NATURAL RESOURCE SURVEY AND INVENTORY

B-BAR RANCH, MONTANA

Capstone Class
Land Resources and Environmental Sciences
Montana State University
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1. Introduction

Traditional large-scale agriculture operations are progressing from a focus on production into a focus on conservation and holistic practices. The goals of these ranches are shifting from quantity production to quality use of the land resources available. To do this effectively, natural resource inventories are necessary to make ranch managers aware of what assets are available to make the best management decisions for the property. The Land Resources and Environmental Sciences senior capstone course for 2005 performed natural resource inventories and surveys for the B-Bar Ranch. The course is designed to give students in the LRES department a chance to apply knowledge gained in previous coursework to a field management problem. The overarching goal of the B-Bar study was to create baseline data by monitoring soils, hydrology, and vegetation and developing maps to provide spatial reference of natural resources and ranch infrastructure.

The goal of the soils group was to determine the accuracy of the NRCS soils map for the Davis meadow, assess soil fertility to maximize hay production, and look at the effects of a change in irrigation on the soil. The hydrology objectives were to analyze ecosystem structure and function based on clean water act parameters for physical, chemical, and biological components of the Tom Miner Creek. The vegetation group's objectives were to describe the tarweed community on ranch property and the impact of vinegar as a natural control method. The spatial group's objectives were to create baseline natural resource maps that the ranch could use to implement their management practices. The data collected by the capstone students can be used to recommend management strategies and to provide baseline data for future monitoring of resources.

The B-Bar Ranch is one of many ranches redirecting their practices from production towards the newer thought of conservation management. Located 39 miles south of Livingston, Montana in the upper end of the Tom Miner Basin (Figure 1.1), the B-Bar Ranch operates under the objectives of restoring natural character, maintaining ecosystem health, following low impact sustainable agriculture, and being a leader in rare breed conservation.

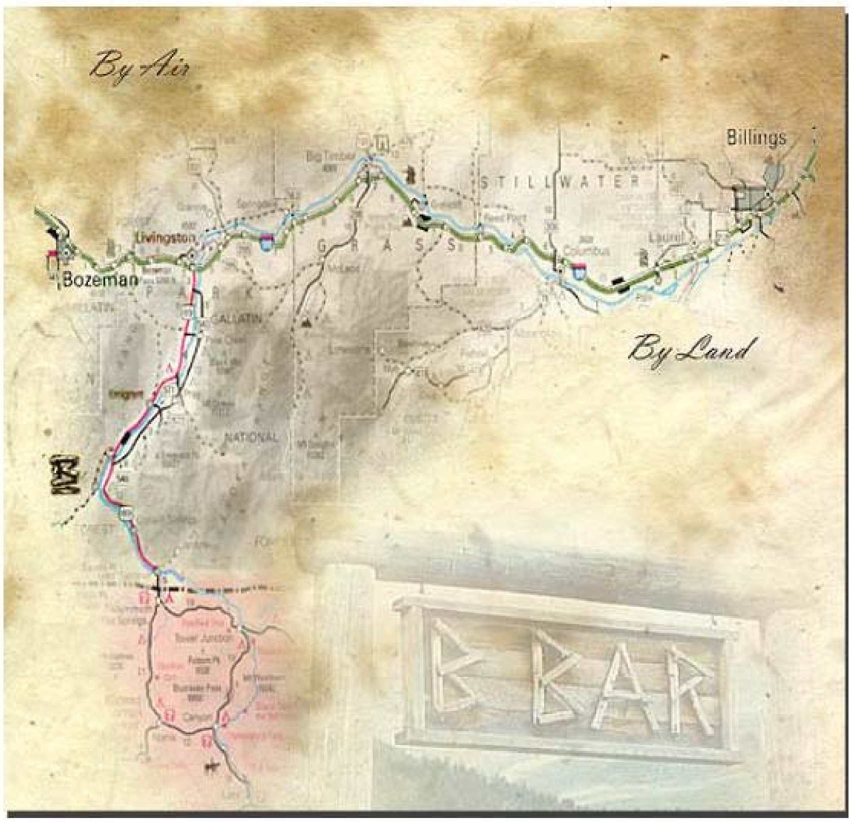


Figure 1.1 The B-Bar Ranch is located 39 miles south of Livingston, MT on the border of Yellowstone National Park.

Purchased by the current owners in 1978, the ranch is composed of 9,000 owned acres and 11,000 acres leased from surrounding forest service lands. Two thirds of the property is forested and riparian areas. The ranch property is surrounded by Gallatin

National Forest Lands and shares its southern watershed boundary with Yellowstone National Park. These natural forest and riparian areas provide habitat for a diverse variety of Montana's fauna including elk, deer, moose, black and grizzly bear, bighorn sheep, mountain lion, lynx, porcupine, badger, beaver, coyote, marmot, and an abundance of bird species. The other third of the property is devoted to agriculture, all of which is holistically managed. Water is diverted from streams for irrigation of the 200-270 tons of hay and grain crops harvested from a single cut per growing season.

The two species the B-Bar strives to preserve are the White Park Cattle and the Suffolk Punch Draft Horse. Both species are originally from England and preserved at the ranch with the hopes that the genetic value of these species will be sustained for future use. During the time of the capstone study, the ranch supported 25 head of cattle. The international population of Suffolk Punch Draft Horses is 1350 and 35 of them are cared for at the B-Bar ranch. The horses are used to harvest 50-70 tons of hay each season. Although the property is not operating as a dude ranch for visitors, the ranch owners let non-profit environmental groups use their facilities for conferences.

2. Spatial Analysis

The goal of the spatial group was to use a Geographic Information System, or GIS, to create maps where data can be visually displayed and spatially referenced. A baseline map (Figure 2.1) of the B-Bar Ranch was created using Global Positioning System (GPS) data, geographic information and GIS software. This map includes pastures, roads, irrigation ditches, headgates, pipelines, ponds and streams. The spatial group used a GPS to map irrigation ditches, pipelines, ponds and head gates in the field. The pastures were delineated manually from points previously collected by the B-Bar staff. The digital orthoquadrangle (DOQ), stream and road information was obtained from the Montana Natural Resource Information System (NRIS) website. (http://nris.state.mt.us/)

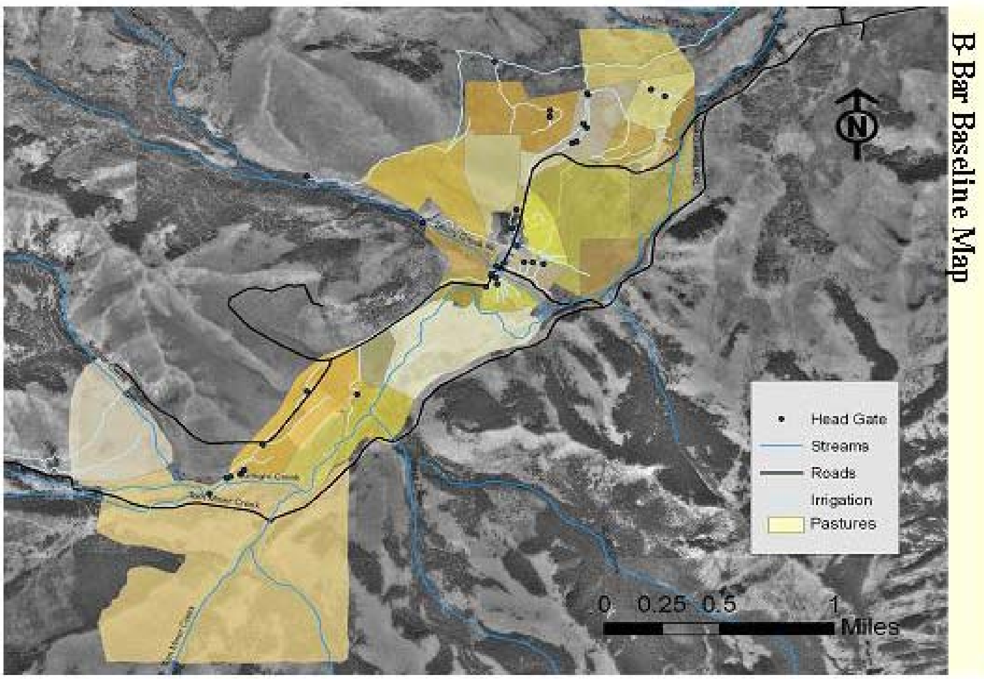


Figure 2.1 Baseline map of pastures, roads, irrigation ditches, head gates and streams.

A map was created to display the Tom Miner watershed (A1.1). This map provides the ability to consider larger scale hydrological processes that influence water quality of Tom Miner creek, and soil erosion and deposition events that occur in the pastures. Delineation was done using a digital flow accumulation function the pasture layer was brought in for spatial reference. The stream layer was brought in to show all the streams within the watershed and the DOQ is used for spatial reference.

A precipitation map (A1.2) was created utilizing statewide precipitation data obtained from NRIS and displayed across the Tom Miner watershed. This map could provide further insight into hydrological processes and be used to create erosion models.

The slope and aspect map (A1.3) was created using a digital elevation model (DEM). This map is could be useful for understanding general vegetation type and distribution and soil formation. Aspect information could also be used if the B-Bar ranch managers were interested in using solar panels to generate electricity on the property. The landownership map (A1.4) was made by using a DOQ and a statewide map of landownership obtained from the NRIS website and applied to the watershed. The map is useful for understanding location in the watershed and securing water rights.

The following habitat maps (A1.5- 1.8) show some of the different wildlife species and their distribution on and around the ranch property. The wildlife distribution data was obtained from NRIS and display on the DOQ. Streams and pastures layers were included in these maps to provide spatial reference. These can be used to implement grazing plans for the domestic breeds on the ranch. Knowledge of the wildlife habitat in the area is important for sustaining the native species diversity on the ranch. These maps will also be useful for preventing disruption of the wildlife that share their homes with the ranch.

Future capstone classes may wish to utilize the GPS data set and GIS applications by conducting analysis based on the spatial distribution data. Future GPS data collection on the ranch could include mapping of riparian areas, structures, and any other feature that the ranch requests. Future analysis could be performed to create maps and databases showing areas susceptible to erosion, soil distribution, vegetation classification, and crop yield.

