protocol for Monitoring vegetation after tamarisk removal

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Table of Contents

Introduction and Background 3

Methods used 4

Best practices for vegetation monitoring 5

For all monitoring projects 5

Level I: Photo points + notes 6

Level II: *Tamarix*/target monitoring (simple) 7

Level III: *Tamarix*/target monitoring (detailed) 7

Level IV: Complete vegetation monitoring 8

Level V: Modified Whittaker plots 9

Non-vegetative sampling 10

Soil Survey 10

Geomorphology 11

Literature Cited 12

Appendices 13

Appendix A: Methods Tested 14

Appendix B: data sheets 18

Data sheets for vegetation monitoring 18

# Introduction and Background

In Colorado, active and diverse partnerships of private landowners, private conservation organizations and state and federal agencies have formed in the watersheds of the Dolores, Purgatoire and Apishapa Rivers and Timpas Creek to conduct riparian restoration in reaches infested by tamarisk (*Tamarix* spp.) and other invasive weeds. The partnerships have expressed a need for standardized and scientific monitoring of restoration activities on these four rivers but have lacked standardized methodologies for doing so. Dr. Anna Sher has been approached by these stakeholder groups (Tackling Tamarisk on the Purgatoire and the Dolores River Restoration Partnership) to develop a plan for systematic monitoring of restoration, and to supervise these efforts. As explained in that agreement, “the monitoring protocols should: 1) be suitable for implementation and ongoing data collection… including landowners, agency and NGO staff, and community volunteers; 2) require minimal start-up and ongoing maintenance expense; 3) be adaptable to a wide array of treatment methodologies; and 4) allow for meaningful data comparison and analysis within watersheds and between basins using similar protocols.”[[2]](#footnote-2)

The information in this report and feedback on the report will ultimately result in a bound manual for distribution to land managers, funded by a Natural Resources Conservation Service Conservation Innovation Grant (NRCS CIG).

# Methods used

The recommendations presented here are based on three years of comparing monitoring methodologies in 25 sites in Colorado: nine sites in three reaches located on the West Slope (Figure 1a) and sixteen sites in five reaches located in the East, within the Arkansas River Valley (Figure 1b). At each site, five transects were established within the boundaries of a 20 x 50m plot established, where the following were systematically measured and compared:

**Accuracy and efficiency of overall method-** Three different sampling methodologies were compared for monitoring understory vegetation cover and species richness (line point intercept, quadrat sampling, and modified Whittaker plots), and three methods for sampling overstory vegetation (line point intercept, line intercept, modified Whittaker ([Stohlgren et al. 1995b](#_ENREF_20)), and densitometer). Nearest neighbor distances were also calculated to determine densities of trees. All of these methods were timed and their relative measurements of cover and richness statistically compared. For each sampling method, data was collected per species, and then summarized in terms of native or exotic (“nativity”) for the purposes of the analysis.

**Optimal size and shape of sampling plots-**Within the quadrat method, three different sizes and two different shapes were compared. Finally, consistency in ocular measurements between observers were tested. In all cases, comparisons were made between measurements taken at the same time and the same place.

**Optimal timing and frequency of measurements-** Each of the primary methods (line point intercept, 1 m2 quadrat, and modified Whittaker plots) was used to measure vegetation at each of 18 plots twice a year (spring and summer) for two years. This was done to determine repeatability of results over time and space.

Descriptions of each method tested can be found in Appendix A. The annual reports for this project (2010, 2011 and 2012) contain the results of these tests, including their statistical analyses. It should be noted that these annual reports also include monitoring results by reach and analyses of cover changes over time. Here I will present overall patterns observed during this period and recommendations for monitoring generally.

# Best practices for vegetation monitoring

The following monitoring methods (Table 1) have been extensively tested in the field to fulfill the following requirements:

* They can be used under a variety of restoration scenarios, including no removal of invasive trees, control of tamarisk using biological, chemical, and mechanical methods, both alone and in combination.
* They can be used to track tamarisk mortality and/or vegetation response to removal
* They require very little equipment, and equipment is cheap and readily available
* They are fast and can be performed by anyone who can transverse the site and is able to identify the vegetation at the level of interest (most basic level- % cover - to most detailed- species identifications)
* They are scientific quality and thus will be useful for comparisons between sites and over time.

