Range Management in the Face of Climate Change

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ABSTRACT

Climate change forecasts predict more frequent and more intense droughts in the West. These droughts will significantly impact wildlife habitat. Today most of our western rangelands are impaired. If restored, the predicted impacts of drought, and thereby, climate change, could be significantly reduced on our rangelands. This study evaluates how the Department of the Interior is measuring ecological health on rangelands and whether agency management effectively restores habitat's resilience, or ecological potential. This in-depth case study of a Bureau of Land Management (BLM) allotment in Utah reviews agency methods and uses five years of the authors' field data to understand if and how current BLM range management is addressing impacts to habitat from climate change. BLM does not inventory the ecological health and resilience of rangelands, and its qualitative ecological assessment methods are inadequate to identify or measure key ecological conditions. While we, as a society, have the capability to manage livestock grazing to restore habitat, the results of our case study shows this is not happening fast enough on the scale needed and degraded habitat is often under reported. Where agency management identifies problems, agency responses often rely on internal faulty habitat information. We found that fewer livestock actually grazed the allotment than were reported, BLM underestimated utilization, and also failed to adequately monitor trend and upland and riparian health. Our capacity analysis, based on forage production, cattle weights and sustainable utilization, determined that the number of livestock permitted is six times more than the carrying capacity of the study allotment. Habitat restoration must be part of the response to climate change. To achieve this, significant changes in range management on western rangelands will be needed.

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INTRODUCTION

Climate change is likely to lead to longer and more intense droughts in the Southwestern U. S. (IPCC 2007). The combination of climate change and habitat impairment represents one of the most potentially serious problems that humans, wildlife and their habitat have ever faced (Root at al. 2003). Severe impacts to ecosystem services are predicted, exacerbating the impacts from current natural and human stress factors (Blate and others 2009).

To date, the responses to climate change have focused primarily on mitigating climate-influencing gas emissions caused by human activities (Climate Action Network 2009). However, the use of range management to control the adverse effects of climate change has been largely neglected. What role does range management have in responding to climate change?

Actions that reduce the vulnerability of natural systems to climate changing influences have been recommended as a means of coping with climate change (IPCC 2007). These actions can include creating redundant populations, maximizing core areas and connectivity, and increasing habitat resilience (Malcolm and Pitelka 2000, Running and Mills 2009). C.S. (Buzz) Holling introduced the concept of resilience in ecological systems, defining resilience as a measure of how far the system could be perturbed without shifting to a different state (Holling 1973, Gunderson and Holling 1997). Increased habitat resilience helps ecosystems better withstand climate change (Blate at al. 2009).

Rangelands play an important role in regulating atmospheric carbon. Worldwide, soil organic matter contains three times as much carbon as the atmosphere (Ecological Society of America 2000, Allmaras at al. 2000, Flynn at al. 2009). Long term intensive agriculture can significantly deplete soil organic carbon (Benbi and Brar 2009). Past rangeland use in the United States has led to similar losses (Follett and others 2001, Neely and others 2009). Soil organic carbon is an important source of energy that drives many nutrient cycles. Increases in soil organic carbon and other organic matter lead to greater pore spaces and more soil particle surface area which retains more water and nutrients (Tisdale and others 1985). Soil organic carbon, which makes up about 50 percent of soil organic matter, is correlated with soil fertility, stability, and productivity (Herrick and Wander 1998).

The future impacts of climate change on western rangelands are predicted to be driven by more severe droughts (IPCC 2007). According to the U.S. Drought Monitor, which assesses the severity of droughts based on precipitation and soil moisture (Palmer 1965, Wilhite 2005), habitat impacts and vulnerability increase with drought intensity (Wilhite and others 2007). According to the National Drought Mitigation Center (2010), a moderate drought (D1) will cause some damage to plants, a high fire risk, and water shortages. An extreme drought (D3) leads to major plant loss, extreme fire danger, and likely widespread water use restrictions.