3. Soils

3a. Introduction

An assessment of soil conditions in the Davis meadow was performed as part of the B-Bar ranch natural resource inventory. The meadows are the primary haying and grazing areas of the ranch. Both are located southwest to the ranch's main buildings. At an elevation of 2011 m, the ranch manager estimates that the growing season lasts between 30 and 60 days per year. Dominant vegetation includes a mix of timothy (*Phleum pretense*) and smooth brome (*Bromus hordesceus*); weedy species such as thistles (*Cirsium arvense, Cirsium vulgar*) and houndstongue *(Hieracium cynoglossoides*) were also present. To sustain an annual yield of one ton of hay per acre year, the meadow is flood irrigated from May until June using water from adjacent Tom Miner Creek. Use of livestock after haying provides the only source of input. The Davis meadow is the ranch's primary source of hay production, hence a thorough understanding of the soils is needed to promote sound land management practices that will enhance soil fertility and ultimately ensure optimal vegetative growth

Soil fertility encompasses the dynamic nature of the soil and includes such properties as texture, organic matter content, hydrology, pH, and nutrient availability (Haynes 2005). Soil properties within the B-Bar ranch have been documented on survey maps developed by the Natural Resources and Conservation Service (NRCS). The Davis meadow lies within the Foolhen-Slocum-Shewag complex (unit 1219); the soil types within the unit are classified as Mollisols. The suborders include aquic for the Foolhen soil and cryic for both the Slocum and Shewag. Requirements for a Mollic order include a mollic epipedon with a base saturation of $\geq$ 50%, organic carbon content of $\geq$ 0.6%, and a Munsell value/chroma of ≤ 2. Unfortunately, map units of representative soil series commonly comprise only 40-50% of the soils designated in the mapping unit name (Pennock 1987). Because soil variability exists within map units, it is crucial to identify areas of similar soil properties and manage accordingly.

Soil nutrient levels are also important for crop production, as they can determine plant biomass capacities (Chapin 1986). Unfortunately, nutrient testing has never been conducted in either meadow. Nutrient testing data can aid the land used in making management decisions. Nutrient testing often includes nitrate, phosphorus, ammonia and carbon. These are some of the nutrients that potentially could be limited within soils typical of this region.

Familiarity with possible effects of irrigation on soil properties is imperative because supplemental water is used to sustain the current hay yield. Water applied in excess or at inappropriate times may cause large losses of mobile nutrients, particularly of nitrogen (Cook 1986). The B-Bar manager indicated interest in switching from flood irrigation to sprinkler irrigation therefore the pros and cons of both irrigation types and their impacts on soil quality and vegetation production were investigated.

With consideration to the issues addressed, specific objectives of this project were to first ascertain whether soil variability within the Davis meadow is reflected in NRCS soil map unit 1219. Secondly, to assess soil fertility to determine whether nutrients are limiting hay production and address concerns related to proposed changes in irrigation practices.

3b. Materials and Methods

Soil samples were collected August 23-24, 2005 from the Davis meadow. Ten transects were created to allow for systematic sampling (Figure 3.1). Sample cores using a corer with a 5.7 cm diameter were taken from 0-10 and 10-30 cm depths in the soil at 15 paces along each transect. Soil texture, color, and dominant vegetation were recorded at even sites. Spatial location of each sample was recorded by a Trimble GeoXT GPS receiver capable of submitter accuracy. Three soil profiles were examined; two located on opposite sides of Tom Miner Creek, and the third in the hayed portion of the Davis meadow next to an irrigation ditch. Dominant horizons, indicated by texture, structure, effervescence, roots, and color were identified.

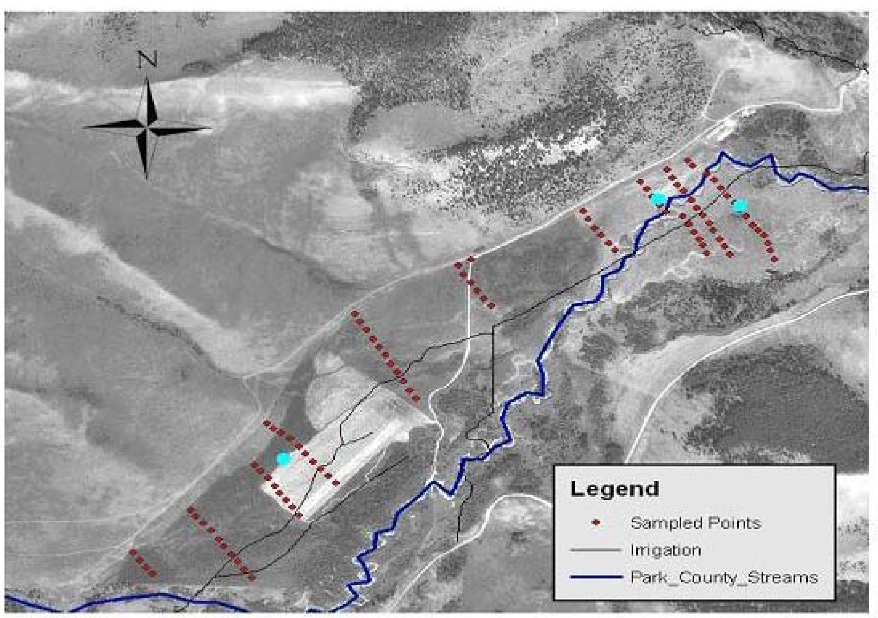


Figure 3.1: Transects and sample points in the Davis meadow. Soil profile sites are indicated by blue markers.

Soil samples were dried at 50 °C for 48 hours, then weighed dry. Coarse fragments greater than 2 mm diameter, along with plant biomass, were removed and weighed. Soil samples were finely ground into a powder using a mortar and pestle and prepared for storage. Samples prepared for carbon and total nitrogen were milled to fine powder in a ball mill (Pica Blender Model 2601).

Lab analysis of Bray phosphorus, nitrate and texture were conducted at the University of Nebraska, Lincoln, while electrical conductivity (EC), inorganic and total C, total nitrogen, and pH were tested at Montana State University. EC was tested with an Oaklon ECTestr High EC probe and pH was determined using Chlorophenol Red and Bromothymol Blue indicators. Total carbon and nitrogen were measured by combustion using a LECO TrueSpec C/N analyzer, and inorganic carbon was obtained using a modified pressure calcimeter method (Sherrod, et al. 2002). Organic carbon was assessed by subtracting the inorganic carbon from total carbon, from which percent organic matter was determined by the Walkey-Black Method (Recommended Soil Test Procedures 1998). Results were spatially depicted using ArcMap 9.0 Geographic Information System software. A summary of analyzed soil properties can be found in Table 1.

3c. Results

Textural Variability: Based on observational and quantitative analysis, some soil variability exists in the Davis meadow. Much of this variability is evident in the three soil profiles. The black matrix, abundance of roots, and strong granular structure found within the Ap horizon (0-23 cm) of Profile One indicate relatively high organic matter content typical of a Mollic epipedon (Figure 3.2). Buried A-horizons, observed at 64-65, 95-96 and 115-117.5 cm, suggest periods of flooding. Both flood evidence and Mollic soil properties are consistent with the NRCS description for this unit.

The profiles near the creek, however, did show variation from the NRCS depiction of Mollic soils within the meadow. Profile Two, north of the stream bank, had a shallow A-horizon developing over a thick alluvial deposit with large fragments (Figure

3.3). A depositional layer underlying a thin A-horizon was also observed in Profile Three, located south of the stream (Figure 3.4). However, the alluvial material in this profile was silt-sized and lacking in large fragments. Buried A-horizons were observed in both profiles. Because the A-horizons for these two profiles are so shallow, it is unlikely that they meet Mollic depth requirements ($\geq$ 18 cm). Differences in depositional material may reflect stream characteristics at the time of flooding. Floodwater may have been more turbulent on the northern side, allowing larger material to be deposited.

Figure 3.2: Soil Profile One, with a deep OM-rich surface and buried A-horizon.

Figure 3.3: Soil Profile Two, with evidence of alluvial deposition overlying buried A.

Figure 3.4: Soil Profile Three, with silt-sized alluvial deposits overlying a buried A- horizon

Variability in soil texture is also apparent across the landscape. From the southwestern to the central portion of the Davis meadow, texture is predominately loam and sandy clay loam (Figure 3.5). A range of textures, including more clayey soils, is observed towards the northeastern corner, indicating hydrologic influence on substrate size.

Nutrient Variability:

Nutrient levels were found to vary within the sampled area. Phosphorus in the soil from the un-hayed field was about twice as high as levels from the hayed field soil, with more variability within the un-hayed field soils (Figure 3.6). The decrease in variability could be the result of the

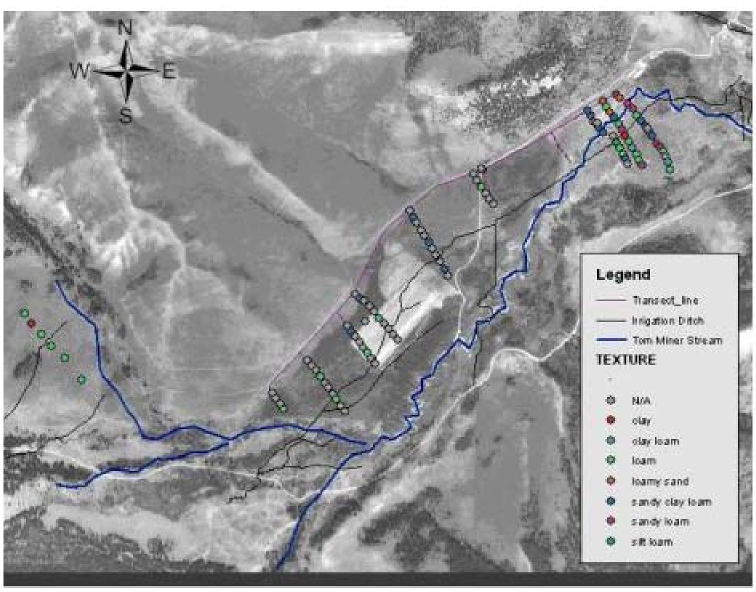


Figure 3.5: Spatial distribution of texture across the Davis meadow. Texture is primarilyloam and sandy clay loam to the southwest and becomes varied in the northeast corner, near Tom Miner Creek.

removal of nutrients with harvested biomass because the soil measurements were taken at the end of the growing season. Areas of sandier soils and optimal pH (between 5 and 7) may create a situation where phosphorus is quite mobile and may leach below the vadose zone and into the groundwater. Phosphorus leaching concerns are further discussed under management implications.