They are also presented in a tiered fashion, so as to give the land manager options, based on their interest and resources (primarily time).

Table : Matrix of recommended monitoring approaches, given monitoring goals. Levels reflect increasing amounts of time/effort required. Note that Level IV has best combined score, although Level V does a superior job capturing rare species. Time to complete per site is an estimate based on a crew that is 1) already warmed up 2) at a site that has already been set up; first sites may take much longer. Amount of time within a site will also be dependent upon vegetation density.

|  |  |  |
| --- | --- | --- |
| *Monitoring Method*  | *Monitoring Goal* |  |
| ***Tamarix*/target mortality**  | **Vegetation Cover** | **Vegetation diversity** | **Time to complete, per site** |
| **Level 1: Photo points and notes** | Good | Poor | Poor | 5- 10 min |
| **Level II: Target monitoring** | Better | NA | NA | 10 min-1 hr |
| **Level III: Target monitoring** | **Best** | Poor | Poor | 30 min-2 hrs |
| **Level IV: vegetation monitoring (PO)** | Best | **Best** | Good | 45 min -2 hrs |
| **Level V: modified Whittaker plots** | Good | Better | **Best** | 15 min-2 hrs |

## For all monitoring projects

In any restoration project, it is critical that **clear objectives** in the context of an overall goal are clearly defined ([Shafroth et al. 2008](#_ENREF_15)). This will determine whether vegetation and soil sampling will be sufficient, as well as the level of detail needed in each of these. For example, if tamarisk are being removed to create a fire break, a simple photo point taken on an annual basis may be sufficient to determine if removal is being successful over time (as described in level I, below). On the opposite end of the spectrum, if a return to ecosystem function is desired, monitoring of species richness and/or percent cover by functional group (such as natives) may be needed, requiring transect sampling (as described in level V, below). Write these objectives down and be sure that all relevant stakeholders be aware of the metrics you are using to define success.

A primary motivation for doing monitoring includes empowering **adaptive management**. As such, be clear about which metrics you require for this (e.g. just being aware of a presence of weeds or their identification and/or density).

Once your needs are clearly defined, you must determine how these data (information being collected, including photos) will be kept in a way that will be useful over time. Monitoring of any type requires keeping **well-organized and backed-up records**, even if one is only doing photo point monitoring. The details of this may be dictated by a land manager’s agency or organization, but where it is not, an appropriately labeled, bound notebook may be sufficient for entry in the field (hereafter “record book”), with data shortly thereafter transferred to a digital format (e.g. entered into an MSExcel spreadsheet). These digital records should then be backed up on a server. We have used Google Docs for sharing and backing up data, which has the advantages of being free and allowing multiple users to view and use data at one time. Dropbox is another free system that can work well.

Each of the following levels can be used alone or in combination with any other level.

## Level I: Photo points + notes

When very rapid monitoring must be done, or there are too many sites to do detailed monitoring, at the very least photos and notes can be taken by site. To do so in the most useful way possible, use the following guidelines:

Box : Tips for success with photo points

* Download, label, and back-up photo files ASAP after taking them
* Organize in folders by date, location, or both; include in folder a document file that includes accompanying information, or states where that information is filed (e.g. record book, where stored)

**Supplies needed:**

* **Record book**
* **Camera**
* **Whiteboard and marker (optional)**
* **GPS (optional)**
1. In your record book, indicate the following for each site you photograph:
	* Essential:
		+ Date
		+ Location description (GPS ideal)
		+ Site reference number
		+ Who is taking the photo and with what camera
	* Good to have:
		+ Other site descriptions, notes about what was observed at the site
		+ What numbering the camera will apply to the start shot at each site (if known).
2. Establish a permanent marker for your site in a standard location relative to the restoration site (e.g. in the down-stream, farthest from channel corner), and/or at a particularly good vantage point (e.g. from a high place, or where there is an obvious visual marker such as a large cottonwood tree). These markers should be lasting: wood or metal (e.g. stake or rebar), or associated with a permanent feature in the landscape (large tree, fence post, building, etc.).
3. Have a system for finding and identifying the marker in the future. Label the marker with a numbered metal tag and/or record GPS coordinates on record sheet.
4. A photo needs to be taken in a standard direction that will not require having the photo as a reference in the future. For example, facing each of the cardinal directions, starting with N and going clockwise, that is, N-E-S-W. A person should be in the first shot of each of these series, holding a sign board (see below).
5. Before you take any pictures at the site, write the site name, and acre plot designation with the date on the dry erase board (“whiteboard”) or paper to specify whether it is a start or end shot in a series (e.g. Disappointment Valley site 1 NORTH/start). This needs to be in the first shot you take at the very least, or can be in each shot (easiest to do if there is a whiteboard).

