Chapter 9: Inventory and monitoring

9.1 Introduction

Inventory and monitoring are essential steps in the restoration process. The purpose of this section is to provide information and guidance for inventorying and monitoring restoration projects in Garry oak ecosystems. It presents key principles and concepts for these two activities, to provide a sound framework. As well, it describes the typical steps in conducting inventory and monitoring and describes methods that are commonly used in the inventory and monitoring of Garry oak ecosystems.

Inventory can be defined as the process of collecting information to describe the state of an ecosystem or ecosystem parameters at a particular point in time. Inventory is needed to assess the current status of a site (does it merit restoration?), to identify what species are present and their abundance. Also, inventory helps in identifying problems requiring attention, e.g., invasive species, that can then be assessed for possible prescriptions. Inventory is also the essential first step in the monitoring chain as inventory data provides the baseline against which future data collection can be tested: without a baseline, change cannot be measured. Finally, inventory is essential to characterize reference ecosystems, which are critical components for setting restoration targets. Reference sites also help enable assessments of progress in the ecosystems being restored, independently of the treated sites.

Monitoring can be defined as repeated measurements to detect changes in a parameter or system over a time interval. Monitoring is the "Achilles heel" of restoration. Too often, considerable time, money, resources and excitement are directed at the initial stages of a restoration project, only to disappear once the initial work is done. This scenario plays out time and again, not only in Garry Oak restoration projects, but in restoration projects generally. It is an unfortunate situation because it is short-sighted. Without monitoring, how can success be judged? Without monitoring how can emerging problems be detected? Without monitoring, how can adaptive management proceed?

Adaptive management is a key principle endorsed by GOERT. For this report, adaptive management is defined as the formal process for continually improving management practices by learning from the outcomes of operational and experimental approaches (Bunnell 2007) (Nyberg 200?)(see MOFR website for other definitions)(See Section 5). Both inventory and monitoring are essential components of adaptive management because it requires an assessment of the current state (inventory) and the measurement of change (monitoring) to assess the success or failure of restoration, and to design and implement appropriate interventions to rectify problems. Without information on either the baseline state or the changed state, adaptive management cannot be implemented. As expressed by Davis and Ogden (1994), long-term restoration must be an ongoing process whereby restoration implementation becomes a continuing series of management decisions. Each decision should be based upon a growing pool of research information, updated measurements of ecosystem responses, and evaluations of degrees of progress in reaching a set of goals or targets that have been identified as indicative of ecosystem recovery.

Successful application of adaptive management strategies calls for significant planning and assessment before any restoration begins. To allow measurement of the progress made toward the restoration goals, it is important to evaluate all the characteristics that are to be improved, as well as the initial biological, physical, and chemical components of the project site before any change takes place.

After goals and objectives are set, a matrix can be created to delineate the expected progression of the restoration project over time, and to predict other alternative states that the restored system could potentially exhibit. This can help a project manager in various ways. For example, when monitoring results indicate that the restoration does not match the expected progression, the matrix may provide an explanation for the situation. The manager can then make a decision to delay action if it is anticipated that the progress will be self-correcting, or alternatively, the manager might find support for recommending or taking action. This process of planning, acting, monitoring, evaluating, and adjusting is the essence of adaptive management. The key to adaptive management is recognizing that there will always be uncertainties about the interdependencies within and among natural and social systems. Instead of relying on a fixed goal for restoration and an inflexible plan for achieving the goal, adaptive management allows for midcourse corrections. Restoration project managers should be encouraged to practice preplanning and to cultivate advanced awareness of potential problems and their solutions; as a result, stakeholders can be asked in a timely manner to set aside funds for responding to project setbacks, thereby maintaining the restoration schedule.

