds and lakes at this time of the year helps define the hydrologic conditions in some Garry Oak stands. Common Rush (*Juncus effusus*) is a useful indicator of sites that are wet during the winter months. Mottled soils are also good indicators of poor drainage.

7.2.4.5 Climate

For most Garry Oak restoration projects, climate information is usually referenced as part of a general description of the study area. The usual parameters of interest are:

- rainfall: average monthly and average annual amounts
- temperature: monthly and annual means; average monthly and annual maxima and minima
- frost-free period

Typically, this information is taken from long-term Environment Canada climate stations, usually located at airports. Since most Garry Oak sites are not at airports, these data may not accurately reflect the local climate of a site. More local records may be available from the University of Victoria's school-based weather system (www.victoriaweather.ca). More than 20 stations have been established in the Greater Victoria school districts, many of which are close to restoration sites. Stations have also been installed as far north as Campbell River, and these may provide local records for Garry Oak sites elsewhere on Vancouver Island. It is also possible to collect weather data inexpensively by using iButtons to measure temperature and relative humidity (www.maxim-ic.com/products/ibutton).

Variation in site-specific climate (also referred to as micro-climate) is of most interest to restoration practitioners. These fine-scale variations are important for selecting plant species and for determining where and when particular species are planted. Noting where late season frost pockets occur is a useful observation when selecting plant species or scheduling planting.

7.3 Monitoring: Assessing Success

Monitoring is the act of making repeated measurements of a meaningful indicator. It involves answering the question: Is the baseline condition changing? Monitoring is an integral part of a restoration project, and corresponds to the seventh stage in the process of conducting a restoration project (see Chapter 5: Restoration Planning). Monitoring is a tool that measures progress in achieving restoration objectives, and identifies problems that might affect their achievement. If recovery of a damaged ecosystem is important enough to invest time and money, then it is equally important to assess whether or not restoration actions are effective. A monitoring program can identify deviations from the projected trajectory of ecosystem recovery, so that adjustments can be made. For example, if a project objective was to eradicate an exotic plant, and monitoring showed that the species was still present after a specified period of time, then an opportunity and need exist to use alternative removal methods before the species recovers to dominate the site again.

This section addresses the following aspects of a successful monitoring program:



- What is monitoring and why is it important?
- What sites should be monitored?
- What should be measured?
- What methods should be used?
- When, how often, and for how long should monitoring be done?

The material in this section is adapted with permission from Hebda (2010) and the Coastal Services Center, National Atmospheric and Oceanic Administration's website (www.csc.noaa.gov/coastal/management/management.htm).

7.3.1 What is Monitoring and Why is it Important?

There are three different types or purposes of monitoring: implementation monitoring (*evaluation*), effectiveness monitoring (*assessment*), and *validation* monitoring. The first type, *evaluation*, involves determining how well a restoration prescription or program was implemented compared to the plans. For example, were techniques applied properly and at the appropriate time, were the designated plant species used and planted according to directions?

Assessment or effectiveness monitoring, involves determining whether or not the prescription had the intended result of restoring the ecosystems. Gaboury and Wong (1999) noted that effectiveness monitoring has at least five important benefits:

- it results in more efficient allocation of effort
- it provides measures of states of recovery
- it identifies areas where research may be required
- it offers technical feedback for refining restoration techniques and approaches, and
- it provides opportunities for training in field methods and for fostering stewardship when local communities are involved

Validation provides measures of the validity of the theories upon which restoration treatments are based. It is used by researchers to test hypotheses and techniques, and it often draws upon data from long-term restoration projects. As this type of monitoring is primarily a research endeavour, it will not be covered in this publication.

Monitoring faces major challenges. Gayton (2003) pointed out the following monitoring challenges for British Columbian grasslands, but they apply equally well to Garry Oak ecosystems:

- Ecosystems vary dramatically over time and space. The magnitude of seasonal and year-to-year variation is often greater than the progressive changes resulting from a treatment.
- Locating areas that are comparable and large enough for reference sites is difficult. This is especially so in Garry Oak ecosystems because of the small natural size of patches and their historical fragmentation.
- All sites have experienced some degree of human disturbance
- Differences among observers and different applications of the same methods by different observers reduce the reliability of data



- Some species are difficult to identify
- Exclosures (fenced off areas) are key tools in measuring change, but are almost non-existent
- Long-term monitoring has problems of staffing, funding, lost plots, missing data, and damage to sampling sites from repeated activity

7.3.2 What Sites Should be Monitored?

Although it may seem necessary to monitor all sites in a restoration area with equal effort, limited resources usually preclude this intensity of monitoring. In fact, such an even-handed approach wastes or misallocates resources because this level of monitoring is usually unnecessary. The challenge is to balance the availability of resources with a level of monitoring that reliably detects changes.

Gaboury and Wong (1999) suggest three levels of monitoring that can be used to help allocate monitoring effort:

- *Routine*: relatively low intensity that uses inexpensive and rapid, routine data collection, and relies more upon indices than direct measurements. Most sites would be monitored in this way.
- *Intensive*: requires special study design with more expensive and time-consuming collection and analysis of data. Only a few sites would be monitored in this way.
- *Operational techniques refinement*: focuses on machinery, techniques, or cost efficiency. As with the intensive level, only a few sites would be monitored in this way, and the focus would be on techniques rather than on the success of the restoration.

