UCUT Wildlife Monitoring and Evaluation Program: Data Collection and Analysis Approaches

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This report provides UCUT wildlife biologists with a description of data collection and analytical methods used in the UCUT Wildlife Monitoring and Evaluation Program (UWMEP). In the first section, we summarize the rationale and field protocol for each taxon group monitored. The second section of the report focuses on our approach to data presentation and analysis. Appendix 1 provides the database structure and description of variables.

Data collection

Four broad taxonomic groups are monitored through UWMEP: vegetation (ground cover plants, shrubs, and trees), small mammals (rodents and shrews), breeding birds, and larval amphibians (frogs and salamanders). For each group, we first summarize the importance of monitoring the group and then detail the field protocols.

Vegetation and habitat structure

General Background

Vegetation is typically the first thing to be addressed in ecological restoration of damaged or degraded terrestrial landscapes, although, in some cases, soil amendments or other changes to the physical environment might be necessary before this can proceed. Vegetation supports wildlife species by directly furnishing requisites such as food, cover, perches, and nests that form the basis of specialized niches and complex food webs. For example, standing dead trees and mid and high story tree canopies supply nesting sites for many breeding birds. Fallen logs and understory plants maintain cover and natural pathways for small mammals. Vegetation also affects microclimate and ecosystem functions such as nutrient cycling, carbon sequestration, and contributions to soil fertility (Hagar 2007).

Monitoring plant species composition (cover and frequency), relative abundance of native vs. nonnatives, and other trends provides information that can determine the effectiveness of management actions in moving habitat towards restoration goals. Vegetation surveys provide information on ground cover, herbaceous vegetation, shrubs, and trees at each study site. It is important that, insofar as possible, vegetation surveys for restoration monitoring identify plants to species. As with all monitoring procedures, consistency of methods is critical for year to year and site to site comparisons. Therefore, having an experienced field technician who knows plant identification and can oversee year-to-year consistency in method is imperative.

Ground Cover Background

For the UWMEP, ground cover is defined as the aerial cover of the soil surface with herbaceous plants, sub-shrubs, mosses, lichens, litter, rock, or bare ground. During the initial monitoring for the Albeni Falls with the Kalispel Tribe (2001-2006) ground cover was monitored by estimating

cover classes of each species in a plot following methods described by Daubenmire (1959). Because the Daubenmire method was used to measure ground cover on the reference and mitigation sites located on Kalispel Tribal properties, this method was retained in the UCUT proposal to BPA. With the start of the UWMEP project in 2008, the expansion of habitat types sampled and project goal to evaluate different monitoring methods, prompted the exploration of a second monitoring method - nested-frequency plots (Smith et al. 1986).

Daubenmire plots provide a measure of aerial cover which is the percent surface covered by ground cover. Cover is a measure of how much a plant dominates the given habitat. It is also good for characterizing habitats across life forms. Because cover is expressed as percent of area, the meaning of cover is the same for grasses, forbs, rocks, etc. Therefore, the relative contribution of plants of different life forms is more easily understood. The nested-plot approach provides a measure of **frequency** as well as aerial cover. Frequency is the number of times a plant species occurs in a given number of plots. Because frequency is a measure of plant presence, it is a more objective measure than estimation of cover. In addition, for perennial plants, it is less sensitive than estimating cover to changes in plant size due to seasonal variation and impacts of grazing or fire. Frequency estimates the probability of finding a species in a given area and is typically expressed as a percentage. Frequency can be used to detect changes in vegetation composition over time. In this way, frequency can be used to assess vegetation trend. Frequency is also used to quantify and describe the distribution of a given species in a community. However, unlike cover, frequency should not be used to compare abundance of different species. This is because of size variation between different species of plants. Measuring frequency is highly dependent upon plot size. For example, it is difficult to detect an increase in a plant's frequency if it occurs in all plots or a decline if the initial frequency was very low. Therefore, plot size should be sized so that the frequency of important species is between 20 to 80%. The appropriate plot size depends on the size and density of the plant; a plot big enough for one species might be too big for a different species. A good plot size for one sampling year might not be appropriate in a subsequent sampling year as site conditions change. It is impractical to conduct a pilot study each year to determine the appropriate plot size for each species. To overcome this "right size" problem Smith et al. (1986), proposed a nested-frequency plot where different-sized quadrats are nested within one plot.

Protocol

At each sampling site, two 64-m transects centered on the permanent sampling point are established perpendicular to each other in the cardinal directions (Fig. 1). Distances are standardized to run 0 to 64-m, south to north and west to east. These transects form the baseline for the different vegetation surveys.