Models used to predict changes in species' ranges due to climate change often describe changes in environmental conditions of habitat based on changes in parameters that drive those environmental conditions (Pearson and others 2006). Today, a majority of western rangelands are in degraded condition and thus the predicted impacts of climate are also based on habitat that has been degraded. As a result, a common unstated assumption of the nine models that Pearson and others (2006) tested is that habitat resilience will be the same in the future as it is today. Clearly, modeling is needed that is based on habitat that is not degraded. We would predict that such modeling (of lands at their ecological potential) will show far fewer impacts than for impacted lands.

There has been little research that compares the impacts of drought on habitat that has lost its resilience with similar habitat that has not (Peterson 2009). Two examples from the Escalante River basin, Utah, offer some insight into the connection between drought and habitat resilience. The Gulch, a perennial stream in the Grand Staircase Escalante National Monument (figure 1) has almost no shading, is shallow and wide with mostly bare banks, resulting in high summer water temperatures. Fish and amphibians are absent. Five miles away is another perennial stream, Deer Creek (figure 2). The cross section of this stream channel resembles the bottom of an hour glass, narrow at the top and wide at the bottom. Mostly shaded, this stream supports persistent populations of both fish and frogs. Both streams are similar in many ways. The geology, soils, elevation, and climate are similar for both sites; thus, they should possess similar habitat characteristics. However, livestock grazing in Deer Creek has rarely occurred for the past 50 years, whereas 300 cow/calf pairs graze in The Gulch from November through March of each year (BLM 2008c). Deer Creek is near its ecological potential, and has resilience. The photos in figures 1 and 2 were taken during a D1 severity drought that has lasted most of the past seven years.

Figure 1. The Gulch (stream) during a drought in 2007. Photo BLM.

Figure 2. Deer Creek during a drought in 2007. Photo David Smuin.

Places like Deer Creek are rare. Most of the streams in the Intermountain West are in a degraded condition similar to that found in The Gulch (Belsky and others 1999, Baker and others 2003, BLM 2005, Milchunas 2006). Most rangelands in the West have been significantly impacted by human activities in the past and remain impaired today (Cottam 1945, PRIA 1978, Burkhardt 1996, BLM 2002, Baker and others 2003, Milchunas 2006). Riparian areas are often impacted by traditionally practiced livestock grazing (Platts 1991, Ohmart 1996) leaving approximately 80 percent of streams and riparian areas damaged in the western United States (Belsky 1999). According to the American Fisheries Society, 15,000 of 19,000 miles, or 77 percent of streams on BLM land are in unsatisfactory condition (Armour and others 1994). The Forest Service states that “Riparian areas throughout the Intermountain Region have been significantly affected over the past several decades. Most of these effects have been negative, including: lowering of water tables, erosion of stream channels, exotic plant encroachment (e.g. tamarisk), removal of beaver populations, concentrated runoff and increased sediment from road construction, and changes in vegetation composition” (Forest Service 1996).

The second example involves Twin Creeks and Mill Hollow, two similar sagebrush steppe habitats in the Uinta-Wasatch-Cache National Forest. In 2007, during a D2 intensity drought, site productivity was measured using the paired plot method (BLM 1996a) at both sites. Grass samples taken at Twin Creeks averaged 1023 kg/hectare air dry weight. This is similar to grass production expected during an unfavorable year for a site in excellent condition or at its ecological potential (Mason 1971). Mill Hollow had grass production of 139 kg/hectare air dry weight or 13 percent of that found at the Twin Creeks site. Soil, elevation, and climate conditions at these two sites are similar. Livestock grazing in Twin Creeks involves trailing for just five days a year, while Mill Hollow is grazed by 300 cow/calf pairs from late June to mid September annually (USFS 2004). This example shows that even during a drought, a site near its ecological potential shows a high level of herbaceous plant productivity, significantly more than that of habitat under typical grazing management.