This approach of dividing sites into different levels of monitoring effort can be used also if more



Biologist Tracy Fleming conducts a vegetation survey at Somenos Garry Oak Protected Area. Use of standardized protocols reduces data variability from different observers. Photo: Dave Polster



than one restoration area is being monitored, e.g., all the Garry Oak restoration projects in a municipality. In this situation, perhaps all but one or two sites would receive routine monitoring, while the remaining representative sites would receive intensive scrutiny.

7.3.3 What Should be Measured?

A key step in monitoring is selecting what to measure. Most importantly, what is measured should relate to restoration objectives. For example, if an objective is to increase the cover of Deltoid Balsamroot (*Balsamorhiza deltoidea*) by 50%, then the monitoring protocol must include a technique for measuring its cover. On the other hand, if the goal is to increase the natural character and species diversity of site by removing invasive species, then a simple list of native plant species year to year might do the job.

Selecting what to measure also involves the following considerations:

- Attributes should be readily sensitive indicators of biological and physical changes that indicate whether or not restoration objectives are being met. Responsive measurables enable early detection of progress or failure and so enable prompt responses to problems. The indicator should not have a wide range of (year-to-year) variation, which would make detecting change difficult.
- Attributes should be scientifically based so that they withstand scrutiny of peers, funding agencies, and management agencies.
- Attributes should be easily measurable and unambiguously observable so that monitoring is reliable, yet kept within the bounds of time and money.
- At least several parameters should be chosen because relying on only one parameter may result in insufficient information being collected, or it may be difficult to understand.
- Attributes should include all major ecosystem components, i.e., soil, vegetation, animals, and water, as measuring only one component may overlook important changes in other components.

7.3.4 What Methods Should be Used?

Another key step in monitoring is selecting the methods that are appropriate to documenting the parameters used. Methods should be robust enough so that variation due to different observers (something that is almost inevitable!) is minimized or is measurable, so that correction factors can be used. The actual methods used will be determined largely by the level of inventory used. Thus, it is critical that the same methods used in inventory be used in monitoring so that data are comparable.

Three basic questions should be asked when selecting methods for monitoring:

1. Do the methods effectively provide accurate data on the parameters of interest?
2. Are the methods repeatable?
3. Are the methods feasible within time and cost constraints?

As noted above, all sampling methods used should follow accepted and documented protocols.



Chapter 7 Ecological Inventory and Monitoring

Table 7.4 Examples of qualitative and quantitative evaluation techniques used for Garry Oak ecosystems

Qualitative measures	Quantitative measures
Plan (vertical overhead) view map showing observation points and estimated vegetation coverage	Scaled vegetation map quantifying coverage areas
Vegetation (species list and qualitative abundance estimates)	Vegetation density, cover, number of individuals of a species and biomass
Fixed-point panoramic photographs	Elevation
Rainfall and water level data	Water quality and soil properties data
Wildlife use observations	Wildlife counts
Invertebrate species list and qualitative abundance estimates	Invertebrate density and distribution

Many agencies have well-developed monitoring standards (e.g., RISC). Examples and sources of monitoring standards are provided throughout this section as well as in the References Cited at the end of this chapter.

For reasons of economy and efficiency, sampling methods should be selected that allow data to be collected on more than one parameter. For example, a soil core sample can provide information on rhizome development, physical and chemical attributes, and invertebrate communities. As well, check for information collected by others, such as local universities and colleges, government agencies (local through to federal), consultants, environmental groups, and landowners. Many agencies and volunteer groups cooperate readily because they have common goals, but ensure permission is obtained before using information, and always acknowledge sources.

Selecting “the best” methods for monitoring is often overwhelming, even for seasoned restoration practitioners. Consider the following three points when selecting monitoring methods:

1. Let your objectives “drive” your selection of methods (and parameters).
2. Use several methods. Since all methods have shortcomings, using several will likely strengthen confidence in conclusions.
3. Decide if your methods should be qualitative or quantitative. Erwin (1990) suggested that quantitative methods should be used when there is uncertainty associated with the restoration technique or when success criteria are related to obtaining specific thresholds. Use qualitative evaluations in situations where success is more likely, and where performance is not tied to specific quantitative criteria. A combination of quantitative and qualitative methods can also be used effectively in the same monitoring program (Table 7.4).

Photographs taken frequently (at least annually) are one of the easiest ways to monitor changes over time, especially vegetation. Each photo in the series should be taken from exactly the same point (establish a permanent marker or a reference point such as a rock knoll) and should be precisely framed to encompass the same area taken on previous occasions. Including a vertical, brightly-painted pole of a known length within the frame allows viewers to estimate heights of





ground vegetation layers. It is important to take each photo at the same time each year so that the series shows long-term vegetation trends, not seasonal changes in foliage. Taking good notes about the photo sessions is essential. Photo-point monitoring is widely used to document changes (See Hall (2002), Case Study 1, and Appendix 7.1 for further information).