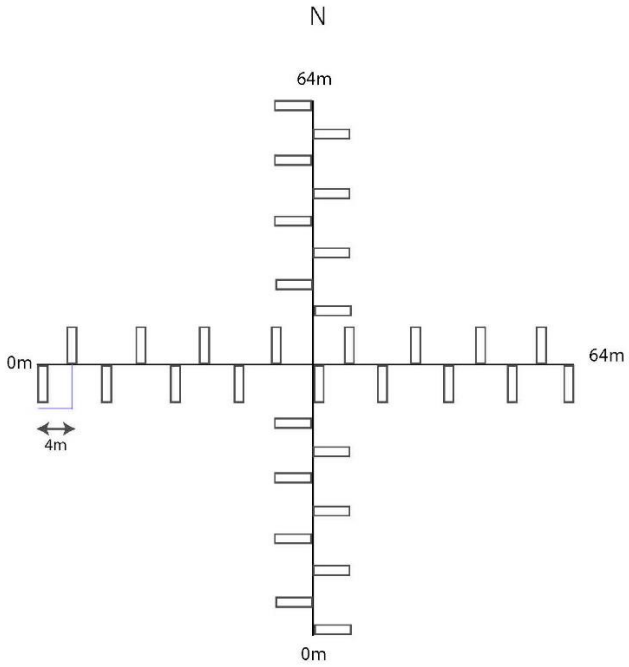


Figure 1. Standard transects for sampling ground cover with 20 x 50-cm (0.1 m^2) plot frames. Nested-frequency plot sampling is conducted at the same locations with a 1-m^2 plot frame.

Ground Cover

Daubenmire Plots - Ground cover is measured using 20 x 50 cm plot frames (Daubenmire 1959). Except when precluded by plant condition (e.g., seedling), all plants are identified to species. The plot frame, is placed with the long (50-cm) side perpendicular to the measuring tape. Plots are recorded once at the center of the sampling point (on the east-west transect) and at 4-m intervals on alternating sides of the 32-m transect radiating from each plot center (Fig. 1). This yields 33 plots per site. Species of herbaceous vegetation are recorded and assigned to one of six cover classes that correspond to a range of percent cover (Daubenmire 1959; Table 1). The midpoint of each range is the value used in cover calculations.

Table 1. Cover classes used in ground cover sampling with Daubenmire plots.

COVER CLASS	RANGE OF COVER	MIDPOINT OF RANGE
1	0-5%	2.5%
2	5-25%	15.5%
3	25-50%	37.5%
4	50-75%	62.5%
5	75-95%	85.0%
6	95-100%	97.5%

Sub-shrubs are included as ground cover. These are forb-like plants but with woody stems such as *Linnaea borealis* (twinflower) and *Eriogonum spp*. (buckwheat). Percent cover of mosses, lichens, bare ground, litter, and rock is measured in the same way. Logs and other downed woody debris are categorized as litter in cover plots. An entry of 'log' is also recorded in cover plots if the wood is solid and has a width ≥ 10 cm. The height (to nearest cm) of the tallest vegetation rooted in the plot is measured at three points along the midline of the plot frame. In tall marsh vegetation, the plot frame used is 3-sided (open on 1 of the 50-cm sides) enabling it to slide into the vegetation rather than resting on top of it. In this instance, the number of stems of cattails and bulrushes are recorded in lieu of assigning cover class. Height of vegetation is measured as above.

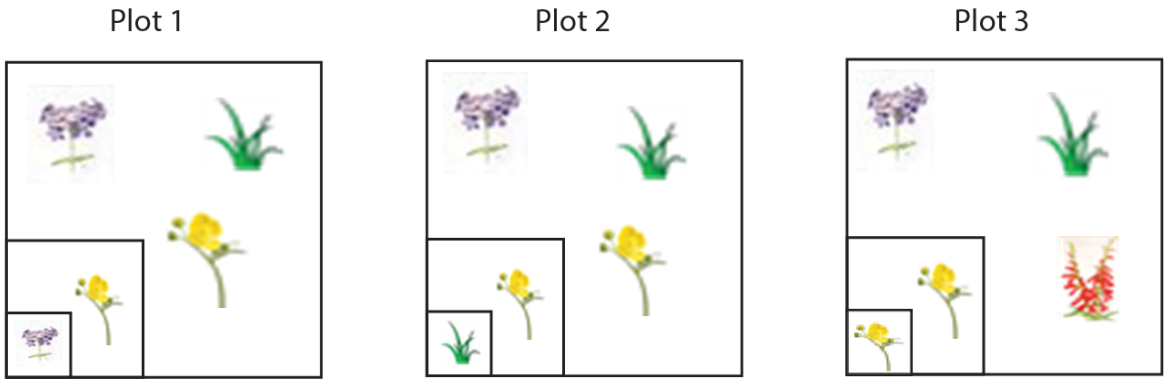
Nested Frequency Plots - Ground cover is also measured using a nested-frequency plot (Elzinga et al. 1998, Smith et al. 1986). This is a 1 x 1-m metal plot frame with 3 nested quadrats demarcated: 10 x 10 cm (1% of frame), 31.6 x 31.6 cm (2-10%); 100 x100 cm (11-100%). The portion of the frame with the smallest nested quadrat is positioned next to the measuring tape and aligned with the Daubenmire frame. As above, this yields 33 plots per site.

To measure herbaceous plant frequency, the smallest quadrat in which the plant occurs (1 = smallest, 2= medium, 3= largest) is recorded. More specifically, species that are rooted in the smallest quadrat are recorded as present in quadrat 1, additional species found in the next larger plot are recorded as present in quadrat 2, and then additional species found only in the largest plot are recorded as present in quadrat 3 (see example in Fig 2.). If a plant is present in the smallest quadrat, it is, by definition, present in the larger quadrat.