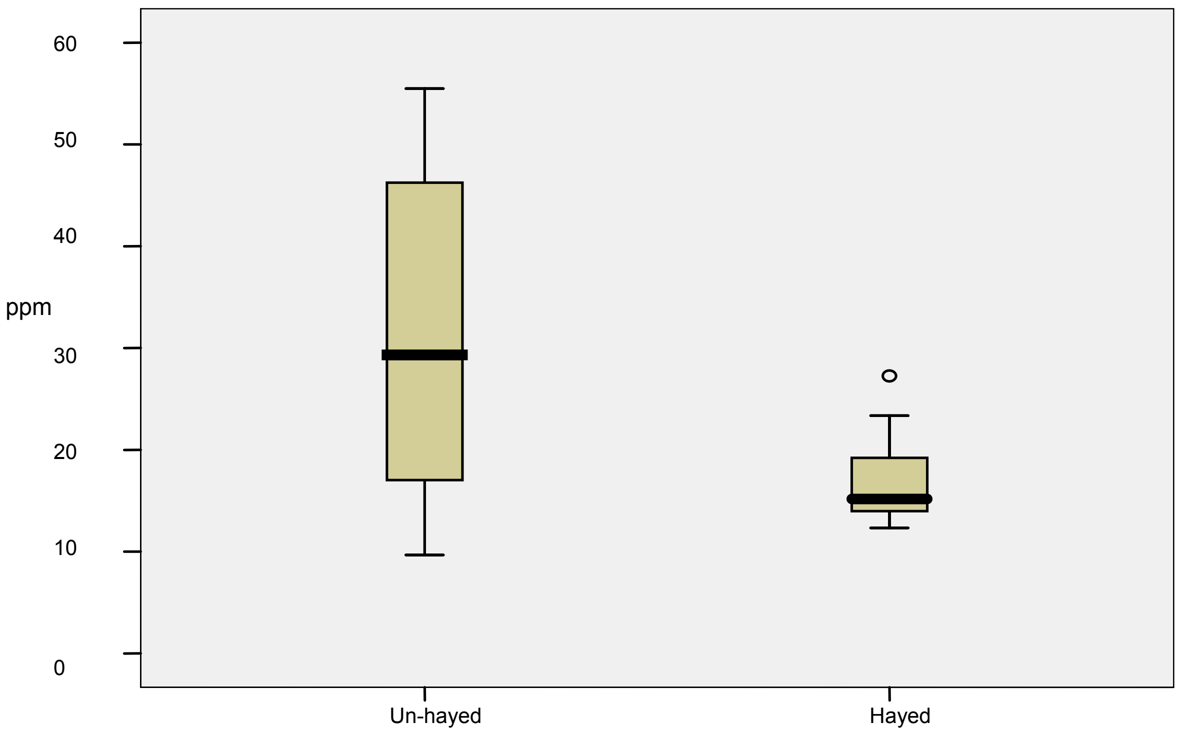


Fig. 3.6 Phosphorus concentrations in un-hayed and hayed portions of Davis meadow. Dark black indicates median, whiskers indicate maximum and minimum values.

Organic matter levels also showed variability across the floodplain. Figure 3.7 shows that greater variability in organic matter content was observed within the un-hayed field than in the hayed field. This was not surprising, as cultivation within a field tends to create a more homogenous soil.

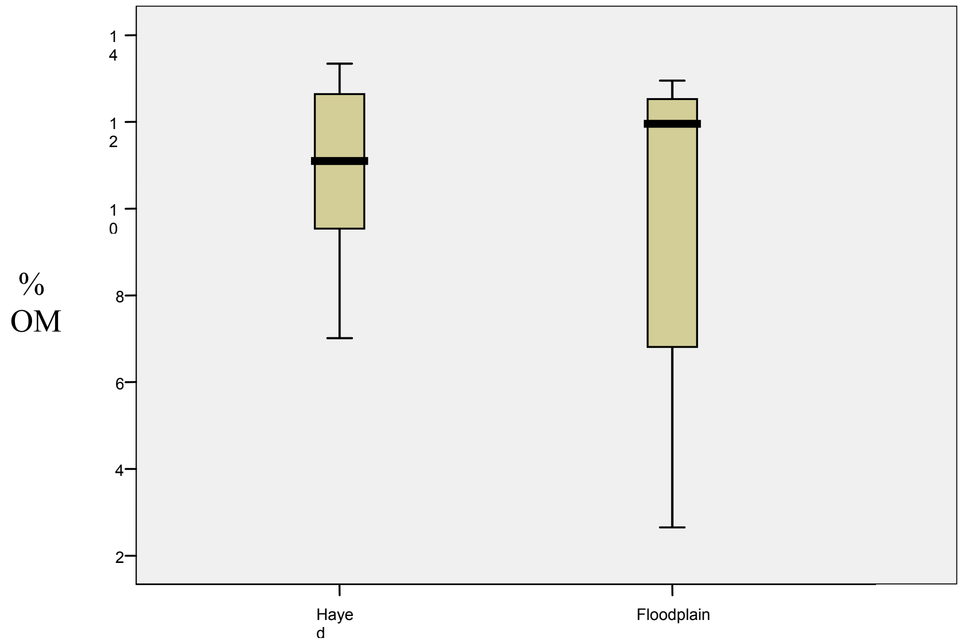


Fig.3.7 Percent organic matter in hayed portions of Davis meadow, and within the floodplain near Tom Miner Creek. Dark line indicates median, whiskers indicate maximum and medium values.

Figure 3.8 illustrates the spatial variability of total nitrogen. Soil variability in combination with the current irrigation system may contribute to nitrogen variability. Differences in water distribution across the meadow may lead to inconsistency in plant productivity, which will inevitably result in varying nitrogen concentrations.

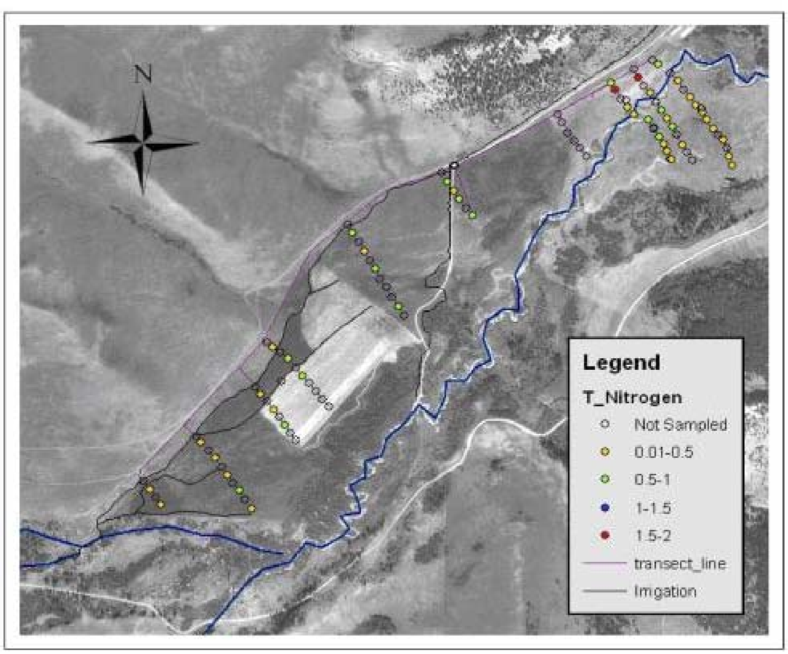


Figure 3.8. Variability in total nitrogen throughout the transects.

Productivity: For the ranch to sustain their current production of one ton per acre of hay, 18 pounds of available nitrogen must be present in the top 10cm of soil (Jacobsen 2003). According to the conducted nutrient analysis taken at the end of the summer, much of the field already contains the 18-pound requirement of measured nitrate (Table 3.1).

Table 3.1. Minimum, maximum, and average values for sampled nutrients.

	OM%	%N	BRAYP_PPM	NO3_PPM	NO3_lb/a	pH
min.	2.65	0.1	9.67	0.61	1.22	6
max	38.82	1.79	55.49	31.18	62.36	6.6
mean	11.06	0.51	23.23	12.05	24.1	6.44

Nitrate levels at the end of the growing season are assumed to be lower than they will be in the spring since plants will have depleted nitrate levels over the growing season. Each percent of organic matter present in a given field can represent up to 15 pounds of available nitrogen per acre. Current levels of organic matter, ranging from 6% to 18%, would suggest sufficient levels of nitrogen for the spring growing season. Production of hay will likely not be limited by nutrient deficiencies but rather by uneven water distribution or climate, as indicated by the short growing season.

Management Implications: The B-Bar Ranch is considering switching from flood irrigation to sprinkler irrigation, which is often done, in an attempt to decrease water use. Sprinkler irrigation also increases the area covered by the same volume of water and may lead to an increase in hay production (Venn, et. al 2004). The basis for this increased yield is that water can be applied and utilized more effectively to the farmed area in a sprinkler irrigation system.

The second benefit of sprinkler irrigation would be a reduced risk of leaching important nutrients from the vadose zone to river or water supply. With flood irrigation, water is flooded across the soils surface, resulting in preferential flow, which is the infiltration of water through pathways of least resistance or preferred pathways (Hillel 2004). Often these pathways are restricted to small pockets within the soil (Jury and Fluher 1992; Flury, et al. 1994; Steenhuis, et al. 1996), resulting in leaching in grasslands or cornfields respectively (Sinaj, et al. 2002, Spalding, et al. 2001). On the B-Bar Ranch, the physical properties of the soil would suggest that nutrients could be susceptible to leaching.

Nutrient levels at varying distance from the irrigation ditch were assessed in Figure 3.10 to determine whether flood irrigation could cause of the variability in OM and total N. Total nitrogen concentration increases with distance from the ditch. Further studies with larger numbers of samples at different times during the growing season may lead to a better understanding of the interactions between water and nutrient concentrations

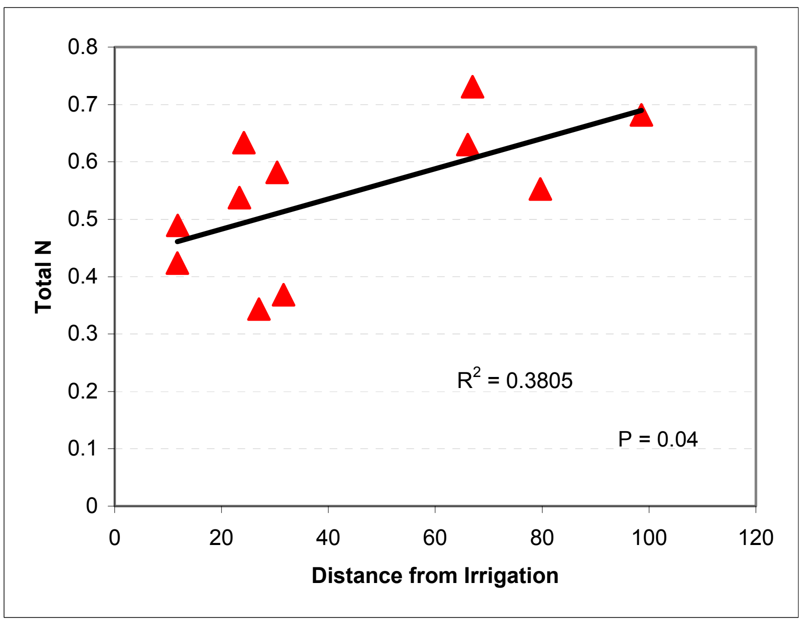


Figure 3.10. Nitrogen concentrations as a function of distance from irrigation ditch.

in the Davis Meadow. Flood irrigation benefits to the ranch are discussed in the hydrology section of the paper.