These two examples demonstrate the hypothesis that habitat near its ecological potential is less vulnerable to climate change than habitat below its ecological potential (Beschta 1987). Thus, the restoration of habitat resilience becomes an important response to climate change. The field of restoration ecology has recently made significant advances in developing the needed theory for restoration (Falk and others 2006); and with better data on the ecological condition of habitat, we can better describe what is needed to achieve recovery of degraded sites. With a new focus on identifying habitat that has lost it resilience, followed by actions for restoration, we can reduce the severity of the impacts from the intense droughts that are forecast for the West.

Climate Change: BLM Ecological Assessments For Meeting Rangeland Health Standards

The Department of the Interior has taken steps to integrate climate change into its programs. The Secretary of the Interior signed Secretarial Order 3226 (DOI 2009), requiring Interior bureaus to analyze climate change in plans and policies. In 2007, Secretary Kempthorne initiated a Climate Change Task Force to report on climate change impacts and strategies relevant to Department of Interior lands. The need to restore habitat resilience was not included among the adaptation opportunities described in this report (Neely and Wong 2009, USGS 2008). In September of 2009, Secretary Salazar issued Secretarial Order 3289 that revised the direction that the Department of the Interior would take in addressing climate change (Salazar 2009a). This order called for coordination among federal agencies to promote three functions – renewable energy production, carbon capture and storage, and climate adaptation (Salazar 2009b). This order established the Climate Change Response Council and eight Climate Change Response Centers to develop response strategies that federal agency Landscape Conservation Cooperatives would act upon. So far, the new Council and Centers have not used the term “resilient habitat,” or discussed the need to restore habitat as a part of adaptation or carbon storage strategies (Haynes 2009). BLM’s 2008 science strategy does not mention climate change as part of the agency’s priorities (BLM 2008a). However, BLM’s 2010 budget does include funding for agency response to climate change (BLM 2009a).

To respond to climate change, it makes sense to review the relevance of past ecological assessment methods that BLM uses in the context of habitat resilience. For more than a decade, the BLM has had ecosystem management policies in place. Rangeland Reform ’94 established national standards for range management to address ecosystem health (BLM 204a, DOI 2004; Nicoll 2005). Each state BLM office has established Rangeland Health Standards, based on these national standards, designed to maintain functioning ecosystems. Utah's rangeland health standards open with, "It is time for change, and BLM is changing to meet the challenge. BLM is now giving management priority to maintain functioning ecosystems. This simply means that the needs of the land and its living and nonliving components (soil, air, water, flora, and fauna) are to be considered first" (BLM 1997). These Standards require that managers make significant progress in four areas: watersheds are in properly functioning condition, ecological processes are maintained, water quality meets state standards, and habitats are meeting special status species needs.

BLM's handbook H-4180-1 (BLM 2001b) describes the practices that BLM follows to implement the Rangeland Health Standards (43 CFR 4180). BLM first conducts an evaluation and then makes a determination of whether rangelands are in properly functioning condition (Standards are met) or functioning at risk (one or more Standards are not met). Where Standards are not met, BLM must determine whether livestock grazing is a factor. If the area is not making significant progress towards meeting Standards and livestock is a factor, change in livestock management is required no later than the next grazing year. To collect field data and assess whether rangelands are in properly functioning condition, BLM relies primarily on the field assessment methods described in three technical references, "Interpreting Indicators for Rangeland Health" (Pellant and others 2000), "Process for Assessing Proper Function Condition for Lentic Riparian-Wetland Areas" (Prichard 2003a), and "A Guide to Assessing Proper Function Condition and the Supporting Science for Lotic Areas" (Prichard 2003b).

Each year BLM compiles the results of all rangeland health assessments (BLM 2009c) in a published report title "Rangeland Inventory and Monitoring Evaluation Report." The results for 2009 are presented in table 1. In Utah, with 68 percent of 1,413 BLM allotments evaluated, 1 percent were not meeting standards or making significant progress towards meeting standards and livestock use was a factor. This means that BLM argues that only a very small number of allotments, 1 percent of the assessed Utah BLM allotments, require changes in grazing management in order to meet rangeland health standards.