The percent frequency of a given species can then be calculated for each quadrat size. For example, for the largest quadrat (i.e., quadrat 3 or the full plot frame) the frequency of a species is calculated as the number of plots in which it was present divided by the total number of plots examined multiplied by 100. For example, the percent frequency of Species A would be:

$$\% \text{ Frequency } Sp_A = \#\text{ of plots in which } Sp_A \text{ occurs} / \text{Total } \#\text{ of plots examined} * 100$$

For the illustration in Figure 2, "red flower" would have a frequency of 33% and the other species would have a frequency of 100%. Three plots are too few, of course, to determine if a particular quadrat size is appropriate for determining change in frequency of a particular species. Recall that we would like a quadrat size that provides a frequency between 20 and 80%.



	Plot 1	Plot 2	Plot 3
Red Flower	-	-	3
Purple Flower	1	3	3
Yellow Flower	2	2	1
Grass	3	1	3

Figure 2. Illustration of how species frequency data would be recorded for four hypothetical plants.

To estimate aerial herbaceous plant cover with these plot frames, species are sorted into categories based upon type and native status (e.g., native perennial grasses, introduced forbs). Each category is then assigned a percent aerial cover within the overall plot frame. Because of multiple strata, numbers may add up to over 100%. The percent cover of the different components of ground cover (lichens, moss, bare ground, litter, or rock) is estimated in the same way.

Shrubs

Shrubs are counted to determine species composition and shrub volume. Shrubs are measured along 2-m wide belt transects radiating 32-m from the center point in each cardinal direction (Fig. 3). Only shrubs that are rooted within the 2-m are measured. The species of each shrub is recorded, being careful not to double-count shrubs near the center point. To determine the volume of each shrub, its length, width, and height are measured. To measure length, as each shrub is encountered along the transect, the start and end points (to nearest cm) are recorded. The width of the shrub is measured perpendicular to the transect in cm. The height of the shrub is assigned to one of four categories (1: ≤ 50 cm [below knee]; 2: > 51 – 100 cm [knee to waist]; 3: > 101-150 cm [waist to shoulder]; 4: > 151 cm [above shoulder]). Any small saplings (i.e., trees < 4 cm in diameter) that fall within the line should be counted as shrubs. In the event that a large

shrub has at least one main stem >4 cm in diameter, the whole plant is considered a tree and therefore recorded under that protocol. A list of woody plant species that can reach 4-cm DBH is in Appendix 2. This reflects the contributions of these shrubs to habitat structure. As indicated above, sub-shrubs are included in ground cover.

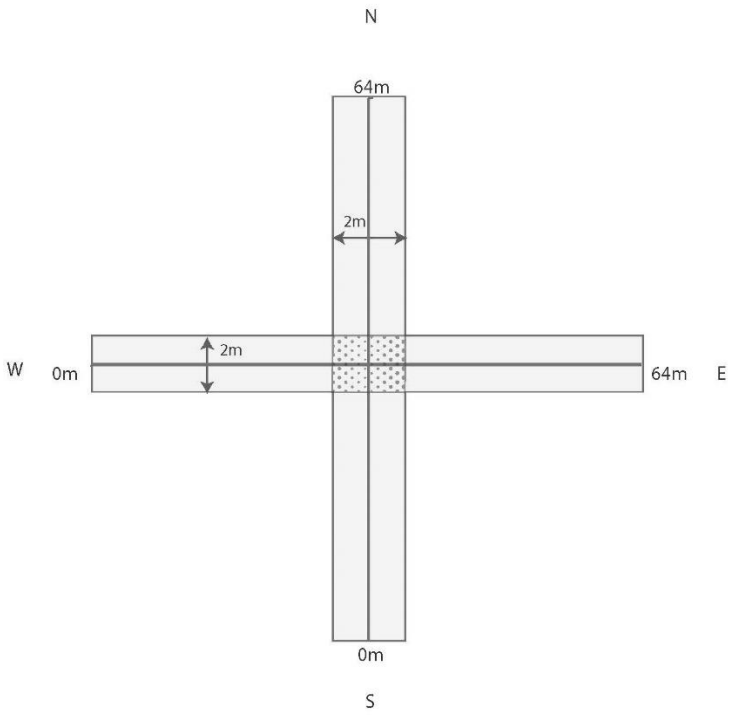


Figure 2. Belt transects used for measuring shrubs. The stippled area indicates where care should be taken not to double count shrubs.

Trees

Live trees are counted to determine species composition, and live trees and standing dead trees (snags) are measured to characterize the structure of forested habitats. As noted above, transects are extended 32-m in each cardinal direction from the center point. Trees are recorded in 32-m plots in each of four quadrats (Fig. 4). Trees with a minimum diameter-at-breast-height (DBH) of 4-cm are categorized by species and placed into one of six size classes: 1) 4-10 cm; 2) 11-25 cm; 3) 26-50 cm; 4) 51-75 cm; 5) 76-100 cm; 6) > 100 cm. Small saplings with a diameter-at-breast height <4 cm are sampled under the shrub protocol and not counted under the tree protocol. Most trees have a single stem, or trunk, however in some instances multi-stem trees occur. The most common examples are large alders (*Alnus spp.*) and hawthorns (*Crataegus douglasii*; Appendix 2). When encountering multi-stem individual this rule applies: if one or more stems is ≥ 4 cm DBH, then the whole plant is considered to be a tree. In this case, the largest trunk of the multi-stem tree is measured as the primary record, with the total additional number of stems ≥ 4 cm recorded in parentheses.