## Level II: *Tamarix*/target monitoring (simple)

The following method can be used for quick monitoring of efficacy of tamarisk treatments over time or for tracking plantings or other individuals of interest. It is not useful for determining change in density or cover of trees as the result of treatments, but will be helpful for adaptive management and assessing effectiveness of treatments.

Box : Tip for Success with Target Monitoring

* Beware ‘oversampling’- number of individuals you track will depend on variability. If you really need to track every tree, then do so, but otherwise a randomly selected subsample of 10 or more trees will likely be sufficient.

**Supplies needed:**

* **Record book**
* **Tags for trees (metal preferred)**
* **GPS (optional)**
1. Choose target trees within the treatment area to represent the whole. Consider identifying one tree per acre or treatment site as a minimum (see Box 2), with accessibility being a key feature of this rapid method.
2. Label with metal tags or some other ‘permanent’ marker (Forestry Suppliers has a variety to choose from with pre-stamped numbers). Record information in record book, including location information for each that can be used in the event that a marker is missing (e.g. GPS or other descriptors, such as “10 ft North of the large cottonwood closest to the road”)
3. Record status of each tree using metrics such as the following:
	1. Height class (1) <3 ft, 2) 3 -6 ft, 3) >6 ft<12 ft, 4) >12 ft)
	2. Greenness category (3) all green, (2) yellowing (some green), (1) no green (all yellow/brown) (0) no leaves
4. Presence of biocontrol (yes/no)
5. Age class: The age class is based on height/diameter same as for tamarisk age class. 1) **Seedling or Resprout**-single stem under 1m tall; if known, indicate whether seedling or resprout. 2) **Sapling**-over 2m tall but largest trunk is under 5cm in diameter. 3) **Mature**-Largest trunk is over 5cm in diameter.

## Level III: *Tamarix*/target monitoring (detailed)

The following method can be used at sites after tamarisk removal to determine efficacy of control methods. NOTE: for control sites that will have no evidence of the trees remaining (e.g. when stumps are chipped or excavator used), preliminary measures should be taken of tree density in the area that will be monitored. Sample data sheets for this method can be found in Appendix B.

**Supplies needed:**

* **Record book**
* **Site marker**
* **Meter or yard tape (50m or long enough to capture variability in the site)**
* **GPS (optional)**
1. Establish a transect through the site. In order to be subjective and repeatable, the starting place needs to be well marked and the direction of the transect clear (e.g. 3 yards from and perpendicular to the stream channel). This information should be clearly recorded in the record book.
2. On your data sheet, clearly indicate means and specific timing of control method (e.g. “basal bark application of imazapyr at concentration X, September 4-10th 2010”).
3. Walk the transect. For each tree or stump encountered within a yard on either side of your transect, indicate each of the following measures of tree status:
	1. Height class (1) <3 ft, 2) 3 -6 ft, 3) >6 ft<12 ft, 4) >12 ft)
	2. Greenness category (3) all green, (2) yellowing (some green), (1) no green (all yellow/brown) (0) no leaves
4. Presence of biocontrol (yes/no)
5. Age class: The age class is based on height/diameter same as for tamarisk age class. 1) **Seedling or Resprout**-single stem under 1m tall; if known, indicate whether seedling or resprout. 2) **Sapling**-over 2m tall but largest trunk is under 5cm in diameter. 3) **Mature**-Largest trunk is over 5cm in diameter.
6. Nearest neighbor distance (when density measure is desired)

## Level IV: Complete vegetation monitoring

The point intercept method (also referred to as PO and “line point intercept”) can be used to characterize substrates and document the major plant species (or vegetation categories, see Box 3) present along transect lines perpendicular to the water’s edge. It has the following advantages:

1. It more objective than plot sampling
2. It is quick and easy
3. It requires very little equipment (rod, tape measure, compass)
4. It works in riparian systems

Our own field testing of the point intercept method was consistent with other studies that have found it to be highly accurate and efficient (Knapp 1984, Caratti 2006). It is understood that this method will under-sample rare species in favor of speed and accuracy for measuring more abundant species. If accurate cover of rarer species is desired, more points can be collected, or the modified Whittaker (level V) used. Sample data sheets for this method can be found in Appendix B.