3d. Conclusions from Soil Assessments

Upon the completion of soil physical and chemical analyses there was significant variability within the NRCS soil map unit 1219. Textural variation could be seen within the Davis Meadow from simple observations made in the field. From studying soil profiles, it was obvious that different parts of the floodplain have a different physical makeup (substrate size) due to the meandering nature of a seasonally powerful stream. Variability could also be seen from the lab analyses conducted by the MSU Capstone Soils Group.

Secondly, the current hay productivity in the Davis Meadow of the B-Bar Ranch does not seem to be limited by any of the macronutrients tested by the MSU Capstone Soils Group. Further tests could be conducted to determine whether there are any nutrients, besides those already tested, which are limiting the production of hay. Other nutrients for possible future testing could include ammonia, potassium, calcium or sulfur. It has been hypothesized by the group, that either water or climate would be most likely limiting factors, although further studies at the B-Bar Ranch would have to be completed to fully answer this question and determine whether the Davis Meadow is capable of producing more than is currently harvested.

Lastly, given the physical and chemical characteristics of the soil in the Davis Meadow there is the potential, under the current irrigation system, for the loss of nutrients. Total nitrogen was found to increase with distance from irrigation ditches, which could be the result of several different factors including plant uptake, leaching of soluble N or even differences in OM accumulation. Given these results, future studies would need to be completed to determine the full effects of the current irrigation practices in use and the potential ramifications of the alternatives to this practice.

4. Hydrology

4.1 Introduction

The B-Bar Ranch has a long history of anthropogenic influences on the surrounding ecosystem, grazing, removal of riparian vegetation, irrigation, logging and the possible removal of beavers, all of which can have negative impacts on riparian areas. Activities such as land use change and stream modification have been shown to cause degradation in ecosystem structure and function. (Novotny, et al. 2005). B-Bar is interested in the current state of Tom Miner Creek with special concern for bank erosion and fish habitat. The focus for hydrology at the B-Bar Ranch was to analyze the current state of Tom Miner Creek and create a baseline of data for future monitoring and management implications. The Clean Water Act of 1972 set standards for measuring the integrity of aquatic ecosystems, including physical, chemical and biological elements. Baseline data for these elements was collected by the hydrology group for analysis and future monitoring.

Physical properties. Physical properties of stream ecosystems influence stream morphology as well as habitat for both aquatic and terrestrial organisms. Assessment of physical properties includes both qualitative and quantitative methods. Stream slope and sinuosity can be measured to quantify stream characteristics, as both have a direct impact on the energy of a stream. Entrenchment and width to depth ratios are also quantitative and describe the shape of the cross sectional profile of streams. Entrenchment ratio is the measure of the degree of channel incision and width to depth ratios are a measurement of the bankfull width divided by the bankfull depth. Bankfull is the stage where a stream is at maximum capacity without flooding and can be indicated by changes in vegetation or changes in bank slope. Cross sectional profiles can be monitored for lateral or vertical movement to determine how the stream channel is physically moving over time. The shape of the stream is important for fish habitat, as previous case studies have found higher trout densities in deep narrow stream habitats (Newman and Wildman 2000).

The importance of entrenchment ratios during periods of peak flow is valuable in determining a streams susceptibility to erosion. Streams with low entrenchment ratios (<1.4) are deeply entrenched and do not utilize the flood plain under high flow events (EPA 2004). This leads to high rates of bank erosion and sediment movement. Flood plains are important for energy dissipation, where vegetation absorbs energy and collects sediment. Stream velocity and discharge are also important factors in stream morphology as they determine the amount of bed load and suspended load the system can carry (Rosgen 1994).

Included in the physical analysis of Tom Miner Creek is quality of fish habitat as well as spawning habitat. Tom Miner Creek is home to Yellowstone cutthroat trout which are considered a species of special concern by the Montana Fish Wildlife and Parks (Young 2002). Particle size is an important measurement for analysis of fish habitat and the stability of the stream bed. Too much suspended sediment can create an unhealthy environment for spawning as the sediment drops out and covers trout eggs, decreasing the oxygen availability and preventing emergence (Kandoff 2000).

Stream morphology can have negative impacts on trout habitat. Erosion of stream banks causes excess sediment to accumulate compromising fish habitat. The presence of habitat such as woody debris and undercut banks can be described qualitatively as a sign of good fish habitat. Vegetation along streams provides bank stability and shade which helps to reduce water temperatures. Vegetation also provides a carbon source for aquatic organisms which are the base of the aquatic food chain. Pool and riffle sequences are important for trout spawning habitat. Riffles provide oxygenated water to the pool areas where trout spawn (EPA 1999).

Optimal stream bed conditions for cutthroat trout include gravel with particles up to 100 mm in diameter, substrate smaller than 32 mm with an average of 16.6 mm, bends present with 1 to 2 riffles in 10 meters of channel and many snags (Young 2002). Substrate size and the degree to which it is embedded are important factors that affect spawning success. Mageel and McMahon, found cutthroat redds consisted of substrate smaller than 25.4mm with a large proportion less than 6.35 mm. Redds are depressions in stream gravel beds where fish deposit their eggs. Optimal flow conditions for cutthroat spawning habitat include: water depths averaging 20 cm besides redds and 22 cm upstream of redds, water velocities between 42 cm/s^2 beside redds and 46 cm/s^2 upstream of redds.

Chemical properties. Chemical properties such as dissolved oxygen, water temperature, and pH are important for aquatic organisms. Ideal temperatures for Yellowstone cutthroat trout are between 10.3 °C and 17.0 °C with the upper lethal limit of 19.7 °C (Bear, et al. 2005). Dissolved oxygen is essential for aquatic organisms and decreases with increasing water temperature. Adequate levels of D.O. for cutthroat trout are between 6 to 15 ppm.

The pH of water is important because levels too high or low will have a negative impact on water quality. Values between 6 and 8 for pH are considered healthy for aquatic systems (Mitchell and Stapp 2000). Total dissolved solids are the amount of dissolved solids (inorganic materials) as well as suspended solids that are present in the water. While total solids are necessary to maintain a natural balance within the water ecosystem, levels too high can be detrimental to stream health (Mitchell and Stapp 2000). When there are too many total dissolved solids, the water absorbs more solar radiation leading to an increase in water temperature, which may be harmful to the habitat or the species present. Water temperature is important because it affects the physical, chemical, and biological characteristics of the stream (Mitchell and Stapp 2000). Temperature affects the amount of oxygen that can be dissolved in water, the rate of photosynthesis, the metabolic rates of aquatic organisms, and the organisms' sensitivity to toxic wastes, parasites, and diseases (Mitchell and Stapp 2000).

Biological properties. Healthy stream ecosystems are often characterized by high species richness and are not dominated by one species (EPA 2005). The domination of one species that is tolerant to stress is an indication of habitat degradation. A diversity of macroinvertabrates is a good indicator of water quality because they are relatively sedentary and often have various ranges of sensitivities to environmental stresses. The pollution tolerance index (PTI) is the measure of the streams sensitivity to pollution and is a good biological assessment for stream health (Mitchell and Stapp 2000). The PTI measures species diversity and richness in the stream by sampling macroinvertebrates.

This reflects the dissolved oxygen levels as indicated by the organisms found in the stream.

4.2 Methods

Physical properties of Tom Miner Creek were measured at sites in Davis meadow and upstream from Davis meadow for comparison. Efforts were focused in the Davis meadow area, which is an area of concern for the ranch because of the newly established channel. Transects were established perpendicular to the stream on straight stable reaches to monitor how the stream is changing over time. Measurements of channel features such as bankfull, entrenchment and width to depth ratio were conducted to quantify channel characteristics. Elevations were measured using a transit to create a cross sectional view of each transect. Stream riffle particle size was measured by taking 100 random samples. Rocks were picked up randomly after each step moving across the channel from left bank full to right bank full to determine the average substrate size of the channel.

Pool substrate size was measured primarily in Davis meadow to analyze fish spawning habitat. A grid was used to analyze substrate size in the pool tails, an area of reduced velocity used by trout for spawning. Grids were placed 25%, 50%, and 75% of the length of pool tail area. Each grid consisted of strings evenly spaced in a square pattern creating a set of intersection points. The number of particles with a size less than 2 mm was then recorded at each intersection point to determine the ratio of fine to large particles. A lower ratio is ideal as spawning habitat is hindered by very fine particles.

Chemical analysis was conducted at water quality sites 1-5, located above, below, and within the B-Bar Ranch. The chemical parameters analyzed were dissolved oxygen, pH, and total dissolved solids measured through electrical conductivity and iron. Bank shade water temperature and mid-channel temperature were also measured at sites 1-5. Other chemical parameters such as nitrate and ammonia were not measured based on knowledge and understanding of the area, land use, and geologic characteristics. D.O. was measured in mg/L using the Hach D.O. single parameter test kit (model # OX-2P). The pH of the stream was measured using a hand held pH meter (model # IQ125). The total dissolved solids were measured using a Hach handheld EC meter.

Biological analysis of the stream was conducted using a pollution tolerance index (PTI) for water quality sites 1-4. The stream bed was disturbed using the Z sampling method of stream disturbance, releasing organisms into the water column. Organic materials and macroinvertebrates shaken from the bed were collected using a net. Indicator organisms were counted and analyzed with a flow sheet leading to a PTI number. Low PTI numbers indicate poor stream health while a high number indicates excellent water quality.

4.3 Results and discussion

Physical parameters were measured to classify the Davis meadow section of Tom Miner Creek as a F4 stream by using the Rosgen classification system. The characteristics of an F type stream are described as a stream that is re-establishing its flood plain and increasing in width. These streams are entrenched and flow through highly erodible substrate making them susceptible to high rates of erosion. F streams generally evolve toward C type streams which have a more developed flood plain.

Trout spawning habitat was assessed in pool tails throughout the Davis meadow reach. Substrate was analyzed for particles less than 2 mm, indicating sediment accumulation. No indication of excess sediment was found using this method. Water temperatures and dissolved oxygen were within healthy parameters for trout. Water depth and velocity was within spawning requirements for cutthroat trout. Trout habitat could be improved with bank stabilization, especially with the addition of vegetation. There is a lack of woody debris through the Davis meadow reach compared to the section above the meadow.

The Yellowstone cutthroat trout were denied endangered species status but are still a species of concern. Landowners that have Yellowstone cutthroat trout in the streams running through their properties can participate in programs to conserve the species in a way that also benefits the landowner. Two programs that are available to landowners are the Landowner Incentive Program on the Yellowstone and the Future Fisheries Improvement Program (Young 2002).

The Landowner Incentive Program is only for the Paradise Valley. Funding for this program comes from FWP, the USDA Natural Resources Conservation Service, the Montana Department of Natural Resources, the Park County Conservation District and others. This program can provide valuable irrigation upgrades, riparian fencing, and off-site water development for livestock (Pierce 2005). Cutthroat habitat gains could include 2,500 feet of restored stream channel & improved spawning habitat and fish passage into and out of a natural spring area.