Responding to climate change requires assessing the condition of habitat and then responding to stressors. To assess the impact of range use, BLM conducts range monitoring, including trend, utilization, and ecological site inventory, which supports annual grazing management decisions. Permanent trend sites, where data are gathered periodically, are established in most allotments.

Table 1. National assessment of BLM allotments that met the Standards for Rangeland Health as of 2009.

Category	**Total BLM allotments (% of assessed)**	**Utah BLM allotments (% of assessed)**
A. Rangelands meeting all standards or making significant progress toward meeting the standard	11,603 (78%)	813 (80%)
B. Rangelands not meeting all standards or making significant progress toward meeting the standards but appropriate action has been taken to ensure progress toward meeting the standards. Livestock is a significant factor.	1,620 (11%)	132 (13%)
C. Rangelands not meeting standard or making significant progress toward meeting the standards and no appropriate action has been taken. Livestock is a significant factor.	335 (2%)	9 (1%)
D. Rangeland not meeting all standards or making significant progress toward meeting the standards due to causes other than livestock grazing.	1,318 (9%)	65(6%)
Total number of allotments that have been assessed	14,876	1,019
Total number of allotments	**21,363**	**1,408**

Source: Bureau of Land Management. 2010. Rangeland Inventory, Monitoring, and evaluation Report, Table 7 Standards for rangeland health cumulative accomplishments.

A number of data collection methods are commonly used on these trend sites, including nested frequency data on plant species and canopy, photo plots, and line intercept transects (BLM 1996b). At the trend sites, BLM often focuses on "key species," usually important forage plants (BLM 1984a, BLM 1989, Elzinga and others 1998).

Annual utilization monitoring relies primarily on observer estimates of the percent of key species that have been removed by livestock and wildlife. This "key species method of herbaceous removal" (BLM 1984c, 1996a) requires that the observer classify the utilization of a key species at a site based on qualitative descriptions. In riparian areas, stubble height data for key plants may be collected to assess utilization (BLM 1996a). The end-of-season reports that the grazing permit holder is required to submit are the most common record of grazing practices conducted on an allotment, which lead to the observed utilization levels.

Based on monitoring, BLM can make changes in the number of livestock to be permitted in an allotment, the season of use, and the length of grazing season (BLM 1984d, BLM 1989). Other potential changes include whether to manipulate vegetation for the benefit of livestock, and whether to construct range improvements (e.g., fences, grazing exclosures, ponds, pipeline with troughs, etc.). BLM also makes decisions on the grazing system, such as rest rotation or deferred rotational grazing.

Do the management tools used by the BLM for range management adequately assess habitat resilience and guide the required response? Because of the breadth of this topic, this paper uses a comprehensive analysis in order to answer this question. Based on the authors' long-term study of a BLM grazing allotment in northern Utah, we are able to explore the ability of BLM's methods to assess rangeland health.

METHODS

Study Setting, Duck Creek Allotment

The Duck Creek Allotment is located in Rich County in northeastern Utah. This area is part of the Intermountain Region, Middle Rocky Mountain Physiographic Province Wasatch Mountain Floristic Zone, which extends for over 200 miles north to south (Cronquist and others 1972). This zone is recognized as a key wildlife corridor connecting the Greater Yellowstone Ecosystem in the north to the Uinta Mountains and southern Rockies in the south (USFS 2003). It is a semi-arid cold desert sagebrush-grassland, or sage-steppe type, in which the majority of the precipitation falls as snow during late fall to early spring, while summers are dry (Holechek and others 2004).