Restoring ecosystems is a complex undertaking. By documenting a project from start to finish, we are able to learn from our mistakes as well as from our successes. Adaptive management principles directly address this type of situation and are applicable across the entire spectrum of Garry oak habitats that could be considered for restoration, including vernal pools, shallow soil, rocky systems and deep soil sites (See Section 5). For others to learn from a restoration project's success or failure, the knowledge gained through monitoring must be shared and translated into improved methods

- protocols
- the need to consider intensive and extensive sites for extrapolation
- the importance of setting clear objectives
- the concept of graded levels of effort (driven by objectives)
- ecological scope varies among projects and can be very narrow or very broad (vascular plants, non-vascular plants, vertebrates, invertebrates, soil, hydrology, landform and surficial geology)
- range of techniques is very broad and diverse for each component. The important challenge to deciding and selecting appropriate methods suitable to the project.
- Acknowledgements

9.1.2. Terms and definitions

- Parameter
- Variable

- Quantitative
- Qualitative
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9.2. Setting objectives in an adaptive management framework

- the importance of setting objectives: often overlooked or under-appreciated…until late in the process (causes of disagreements, lost opportunities, additional expenditure of time or money or both, overlooking important data, etc.
- Setting specific goals and measurable objectives for the restoration project is critical. It is more difficult to evaluate the success of a project when its goal is stated broadly, such as "to restore the native plant community," than it is to do so when the goal is clearly defined, such as "to decrease distribution and abundance of snowberry by burning. When objectives are defined before a project begins, it simplifies the development of a monitoring plan that will be able to measure progress directly.
- what characterizes good objectives? Several avenues, but SMART objectives is a common ways.
- What are SMART objectives?
  - S: Specific
  - M: measurable
  - A:
  - R: realistic
  - T: time-bounded

Setting specific goals and measurable objectives for the restoration project is critical. It is more difficult to evaluate the success of a project when its goal is stated broadly, such as "to restore the native plant community," than it is to do so when the goal is clearly defined, such as "to decrease distribution of /Phragmites australis /by restoring tidal hydrology, thereby increasing *porewater salinity * and reducing standing freshwater ponds." When the objectives are defined before the project begins, it simplifies the development of a monitoring plan that will be able to measure progress directly.

AM is a formal process for continually improving management practices by learning from the outcomes of operational and experimental approaches. Bunnell (2007)

9.3. Determining what is present (inventory)

9.3.1. Design considerations

One important design consideration for inventory is the need to describe reference sites. In planning restoration projects, the usual objective is to restore an ecosystem so that it resembles what historically was found on the site (but see Section on novel ecosystems). Usually, a site is so degraded (or else it would not be a candidate for restoration) that it no longer resembles its historical antecedent. A variety of approaches are used to determine what the target ecosystems should look, but the standard one is locating one or more reference sites that are ecologically comparable but not degraded (This is much easier said than done since essentially all Garry oak ecosystems are degraded, at least to some extent).

A second important design consideration is the need for controls. Since any restoration is an experiment, it is important when describing ecosystems to identify an area that can be set aside as a control, that is, and area that is similar as possible to the area being treated, but which is not treated. This type of design enables the effects of the treatment to be disentangled from the effects due to other factors, such as a drier than average spring or unexpectedly late frost.

A third design consideration is the need for replication. Although replication is not required in all inventories, it is recommended because it strengthens the confidence in interpreting results. When only one plot or site is inventoried, it is never clear just how well that plot represents the entire site. Typically in Garry oak ecosystems, sites are quite variable, going from rocky to vernal pools to areas of deep soil over a short distance. This is a sampling nightmare because it is difficult to design one sampling system that is equally suitable to all component ecosystem, but replication at least will characterize that variability. The desirable number of replicates can be calculated by statistical formulae that consider the desired degree of confidence in the results and the range of detectable differences. As a general rule, more is better, but fifteen is often a good number to aim for. One caution is to avoid what s termed pseudo-replication. Pseudo-replication occurs when…