The Future Fisheries Improvement Program includes $433,000 in funding approved by the Montana Fish, Wildlife & Park Commission that is matched by more than $1.2 million from outside sources. The program includes: riparian fencing and re-vegetation, stream channel and spawning habitat improvements, installation of hiding and rearing cover, stream bank stabilization using natural materials, fish passage improvements, fish screens on irrigation diversions, water management that improves stream flows, and installation of a barrier to protect a genetically pure population of Yellowstone cutthroat trout (Timpton 2005).

The water quality parameters discussed above were measured at five different sites, located above the Ranch, within the Ranch boundary, and below the Ranch. At water quality site 1, the PTI was poor indicating that species diversity was low in the area. The pH was also found to be high at this site at a value of 8.7. Although not conclusive, the high pH may be due to a prior influx of bentonite in the stream channel following a recent rain event. This may have been a short term pulse event and may not reflect the true pH of the stream at those points. The geology of the surrounding area contains beds of bentonite, that when broken down, may have entered the stream channel thus increasing the pH. The pH was also high for water quality sites 2 (pH 8.8) and 3 (pH 8.9), again, based on speculation, and may be due to the surrounding bentonite. At water quality site 5, the D.O. was at a level which would cause stress to aquatic life. This site was basically an iron seep next to the stream, the lower level of D.O. could be caused by warmer stagnant water compared to the actual stream. The iron level in the seep was 1.5 mg/L. This amount of iron was much higher than the adjacent stream, which contained no iron at all. The rest of the water quality sites had good to excellent levels of D.O., pH, EC, temperature, and (PTI) numbers. Table 4.1 reflects the water chemistry measurements taken at each site.

Table 4.1 Water Chemistry of Tom Miner Creek

Parameters	WQ1	WQ2	WQ3	WQ4	WQ5	Ratings
Dissolved Oxygen (mg/L)	9	8	9	9	6	(okay 6-15, stressed 4-6, dying 1-2, death 0-1)
pH	8.7	8.8	8.9	8.2	7.6	(6.5-7.5 excellent, 6.0-6.4, 7.6-8.0 good, 5.5-5.9, 8.1-8.5 fair, <5.5, >8.6 poor)
EC (ppm)	40	40	40	50	70	(<100 excellent,100-250 good, 250-400 fair, >400 poor)
Fe (mg/L)	n/a	n/a	n/a	n/a	1.5	
Water temp (°F)	52	58	61	46	59	(>68 poor, 68-61.5 fair, 61.5-55 good, 55> excellent)
PTI	poor	fair	good	excellent	n/a	

B-Bar Ranch is concerned with the amount of erosion that is taking place along Tom Miner Creek. This concern led the ranch to contact Trout Headwaters Inc. to provide consultation to combat the erosion along the creek. The restoration techniques that were advised included the use of soft armoring of the creek bank using willow fascines and dormant willow stakes. Fascines are bundles of woody vegetation, willows in this case, that are harvested while in dormancy. These bundles are then tied or wired together in lengths of approximately 12 ft with a diameter between 8-12 inches. The use of willow fascines aids in the dissipation of water. These fascines protect the banks as well as collect sediment behind the fascines which will begin to rebuild the eroded area. If installed correctly, fascines over time will begin to sprout and eventually form erosive resistant root mats as well as healthy riparian vegetation. For the fascines at B-Bar, the willows were harvested on the ranch, while in a dormant state. Many sprouts were observed while in the field, suggesting that some of the willows were rooting in sediment. Continued use of fascines and stakes will greatly reduce the chance for the creek to undergo avulsion (jump out of channel). Fascines lower stream power, decrease erosion, and promote sediment deposition.

B-Bar Ranch does not allow grazing by their livestock within the riparian area. Grazing on the riparian area leads to increased erosion. Livestock grazing can affect all components of the aquatic system (Trout Headwaters 1999). Grazing can affect the streamside environment by changing, reducing, or eliminating vegetation bordering the stream. Channel morphology can be changed by accumulation of sediment, alteration of channel substrate, disruption of the relation of pools to riffles, and widening of the channel. The water column can be affected by increasing water temperature, nutrients, suspended sediment, and by changes in the timing and volume of stream flow. Livestock can compress stream banks, causing banks to slough off, creating false or retreating banks, and accelerating bank erosion (Trout Headwaters 1999).

Proposals to reduce erosion on the ranch include diverting water around Tom Miner Creek by flooding the Styres Swamp or by using ditches to remove water during times of high flow. B-Bar has an extensive system of ditches and canals and has used flood irrigation since they began land ownership.

B-Bar Ranch holds a strong belief in managing the resources found on their property in a holistic manner. With this in mind, the hydrology group looked into other methods of soft armoring. Proposed alternatives fall within the boundaries of the holistic approach to management on the ranch. Areas of concern are dominated by a highly erosive material. B-Bar Ranch was not interested in reshaping stream banks using heavy machinery. In many sections of the creek there are areas where stream bank slope needs to be reduced. The use of shovels, mauls, picks and other hand operated machinery could be used to reshape areas of extreme erosion. Reshaping banks would result in accelerated succession of stream morphology leading to a steadier stream type.

In conjunction with bank reshaping, the use of erosion control blankets (ECB) will increase the stabilization of the bank. Erosion control blankets (ECB) are made from many different fibers. Some are biodegradable while others are composed of a plastic mesh. These blankets are typically made with coconut and straw. A native seed mix is typically planted beneath this fabric which holds moisture and decreases wind and stream erosion. The seeds are not impeded by the blanket and revegetation is highly successful (Bitterroot Restoration 2005). The results of this method are typically an increase in soil accumulation as well as the presence of vegetation and more importantly their root systems to dissipate stream flow and decrease erosion (Bitterroot Restoration 2005). The use of brush layering and brush mats in areas of erosion decrease the erosive forces of a stream. Stacking layers of live and dead branches in mats up to a foot thick, then securing them with stakes and ECB. The live cuttings and dormant willow stakes begin to sprout and establish solid vegetation. The mat physically protects the stream bank, captures sediment during high flows, and enhances the establishment and growth of native vegetation.

As discussed earlier there is a lack of woody debris in the area of Tom Miner Creek that is experiencing increased erosion, implementation of large woody debris

(LWD) into the Davis meadow would assist in the rehabilitation of Tom Miner Creek. Root balls sunk into the bank as well as logs placed along the creek decrease water flow against the bank while providing excellent habitat for trout. Materials can be harvested from the Ranch, dead logs are abundant and easily found on any wooded area.

Human influences such as logging and the spraying of willows may have increased the potential for avulsion and subsequently increased rate of erosion; however, the stream is under recovery. The farther upstream one travels, the more you can see that the river is repairing itself. The slumped and eroded banks are supporting thriving communities of healthy native riparian vegetation. Evidence of this occurring on the lower reaches is present, but not as abundant as upper reaches of the creek. Given time this dynamic stream will restore itself; human influences including many of the soft armoring techniques discussed may help accelerate the process. This stream will continue to function in a healthy and changing manner, ensuring quality habitat for a number of native flora and fauna common to the Greater Yellowstone Ecosystem.

Future analysis of Tom Minor Basin can focus on changes at the same study sites due to the GPS coordinates, which were taken at all of our study areas. Each cross section, pebble count, pool tail fine, valley cross section, bank pin and water quality site was documented and marked for future monitoring. This will allow students to document any changes in stream quality or position. Bank pins will be easily monitored, as students will be able to see whether there is an increase in erosion or an increase in sedimentation behind the fascines simply by measuring the length of rebar left unburied.

The portion of Tom Miner Creek that flows through the B-Bar Ranch is a healthy stream. All data collected by the hydrology group reiterates that this section of stream is a healthy functioning ecosystem. The parameters measured were taken at one point throughout the year; this does not allow us to make conclusions for all time periods.

Some possible management alternatives are to use native riparian vegetation to lower erosion. One possibility is to divert the stream back through Styres Swamp which will lower stream power through the riparian vegetation already present. There have been recent signs of beaver activity as they have utilized their ability to dam the creek in parts, benefiting the stream. Beaver dams lower the power of the stream by regulating flow allowing sediment to settle out slowly raising the channel. Debris that comes down stream is trapped within the structure. The blocking and slowing of the water forms a pond that is above the lower section of the stream, the pond will eventually cause the water table in the surrounding areas to slowly rise often allowing more water to be plant available creating a larger surplus and a stable water supply. Ponds created by beaver dams provide habitat for fish, water fowl, beaver and other wildlife *Figure 1*. Beaver dams have increased vegetation and debris that provide protection and food for young fish. The protection provided in the first year when fish are the most vulnerable is important for survival, could increase the population of native cutthroat (Ecology of the Beaver 2005).

Figure 1. Beaver activity observed above Davis meadow

Ranch management is looking into a switch from flood irrigation to sprinkler irrigation. The advantages and disadvantages in respect to soil were discussed in section three. Flood irrigation has benefits, most importantly the reduction in kinetic energy that the stream has from spring melting events. As the watershed warms in the spring, large volumes of water from the hills above the B-Bar Ranch are directed towards the Tom Miner Creek. These large melting events cause the stream to increase its flow as well as its strength and power. It is during this time of high flow that the ranch currently diverts water from the stream to be used for flood irrigation. As a result of this divergence, the kinetic energy of the stream is decreased, as are the erosive effects associated with it.

The second benefit of flood irrigation is the potential for ground water recharge. Groundwater is the water stored within aquifers below the soil surface and can contribute to stream flow throughout drier summer months (Venn, et al. 2004). A study conducted by (Venn, et al. 2004) was able to show a decrease in groundwater recharge and an increase in depth to groundwater after switching from a flood irrigation system to a sprinkler irrigation system (Venn, et al. 2004). The results of decreased groundwater recharge can include lowered flow rates, increased stream temperatures and decreased dissolved oxygen within the stream, all of which can have adverse effects on fish habitat in the Tom Miner Creek.

In general wheel line irrigation uses 1/3 less water than flooding which generally benefits the stream. However sprinkler irrigation water is generally taken during times of low flow which could affect the stream and riparian system. If a switch is made from flood to sprinkler irrigation, monitoring of the stream flow is recommended.

5. Vegetation

5.1 Introduction

Weed management is an important aspect of natural resource management, as weeds can decrease native plant diversity, decrease forage and change ecosystem structure and function (D'Antonio and Vitousek 1992). Weeds often have a competitive advantage in their new environments as they no longer have the pathogens and herbivores of their native environment that limit population growth. This can lead to rapid population increases and substantial changes to the native species plant community. The B-Bar is committed to using the most environmentally benign control methods available.