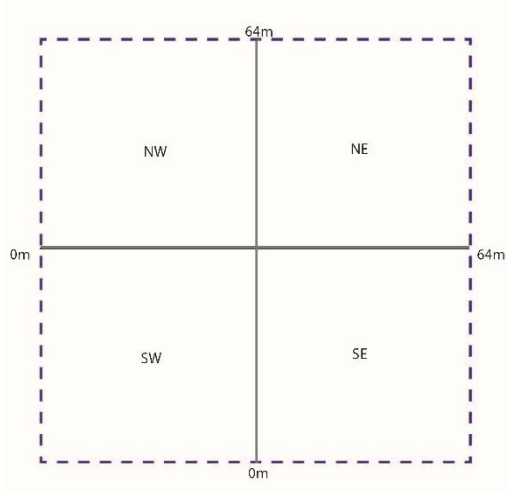


Figure 3. Trees are sampled within four quadrats defined by the transects used for other vegetation sampling.

The number of standing dead trees (i.e., snags) is recorded using size classes listed above and decay classes following Parks et al. (1997). Each snag is first classified as one of three decay classes irrespective of species. These are: (1) recently dead, little decay, retention of bark, branches and top, (2) evidence of decay, loss of some bark and branches and possibly part of the top, and (3) extensive decay, missing bark and most branches, and broken top. In the event that a snag leans or tips sufficiently to rest below breast height it is not counted, nor are stumps counted. Fallen dead trees are considered *'logs'* and are not measured. Logs and other downed woody debris are categorized as litter in cover plots. An entry of 'log' is also recorded in cover plots if the wood is solid and has a width ≥ 10 cm.

Small Mammals

Background

The small mammal community is an important component of biological diversity in most ecosystems. Small mammals act as seed dispersal agents, their burrowing disturbs soil and creates microsites for seedling development, and they provide a prey base for higher trophic level consumers (Hallett et al. 2003, Martin 2003). Small mammals can be useful indicators of environmental change for several reasons. They respond rather quickly to disturbances in habitat structure or plant composition, are sufficiently mobile to leave unsuitable sites and relocate to suitable ones but at the same time are dependent upon a localized area for survival, and are ubiquitous and suitably fecund (Leis et al. 2008). Monitoring small mammal species abundance, community diversity, and trends provides information that can be used to determine the effectiveness of management actions in moving towards conservation or restoration goals. Monitoring the reproductive status of all individuals provides an indication of habitat quality. For example, if all adults of a species in a one area are reproductive and no adults are reproductive in a second area, the first would represent better habitat quality. Removal trapping is used rather than live-trapping because (1) it allows for positive species identification using skull and teeth morphology, (2) reproductive condition can be determined, and (3) it is more efficient at small-mammal capture (Eulinger and Burt 2011).

Protocol

Field Collection - Small-mammal populations are sampled by removal trapping on a 9 by 5 grid with 12-m spacing and centered on each sampling point. A compass is used to lay the long axis of the grid in a north-south orientation. Each station is marked with a flag and assigned a letter-number combination for a total of 45 unique grid points (A-E, 1-9; e.g., B9). For consistency the position of A1 is always established in the southwestern-most position on the grid. Two Museum Special snap-traps (Woodstream Corporation; 14 x 6-cm) are placed at each grid point and baited with a mixture of oats and peanut butter. Sampling is conducted for 3 consecutive days per site per field season. Traps are set in the afternoon of the first day and checked the following 3 consecutive mornings for a total of 270 trap nights per sampling point. A trap night is equal to one trap set for one night. In some cases, the trapping grid might need to curve or otherwise be adjusted to fit the target habitat type (e.g., riparian strips). Small-mammal trapping is conducted from July until early September.

Field Processing - Each captured animal is placed in a small plastic bag with a label affixed to the inside denoting the following information: date, collector's initials, a unique collector number, sampling site, grid point, and taxon (final species designation occurs after laboratory examination). A single worker acts as collector for the day and records all information on a data

sheet. At the field office, each animal is weighed (to the nearest 0.1 gram) and examined for sex. Total body length, tail length, hind foot, and ear are then measured. *For Total Body and Tail Length* - hair tufts extending past the tip of the tail are not included in the measurement. *For Hind Foot* - toenail is included in the measurement. *For Ear* - tufts of hair extending past outer edge of the pinnae are not included in the measurement. After field processing, all animals are placed into a large Ziploc bags with the date and site labeled on the outside. Bags are then stored in the freezer until they can be processed in the lab.

Autopsy and Final Species Identification - After the field season, small mammals are dissected in the lab for reproductive data. For females the following data are recorded: 1) relative size of nipples (small, medium, large), 2) length and width of ovaries, 3) number of placental scars (dark spots on the uterine horns that are indicative of past pregnancies), 4) number s of any embryos on each uterine horn and 5) the average crown-rump length of a litter (the crown-rump length is the distance from crown of skull to rump of embryo). . For males, the following data are recorded: testes length and width and length of the seminal vesicles when present. All measurements are in mm. The amount of fat that is between the scapulae (shoulder blades) is designated into one of three categories: low fat, fat, very fat. Skulls are labeled and cleaned for positive species identification using guides in O'Connell (2008) and some specimens are prepared as voucher specimens.