The fourth consideration is distribution of sample plots. Three choices are open to the restorationist: systematic, random and representative. All three designs have been used in Garry oak restoration, notwithstanding important difference among them with respect to the scientific validity of results. From a strictly statistical point of view, an element of randomness should be incorporated into a sampling design: all potential plots should have an equal chance of being selected for measurement. This can be achieved in a variety of ways, but it is necessary to ensure that randomness is introduced appropriately. Systematic sampling is not random sampling as not all plots have equal chances of being selected. A common way of distributing sample plots is by using a table of random numbers to select cells shown on an overlay map of the site. In systematic sampling, plots are distributed over a site according to a regular spacing rule, e.g., every tenth meter on a set of transects spaced evenly 25metres apart. Finally, representative sampling means that the observers select site(s) that they think fairly represents a site. This is a subjective assessment, but one that is commonly used in British Columbia for characterizing forest vegetation (DEEF), and it is also used for reconnaissance surveys or where only general impressions are needed.

It is important to bear in mind that whatever the sampling systems being employed, however many replications are sampled, and whatever reference sites are chosen, the same inventory methods must be used during the life of a project, or else comparisons among plots and sites will be impossible.

9.3.2. Methodologies for measuring ecosystem components

Except possibly for the most of basic surveys and the small homogeneous sites, most inventories have two major parts: classification and description. Classification involves stratifying the restoration site into its component ecosystems. Description involves recording the make-up of each ecosystems (at least the most significant ones!), e.g., by listing all vascular plants. Defining the ecosystematic make-up of a site is often straightforward because the systems are obvious even to the "untrained" eye. The difference between a shallow soil system and a deep soil system is readily apparent. The restoration units defined by Ted Lea in Section 2 serve as practical units into which most Garry oak sites can be classified. Of course, even these ERU's can be subdivided into smaller, more homogeneous units. Sometimes this finer breakdown is important, such as defining small vernal pools containing species-at-risk, but for most purposes the units described by Lea in Section 2 will suffice.

The appropriate level of classification and the scope and depth of description depend importantly on objectives, which in turn, depends on the restoration problem, the rigor intended for assessing success, and desired future condition of a site.

As noted earlier, many methods exist for the inventory of ecosystems, and their selection can be challenging. The following considerations will provide some assistance (narrow the choices) in selecting methods. First, it is critical to ensure that the selected methods relate clearly to the objectives. In other words, the data collected by the chosen methods must address the intent of an objective. For example, if an objective was to decrease the cover of exotic grasses, then a technique that measures plant cover of grasses must be used.

Second, it is important to use recognized methodologies, e.g., RISC standards, EMAN protocols or Smithsonian biodiversity plots, to enable comparisons of data among restorationists and augment data bases for meta-data studies.

Although many ways of sampling vegetation and other components of ecosystems are available, the following approach is suggested as suitable, straightforward and one that lends itself to progressive effort based on objectives. Inventory can be viewed as a series of four levels of increasing scope and detail:

- Level I: basic description; minimal effort (photographs/photo-point monitoring)
- Level II: lists of plant and animals (presence)(reconnaissance-level)(whole area surveys, plot-based surveys)
- Level III: quantifying abundance and distribution (plot-based)
- Level IV: detailed study (productivity, precision and accuracy criteria, experimental design, plot-based, comprehensive coverage of all ecosystem components)

Table 9.1. Comparisons of four different levels of inventory according to cost and effort, information collection system, rigor, reliability and utility and ecosystematic scope.

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	Minimal	Whole area; no replication	Subjective; low rigor applies only to site; reconnaissance level	Most components covered but not in depth; overall picture recorded; qualitative

II	Modest	Representative sampling; some plot-based sampling; little or no replication	Subjective or without estimate of error, improved reliability	Vascular plants; conspicuous animals, mostly vertebrates; little to no attention to soils and hydrology; quantitative
III	Moderate	Systematic or random; plot-based with replication	Improved reliability and utility; results publishable in grey literature	Vascular and non-vascular plants; vertebrates and many invertebrates; increased attention to soils and hydrology; quantitative; basic statistical analyses
IV	Most	Plot-based, random design, replication; precision and accuracy criteria explicit	Rigorous and reliable; publishable in peer-reviewed journals; wide utility; research quality	At least some components in detail (soils, plans animals, water); very quantitative; sophisticated statistical analyses