There are three primary weeds of concern to B-Bar managers: spotted knapweed (*Centaurea maculosa*), hounds-tongue (*Cynoglossum officinale*) and Chilean tarweed (*Madia sativa*). Spotted knapweed and hounds-tongue are cut and hand pulled to prevent their spread. Vinegar (30% acetic acid) is currently used to spray tarweed. Vinegar use for weed control is a relatively new method and increasingly popular in organic systems. The strong acid burns plant tissue, killing indiscriminately. Little research has been done on vinegar use, so long-term effects on soils and efficacy of population control are unknown.

Chilean tarweed (*Madia sativa*) is a non-indigenous weed, and therefore a concern to land managers attempting to maintain native communities. In 2004, a range assessment identified the presence of *Madia sativa* along ranch roads (Sindelar and Ayers 2004). That fall, the B-Bar began controlling tarweed by mowing and spraying with vinegar. Our comparison of tarweed samples taken from the B-Bar Ranch to MSU herbarium specimens revealed that the tarweed present at the B-Bar is mountain tarweed (*Madia glomerata*), a closely related, but native tarweed species (Lavin 2005).

Mountain tarweed is a winter annual in the *Asteraceae* family and is common in arid rangelands (Hull and Cox 1968). Palatable when young, tarweed becomes woody and resinous with maturity, with a distinctive tar-like odor (Perrier, et al. 1992). Because it is a native species, it may no longer be of concern to B-Bar land managers. However, the ecology of tarweed is still interesting. Tarweed may be beneficial to the area, providing plant cover on the roads and preventing the establishment of less desirable non-native species.

Our objectives were to give a baseline description of the plant community within tarweed patches and to determine the effects of vinegar use on tarweed. Our baseline description of tarweed communities included mapping their presence along Skully Loop trail road and measuring tarweed patch areas. A plant survey along the road was done to determine species richness and evenness (diversity) inside and outside tarweed patches. A population demographic model was constructed to predict population growth rate. Population models use growth parameters, or vital rates to forecast how a population will change over many generations. We built a predictive map to indicate the probability of tarweed occurrence along ranch roads. Permanent monitoring plots were established to measure population change in future years.

5.2 Methods

To survey tarweed populations we continuously sampled along roads and recorded the presence of tarweed populations using a Trimble Geo3 GPS, and used adaptive sampling to find adjacent populations (Thompson 2002). A predictive map was built to indicate where new patches are likely to occur (Rew, et al. in press), using environmental variables obtained from a digital elevation map (DEM).

Vinegar effects were measured on both seed viability and mycorrhizal fungi. Soil was collected within and outside vinegar treated areas to determine the impact of vinegar on soil mycorrhizal community and on soil pH. Mycorrhizae are a plant-fungi relationship forming between fungi and many plant species. Generally it is a symbiotic relationship; in exchange for carbon, mycorrhizal fungi provide the plant with nutrients that are difficult for the plant to obtain, especially phosphorus. Mycorrhizal infectivity potential is a measure of fungal colonization in plants grown in contrasing soils and measures viable fungal propagules. We hypothesized that the soil treated with vinegar would have lower mycorrhizal colonization because of decreased soil pH. Seeds from both vinegar-sprayed and unsprayed areas in late August were collected to determine the effect of vinegar on seed viability.

Survey: Tarweed populations along the roads were identified for monitoring. We calculated the area of the patches using the azimuth-radii method (Maxwell and Rew, not published). Each patch was divided into segments and each radii and azimuth was measured (Figure 5.1). The patch area is determined by calculating the area of the eight triangles created when the ellipse is divided by the 8 radii for the TMR8 method (Maxwell, et al. 2005).

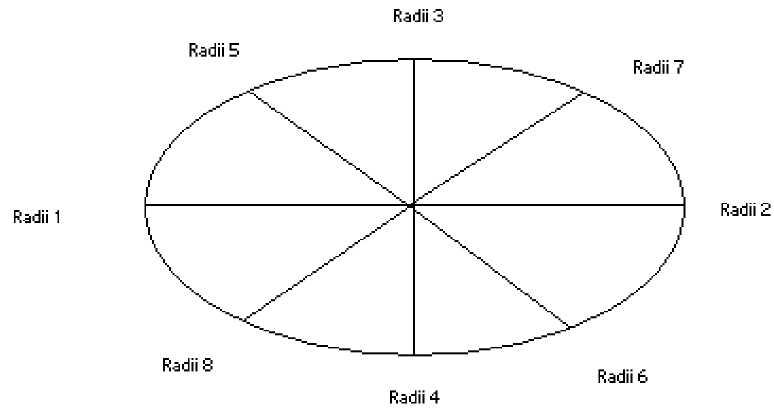


Figure 5.1 Diagram of Azimuth-radii method of patch measurement.

Plant density was measured using a $1m^2$ frame set within a tarweed patch. The corners were marked with road-hairs for future measurements. We recorded the type and density of species present within four of the 16 quadrants. The frame was then flipped to lie over the edge of the tarweed patch, its location marked, and species counted.

Population Growth Rate Estimation: Using Microsoft Excel, a population ecology model (Figure 5.2) was created to predict the population growth rate. The tarweed life cycle was divided into 4 states, seed-bank (SB), seedlings (SDL), flowering plants (FP), and seed produced (SP). The transition rates between states were gathered from the literature (Perrier, et al. 1992). Seed produced per plant was estimated from sample plants that we collected at the B-Bar Ranch. Seed germination was estimated using the seed that we collected. These transition rates were used to build a preliminary population model. The vital rates include: germination rate (emrg), seedling survival (s), seed produced per plant (spp), seed rain (m) and seed-bank survival (sbs) (Tables 5.1 and 5.2.). Monte Carlo simulation was introduced into the model to represent variable environmental conditions. The simulation was repeated 60 times to determine the average rate of change in the density of the population.

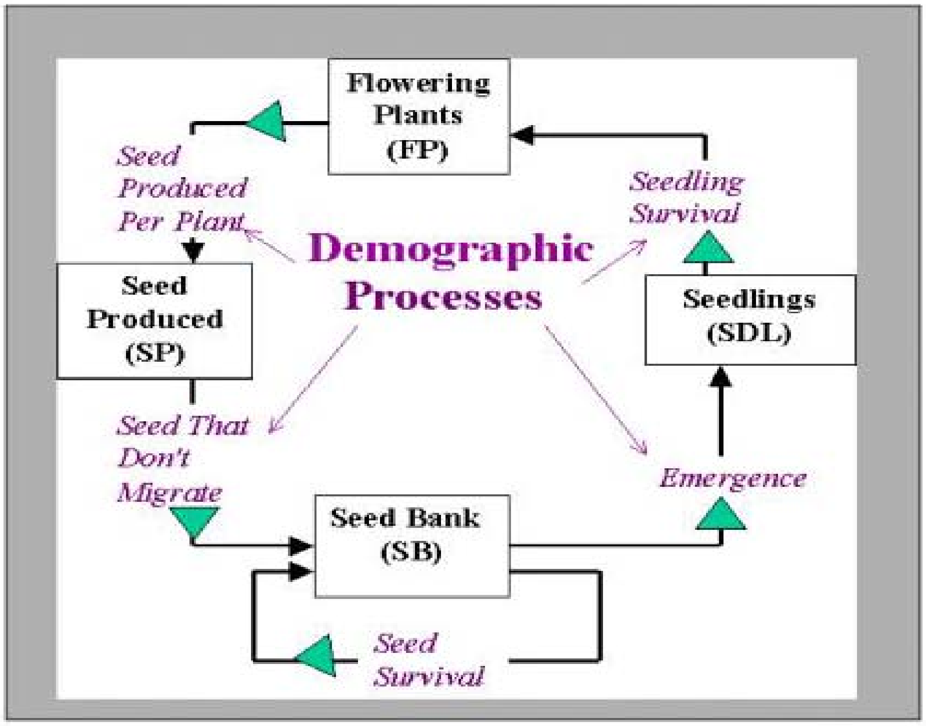


Figure 5.2 Population Ecology Model diagram showing life stages and demographic processes of vascular plants.
(Maxwell, et al. 2005. http://weedeco.msu.montana.edu/class/lres443/lres443.htm)

Table 5.1 Tarweed starting population values

SDL (seedlings)	74
FP (flowering plants)	11
SP (seed produced)	272
SB (seed-bank)	160

Table 5.2 Demographic Rates

sbs (seed-bank survival)	0.27
emrg (emergence)	0.46
s (seedling survival)	0.55
spp (seeds produced per plant)	25
m (seed rain)	0.5

Mapping: The upper ranch roads were surveyed with a Trimble Geo3 GPS, marking points where patches were located. Concentric paths were walked from an identified established tarweed patch, in 10-meter increments around the patch while looking for new patches. This was done until a path 50 meters from the initial patch had been walked. When new patches were found, the process was repeated using the adaptive sampling approach (Thompson 2002). (Figure 5.3)

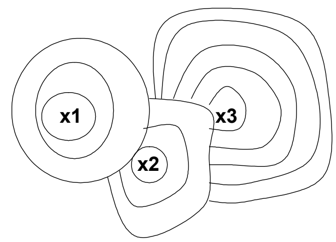


Figure 5.3 Spiral monitoring diagram for adaptive sampling to find new tarweed colonies around identified source populations.

A map was constructed, using the initial road survey that recorded the presence or absence of tarweed. S-Plus 2000, a logistic regression model was used to predict the presence of tarweed with elevation, slope, aspect, LandSat bands, presence/absence of trees and distance from roads as independent variables. The logistic regression model was used to calculate the probability of occurrence within a 40m swath centered on the road and extrapolated to all roads in the area where the infestation is thought to be located on the ranch. Inputting the variable coefficients into a specialized extension written for Arc View 3.2, the map was created.

Vinegar treatment: Seed viability tests were done to determine the effect of vinegar treatments on tarweed populations and whether timing of spray affected seed viability. Seeds were collected from plants in flower and those just beginning to fruit. They were taken from vinegar-treated sites as well as from adjacent non-treated patches. Additional seeds were collected three weeks later, in mid-September when plants had mature fruits. These plots were sprayed after our initial visit; samples from areas adjacent to the sprayed patches were also collected. Tetrazolium- (TZ) and germination-tests were used to assess seed viability. For the TZ-tests, seeds were soaked in tetrazolium blue solution at 1% concentration. The TZ solution stains red in the presence of oxidation-reduction with live tissue, leaving the dead tissue white.

To test for mycorrhizae as an indication of the impact of vinegar on the soil microbial community, soil samples were taken from six vinegar treated and six adjacent non-treated areas. In the greenhouse the soils were placed in pots and seeded with Sudan grass (*Sorghum Sudanese*). Sudan grass is fast growing, with a fine root mass and a high capacity for mycorrhizal colonization. After three weeks of growth, the plants were harvested and the roots cleaned. Root sections were cleared, stained and mounted on slides; 12 root-segments per slide and two slides per pot. Presence/absence counts were taken of hyphae, arbuscules, and vesicles along a grid (Brundret, et al. 1996). The mean colonization levels were determined and using the statistics program SPSS, a t-test was preformed to determine whether there was a significant difference in mycorrhizal fungal propagules in vinegar-treated versus non-treated soils.