7.3.5 When, How Often, and for How Long Should Monitoring be Done?

Successful monitoring programs are designed before conducting baseline studies, so that methods remain constant over the various phases of the project and costs are minimized. Timing, frequency, and duration of monitoring are influenced by the ecosystem type and its complexity, the uncertainty of restoration methods used, and study objectives. Sometimes controversial projects require a higher degree of scrutiny which increases the level of monitoring effort needed. Seasonality must also be taken into consideration. For example, if a particular plant species is conspicuous only during spring flowering, sampling must be conducted at that time.

Successful monitoring programs also have a systematic timetable that includes a start date, the time of the year when field work will take place, the frequency of field work, and the end date for the program.

Monitoring of restoration and associated reference sites can be performed in two ways: 1) by concentrating all tasks during a single site visit, or 2) by carrying out one task or a similar set of tasks at several sites in a single day. The second strategy is preferable, because it minimizes seasonal effects and variability in conditions from day-to-day. Repeating the same task on the same day may save time. However, it is not always practical if sampling sites are far apart or difficult to access. Sampling of specific parameters in reference areas should be done at the same time of year as sampling in restored areas.

Frequency of sampling can vary within years as well as among years. In general, new ecosystems

Table 7.5 Monitoring plans for selected Garry Oak restoration projects

Study area	Monitoring frequency	Monitoring indicators	Sources and notes
Anniversary Island (polygon B)	Annually for four years	Changes in cover of native vascular plants	Parks Canada Western and Northern Service Centre (2008a)
Eagle Island	Twice annually (April, September) for four years		Parks Canada Western and Northern Service Centre (2008b)
Somenos Garry Oak Protected Area	Annually for both general vegetation and rare species	Rare species number of individuals and changes in vegetation	Roemer (2004)
Mill Hill Regional Park	Annually	Changes in the number of plant species and their abundance	Maslovat (2009)



change rapidly and should be monitored more often than older ones. This is especially true for ecosystems for which success is highly uncertain. By sampling more often, deviations from the expected stages of development may be corrected more easily than those allowed to progress further. As the system becomes established, it is generally less vulnerable to disturbances, and monitoring can be done less frequently.

Determining the duration of the monitoring program is a challenging issue. In general, monitoring should extend beyond the period of most rapid change and into the period of stabilization. Monitoring over this time period will enable the success (or failure) of the restoration plan to be assessed. New, constructed ecosystems that start with no vegetation take a longer time to develop than systems in which only minor adjustments of existing habitats are necessary.

Beyond the initial period of rapid development, sampling frequency can change from once or more per year to once every few years. The timing of this adjustment depends on the response of the ecosystem to restoration and the degree of impact restoration activities have on the site. Less frequent sampling (once every several years) is appropriate if the ecosystem response is considered appropriate and stabilizing, but more frequent sampling (every year or several times each year) is appropriate when ecosystems depart from expected pathways or significant changes continue to occur annually. Table 7.5 provides examples of monitoring plans.

Garry Oak ecosystems are the result of disturbance regimes, therefore monitoring must address changes resulting from either re-establishment of the disturbance regime or some surrogate, or provide corrections to account for the lack of historical disturbance regimes. Low-intensity fire is considered the dominant disturbance regime of Garry Oak ecosystems so where fire is not re-introduced, some means of accounting for the lack of fire needs to be incorporated with the monitoring program.

SOME FINAL POINTS TO REMEMBER:

- Make sure you have enough money or committed human resources
- Make sure the monitoring stage is explicit in the plan
- Include a compulsory monitoring report that includes evaluation and assessment and makes recommendations



7.4 References

- BC Ministry of Forests and Range and BC Ministry of Environment. 2010. Field manual for describing terrestrial ecosystems, 2nd ed. Land Management Handbook Number 25. Crown Publications, Victoria, B.C. www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh25-2.htm. (Accessed 2010).
- BC Ministry of Forests and Range. 2007. Vegetation resources inventory ground sampling procedures v 4.7. Crown Publications, Victoria, B.C. www.for.gov.bc.ca/hfd/library/documents/bib46612_2007.pdf. (Accessed 2010).
- Bertram, N. A. 2004. Ecology of the introduced European Wall Lizard, *Podarcis muralis*, near Victoria, British Columbia. M. Sc. Thesis, University of Victoria, Victoria, B.C.
- Blackwell, B.A. 2007. Parks Canada southern Gulf Islands terrestrial ecosystem mapping (in draft). B.A. Blackwell and Associates Ltd., North Vancouver, B.C.
- Brayshaw, T. C. 1996. Plant collecting for the amateur. Royal BC Museum, Victoria, B.C.
- Beckwith, B. R. 2002. Restoration management plan for the Garry Oak restoration project sites, plus site action plans for nine sites. Reports prepared for the Municipality of Saanich, B.C.
- Capital Regional District Parks, 2002. Mill Hill Regional Park restoration plan. Unpublished report, August 2002, Victoria, B.C.
- Capital Regional District Parks, 2003. Thetis Lake, Francis/King, and Mill Hill Regional Park draft management plan. Unpublished report, March 2003, Victoria, B.C.
- Carere, D., K. Harding, E. Rafuse, and R. Underhill. 2010. 2010 annual report for restoration at Fort Rodd Hill National Historic Site. Parks Canada Agency, Government of Canada, Victoria, B.C.
- Caughley, G. 1977. Analysis of vertebrate populations. Wiley, New York.
- Coastal Services Center, National Atmospheric and Oceanic Administration. www.csc.noaa.gov/coastal/management/management.htm. (Accessed March 12, 2011).
- Costanzo, B. 2010. Personal Communication. Senior Vegetation Specialist, Ecosystems Branch, BC Ministry of Environment, Victoria, B.C.
- Day, J.H., L. Farstad, and D. G. Laird. 1959. Soil survey of southeast Vancouver Island and Gulf Islands, British Columbia. B.C. Soil Survey, Rept. No. 6, Can. Dept. Agric.
- Delesalle, B.P., B.J. Coupe, B.M. Wikeem, S.J. Wikeem. 2009. Grasslands monitoring manual for British Columbia: a tool for ranchers. Grasslands Conservation Council of British Columbia.
- Demarchi D.A. 1995. Ecoregions of British Columbia, 4th ed. British Columbia Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria BC. Map (1:2,000,000).
- Douglas G.W., J. Penny, and R. E. Maxwell. 2002. Composition, phenology, stand structure and soils of a *Quercus garryana* (Garry Oak) woodland at Quamichan Lake, Vancouver Island, British Columbia. British Columbia Conservation Data Centre. Ministry of Sustainable Resource Management. Victoria, B.C.
- Duncan, N., Burke, T., Dowland, S., and P. Hohenlohe. 2003. Survey protocol for survey and manage terrestrial mollusk species from the Northwest Forest Plan. Version 3.0. Bureau of Land Management, U.S. Department of Interior and U.S. Forest Service.