To characterize a site, the following parameters are typically measured, as adopted from Describing Ecosystems in the field (????): elevation or elevational range; slope; topography at micro, meso and macro scales;

For vegetation inventory, the most commonly used methods are as follows. To measure understory (mostly vascular plants), a plot technique is typically used. The two main plot sizes are 1 m squares and 20- x 50-cm quadrats. The most commonly used method in the province for measuring grassland is the 20 x 50 Daubenmire frame (Gayton 2003). In both plot-based methods, cover is usually in cover classes, as estimated by eye. In the Daubenmire method, six cover classes are used to reduce observer error although a seventh class has added by an inter-ministry habitat monitoring committee. Another commonly used cover class system is that developed by Braun-Blanquet (???), which also has six cover classes (Table 9.2.)n his system, cover classes range Line and point intercept methods are not commonly used in Garry oak ecosystem restoration projects, nor are frequency and density techniques.

Distribution of sample plot is usually along transects that are oriented across the slope of the site. Spacing of quadrats along the transects is not standardized, ranging from 5-?? metres. As well, the spacing of transects is not standardized because it varies from site to site.

Table 9.2. A comparison of cover classes used to assess vegetative cover.

Cover class	Daubenmire	BC adjusted method	Brain-Blanquet
1			
2			
3			
4			

5			
6			
7			

For animal inventory

For soils inventory

For hydrological inventory

9.4. Assessing success, i.e. why monitoring is critical: why, where, how long
Monitoring is used as a tool to assess progress to success and to identify any problems that might affect achievement of the project goals. Broadly speaking, the options available to the restorationist are no action, maintenance of the system, and modification of the project goals. If the monitoring program identifies deviation from the predicted trajectory of ecosystem development, adjustments can and should be made. For example, a project goal might be to eradicate an exotic plant and increase native vegetation through changes in hydrology. If monitoring showed that the exotic was still dominant after a period of time then additional restoration actions might be employed, such as exotic removal and native species plantings.

This section addresses the following key aspects of successful monitoring program:
1) What is monitoring and why is monitoring important?
2) What sites should be assessed?
3) What should be measured?
4) What methods should be used?
5) How often and how long should monitoring be done?

9.4.1. What is monitoring and why is it important?
Monitoring is the "Achilles heel" of restoration. Too often, considerable time, money, resources and excitement are directed at the initial stages of a restoration project, only to disappear once the initial work is done. This scenario plays out time and again, not only in Garry Oak restoration projects, but in restoration projects generally. This scenario is unfortunate because it is short-sighted, for without monitoring, how can success be judged?

Typically, monitoring has three aspects, implementation monitoring, effectiveness monitoring and validation monitoring (see Section 5).. The former refers to determining if a restoration prescription or program was implemented according to plans. Effectiveness monitoring refers to detemining if the prescription had the intended effect in restoring the target ecosystems.

Challenges facing monitoring can be daunting. Gayton (2003) pointed out the following challenges for British Columbian grasslands, but they apply equally as well to Garry oak ecosystems:

- Ecosystems vary dramatically over time space, season and year and are often greater magnitude than changes resulting from a treatment. Locating large enough and comparable areas for reference sites is difficult.
- All sites have experienced some degree of human disturbance.
- Quantitative methods are still not satisfactorily developed: difference among observers and different applications of the same methods by different observers are constant problems.
- Some species are difficult to identify.
- Exclosures, a key tool in measuring change, are almost non-existent
- Changes in Garry oak ecosystems can often be slow, leading to problems in staffing, funding, inconsistency in measuring methods, lost plots, missing data, damage to sampling sites, etc.