Breeding Birds

Background

Monitoring the health and long-term stability of bird communities can provide an important measure of overall environmental health and (Smits and Fernie 2013) effectiveness of management decisions (Noson and Hutto 2005). Birds are good environmental monitors for several reasons: many species can be monitored simultaneously with a single method, methods for monitoring are well understood and standardized, birds occupy all habitat types, and as a community represent several trophic levels and habitat-use guilds. Monitoring species abundance, community diversity, and trends provides information that can be used to determine the effectiveness of management actions in moving towards restoration goals.

Point counts are the most widely used quantitative method used for monitoring land birds and involve an observer recording birds from a single point for a standardized time period (Ralph et al. 1995). The methodology follows recommendations by Ralph et al. (1995) and is consistent with that employed by the USDA Forest Service Northern Region Land Bird Monitoring Project (Hutto et al. 2001) and recommendations for the Idaho Partners in Flight Bird Monitoring Plan (Leukering et al. 2000). Fixed-radius plots (where the radius is arbitrarily small) reduce the

interspecific difference in detectability by assuming that: a) all the birds within the fixed-radius are detectable; b) observers do not actively attract or repel birds; and c) birds do not move into or out of the fixed-radius plot during the counting period. This allows for comparisons of abundance among species. Unlimited radius plots maximize the amount of data collected because they include all detections and are appropriate when the objective is to monitor population changes within a single population (Ralph et al. 1995). Birds should be tallied in two distance bands, one 0-50 meters from the point center and one >50 meters from the point center. This maximizes data collection while permitting interspecific analysis. Additional information on establishing point count stations, data collection, and sample data forms can be found in Ralph et al. (1993), Ralph et al. (1995), and Huff et al. (2000).

Protocol

Bird populations are sampled by the point-count method. Each sampling point is the center of a point-count station. The focal survey area consists of a 50-m radius circle around each point. All birds detected within the point-count circle are recorded. Bird surveys are conducted from mid-May through early July beginning at approximately 0500 hours and completed by 1000 hours. A single observer spends 8-min at each birding station recording in three intervals (0-3 min, 3-5 min, and 5-8 min). All birds seen or heard within these three time periods are recorded. Species are identified using a four letter code based on common name (e.g., RWBL for Red-winged Blackbird). A generic code is used if the species cannot be identified. Birds encountered are assigned a group type from among the following: male (M), female (F) pair (P), nest (N), flock (FL) or unknown (U). An observation type is also assigned: (singing (S), calling (C), visual (V) or drumming (D). For flocks, the approximate number of individuals is noted. Birds that observed flying within the plot, but do not appear to be using the area are noted as flyovers. Presence of an individual, pair, or flock observed outside of the 50-m radius circle is recorded. Weather conditions can have a great influence on the effectiveness of a survey. Upon arrival to each site, weather conditions are noted as: clear (C), partly cloudy (P), overcast (O), drizzle (D), rain (R), or fog (F). Because most birds are observed by sound, wind or rain can mask songs or call notes enough that they are not discernible to the observer. High wind and heavy rain can also force high canopy foragers to take shelter or generally decrease the morning activity of most birds. Surveys are not conducted, or are discontinued, if these weather conditions exist.

All stations should be visited seven times during the breeding season (mid-May to early July) with from 6-8 days between counts. Exact timing of sampling will vary due to conditions outside our control (e.g., road and weather conditions), and in some cases only 6 entries have been possible. Subsequent analyses are weighted by the number of entries. To the extent possible, the order of daily visits to the point-count stations is reversed for each entry to increase the probability of observing both early and late morning singers across the point count stations. To

maximize the probability of recording all bird species present on a site regardless of variable arrival and breeding times, surveys are scheduled so that each site is visited throughout the breeding season.

Larval Amphibians

Background

Amphibians are important components of ecosystem biodiversity that are frequently overlooked by fish and wildlife habitat managers. In recent decades there has been worldwide concern about declines in populations of amphibians (Blaustein et al. 2011, Liu et al. 2013). Factors such as pollution, habitat loss, competition from non-native species, infectious disease, and climate change have all played a role in these declines. Permeable skin and a life cycle that involves both aquatic and terrestrial habitats make amphibians especially susceptible to altered environmental conditions. They can serve as indicators of environmental health (DeGarady and Halbrook 2006) and their response to management efforts can help assess directional change as aquatic habitats undergo restoration (Vasconcelos and Calhoun 2006).

Local management activities may disproportionately affect amphibians because they are relatively sedentary in contrast to larger mammals and birds which have greater mobility. Many wildlife mitigation properties have never been intensively surveyed for herpetofauna. We have designed this monitoring program to provide managers with information about the species that presently occur on individual projects (the inventory phase) and about the effectiveness of their habitat management practices (monitoring phase) in restoring or maintaining the species assemblages that occur there. Because of their vulnerable status and usefulness as indicators, we have made amphibian monitoring a priority in all permanent or seasonally wet habitat types (riparian forest, riparian shrub, emergent wetland, wetland meadow). We use standards in Heyer et al. (1994) for larval trapping, a method well suited for amphibians.

Protocol

Amphibian populations are monitored by larval trapping using collapsible minnow traps (Miller Net Company, Inc) where appropriate (i.e., water ≤ 500 m from sampling point). Larval traps are 25 x 40-cm collapsible minnow traps modified to reduce the size of the opening to 2 cm. Transects are established in open water areas near the sampling point. Five traps are placed at each location, with each trap attached to a single rebar pole. Traps are set out for 5 days at each site during each of two trapping periods, one in early summer (early June through mid-July) and again in late summer (August through mid-September) to accommodate life-histories of different species.