The Duck Creek allotment lies in the Bear River Plateau which contains nearly level to steep uplands dissected by numerous small drainages. These small streams range from perennial to ephemeral. Many are diverted or dammed into reservoirs for irrigation before reaching the Bear River. Annual precipitation varies from approximately 305 mm/year (12") at lower elevations to 406 mm/year (16") at higher elevations (SCS 1982). Temperatures range from a minimum monthly average of -17° C in January to a maximum monthly average of 27° C in July (Western Regional Climate Center 2010). During the 26-year period 1982 to 2009, the nearest climate station (14 km south), recorded 15 years with below average precipitation (figure 3). During the period 2000 to 2009, the U.S. Drought Monitor assessed three years as normal with seven years in various stages of drought (U.S. Drought Monitor 2010).

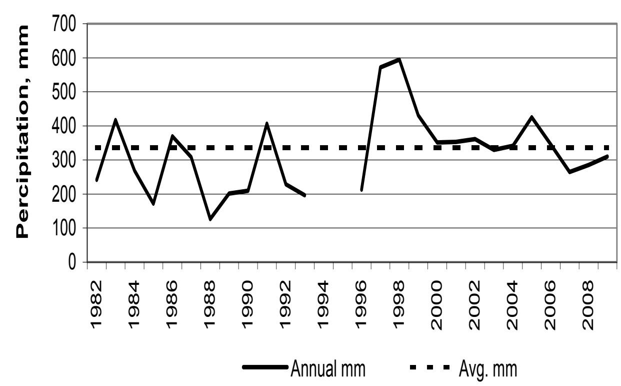

Figure 3. Annual Precipitation for Randolph, Utah, near the Duck Creek Allotment.

Elevations on the Duck Creek allotment range from 1,920 to 2,220 meters. The allotment contains 9,053 ha (22,371 acres) of which 5,297 ha are BLM lands, 3,474 ha are private, and 427 ha are State lands. Perennial streams on BLM lands within the allotment include Duck Creek, Six Mile Creek and North Fork Sage Creek. Twenty-nine springs occur on BLM lands within the allotment (BLM 2008b).

The plant community consists of shrubs dominated by sagebrush, including: Wyoming big sagebrush (*Artemisia tridentata wyomingensis)*, low sagebrush (*A. arbuscula*), black sagebrush (A. nova), basin big sagebrush (*A. t. tridentata*), green rabbitbrush (Chrysothamnus viscidiflorus), bitterbrush (Purshia tridentata), serviceberry (Amelanchier utahensis), snowberry (Symphoricarpos oreophilus), and winterfat (Krascheninnikovia lanata). Small groves of aspen (*Populus tremuloides*) and Utah juniper (*Juniperus osteosperma*) are present. Willow (*Salix spp*.) are rare in riparian areas, which are dominated by Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis spp*.), and Nebraska sedge (*Carex nebraskensis*). Perennial grasses present include: bluebunch wheatgrass (Pseudoroegneria spicata), *Indian ricegrass (*Orozopsis hymenoides*), western wheatgrass (*Pascopyrum smithii*), and Sandberg's bluegrass (*Poa Sandbergii*)*. Broad-leaved flowering plants include: arrowleaf balsamroot (*Balsamorhiza sagittata*), buckwheat (*Eriogonum* spp.), spiny phlox (*Phlox hoodii*), pussytoes (*Antennaria microphylla*), and yarrow (*Achillea millifolium*). Some areas on south-facing slopes are invaded by cheatgrass (*Bromus tectorum*) and noxious weeds such as black henbane (Hyoscyamus niger), Canada thistle (Cirsium arvense**)**, musk thistle (Carduus nutans), and houndstongue (Cynoglossum officinale) occur in valley bottoms. Based on herbaria collections, the Utah Plant Atlas identified 131 vascular plant species as occurring in the Duck Creek Allotment (Ramsey and others 2004, Schultz and others 2006).