Box : Tips for Success in Vegetation Monitoring

* This method can be used to track specific species or categories of species (grass vs. forb, or exotic vs native); the more general the category, the faster the data collection will be, but it is usually better to get more information than less.
* Create a system for referring to species/category, make a key in your record book, and BE CONSISTENT. Sometimes referring to Cheatgrass as “cheat” and other times as “Bromus” can get you in trouble later. Similarly, using “invasive” sometimes and “exotic” others (when they are referring to the same thing) can be misleading.

**Supplies needed:**

* **Record book**
* **Site marker**
* **2 measuring tapes (or 1 tape and 1 rope)**
* **1 yd rebar or other rod to serve as “point”**
* **GPS (optional)**
* **Compass (optional)**
* **Plant press and/or camera (to later identify unknown species, optional)**
1. Fill out site information on the top of your datasheet in your record book.
2. Establish your acre plot in a representative area of the site. If no such ‘representative acre’ exists, you can separate into two, or establish two (or more) acre-plots. Note that if a site is narrow, the shape of the acre plot will be different, and longer than 1 acre. Put a permanent marker and GPS the downstream, closest to river corner of the plot.
3. We will use a 0.75cm diameter, 2m tall point and take a reading every 0.25m, providing 200 points per transect for a 50m transect and 1000 points/acre if 5 transects are run. Determine how many transect lines you will run within your restoration area, perpendicular to the channel, to obtain 1000 points. If there are obvious breaks in vegetation reflecting geologic or historical (management or disturbance) differences, make sure you have enough lines to capture all of this variability. For a general rule of thumb, there should be a minimum of 5 transects run per acre.
4. Placement of these lines should be random along the channel, within each of any pre-determined breaks in vegetation. To establish these random start points, use the 1/10 second feature available on most stop watches to determine distances between transects, between 1 m and 20 m, depending on size of area being monitored. If the number generated is greater than this, the digits can be summed.
5. Run the measuring tape perpendicular to the channel until you reach the far edge of the area you are interested in monitoring. A compass may be useful for maintaining direction. The idea is to capture as much as the variability as possible that may occur as you move away from the water. If your area is extremely wide (e.g. > .5 mile), you may have to do a series of 50 m lines. Optimal length of line will be between approximately 10 and 50 m.
6. For each point: We will note the species identity of all live plants in contact with the pole, or in the case of very high overstory, would contact the pole should it continue indefinitely into the sky. To read, stand on the left and read the pole on the right facing downstream from 0 point or beginning of transect. Place a dot in the space provided when each species is encountered, entering new species as they are encountered. If there is an unknown species, either create a code for it and collect it in the plant press (and/or photograph it) for future identification (preferred) or simply create a general ‘unknown’ category in the species list.[[3]](#footnote-3) Add pages as needed, indicating page number in the space provided. If the species is a tree, tally dead trees as well, indicating status of the species (living or appears dead) in the space provided.
7. When finished with an acre plot, add the dots for each species along each transect in the space provided.

## Level V: Modified Whittaker plots

Modified-Whittaker plots ([Stohlgren et al. 1995b](#_ENREF_20)) are specifically designed to capture species diversity by using a nested plot design, typically with plots that measure 1 m2, 10 m2, 100 m2, and 1000 m2. Establishing the macro-plots can be very difficult and time intensive, especially in dense vegetation, but if an area is open and easy to transverse, this method is preferable to even the point intercept method. It is fastest, best for obtaining a near-complete species count, and can be used for capturing percent cover of understory vegetation (in the smallestplots), and overstory cover (in the next larger plots). Richness (species numbers) are counted for all sizes. It should be noted that the .5m x 2m sampling quadrats are cumbersome to carry, and our own research found no difference between 1m2 and 0.5m2 plots, however we did find a difference in the amount of richness captured in oblong vs. square plots[[4]](#footnote-4). Thus, we recommend a Modified-Whittaker plot with the dimensions described in Figure 1.