Germination tests were conducted by putting seeds on blotter paper soaked in de-ionized water, and refrigerated at 5^{o} C for five days. After the pre-chill period, seeds were moved to an incubator for two weeks at a temperature of 15-25^{o} C.

5.3 Results and discussion

Survey: Ecosystems are complex and difficult to measure. Calculating vascular plant diversity is one way of assessing an ecosystem response to an invasive species. Species diversity is comprised of species richness and species evenness. Species richness is the number of species present in an area, and species evenness is the relative abundance of species in an area. Species diversity data can tell us how species interact within a community.

We hypothesized that as tarweed increased, plant species richness would

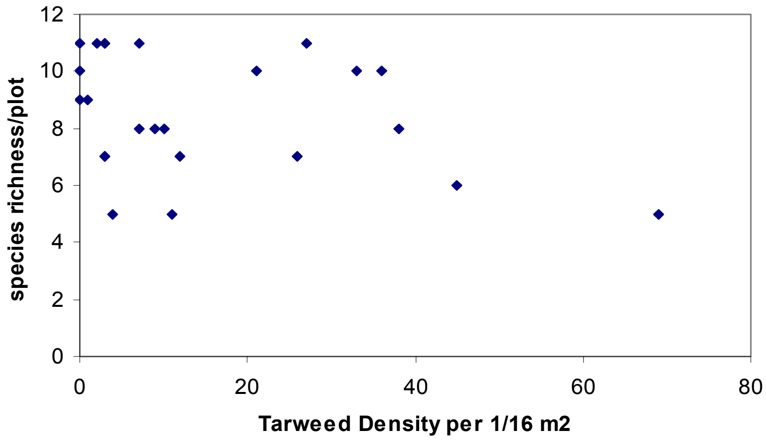
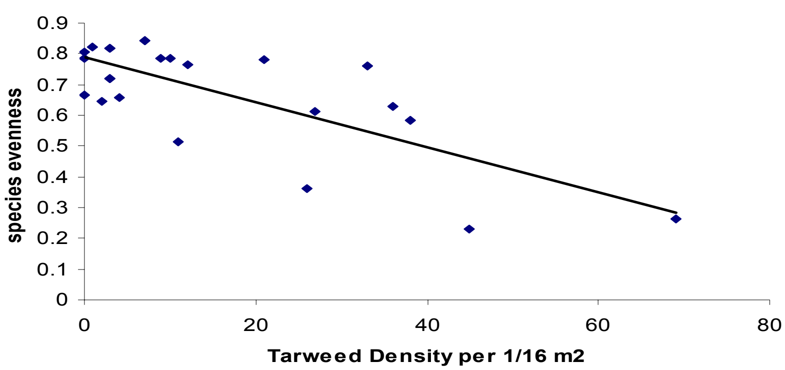


Figure 5.4 Species richness within tarweed

decrease because tarweed demonstrates some invasive qualities. Using regression analysis, we found that there may be a trend in the data toward decreasing species richness with increasing tarweed density (Figure 5.4), but it was judged to be not significant.

Likewise, species evenness decrease with tarweed density (Figure 5.5). This relationship could suggest that increasing tarweed populations cause a decrease in species evenness within this plant community, or that tarweed is attracted to areas where there is low species richness and thus it easily becomes a dominant species in these areas because it tolerates the disturbed conditions associated with roads.



Native species are often the desired plant species within a community, especially when managed for conservation purposes. Native species have evolved in the ecosystem and their populations are kept in check by climatic factors, native predators and competition. Nonnative species are sometimes intentionally introduced for forage or other reasons. The two primary introduced species on the B-Bar Ranch were smooth brome (*Bromus inermus*) and timothy (*Phleum pretense*), both of which are good forage plants for livestock and wildlife. These species are present over most of the ranch and may be considered desirable plant species because of their livestock forage qualities.

Tarweed density showed no relationship to nonnative species density. Tarweed density was positively related to native species density (Figure 5.6). Tarweed may be playing a beneficial role in this community by somehow promoting native species growth. It is also possible that the areas where tarweed does well are areas where non-native species (timothy, smooth brome, kentucky bluegrass) do not do well.

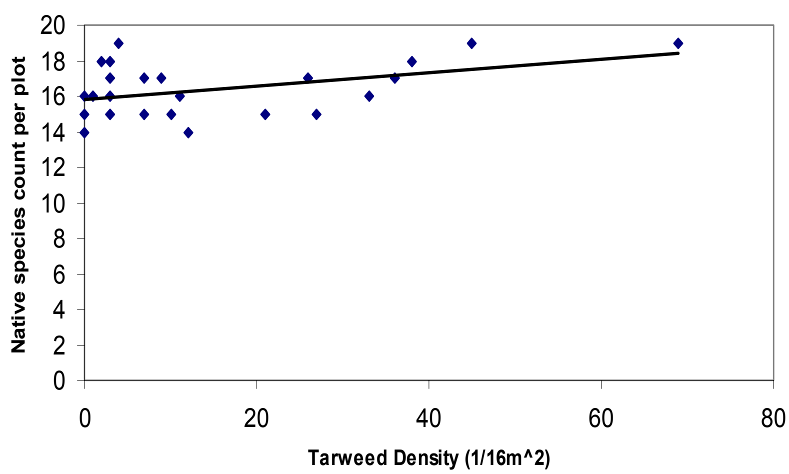


Figure 5.6 Native species density in tarweed patches.
$y = 0.0374x + 15.841$, $R^2 = 0.1907$, $p = 0.033$

Native and nonnative relationships can be important implications for ecosystem health, but the desirability of species should also be taken into account. We defined desirable species as all grass, forb, and shrub species except Canada thistle and hounds-tongue found in each plot. There is a strong correlation between tarweed densities and desirable plant species of tarweed having a positive influence on the desired plant community (Figure 5.7).

There was not a significant relationship between tarweed density and undesirable species (Canada thistle and hounds-tongue) but a trend shows undesirable species decreasing with increasing tarweed density, another possible benefit that tarweed might be having on the plant community (Figure 5.8).

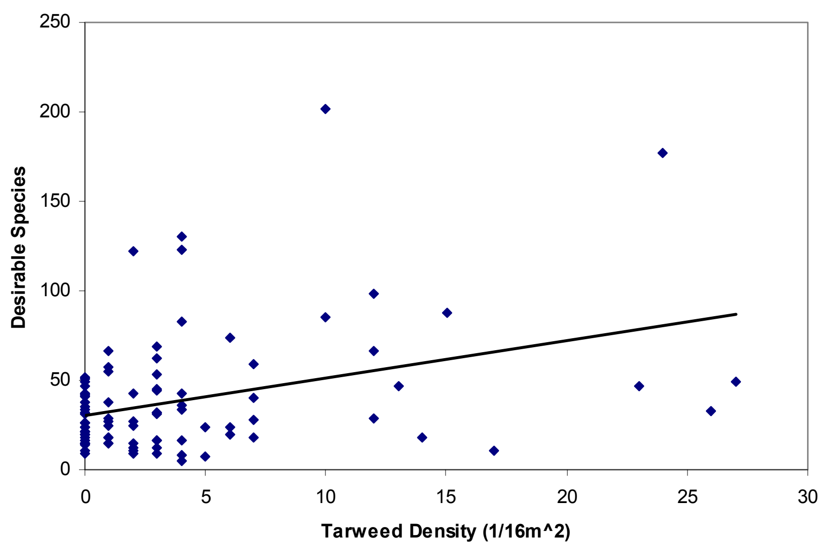


Figure 5.7 Desirable species density within tarweed patches. $y = 2.1068x + 30.193$, $R^2 = 0.1326$, $p < 0.01$

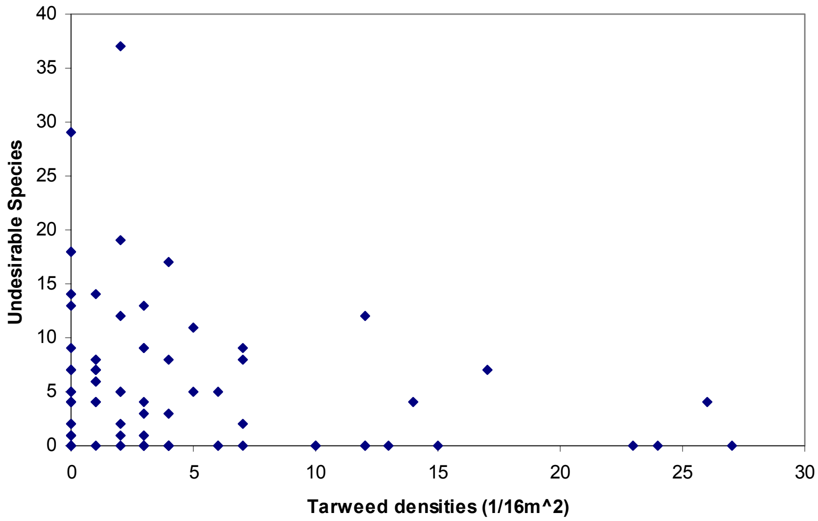


Figure 5.8 Undesirable species density within tarweed patches.

The density and area measurements of tarweed will serve as the starting point for future monitoring. Using the population ecology model, we estimated that tarweed populations are increasing slightly; our lambda (population growth rate) over 60 generations was 1.05. A rate less than 1.0 indicates a population in decline, a rate of 1.0 indicates a population at equilibrium and greater than 1.0 is a population that is growing.

Population ecology models are useful for determining how populations change over time and where weaknesses in the life cycle occur. These weak links can be useful targets for management strategies. The model has limitations because many of the vital rates were taken from literature and not our specific field site. Future classes may be interested in measuring these rates to build a stronger model.

Mapping: Predictive maps are useful for land managers to focus management on areas with a high probability of occurrence, rather than having to monitor the entire property (Figure 5.9). We found that tarweed patches were indeed present in areas of higher probability and not existent in areas of low probability (Figure 5.10). The low number of parameters used to build this model limits its accuracy. A more reliable prediction would require more parameters, such as habitat-type preferences, and samples taken from a much larger area. Future classes may want to expand on this, as well as visit areas indicating high tarweed probability in order to test the accuracy of the model.