The Duck Creek allotment contains habitat for BLM sensitive species including sage grouse *(Centrocercus urophasianus),* short-eared owl *(Asio flammeus),* ferruginous hawk *(Buteo regalis)*, golden eagle *(Aquila chrysaetos)*, and pygmy rabbit *(Brachylagus idahoensis*) (BLM 2008b). Large ungulates include mule deer *(Odocoileus hemionus)*, Rocky mountain elk *(C. canadensis nelsoni)* and pronghorn (*Antilocapra americana).* Small mammals include white-tailed jackrabbit (*Lepus townsendi*), cottontail (*Sylvilagus nuttali*), yellow bellied marmots (*Marmota flaviventer*), Uinta ground squirrels (*Citellus armatus*), least chipmunk (*Eutamias minimus*), and badger (*Taxidea taxus*). Over 90 migrant bird species that occur in the area include Brewer's sparrow *(Spizella breweri),* sage sparrow *(Amphispiza belli),* and sage thrasher *(Oreoscoptes montanus)* (BLM 1980a, b).

Eight range sites occur on the allotment: mountain loam, semidesert loam, semidesert stony loam, upland loam, upland shallow loam, upland shallow loam (juniper), upland stony loam, and woodland (aspen). The soil survey for this allotment identifies 26 different soil map units which are dominated by high or very high erosion hazard (SCS 1982). Riparian areas are not described in the soil survey, but are associated with the springs and streams. The streams have become incised and have lost access to their historical floodplains.

Livestock, including cattle, sheep and horses, have grazed Rich County and the Duck Creek allotment since settlement of the area in the 1800's. Currently six individual permits allow 400 cattle, 14 horses, and 765 sheep to graze on BLM lands and an additional 241 cattle and 305 sheep are allowed under exchange of use with private and state lands within the allotment boundary. The grazing season for cattle is May 10 thru September 7. Sheep graze under two permits, during spring from May 10 to July 1 and in fall from September 20 until December 1. Total AUMs under Active Use are 2,134 with an additional 1,176 allowed under Exchange of Use, for a total permitted use of 3,310 AUMs (BLM 2004b, 2008b).

Structural range facilities include the allotment boundary fence and two internal pasture fences that divided the allotment into four pastures in 2006. Prior to that time, the allotment lacked internal pasture fences. Water developments on BLM lands include fourteen troughs, eleven spring developments and six excavated ponds. (BLM 2009b).

Authors' Data Collection Methods

In 2001, BLM determined that the Duck Creek Allotment did not meet the Standards for Rangeland Health (BLM 2001c). In response to a long-term regional drought and issues raised by some members of the conservation community (Carter and Bloch 2001), in 2002 Rich County initiated a collaborative process to improve wildlife habitat and livestock grazing management in the county (Rich County 2007).

The Duck Creek Study area was chosen by the Rich County Coordinated Resource Management Collaboration (CRMC) as a priority area for implementing practices to achieve their goals for improved management of wildlife and ranching. To implement these goals, the CRMC developed a multipasture rotation proposal with new upland water troughs and a distribution system (BLM 2004b), which BLM proposed to adopt in a Draft Allotment Management Plan for Duck Creek in 2004 (BLM 2004b). A modified proposal (BLM 2008b) was implemented in 2009, with construction of a 14 km pipeline and 6 additional watering locations in the southern half of the allotment.

The Utah Division of Wildlife Resources and others began studies focused on the Duck Creek Allotment beginning in 2005 (Norvell 2008). In 2005, the CRM established a monitoring committee. Working with this monitoring committee, the authors developed a monitoring plan that would augment other data being collected in this allotment. This study presents the data collected from 2005 to 2009 on herbaceous plant annual production and utilization, riparian residual stubble heights, canopy and ground cover, water quality, and number of cattle on the allotment.