Ocular estimates of cover in plots are subjective, and prone to inter-observer error. However, we have found that this error can be greatly decreased with a few minutes of training such that at least everyone within a field crew will have similar estimates (e.g. ‘this is what 50% looks like’). Instructions on how to do Whittaker plots can be found in Appendix A and in Stohlgren et al. (1995).

**Supplies needed:**

* **Record book**
* **Site marker**
* **2 yard or meter tapes (100m and 50m ideal)**
* **PVC pipe 1m2** plot (.5m x 2m)
* **GPS (optional)**
* **Compass (optional)**
* **Plant press and/or camera (to later identify unknown species, optional)**

A

B

a

b

c

d

e

f

j

i

h

g

4m

1.5m

15m

4m

15m

40m

Figure : Modified Whittaker sampling plot is 600 m2 with 1 – 60 m2 subplot, 2 – 6 m2 subplots (A & B), and 10 – 1 m2 subplots (a – j, 0.5 x 2 m), from ([Bay 2006](#_ENREF_3)).

## Non-vegetative sampling

The following are from the Dolores Monitoring Protocol ([Sher 2010](#_ENREF_16)). More detailed geomorphology sampling, designed by Chris Massingill, can be found in that document.

### Soil Survey

1. Five random points shall be selected along each of three transects per site for the measurement of soil pH, soil moisture content, soil temperature and soil salinity using instrumentation (if available) or by collection into well-marked bags (plastic or paper) for analysis in the lab.
2. If collecting soil, the top 6 inches should be dug using a soil auger (ideal) or trowel, taking care to get equal proportions of each depth. Soils from each transect can be combined in to a composite sample for analysis (i.e. 5 bags per acre plot). These should be stored in a cool, dry place until they can be sent for characterization (e.g. CSU Soil Testing Lab). For soil texture, can characterize using flow diagram from NRCS- Modified from S.J. Thien. 1979. *A flow diagram for teaching texture by feel analysis.* Journal of Agronomic Education. 8:54-55. <http://soils.usda.gov/education/resources/lessons/texture/>

### Geomorphology

1. We recommend that slope, aspect, and elevation should be recorded for each of the five transects in each acre-plot.
2. Slope is measured from the termini of each transect to the channel bank. Note that it is not possible with low tech methods to take slope measurements before tamarisk removal.
3. Aspect is determined with a compass.
4. Elevation is measured at the beginning and end of each transect using a GPS instrument.

# Literature Cited

Anderson, R., G. Richard, A. Wilcox, D. Merritt, J. Siscoe, D. Graf, A. Mäki-Petäys, B. Nehring, D. Kriegshauser, and P. Somers. 2005. Core Science Report For The Dolores River Dialogue (July 2005). Pages 1-136.

AOAD. 1982. Range Land Survey and Development in Libya., Libya.

Bay, R. F. 2006. Success of Active Revegetation After *Tamarix* spp. Removal in Southwestern Riparian Ecosystems: A quantitative Assessment of Past Restoration Projects. . University of Denver.

Brady, W. W., J. E. Mitchell, C. D. Bonham, and J. W. Cook. 1995. Assessing the Power of the Point-Line Transect to Monitor Changes in Plant Basal Cover. Journal of Range Management **48**:187-190.

Campbell, P., J. Comiskey, A. Alonso, F. Dallmeier, P. Nunez, H. Beltran, S. Baldeon, W. Nauray, R. De La Colina, L. Acurio, and S. Udvardy. 2002. Modified whittaker plots as an assessment and monitoring tool for vegetation in a lowland tropical rainforest. Environmental Monitoring and Assessment **76**:19-41.

Caratti, John F.  2006.  Point Intercept (PO).   In: Lutes, Duncan C.; Keane, Robert E.; Caratti, John F.; Key, Carl H.; Benson, Nathan C.; Sutherland, Steve; Gangi, Larry J. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. PO-1-17.

Clark, P. J. and F. C. Evans. 1954. Distance to Nearest Neighbor as a Measure of Spatial Relationships in Populations. Ecology **35**:445-453.