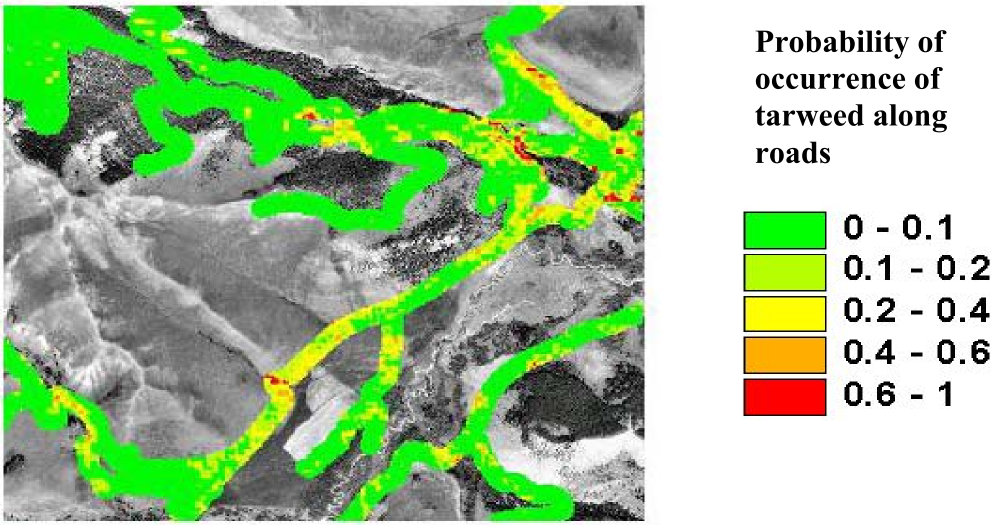


Figure 5.9 Predictive map showing probability of tarweed occurrence along ranch roads.

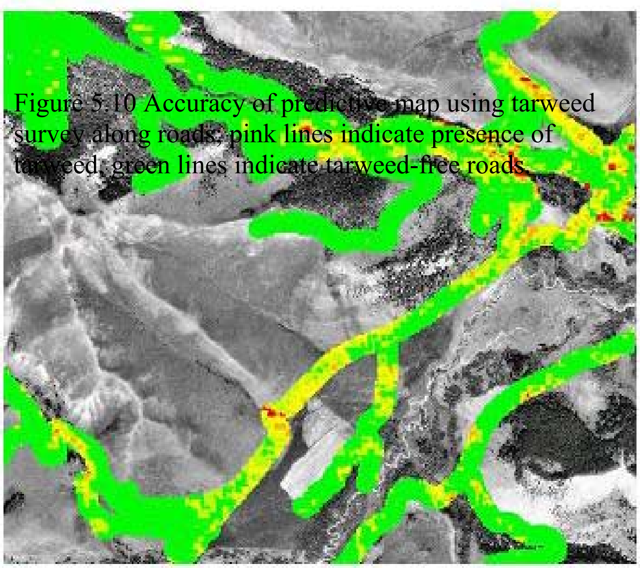


Figure 5.10 Accuracy of predictive map using tarweed survey along roads: pink lines indicate presence of tarweed; green lines indicate tarweed-free roads.

Vinegar: There was no significant difference in mycorrhizal populations in the treated and untreated soils (p-value = 0.749). This does not suggest that the vinegar has no effect on all the soil biota, but only that it did not affect mycorrhizal fungal populations.

After vinegar treatment, tarweed seed viability in early September was 19%, compared to 78% viable seed from populations sprayed later in the season. These were both compared to the 98% viability from non-sprayed areas (Figure 5.11).

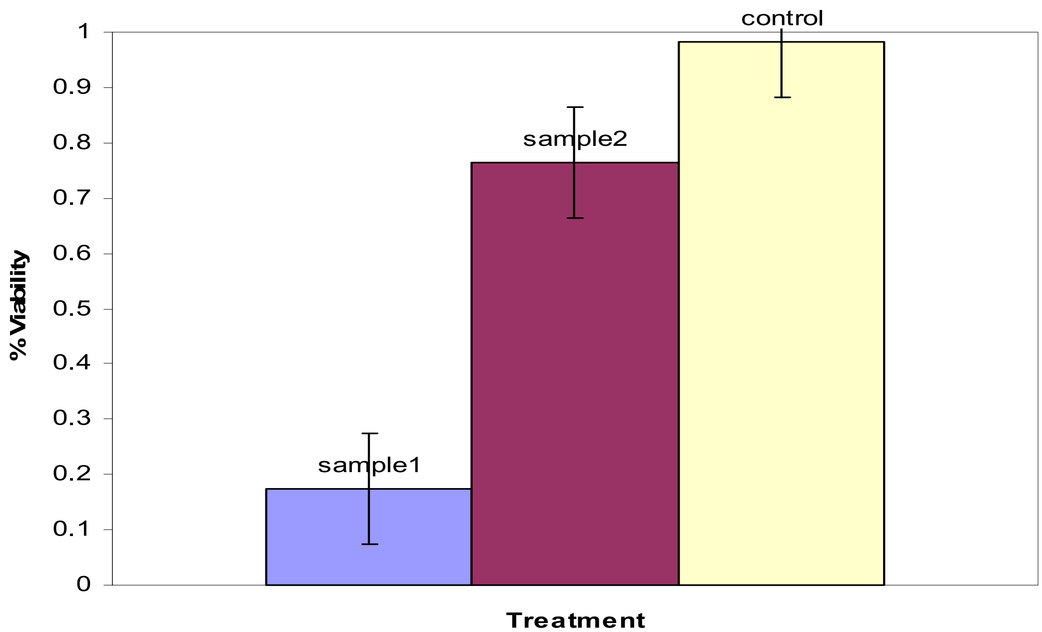


Figure 5.11 Tarweed seed viability, sample 1 was taken late August and sample 2 was taken mid September.

Germination tests were unsuccessful with all seed samples. Theoretically, germination tests and TZ tests should have similar results, plus or minus 10%. TZ tests assess for viable seed, however there may be other requirements for seeds to actually germinate, such as stratification. The literature states that tarweed requires a stratification period prior to germination (Perrier, et al. 1992). The brevity of our cold treatment may account for the failed tests

5.4 Conclusions

Tarweed density shows interesting correlations with population density of native and desirable plant communities. Since the B-Bar manages for natural diversity, it is our recommendation that tarweed not be managed with vinegar treatments. If managers continue using vinegar application, timing is critical for maximum effectiveness. Vinegar should be applied during the flowering stage, before seed production. Monitoring over consecutive years will show how tarweed populations are changing and what management practices are necessary. If it is decided that tarweed will no longer be managed with vinegar treatments, then more management efforts can be placed on spotted knapweed and houndstongue, species that are also a concern to the ranch.

Future classes may be interested in testing and expanding on the population and predictive models, by testing more parameters in the field and sampling a larger area. Our data builds a very rudimentary description of the tarweed population and infested communities on the B-Bar ranch. For a more substantial description of the community, multiple years of data will be necessary.

6. Conclusions

The natural resources survey of the B-Bar ranch was comprised of an analysis of the soils in the Davis meadow, the Hydrology of the Tom Miner creek, and assessment of Tarweed; a plant species identified as a weed problem. In addition, multi layer GIS maps including natural resources and some of the ranch infrastructure were created.

Soils within the NRCS mapping unit 1219 were variable, particularly soils in the flood plain, which showed high variability in large course fragments, very little organic matter, and a shallow A horizon. The soil nutrient levels were sufficient for the production needs of one ton per acre per year of hay in the Davis meadow. Finally, the decision to potentially change from flood to wheel line irrigation was examined from a soil nutrient and texture perspective. Nutrients can be leached through a soil profile, especially when there is low clay content, as in the Davis meadow. There is a higher potential for nutrients to be leached through the profile to a depth where they are unavailable for plant uptake when flood irrigation is used. The results from our soil samples relative to distance from the irrigation ditch indicate flood irrigation may have been leaching total nitrogen. However there are alternative explanations for an increase in nitrogen with increasing distance from irrigation ditches. First, plant growth maybe greater near a water source (ditch). This increase in plant growth would remove more nitrate from the soils in that area. This would indicate that lower nitrate levels near the ditch could be do to plant productivity, not flood irrigation. Further, study will be required to fully understand the impact of flood irrigation on soil nutrient distribution. However one may conclude based on general principals the soil nutrients may be better managed under a wheel line sprinkler system than flood irrigation.

The hydrology of the Tom Miner creek was studied for two primary reasons. The first was to assess the high erosion rate due to new channel formation and secondly to determine the quality of the Cutthroat trout habitat. It was the goal of the hydrology group to address all of these concerns and possibly recommend some management techniques to ensure stream qualities consistent with the objectives of the ranch including providing for the best habitat possible for the native trout species that live in the creek. Slope, sinuosity and pool tail fine particle measurements indicated that the Tom Miner creek was an F4 type stream. F4 streams are classified as having a natural high erosion rate. Tom Miner creek is a F4 type stream with adequate habitat to support a population of Cutthroat Trout. Changing from flood to wheel line irrigation, although generally beneficial to soil nutrients, may have a negative effect on the stream if flood irrigation is a large contributor in the dry season to the Tom Miner creek. Although, the reduction of water removed by switching to sprinkler irrigation may more than make up for any ground water recharge. To slow down the erosion rate, preserve trout habitat and accelerate the succession of the stream channel, it is recommended that the ranch continue to use soft armament with vegetation and fascines. Changing irrigation techniques will probably not have detrimental effects, although hydrological effects and seasonal stream flow should be monitored.

The tarweed at the B-Bar is a native weedy species that colonizes disturbed areas like roads. A population demographic model estimates that the populations are growing, but at a slow rate. The vinegar treatment was effective in killing tarweed plants, but its success for limiting population growth by decreasing viable seed production is dependent on treatment timing. Mountain tarweed is a native species so management is not mandated. If the management decides to continue to limit Tarweed populations it is advised they treat the plants before they go to seed to decrease population growth. It was determined that the applied vinegar to the tarweed patches did not affect mycorrhizae populations as shown through the Sudan grass experiments.

A multi layer GIS map providing spatial representation of the natural resources and some of the ranch infrastructure was created to help management make more informed and effective decisions consistent with their general management goals.

All of the measurements taken this year by the groups of the capstone class will provide baseline data that will be useful for future classes and researchers. Gathering baseline data is the starting point for most research. Having this kind of information will allow monitoring to take place that will hopefully uncover negative trends and give management a more accurate description of what is happening on the ranch.

The 2005 LRES Capstone class has concluded that the B-Bar Ranch is generally in good environmental condition. There were no major areas of concern. The B Bar Ranch has fertile soils in the Davis Meadow adequate for their current hay production needs and the Tom Minor Creek is a F4 stream that can support a population of cutthroat trout. A change in irrigation systems is unnecessary for hay production needs. If irrigation is changed from flood to sprinkler systems there could be a negative effect on hydrology of the area. Mountain tarweed is native to the area, but early treatment is essential to have greater success in reducing the population. The acid did not affect mycorrhizae populations in the soil. The B-Bar Ranch appears to be operating according to their mission goals and objectives.

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