Traps at each site are submerged the morning of the first day and then checked once daily for 5 consecutive days. Salamander and frog larvae captured in traps are identified to species using keys in Nussbaum et al. (1983) and measured for snout-vent length (in mm). Frog larvae only are assigned to a developmental stage class as follows: 1-No Legs; 2-Limb Buds; 3-Hind legs only; 4-Four legs with tail; 5-Fully metamorphosed. Fish caught in traps are identified to species using keys in Scholz and McLellan (2009) and counted. Aquatic macro-invertebrates are not recorded. All captured animals are released at the site of capture.

The following information is recorded for each trap where one or more captures occur: water depth (in cm) and distance from edge (in meters). For each site, a description of the water body is noted (e.g., creek, slough, vernal pool).

Analytical approaches

Measures of diversity are frequently used to provide a shorthand way to categorize the species composition of ecological systems. Three common measures are species richness, species diversity, and species evenness (Magurran 1998).

The simplest measure of diversity is **species richness**, which is a count of the total number of species in a defined sampling unit (denoted as *S*). However, species are rarely represented in even numbers in a habitat. Typically, a few species will be very abundant, some will have moderate abundance, whereas most will be represented by only a few individuals. Therefore, a more complex analysis of diversity considers species abundance and species evenness, a measure of the degree that species differ in abundance.

Measures of **species diversity** have been developed to account for both the number of species present and the relative abundance of each species at a sampling unit. Relative abundance is the proportion of individuals of one species relative to the total number of individuals counted. We report the Shannon-Weiner measures of diversity. This measure typically ranges from 1.5 to 3.5, with larger numbers equating to greater diversity. This is calculated as

$$H = -\sum p_i \ln p_i$$

where p_i is the proportional abundance of species i.

Species evenness is the degree to which the abundance of each species is similar. It is calculated by dividing the observed diversity value (*H*) by the diversity value if all species are equally abundant or maximum diversity,

$$H_{max} = \ln S,$$

where S is the total number of species (richness). Evenness is then

$$E = \frac{H}{H_{max}}.$$

Therefore, an evenness value of 1 indicates that all species are equally abundant in a sampling unit. Both species diversity and evenness assume that all species are included.

Although species richness and diversity can reflect differences across sampling locations, they do not provide insight into the underlying changes in composition. Moreover, one might demonstrate an increase in species richness, for example, but this might be due to an increase in non-native invasive species. Our monitoring approach anticipates that ecological restoration will result in changes in the composition of biotic communities. This reflects the objective of ensuring that characteristic assemblages are restored on mitigation units. Moreover, it follows the general shift from monitoring strategies that focus on single species ("umbrella" species) or focal taxa to the biotic communities themselves (Su et al. 2004). We have adopted indices of community similarity to evaluate if management activities at restoration sites are moving them toward the reference condition.

Community similarity is a measure of the compositional similarity of two sampling locations bounded by 0 (no similarity) and 1 (complete similarity). Some similarity measures such as the classic Jaccard are based on presence/absence data:

$$J_{classic} = \frac{A}{A + B + C}$$

where A is the number of species shared at two locations and B and C are the number of species unique to each location. These measures give greater weight to rare species which can make communities appear more similar than they are.

Consequently, we employ community similarity measures that incorporate relative abundance (Chao et al. 2005). Consider a comparison of two locations that share some species in common and where relative abundance is known for each species at each location. We can sum the

relative abundances of the shared species at each location and designate these as *U* for location 1 and *V* for location 2, respectively. The classic Jaccard formula can then be modified following Chao et al. (2005) to one based on relative abundance:

$$J_{Abund} = \frac{UV}{U + V - UV}$$

This equation is the starting point for estimators such as the Chao-Jaccard that attempt to compensate for the difficulty of detecting all species and their relative abundances given limited sampling. These probabilistic models incorporate relative abundance and consideration of shared species that might not be detected during sampling for estimating compositional similarity. Details of the machinery for calculating Chao-Jaccard similarities are provided in Chao et al. (2005).

Once a measure of similarity or distance is calculated, the issue of how to represent and analyze relationships becomes important (e.g., do reference and mitigation sites differ?). Traditional statistical methods such as analysis of variance or multivariate analysis of variance (MANOVA) must be replaced by nonparametric methods because the underlying assumptions (e.g., normality and equal variances) of these methods are typically violated for analysis of ecological data that involves species abundances (McArdle and Anderson 2001). Our work rests on using a permutational or nonparametric MANOVA following Anderson (2001) and McArdle and Anderson (2001). More recently we have begun exploring another method called Analysis of Similarities (ANOSIM), which may better handle differences in similarity (Clarke 1993). ANOSIM tests whether there is a significant difference between two or more groups (e.g., reference versus mitigation sites).

A number of different approaches to visualizing community relationships using similarity measures are available (e.g., principal components analysis and cluster analysis; see Minchin 1987). We use non-metric multidimensional scaling (NMDS) because it does not make assumptions about the underlying distributions of the data (Cox and Cox 1994). NMDS allows for representation of data in multidimensional space using a reduced number of dimensions that can be easily plotted and visualized. A matrix of dissimilarities (i.e., 1 – similarity) is the starting point for construction of sample maps (i.e., ordinations) in two or more dimensions (Fig. 5). The distances between points have the same rank order as corresponding dissimilarities between sampling sites. Sites that are more similar in composition and abundance are closer together, whereas those that are less similar are further apart. Calculation of the NMDS axes is an iterative process, and a measure of "stress" is calculated to get the best representation of the data and to

determine if a third axis may be required. Unlike other ordination techniques, no axis is of greater importance than any other (Cox and Cox 1994).