Chapter 7 Ecological Inventory and Monitoring

- Dunn, J. L., and J. Alderfer, (editors). 2006. Field guide to the birds of North America. National Geographic Society, Washington, D.C.
- Erickson, W.R., and D.V. Meidinger. 2007. Garry Oak (*Quercus garryana*) plant communities in British Columbia: a guide to identification. BC Ministry of Forests and Range, Research Branch. Victoria, B.C. Technical Report 040.
- Forsyth, R. G. 2004. Land snails of British Columbia. Royal British Columbia Museum. Victoria, B.C.
- Gayton, D. V. 2003. British Columbia grasslands: monitoring vegetation change. FORREX-Forest Research Extension Partnership, Kamloops, B.C., Canada. FORREX Series 7.
- Gaboury, M. and R. Wong. 1999. A framework for conducting effectiveness evaluations of watershed restoration projects. Watershed Restoration Technical Circular 12. B. C. Ministry of Environment, Lands and Parks, and Ministry of Forests, Victoria, B.C.
- Giasson, M. and R. E. Maxwell. 2002. Soil mapping for the Garry Oak restoration project. Report prepared for the Municipality of Saanich, Saanich, B.C.
- Green, R.N. and K. Klinka. 1994. A field guide for site identification and interpretation for the Vancouver Forest Region. B.C. Ministry of Forests Land Management Handbook No. 28, Victoria, B.C. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh28.htm. (Accessed 2010).
- Groos, W. E. 1995. Winter bird assemblages in urban fragments of Garry Oak (*Quercus garryana*) ecosystems. B.Sc. Honours thesis, Department of Biology, University of Victoria, Victoria, B.C.
- Hall, F. C. 2002. Photo point monitoring handbook. Forest Service, US Dept. Agriculture. www.treesearch.fs.fed.us/pubs/3255. (Accessed 2010).
- Harcombe, A. 2009. Personal Communication. Terrestrial Ecologist, Nature Conservancy of Canada, B.C. Region.
- Hebda, R.J. 2010. Course Guide and Course Manual ER 311. Principles and concepts of ecological restoration. Division of Continuing Studies, University of Victoria, Victoria, B.C.
- Hobbs, R. J., E. Higgs and J.A. Harris. 2009. Novel ecosystems: implications for conservation and restoration. *Trends in Ecol. and Evol.* 24(11):599–605.
- Hobbs, R.J., S. Arico, J. Aronson, J.S. Baron, P. Bridgewater, V.A. Cramer, P.R. Epstein, J.J. Ewel, C. A. Klink, A.E. Lugo, D. Norton, D. Ojima, D.M. Richardson, E. W. Sanderson, F. Valladares, M. Vila, R. Zamora and M. Zobel. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecol. Biogeogr.* 15:1–7.
- Johnson, B. L. 1999. The role of adaptive management as an operational approach for resource management agencies. *Conservation Ecology* 3(2):8. www.consecol.org/vol3/iss2/art8. (Accessed 2010).
- Jungen, J.R. 1985. Soils of southern Vancouver Island. Victoria: Ministry of Environment Technical Report 17, Victoria, B.C.
- Krebs, C.J. 1999. Ecological methodology, 2nd ed. Addison-Wesley Educational Publishers, Inc. University of California Press
- LeBuhn, G. 2010. The great sunflower project. *Wings* 33(1): 25–28.