9.4.2. What sites should be assessed?

9.4.3. Selecting what to measure (adapted from NOAA website)
Two key steps in monitoring are selecting what to measure and selecting the methods that are appropriate to what is measured.

Selecting what to measure involves several considerations. First, they should be readily sensitive indicators to changes in the ecosystem, including both the restoration effort as well as any remaining impacts affecting the site. Sensitive and responsive measurable also enable early detection of progress or failure thus enabling prompt adaptation to the problem. Second, they should be scientifically based so that they withstand scrutiny of peers, funding agencies and management agencies Third, they should be easily measurable so that monitoring is kept within the bounds of time and money. Fourth, at least several parameters should be chosen because relying only on one parameter may result in insufficient information being collected, or it may be difficult to understand. Fifth, all several major components, e.g., soil, vegetation, animal, water, and measuring only one aspect of one component may overlook important changes. Sixth,

9.4.4. What methods should be used?
NOAA poses three basic questions to ask when selecting methods for monitoring are as follows:

1. Does the method efficiently provide accurate data on the parameters?
2. Is the method repeatable?
3. Is the method feasible within time and cost constraints?

As noted above, all sampling methods used should follow accepted and documented protocols. Examples and sources of documentation are provided throughout this section as well as in the References Cited at the end. Many agencies have well developed standards, e.g, RISC, NOAA. (other sources) and many textbooks present methods,

For reasons of economy and efficiency, choose sampling methods that allow you to collect data on more than one parameter. For example, a soil core sample can provide information on rhizome development, physical and chemistry attributes, and invertebrate communities. As well, make sure you have checked for existing 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 of sympathetic goals, but ensure prior permission is obtained before use, and always acknowledge sources.

One bewildering aspect of selecting methods is the tremendous variety of techniques that are available. Selecting "the best" methods is often overwhelming, even for seasoned restorationists. Four points to bear in mind when selecting methods are:

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 (The use of several methods is sometimes referred to as triangulation).
3) Decide if your methods should be qualitative or quantitative. NOAA quotes Erwin (1990) who 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. In situations where there is more certainty of success, and where performance is not tied to specific quantitative criteria, use qualitative evaluations. A combination of quantitative and qualitative methods can also be employed effectively in the same monitoring program, e.g, Table 1).

Table 9.3. Examples of qualitative and quantitative evaluation techniques used for Garry oak ecosystems.

Qualitative measures	Quantitative measures
Plan 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, and biomass
Fixed point panoramic photographs	Elevation
Rainfall and water level data	Water quality and soil properties data
Wildlife utilization observations	Wildlife counts
Invertebrate species list and qualitative abundance estimates	Invertebrate density and distribution

9.4.5. Timing, frequency, and duration of monitoring

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 are dependent on the ecosystem type, complexity, uncertainty and study objectives. Sometimes controversial projects require a higher degree of scrutiny that increases the level of monitoring effort. Seasonality must be taken into consideration. For example, if a particular plant species of interest is conspicuous only during spring flowering, sampling must be conducted during its period of bloom.

Successful 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 sites 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 latter strategy is preferable, because it minimizes seasonal effects and variability in conditions from day to day, and repeating the same task on the same day may be more efficient. However, it is not always practical if sampling sites are far apart or difficult to access. Sampling of specific parameters in reference areas should take place during 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 systems change rapidly and should be monitored more often than older systems. This is especially true for systems in which success is highly uncertain. By sampling more often, deviations from the expected trajectory 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 less frequent.

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. This will enable determination if there is reasonable assurance that the system has met its performance criteria, will meet them, or will not likely meet them. 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 imposed 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 trajectories or significant changes continue to occur annually.

9.5. Conclusions and future needs

9.5. References cited

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Anon. Describing ecosystems in the field

A PROPOSED FIGURE

Figure x. A checklist for inventorying and monitoring programs.

INVENTORY

MONITORING
Tiining
Frequency
Duration

PARKING LOT

- Community based mapping report by Penn et al.