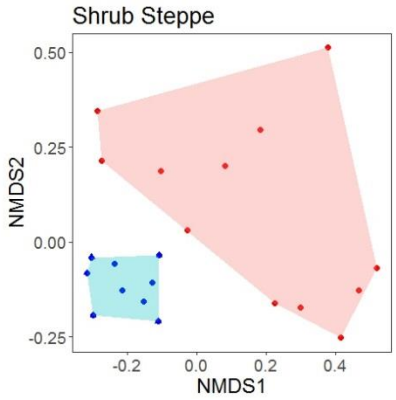


Figure 4. Example non-metric multidimensional scaling graph for herbaceous vegetation in shrub steppe habitat for reference (blue) and mitigation sampling locations (red). Each point represents a sampling location and year. The three reference sites were sampled over 3 years for a total of 9 points. The distribution of the sampling locations on the two axes reflects their similarity relationships to other locations. Locations that are closer together are more similar in composition and abundance. The greater spread of the mitigation sampling points reflects their greater variation in species composition. For this example, reference and mitigation groups were significantly different (ANOSIM, $P < 0.05$).

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Appendix 1

The following tables describe the data as collected and as will be provided to each Tribe. For clarity these tables include scientific and common names rather than species codes, and include all descriptors for each sampling point.

Table A1. Cover variables collected with 20 x 50-cm plot frames.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	Habitat (conifer woodland, mixed conifer, shrub-steppe, grassland steppe, riparian forest, riparian, wetland meadow, emergent wetland)	
Northing	Floating point number	GPS coordinate	UTM NAD 27
Easting	Floating point number	GPS coordinate	UTM NAD 27
Date	Date	Day, Month, Year	
Direction	Character	N = North S = South E = East W = West	
Distance	Integer	Distance from center on transect	m
Scientific Name	Character	Genus and species	
Common Name	Character	Common name or attribute	
Cover	Integer	Cover class from 1 to 6	
Height	Decimal number	Height of vegetation at 3 points	cm

Table A2. Nested plot frequency. Variables 0 to 64 indicate the location on each transect.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	Habitat (conifer woodland, mixed conifer, shrub-steppe, grassland steppe, riparian forest, riparian, wetland meadow, emergent wetland)	
Northing	Decimal number	GPS coordinate	UTM NAD 27
Easting	Decimal number	GPS coordinate	UTM NAD 27
Date	Date	Day, Month, Year	
Direction	Character	N-S = North-South transect E-W = East-West transect	
Form	Character	F = Forb G = Grass S = Shrub T = Tree	
Status	Character	N = Native I = Non-native	
Duration	Character	A = Annual P = Perennial	
Scientific Name	Character	Genus and species	
Common Name	Character	Common name or attribute	
0	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
4	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
8	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
12	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
16	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
20	Character	1 = Small plot 2 = Medium plot 3 = Large plot	

Table A2. Continued.

Variable	Data type	Definition	Measurement unit
24	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
28	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
32	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
36	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
40	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
44	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
48	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
52	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
56	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
60	Character	1 = Small plot 2 = Medium plot 3 = Large plot	
64	Character	1 = Small plot 2 = Medium plot 3 = Large plot	

Table A3. Nested plot cover percentage. Variables 0 to 64 indicate the location on each transect.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	Habitat (conifer woodland, mixed conifer, shrub-steppe, grassland steppe, riparian forest, riparian, wetland meadow, emergent wetland)	
Northing	Decimal number	GPS coordinate	UTM NAD 27
Easting	Decimal number	GPS coordinate	UTM NAD 27
Date	Date	Day, Month, Year	
Direction	Character	N-S = North-South transect E-W = East-West transect	
Cover type	Character	Cover types include: Annual grasses (native) Annual grasses (introduced) Perennial grasses (native) Perennial grasses (introduced) Forbs (native) Forbs (introduced) Shrubs Trees	
0	Character	Cover percentage	
4	Character	Cover percentage	
8	Character	Cover percentage	
12	Character	Cover percentage	
16	Character	Cover percentage	
20	Character	Cover percentage	
24	Character	Cover percentage	
28	Character	Cover percentage	
32	Character	Cover percentage	
36	Character	Cover percentage	
40	Character	Cover percentage	
44	Character	Cover percentage	
48	Character	Cover percentage	
52	Character	Cover percentage	
56	Character	Cover percentage	
60	Character	Cover percentage	
64	Character	Cover percentage	

Table A4. Shrub variables.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	Habitat (conifer woodland, mixed conifer, shrub-steppe, grassland steppe, riparian forest, riparian, wetland meadow, emergent wetland)	
Northing	Decimal number	GPS coordinate	UTM NAD 27
Easting	Decimal number	GPS coordinate	UTM NAD 27
Date	Date	Sampling Date (Day, Month, Year)	
Direction	Character	North, south, east, or west	
Start	Decimal number	Start point of shrub on measuring tape	to the 10th of m
End	Decimal number	End point of shrub on measuring tape	to the 10th of m
Species	Character	Genus and species	
Width	Decimal number	Shrub width	cm
Length	Decimal number	Shrub length	cm
Height	Integer	Shrub Height Class 1 = 1-50 cm 2 = 51-100 cm 3 = 101-150 cm 4 = 151+ cm	