- LTABC The Land Trust Alliance of BC. 2006. LTABC guide to baseline inventories. http://landtrustalliance.bc.ca/docs/LTABC_Guide_to_Baseline_Inventories_2006.pdf (Accessed 2010).
- Luttmerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger and T. Vold. 1990. Describing ecosystems in the field, 2nd ed. MOE Manual 11. Ministry of Environment. Victoria, B.C.
- Maslovat, C. 2008. Analysis of old and new permanent vegetation monitoring (PVM) plots, Mill Hill Regional Park. Unpublished report prepared for Capital Regional District Parks, Victoria, B.C., October 2008.
- Maslovat, C. 2010. Personal Communication. Biologist, Salt Spring Island, B.C.
- Meidinger, D. and J. Pojar (eds.), 1991. Ecosystems of British Columbia. B.C. Ministry of Forests, Special Report Series 6. Victoria, B.C.
- Mercer, G. 2006. Deer pellet count monitoring protocol, Gulf Islands National Park Reserve. Unpublished report prepared for Parks Canada Agency, Government of Canada, Sidney, B.C.
- Murphy, D. D. 1988. Are we studying our endangered butterflies to death? *The Journal of Research on the Lepidoptera* 26:236–239.
- Muller, J.E. 1980. Geology Victoria Map 1553A. Ottawa: Geological Survey of Canada.
- Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, Toronto.
- Oosting, H. J. 1956. The study of plant communities: an introduction to plant ecology, 2nd ed. W. H. Freeman, San Francisco, California.
- Ovaska, K. and L. Sopuck. 2010. Surveys for the blue-grey tailed dropper and other gastropods at risk with focus on Capital Regional District Parks. Fall 2010. Prepared for Habitat Acquisition Trust, Victoria, B.C.
- Parks Canada Western and Northern Service Centre. 2008a. Restoration plan for Anniversary Island in Gulf Islands National Park Reserve. Prepared for Parks Canada Agency, Government of Canada.
- Parks Canada Western and Northern Service Centre. 2008b. Restoration plan for Eagle Island in Gulf Islands National Park Reserve. Prepared for Parks Canada Agency, Government of Canada.
- Pollard, E. 1977. A method for assessing changes in the abundance of butterflies. *Biological Conservation* 12:115–134.
- Polster, D. 2009, 2010. Personal Communication. Restoration ecologist, Duncan, B.C.
- Resources Inventory Committee (RIC). 1998. Standard for terrestrial ecosystem mapping in British Columbia. B.C. Ministry of Environment, Resources Inventory Committee, Victoria, B.C.
- Roemer, H. 2003. Baseline description of permanent vegetation monitoring plots at Mill Hill Regional Park. Unpublished report prepared for Capital Regional District Parks. September 2003. Victoria, B.C.
- Roemer, H. 2004. The 2004 survey of red and blue listed plants of the Somenos Garry Oak Protected Area. Report prepared for the Garry Oak Ecosystems Recovery Team. Victoria, B.C.



Chapter 7 Ecological Inventory and Monitoring

- Roemer, H. 2006. 2006 analysis of permanent vegetation monitoring plots, Mill Hill Regional Park. Unpublished report prepared for Capital Regional District Parks. October 2006. Victoria, B.C.
- Steinfeld, D. E., Riley, S. A., Wilkinson, K. M., Landis, T. D., and L. E. Riley. 2007. Roadside vegetation: an integrated approach to establishing native plants. Technology Deployment Program, Western Federal Lands Highway Division, Federal Highway Administration, Vancouver, Washington, USA.
- Thien, S. 1979. A flow diagram for teaching texture-by-feel analysis. *Journal of Agronomic Education* 8:54-55.
- Vesely, D., and G. Tucker. 2004. A landowner's guide for restoring and managing Oregon White Oak habitats. United States Bureau of Land Management, Salem District, Oregon. www.blm.gov/or/districts/salem/files/white_oak_guide.pdf (Accessed March 30, 2010).
- Water, Land and Air Protection. 2003. Garry Oak ecosystem mapping for the Somenos Garry Oak Park. Mapsheets 092B.083, 092B.073. March 2003. Ministry of Water, Land and Air Protection, Environmental Stewardship, Vancouver Island Region.
- Zar, J. H. 2009. *Biostatistical analysis*, 5th ed. Prentice Hall, Upper Saddle River, New Jersey, USA.



Appendix 7.1

Photo-point Monitoring Protocols and Analysis Methods Used in Restoration Monitoring at Fort Rodd Hill National Historic Site

The following protocols have been adapted from the 2010 annual report for restoration at Fort Rodd Hill National Historic Site (Carere et al. 2010).

Camera Calibration and Photo Monitoring Instructions

CAMERA INFORMATION

CAMERA: CANON 30D

LENS = 24 MM FIXED LENS

ISO = HOW SENSITIVE THE SENSOR IS TO LIGHT (RANGE OF 100–1600)

Generally we want a low ISO (range of 200–800)

APERTURE = THE SIZE OF THE HOLE LETTING LIGHT THROUGH

A higher aperture # = *smaller* aperture (hole size)

The higher aperture # the more the image is in focus

Generally, below 3 is not good (hole too wide)

SHUTTER SPEED: 60 (1/60TH OF A SECOND) IS STANDARD

A faster shutter speed will be needed to take a sharp photo on windy days.