Floyd, D. A. and J. E. Anderson. 1987. A Comparison of Three Methods for Estimating Plant Cover. Journal of Ecology **75**:221-228.

Heady, H. F., R. P. Gibbens, and R. W. Powell. 1959. A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation. Jour Range Management **12**:180-188.

Jimenez-Valverde, A. 2012. Insights into the area under the receiver operating characteristic curve (AUC) as a discrimination measure in species distribution modelling. Global Ecology and Biogeography **21**:498-507.

Knapp, R. Ed. 1984. Sampling methods and taxon analysis in vegetation science. Handbook of Vegetation Science 1. Part 4. Hague.

Lawrey, J. D. 1991. The Species-Area Curve as an Index of Disturbance in Saxicolous Lichen Communities. Bryologist **94**:377-382.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. Wiley, New York,.

Ohrtman, M., A. Sher, and K. Lair. 2012. Quantifying soil salinity in areas invaded by< i> Tamarix</i> spp. Journal of Arid Environments **85**:114-121.

Rice, E. L. and R. W. Kelting. 1955. The species-area curve. Ecology **36**:7-11.

Scott, M. L., E. W. Reynolds, Northern and Southern Colorado Plateau Park Networks., and Geological Survey (U.S.). 2007. Field-based evaluations of sampling techniques to support long-term monitoring of riparian ecosystems along wadeable streams on the Colorado Plateau. Pages iv, 57 p. digital, PDF file. Open-file report 2007-1266. U.S. Geological Survey,, Reston, Va.

Shafroth, P. B., V. B. Beauchamp, M. K. Briggs, K. Lair, M. L. Scott, and A. A. Sher. 2008. Planning riparian restoration in the context of Tamarix control in western North America. Restoration Ecology **16**:97-112.

Sher, A. 2010. Dolores Monitoring Protocol. Dolores River Restoration Partnership Monitoring Subcomittee, University of Denver.

Sher, A. A., S. Gieck, C. S. Brown, and S. J. Nissen. 2008. First-year responses of cheatgrass following Tamarix spp. control and restoration-related disturbances. Restoration Ecology **16**:129-135.

Sher, A. A., D. L. Marshall, and S. A. Gilbert. 2000. Competition between native Populus deltoides and invasive Tamarix ramosissima and the implications for reestablishing flooding disturbance. Conservation Biology **14**:1744-1754.

Stohlgren, T. J., M. B. Falkner, and L. D. Schell. 1995a. A Modified-Whittaker nested vegetation sampling method. Kluwer Academic Publishers **117**:113-121.

Stohlgren, T. J., M. B. Falkner, and L. D. Schell. 1995b. A Modified-Whittaker nested vegetation sampling method. Vegetatio **117**:113-121.

Wade, G. L. and R. L. Thompson. 1991. The Species-Area Curve and Regional Floras USA. Transactions of the Kentucky Academy of Science **52**:21-26.

Whitman, W. C. and E. I. Siggeirsson. 1954. Comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. Ecology **35**:431-436.

# Appendices

## Appendix : Methods Tested[[5]](#footnote-5)

Figure *: Sampling design used. Each quadrat contains nested 1, 10, 100 and 1000m2 Modified Whittaker sampling plots, as well as five randomly placed 50m line transects, each containing 10 1m2 quadrats. Transects were used for ---list methods here--- (figure adapted from one created by R. Bay, based on Stohlgren et al. 1995).*

**Nested Whittaker plots (modified Whittaker)**

Also known as the nested quadrat method, the main plot area is 1000m2 with dimensions of 20m x 50m, placed perpendicular to the stream (Figure 2). Within the main plot, several smaller plots of various sizes are distributed throughout to measure different vegetative parameters. Ten small quadrats with dimensions of 0.5m x 2m are distributed evenly around the inside edges (three in each of 50m sides and two in each of the 20m sides), for a total area 10m2. Two 2mx 5m quadrats (for a total of 20m2) and one 5m x 20m quadrat (for a total of 100m2) are placed in the center of the main plot. In sites where the 20m x 50m plot would not fit (two sites out of the 25), we used Whittaker plots with the dimension of 25m x 40m (parallel with the stream) in order to keep the total areas consistent.