Herbaceous Plant Annual Production and Utilization

The upland herbaceous plant community was sampled using the paired plot method (BLM 1996a). Utilization cages (1.2 m^2) were placed in riparian and upland locations prior to the start of livestock grazing (figure 4). These cages excluded herbivory by rabbits and larger animals. Sampling sites were chosen to represent soil map units that covered a majority of the allotment, key range sites identified by BLM, riparian areas, and Utah Division of Wildlife Resources wildlife survey sites. At each location, a sample frame (0.84 m^2 or 9 ft^2) was used inside the cage and on ten sites outside the cage to establish plots within which total residual herbaceous plant biomass was clipped. The frames in grazed areas were placed at 15.2 m (50 feet) and 30.5 m (100 feet) along five transects with headings of 72 degrees apart radiating outward from the cage. All herbaceous species in each sample plot were collected. This avoided the uncertainty of collecting only certain forage species which may be difficult to identify when grazed and may not be representative of the community as a whole. Samples were air dried and weighed to the nearest 0.1 gram.

In riparian sites after the end of the grazing season, a 0.82 m^2 sample frame was used for plots inside the utilization cage and in two plots 15.2 m and 30.5 m upstream and downstream from the cage, for a total of four grazed plots at each location. Stubble heights (BLM 1996a) of Nebraska sedge were measured on a transect along the greenline, the first grouping of perennial vegetation along the water's edge (Winward 2000), in the vicinity of the riparian utilization cages. Stubble heights were then correlated with paired plot utilization data.

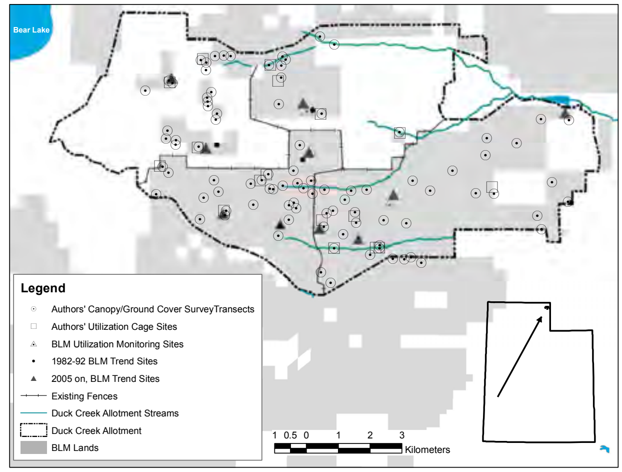

Figure 4. Location of authors' utilization and canopy cover survey sites.

Canopy and Ground Cover Surveys

In 2005, BLM conducted ecological site inventories (ESI) to describe the current status of the plant communities in terms of species, production and cover. The authors selected a number of sites that represented similar conditions found in representative BLM ESI locations where BLM also conducted rangeland health evaluations. The authors collected canopy and ground cover data (figure 4) for comparison to BLM data and to published canopy guidelines for sage grouse habitat (Connelly et al 2000). BLM data were collected in June and July, 2005. The authors' data were collected in May, June, July, September, and October 2008.

Ten sites were monitored from spring through fall in the south half of the allotment; an additional six sites in the north half were monitored during July. The quantitative line point transect intercept method (Herrick and others 2009) was used to collect canopy and ground cover. Radial transects (100' or 30.5 m) were placed in directions chosen from a random numbers table (Ott 1977). At each foot mark (0.3 m) on the tape, a metal pin was dropped through the vegetation layers and "hits" recorded for canopy of shrub, grass, forb and for grass >18cm and forb >18cm. Basal hits for bare ground, rock, crust, grass, forb, shrub and litter were also recorded. During the May and June samples, two transects at headings of 104° and 223° were surveyed for a total of 200 points at each location for each month. Two transects were added (at 241° and 289°), bringing the total points for each location to 400 for the July, September, and October surveys. This gave a total of 16,000 data points for these 10 transects (160 total transects) for these five time periods. The July survey of the six additional locations in the north portion of the allotment recorded data from 24 transects and 2,400 data points.