A lower shutter speed should be avoided, but may be necessary when under dense canopy

AUTO EXPOSURE BRACKET (AEB):

Used to capture the image with 3 exposure levels to minimize the loss of data or need to retake photos due to overexposed or under exposed shots

CAMERA SETTINGS

- Focus set to 10 metres (done by rotating the lens)
- Mode is on “P” for program
- Set bracketing to automatically take 3 different exposures
- Menu button: select AEB (auto exposure bracket), adjust until 3 exposures (-1, 0, +1) are underlined, push enter and exit Menu (this needs to be redone every time the camera is turned off).
- Take images as RAW + Large JPG files (RAW files are used for high quality editing/analysis though large JPG files have been typically used for photo analysis)

SETTING UP THE TRIPOD AND LINING UP THE PHOTOGRAPH

- Centre the tripod according to the description and/or marker in photo-point binder



- Measure the appropriate lens height and level the tripod. New photo points should be set up with the lens at a standard 1 m height, but older photo points had a variable height which must be used for consistency.
- Check that all views can be lined up from the tripod position before pictures are taken. If photos are not lining up check that tripod is located accurately.
- Measure 10 m from tripod centre to scale pole, place the pole according to previous photos and ensuring that the pole is not leaning: this is important for analysis of the photos
- Make sure the scale pole's tripod does not obscure the camera's view of the coloured 25 cm increments (i.e., make sure you can see the edges of all the red paint marks)
- Align the left side and top of view through camera with previous photos (the focus length is slightly different with the new camera so the entire photo won't line up properly)
- Record the date, site, and view on chalkboard and place in lower left hand corner of photo. Date format: year-month-day (e.g., 2007-04-30)
- Take three photos (one at each exposure) for each view

UPLOADING AND ARCHIVING PHOTOS

Uploading and archiving of the photos should be done soon after photo-monitoring is complete in case any sites are missed or need to be redone.

PHOTO-POINT ANALYSIS DIRECTIONS USING THE PHOTO EDITOR GIMP 2.6.1

The basic idea is that a photo-point picture is opened with GNU Image Manipulation Program (GIMP) and a grid overlaid on the photo. Next grid intercepts which overlap a species of interest are marked with coloured dots and dots are automatically counted using the GIMP's built in tools. This method provides a relatively quick and easy relative abundance measure, and avoids laborious manual counting. What follows is a detailed account of how to implement this method using the free GIMP software. The analysis is based on Scotch Broom and *Camassia* spp. but can be adapted to any species which is readily identifiable at a distance in a photograph.

First you need the GIMP. It is available for a variety of operating systems including Microsoft Windows, Linux, and Mac OS X. Source code and binaries for the latest version can be found at www.gimp.org; however, most people will probably want the ready to install windows version which can be found here www.gimp.org/windows. Once you have the GIMP installed you can follow the directions below to analyze monitoring photos. Note that these instructions are based on a particular version of the software and while the process should be similar for newer versions, specific steps may be different. It should also be noted that these directions are base on a windows operating system. There is lots of help for the GIMP on-line, so if you need additional help, check your favorite search engine.

Below are step-by-step guidelines for effectively preparing and analyzing the photo-point pictures: for analysis you will be using only spring photos because these show the flowering *Camassia* spp. and Scotch Broom. You can use late-summer photos to help you determine what is or isn't broom, but note that late-summer photos have been taken after most of the plants have been removed, so they do not always show where the plants were. Next, decide which of the three exposures best shows the blooming broom and camas. Some photos may be too bright, blurry or washed out, so find the photo that will be easiest to analyze. Make note of the photo number, e.g., IMG_1334. In the following step you will need to know the image resolution. In Windows XP (and possibly later



versions) you should be able to obtain this information by viewing the image properties from Windows Explorer or My Computer (right click on the image file, select Properties, and click the Summary tab). Make note of the photo width and height in pixels (e.g., a pixel dimension of 2048 x 1536). Alternatively this information can be obtained from most image editing software: the GIMP displays the pixel dimensions (along with other information) in the title bar of each image's window.

- **Starting GIMP:** When the GIMP is running, three windows will pop up: a GNU Image Manipulation screen and a Toolbox and Layers screen. In The GIMP dialogue box “*GNU Image Manipulation Program*”, click *File–New*. A box will pop up in which you must check the pixel width and height of the photo you chose. If GIMP shows different values, change them to what the initial photo values are. Press *Enter*. A blank working space, “*Untitled–1.0 (RGB, 1 layer) 3504 x 2336 – GIMP*” will pop up in the main dialogue area.
- **Opening a File as a Layer:** When you open a file as a layer a new box will pop up in which you will search the drive for the file you chose in step 1. Once you find that file, double click on it or click *Open* and it will show in the *Untitled–1.0 box*. Note that at the bottom of the screen you can set the photo to various pixel magnifications. Manipulating screen size will make it easier for you to find the broom and camas
- **Saving:** In the *Untitled project dialogue box*, click *File–Save As*. Re-name the file in this format: *2011 10–1–1* (this is the year followed by the image identification number). Use the drop down menus to select for file type *.xcf* and save the file. Saving the file to *.xcf* format means that all the working layers are saved. Essentially all your work will be saved in this format.
- **Editing Brightness:** Once the photo is open you can now play with the light levels to get the photo at the right lighting. GIMP has many tools that allow you to do this. The *Levels* tool is commonly used and is located in the *Colours* menu at the top of the screen. You'll see a bell curve that has three little black triangles at the base that you manipulate. Move the far left triangle so that it is directly under the base where the bell curve hits the horizontal. The other triangles can also be manipulated. The only other tool normally used is the *Sharpen* tool, which is located under *Filters / Enhance / Sharpen*. Remember, if you want to edit the photo in any way you must first highlight that layer in the layers dialogue box. This is described below.
- **The Layers, Channels, Paths Window:** When creating a new *.xcf* file or opening an existing file a window should be displayed that is titled “Layers, Channels, Paths, Undo”. From this window one can select between multiple layers and create new layers. In an existing *.xcf* file the layers that will appear will most likely be a photo layer (of the photo to be analyzed), a white background layer, an outline layer (on which the dots are placed), and several text layers that provide pertinent information.