This method provides measurement of percent cover for understory vegetation (herbaceous & shrubs) plus species richness ([Stohlgren et al. 1995a](#_ENREF_19), [Campbell et al. 2002](#_ENREF_5)). The 5m x 20m quadrat located in the center of Whittaker plot ware also used for woody visual estimate only for the comparison of combined method.

**Line-point intercept**

In this method, by using a stratified random method, I placed five 50m transects inside the Whittaker plot, one line-transect per interval of four meters. I then recorded all plants that intercept a point on the line-transect every 10cm. Therefore, each of the five transects had a total of 500 points, giving 2500 points for each site. In cases where more than one species was present in a single point (if the vegetation overlapped) and when understory and overstory vegetation was present, all plants were recorded in that point. The percent cover was calculated for each transect as the total number of points for plant species (A) that intercepted with the line-transect divided by total number of points along the transect (500) multiplied by 100. This method was used to calculate the percent cover for both over and understory vegetation, as well as for species richness.

Line-point intercept is a common method that has been used for vegetation measurements and detecting vegetation response after invasive removal ([Whitman and Siggeirsson 1954](#_ENREF_22), [Heady et al. 1959](#_ENREF_8), [Mueller-Dombois and Ellenberg 1974](#_ENREF_11), [Floyd and Anderson 1987](#_ENREF_7), [Brady et al. 1995](#_ENREF_4), [Sher et al. 2000](#_ENREF_18), [Anderson et al. 2005](#_ENREF_1), [Scott et al. 2007](#_ENREF_14), [Sher et al. 2008](#_ENREF_17)). This method is also preferred in cases when the majority of different vegetation types and richness in the ecosystem are targeted for monitoring ([Floyd and Anderson 1987](#_ENREF_7)).

**Nearest neighbor:**

In this method we recorded the trees that intercepted with the line-transects and the distance to the nearest neighbor to each tree intercepted ([Clark and Evans 1954](#_ENREF_6)). This method is used for the comparison woody species richness and for time efficiency comparison.

**Line transect:**

This method was used to calculate and compare both species richness and percent cover of woody species. I recorded the width of the canopy for trees vegetation to measure the vegetation cover by species. The percent cover was calculated as the total length of plant species (A) that intercepted with the line-transect divided by the length of the-transect, multiplied by 100. It has been indicated that this method is objective and requires less time when the monitoring of only woody vegetation is desired ([Heady et al. 1959](#_ENREF_8)). The same method was used to calculate the density of woody vegetation (Chapter 4).

**One-meter square quadrats:**

In this method, ten 1m2 quadrats were randomly placed in every five-meter intervals on each transect. This method was used to measure and compare the percent cover of understory vegetation and species richness. This method was also used to calculate three parameters for understory vegetation: density, frequency, and cover, then the Importance Value (IV), which is the summation of relative density, relative frequency, and relative cover (Chapter 4). With IV, we assess the most important plant species in the area as a way of defining the plant communities, including change over time ([AOAD 1982](#_ENREF_2)).

**Densiometer:**

This method was added in the year of 2012 and combined with the quadrat method for time efficiency comparison and used to estimate the percent of overstory vegetation cover, whereas the quadrat method used to estimate the cover percentage of understory vegetation. Using stratified random method, the center of each 1m2 in the quadrat method were used to locate and take the estimated cover by spherical

convex densiometer instrument (Figure 3).

I compared time efficiency of five different methodologies (Nested Whittaker plots, line-point intercept, nearest neighbor, line transect, and 1m2 quadrats) in a natural population of riparian zone ecosystem in 2011. Comparison of time efficiency between these five methods was recorded in six sites, three in the east slope with three various levels of diversity (low, medium, and high) and three in the west slope with three different level of density (low, medium, and high). Some of the above methods were combined to measure the time it took to sample both over- and understory vegetation:

Figure : Spherical convex densitometer

1. Line-point transect vs. quadrat plus densiometer vs. line-intercept plus quadrat vs. Whittaker plot. These methods were used for precision of measuring total cover percentage and time efficiency comparison.
2. Line-point intercept vs. line intercept vs. densiometer vs. Whittaker for species richness and overstory cover percentage comparison.

 Given that line-point intercept is the only method that measures both over and understory vegetation, I expected that it would be more efficient than a combination of 1m2 quadrats plus line intercept methods if the measurement of all vegetation types (e.g. over and understory vegetation) are desired.