Table A5. Tree variables.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	Habitat (conifer woodland, mixed conifer, shrub-steppe, grassland steppe, riparian forest, riparian, wetland meadow, emergent wetland)	
Northing	Decimal number	GPS coordinate	UTM NAD 27
Easting	Decimal number	GPS coordinate	UTM NAD 27
Year	Integer	Year	
Scientific Name	Character	Genus and species	
Common Name	Character	Common name	
DBH 4-10	Decimal number	Diameter at Breast Height (4-10)	cm
DBH 11-25	Decimal number	Diameter at Breast Height (11-25)	cm
DBH 26-50	Decimal number	Diameter at Breast Height (26-50)	cm
DBH 51-75	Decimal number	Diameter at Breast Height (51-75)	cm
DBH 76-100	Decimal number	Diameter at Breast Height (76-100)	cm
DBH >100	Decimal number	Diameter at Breast Height (> 100)	cm

Table A6. Small mammal variables.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	Habitat (conifer woodland, mixed conifer, shrub-steppe, grassland steppe, riparian forest, riparian, wetland meadow, emergent wetland)	
Northing	Decimal number	GPS coordinate	UTM NAD 27
Easting	Decimal number	GPS coordinate	UTM NAD 27
Date	Date	Collection date (Day, Month, Year)	
X Grid	Character	Location on sampling grid (A-E)	
Y Grid	Integer	Location on sampling grid (1-9)	
Scientific Name	Character	Genus and species	
Common Name	Character	Common name	
Sex	Character	M= Male F = Female U = Unknown	
Weight	Decimal number	Weight	grams
Total Body	Decimal number	Total body length	mm
Tail	Decimal number	Tail length	mm
Hindfoot	Decimal number	Hind foot length	mm
Ear	Decimal number	Ear length	mm
Testes Length	Decimal number	Testes length	mm
Testes Width	Decimal number	Testes width	mm
Seminal Vesicles	Decimal number	Seminal vesicles length	mm
Nipple Size	Character	S = Small M = Medium L = Large	mm
Ovary Length	Decimal number	Ovary length	mm
Ovary Width	Decimal number	Ovary width	mm
Scars Left	Decimal number	Scars on the left uterine horn	Total number
Scars Right	Decimal number	Scars on the right uterine horn	Total number
Embryos Left	Decimal number	Embryos on the left	Total number
Embryos Right	Decimal number	Embryos on the right	Total number
Crown Rump	Decimal number	Average embryo length	mm
Fat	Character	LF = Low Fat F = Fat VF = Very Fat	

Table A7. Bird variables.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	Habitat (conifer woodland, mixed conifer, shrub-steppe, grassland steppe, riparian forest, riparian, wetland meadow, emergent wetland)	
Northing	Decimal number	GPS coordinate	UTM NAD 27
Easting	Decimal number	GPS coordinate	UTM NAD 27
Date	Date	Day, Month, Year	
Time	Time	Start of time period	
Common Name	Character	Common name	
Scientific Name	Character	Scientific name	
Greater than 50 m	Logical	True if observation > 50 m away	
Observation Type	Character	S = Singing C = Calling V = Visual D = Drumming	
Group	Character	M = Male F = Female P = Pair N =Nest F = Flock U = Unknown	
Number	Decimal number	Number of individuals	
Flyover	Logical	True if a flyover	

Table A8. Amphibian variables.

Variable	Data type	Definition	Measurement unit
Owner	Character	Tribe or Agency	
Station	Character	Sample point	
Unit	Character	Mitigation unit	
Habitat	Character	River, slough, oxbow, creek, cattail marsh, pond, river, flooded meadow, etc.	
Northing	Decimal number	GPS coordinate	UTM NAD 27
Easting	Decimal number	GPS coordinate	UTM NAD 27
Date	Date	Day, Month, Year	
Scientific Name	Character	Genus and species	
Common Name	Character	Common name	
Season ID	Integer	1 = Early 2 = Late	
Trap	Integer	Trap number (1 to 5)	
Water Depth	Decimal number	Water depth	cm
Distance	Decimal number	Distance from the water's edge	m
Count	Decimal number	Total number observed	
SV Length	Decimal number	Snout-vent length	mm
Stage	Character	Larval stage class: 1 = no legs 2 = limb buds 3 = hind legs 4 = 4 legs 5 =adult	
Taxon	Character	Amphibian, fish	

Appendix 2

Woody plants that take the form of large shrubs or small trees at maturity.

Species	**Common Name**
Acer glabrum	Rocky Mountain Maple
Alnus species	Alder
Amelanchier alnifolia	Serviceberry
Cornus sericea	Red-Osier Dogwood
Corylus cornuta	Beaked Hazelnut
Crataegus douglasii	Black Hawthorn
Holodiscus discolor	Oceanspray
Philadelphus lewisii	Lewis' Mockorange
Prunus emarginata	Bitter Cherry
Prunus virginiana	Chokecherry
Salix species	Willow
Sambucus nigra	Blue Elderberry
Taxus brevifolia	Pacific Yew