Layers can be renamed by double-clicking on the name (the name is to the right of the ‘eye’ icon). Typically photos are named to correspond to their year and season e.g., “2010 Spring.” If you cannot find the layers dialogue box, use the shortcut *Ctrl–L* and it will appear. The layers can be arranged so that you can see the photograph with the grid with colour dots overlaid.



The layers will be saved in the end so that you can always go back and re-work a photo without losing information.

- **Adding New Layers:** At the bottom of the *Layers* dialogue box you will see a series of icons. Click on the first one (looks like a tiny piece of paper) at the bottom left-hand corner—it will allow you to add a new layer to your project. In order to create a new “*Outline*” layer name the new layer “*Outline*” and set it to “*Transparency*”. Click OK. Make sure the *Outline* layer is always above the photo layer in the dialogue box. You can drag layers to whatever location within this box. Similarly, to create a background layer create a new layer title ‘*Background*’ and set it to *white*. You can toggle between layers; whichever layer is highlighted is the one that your edits will be on. You can turn layers on or off by clicking the eye icon to the left of each layer. Make sure that all edits are made on the *Outline* layer. If, by accident, you paint on the photo layer itself and then find that you made a mistake and must erase your work, you may run into problems. Either you will end up erasing a part of the photo or you will be clicking the back button to undo your work.
- **Setting the Grid:** With the photo layer turned on, go to the bottom of the screen and increase the magnification of the photo to 200%. Navigate to the height pole in the photo and go to where you can clearly see a red increment—you are going to measure this increment in pixels (NB in this project the scale pole is 200 cm long and painted in alternating 25 cm increments). Go to the *Toolbox* and click the *Measure* tool. Move the tool over the base of where a red increment begins. Click, hold and drag the measure tool up to where the cross hairs meet the top of the red increment. You can sway the measure line with your mouse while looking at the base of the photo and watching when the degrees reach 90°. Depress the mouse when at 90°. The number to the left of the degrees is the number of pixels in one scale pole increment, e.g., 97.0 pixels. When setting the grid aim to have **two grid squares** per red increment. Divide the pixel number by 2. In this case the value becomes 48.5 or 48 pixels. Now click on *Image/Configure Grid*. Under *Spacing Width*, type in 48. Click in the *Height* area and it will automatically change to reflect the width. Click ‘OK’. Go to *View/Show Grid* and turn that on. While you are there also turn on the *Snap to Grid*. The latter causes all pencil dots to snap directly to grid intercepts. The photo should now be covered with a calibrated fine grid overlay. You can turn the grid on and off from the main menu when needed. Reset the photo magnification to 100% or to whichever magnification allows you to determine where the Scotch Broom or *Camassia* spp. are located.
- **Tracing the Scale Pole:** Trace the height pole as a reference in the final map. To do this, make sure that the *Outline* layer is turned on. You might want to magnify the photo first. Use the pencil tool at brush size 01 set to black and with *Fade Out* turned off in order to outline the height pole and its increments. Do not trace the tripod. To make a straight line, first click at the top of the pole and release the mouse button; remember to turn off the *Snap to Grid* setting to ensure smooth tracing. Click and hold the Shift key while moving the mouse to the base of the pole. Click the mouse and let go of the shift button. You may need to move the line back and forth somewhat in order to get a straight line before you make the final click. Repeat this procedure to complete the pole and its increments. Use the *Bucket Fill Tool* set at red to fill in the increments.