 Even though the plot size in our study has been determined using the species area curve ([Rice and Kelting 1955](#_ENREF_13), [Lawrey 1991](#_ENREF_10), [Wade and Thompson 1991](#_ENREF_21), [Jimenez-Valverde 2012](#_ENREF_9)) (Figure 12), this relatively large plot (1m2)was difficult to establish in certain vegetation types (e.g. under very dense New Mexican privet, *Forestiera pubescens*). For that reason, we tested whether we can reduce the plot size and get the same accuracy in monitoring the percent cover in such riparian ecosystems. Also, we tested the hypothesis that an oblong shaped plot will capture more species compared with the square shape of equal area.

## Appendix : data sheets

## Data sheets for vegetation monitoring

Line Point Intercept From: Caratti, John F.  2006.  Point Intercept (PO).   In: Lutes, Duncan C.; Keane, Robert E.; Caratti, John F.; Key, Carl H.; Benson, Nathan C.; Sutherland, Steve; Gangi, Larry J. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. PO-1-17.

Note: Project ID is the site

Plot is the Acre plot # INCLUDE GPS of downstream, closest to stream plot marker

**Point Intercept (PO) Form**

**Transects**

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

RegistrationID: \_

\_ \_ \_

PO Page \_

\_ of \_ \_

ProjectID: \_

Plot Key

\_ \_ \_ \_

\_ \_ \_

PlotID: \_ \_ \_

Species

Transect 1

Hits

Height

(ft/m)

Transect 2 Transect 3

Hits Hits

HHeeiightght

(f(ftt//m)m)

HHeeiightght

(f(ftt//m)m)

Transect 4 Transect 5

Hits Hits

HHeeiightght

(f(ftt//m)m)

HHeeiightght

(f(ftt//m)m)

Notes:

Item

Code

Including list of species seen but not encountered by points

Dot Tally Space

Adapted From: Caratti, J.F. 2006. Point Intercept (PO). In: Lutes, D. C. et al. FIREMON. Gen. Tech. Rep. RMRS-GTR-164- CD. Fort Collins, CO: USDA FS, Rocky Mountain Research Station. p. PO-1-17.

TREE DATA SHEET

(note: when possible, GPS trees that are encountered on the line. If there are important trees of interest at the site you wish to document (e.g. a large cottonwood), add these here as well, and explain in the additional notes).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (ref. only)1 | Date: | Site: | AcrePiot | **Transect**# | GPS**transect** | **Tree species** | Height**Class** | **Greenness** | **Presence of beetles** Y/N | **ageclass** | NND (optional) | **Additional****Notes:** |
|  |  |  |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |  |  |  |  |
| 8 |  |  |  |  |  |  |  |  |  |  |  |  |
| 9 |  |  |  |  |  |  |  |  |  |  |  |  |
| 10 |  |  |  |  |  |  |  |  |  |  |  |  |
| 11 |  |  |  |  |  |  |  |  |  |  |  |  |
| 12 |  |  |  |  |  |  |  |  |  |  |  |  |
| 13 |  |  |  |  |  |  |  |  |  |  |  |  |
| 14 |  |  |  |  |  |  |  |  |  |  |  |  |

1. \* These protocols are still under development; we encourage your feedback. A manual will be developed for distribution by 2014. Please contact anna.sher@du.edu [↑](#footnote-ref-1)
2. TNC Contract 02052010, “CWCB Dolores River”, exhibit A, Scope of Work p 1 and SE Colorado Tamarisk Removal Monitoring Project, attachment 1A, p 1 [↑](#footnote-ref-2)
3. For the ability to identify a plant later, it is important that at least a portion of the root be collected/photographed (to determine whether it is an annual or perennial), as well as reproductive structures (flowers and/or fruit). Even with these, there are some species that grow in these ecosystems that are nearly impossible to positively identify to species without genetic analysis, but these cases are very rare. [↑](#footnote-ref-3)
4. Third Annual Report. 2013. Submitted by A. Sher to The Nature Conservancy and the Branson Trinchera Conservation District. [↑](#footnote-ref-4)
5. From El Waer, H. 2013. Chapter 3: Comparing different sampling methodologies. Doctoral Dissertation, University of Denver, Denver, CO. [↑](#footnote-ref-5)