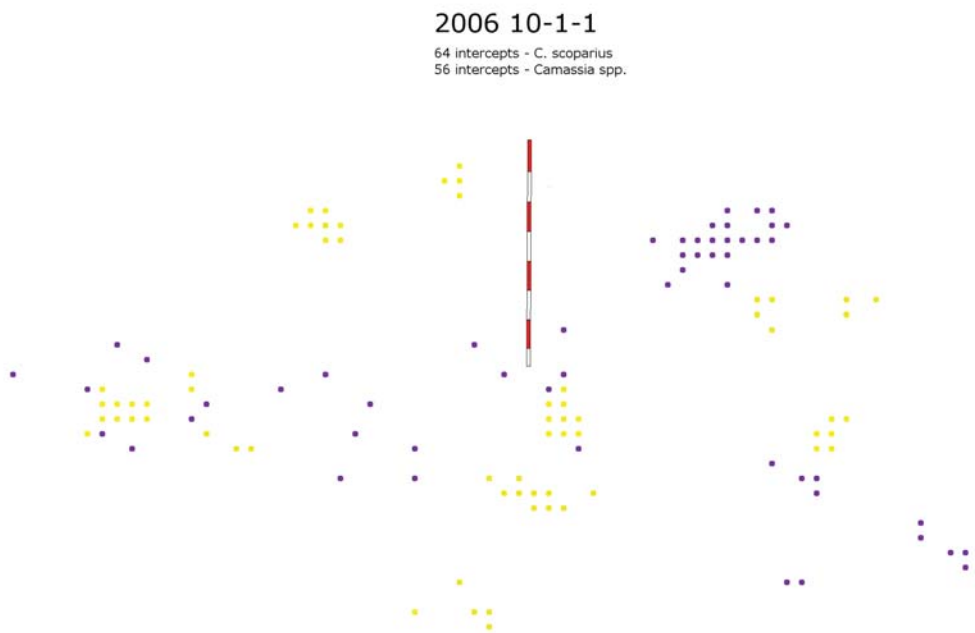


Figure A7.1. Example of final analysis map. Purple dots indicate grid intercepts with *Camassia* spp., and yellow dots indicate grid intercepts with Scotch Broom (*Cytisus scoparius*).

- **Selecting and Calibrating the Pencil Tool for Dots:** Go to Tools and click on the *Pencil Tool*. You will see two colour boxes. Change the top box to the appropriate colour: yellow for Scotch Broom and purple for *Camassia* spp. Once you have set the colour, it is available to you in the colour chart throughout the session. Under *Pencil Opacity*, leave the value at 100.0. You will have to experiment to find a suitable brush size for your photos. Brush sizes used for analyzing the Fort Rodd Hill photos are as follows: when analyzing photos from 2003 to 2006, use **brush size 11 (pixel size 109)**. When analyzing photos from 2007 onward, use **brush size 17 (pixel size 241)**. Click on *Fade Out*. Turn on the *Outline* layer. It is very important for the next steps that all your coloured dots are the same size.
- **Adding Coloured Dots:** Make sure the grid is turned on and the *Snap to Grid* option is selected. Search the photo for any instance where a grid intercept is crossed by Scotch Broom or *Camassia* spp. Make sure the *Pencil Tool* is turned on and calibrated and that the *Outline* layer is activated. Create a dot on the intercept to mark where the plant crosses; flowers, stalks, and leaves can be counted when they cross an intercept. Make sure the dot snaps to the intercept (grid crossing). Remember, sometimes you have to increase the magnification or play with the lighting in order to more clearly see where the plants are located. Scotch Broom tends to have a characteristic shape and green shade and is typically distinguishable from other plants.

TIP: Load the different exposures of the same photo-point photograph as layers. In some cases you might find it useful to add a photo from another season as a layer for reference.



- **Counting Pixels:** Once you have placed all the yellow and purple dots at corresponding intercepts, they can be counted. The program uses a histogram function that counts pixel colours. This saves you eye strain and time. The *Pencil Tool* makes it so that the dot you are using has a solid outline. This means that only pure yellow and purple dots are counted. Make sure you know the number of pixels within one dot of your chosen brush size. To do this you can use the *Fuzzy Select Tool*. Under the attributes of this tool change the *Threshold* to 0. Select one of the colour dots; the dot will be outlined. Go to the main menu and click on *Windows/Dockable Dialogue/Histogram*. To unselect dots go to the main menu *Select/None*. For example: Brush Size 11 (2003–2006) = 109 Pixels Brush Size 17 (2007–present) = 241 Pixels. If you already have all the dots placed and you know the pixel number per dot, then use the *Select by Colour Tool* located in the toolbox. Under the attributes make sure that the threshold is set to zero. Click one dot on the photo and all the dots of that colour will be highlighted. Go to *Dockable Dialogue/Histogram* again and note the number of pixels e.g. 3615 for a size 17 brush (241 pixels). Divide the total number of pixels by 241 and the final value is your relative abundance count for Scotch Broom or *Camassia* spp. for that photo. In this case, the count is 15. You can record these relative abundance counts in your spreadsheet and perform further analysis.
- **Final Touches:** You should now have an outline layer that shows all the Scotch Broom or *Camassia* spp. intercepts and the traced height pole with red increments. Create new text layers that specify the photo title (ex. 2011 10-1-4) as well as the intercept count number for Scotch Broom or *Camassia* spp. Make the 'photo' layer invisible. Make sure all text and number layers, as well as the outline layer, are turned on before you save this file. All layers will be saved in the program layer dialogue box so that you can go back and re-analyze later if needed. Save the file as a .xcf file in this format: 2011 10-1-4. You can also save it as an exported jpg. Figure A7.1 shows an example of what the final map should look like. Make sure all final maps are well organized in the file directory.

A COMMON SOURCE OF ERROR: FOREGROUND VS BACKGROUND PLANT COUNTS

One obvious issue is that plants in the foreground of the picture will increase the intercept counts more so than those in the background, even if those in the background may be larger and/or more abundant. Due to the fact that we are analyzing a three dimensional representation as if it had only two dimensions issues will arise as varying depths of field and natural obstructions hinder the ability to accurately state the relative abundance of these plants. This is the primary downfall of this technique; however, when comparing individual photo-point views over multiple years this issue appears to be less influential as the obstructions in the individual views generally remain constant.

References

- LTABC The Land Trust Alliance of BC. 2006. LTABC guide to baseline inventories.
http://landtrustalliance.bc.ca/docs/LTABC_Guide_to_Baseline_Inventories_2006.pdf
(Accessed 2010).