Livestock Distribution and Census

The number of livestock that graze in an allotment, and the duration of grazing, are recorded by the grazing permit holder in "actual use reports." These can be validated but almost never are by field counts, including aerial surveys, of livestock (BLM 1984b). The authors counted the number of cattle grazing in the Duck Creek allotment during two aerial surveys conducted in 2006 and 2008. These used a fixed-wing aircraft traveling at approximately 150 km/h at an elevation of 250 m above the ground. A minimum of eight transects were flown. Where cattle were concentrated, quadrant surveys (circling of the aircraft) were conducted to note the location and number of cattle within each transect. The count at each location was checked a minimum of four times. Data were recorded on a field map and later entered in a GIS layer for display and tabulation.

Water Quality Monitoring

The authors sampled water quality in seven streams on BLM lands in Rich County during August, 2009. EPA-approved methods were used to monitor for key water quality parameters such as E. coli/fecal coliform, temperature, pH, dissolved oxygen, and turbidity. Streams monitored were Duck Creek, Six Mile Creek, and the North Fork of Sage Creek. A Hach HQ20 Portable LDO Dissolved Oxygen meter was used at each site to collect water temperature and dissolved oxygen data. As a quality control check, additional readings for temperature (water and air) were taken with an H-B Instrument Co. Enviro-Safe thermometer. A Hach 2100P turbidity meter was used to measure sample turbidity for each site visit. A Hach SensION2 portable pH/ISE meter was used to measure pH. A Garmin eTrex GPS unit was used to collect location data in latitude and longitude at each site. The *E.* coli/Fecal coliform analyses were conducted using IDEXX Laboratories equipment to run Colilert® tests for each sample. The equipment set includes a Quality Lab Model WW-64835-00 Incubator, the IDEXX Quanti-Tray® Sealer Model 2X, sealing tray(s), Quanti-Tray® 2000 cards, ampuoles of Colilert® reagent, a Spectroline EA-160 ultraviolet lamp for *E. coli* delineation, and 100ml Whirl-Pak® bags to collect samples. Samples were diluted 10:1 for streams with expected high coliform concentrations. Temperature, pH, dissolved oxygen, turbidity, and E. coli/fecal coliform were sampled 5 times within 30 days (separated by at least 3 and no more than 7 days between samples) to allow calculation of a monthly geometric mean for *E. coli* at each site.

BLM's Data Collection Methods

Utilization Data Collection

BLM conducted utilization monitoring from 2005 to 2008 using the key species method (BLM 1996a). This qualitative assessment uses an ocular estimate of the amount of forage removed by weight on an individual key species plant. Examiners walk along a transect and estimate the amount of utilization based on descriptions found in table 2. This method recommends that an ungrazed reference area be available for comparison. Training of observers involves comparison of estimated utilization with clipped and weighed sample plots. Utilization monitoring typically is a qualitative measure of the general appearance of a few key species.

Table 2. BLM qualitative key species method utilization classification system.

Utilization Class	Class Description
0-5% utilized	"the key species show no evidence of grazing use or negligible use"
6-20%	"the key species has the appearance of very light grazing. Plants may be topped or slightly used. Current seed stalks and young plants are little disturbed"
21-40%	"the key species may be topped, skimmed, or grazed in patches. Between 60 and 80 percent of current seed stalks remain intact. Most young plants are undamaged"
41-60%	"half of the available forage (by weight) on key species appears to have been utilized. 15-25 % of current seed stalks remain intact"
61-80%	"more than half of the available forage on key species appears to have been utilized. Less than 10% of the current seed stalks remain. Shoots of rhizomatous grasses are missing"
81-94%	"the key species appears to have been heavily utilized and there are indications of repeated use. There is no evidence of reproduction or current seed stalks"
95-100%	"the key species appears to have been completely utilized. The remaining stubble is utilized to the soil surface"

Source: BLM. 1999. Technical Reference 1734-3, Utilization studies & residual measurements, key species method, pages 81-85.

Ecological Site Inventories

Ecological site inventories collect data including plant species and productivity. When these data are compared with the plant community at its ecological potential, a similarity index can be determined (Habich 2001). The similarity index is calculated by comparing the occurrence of plant species for a sample site to reference areas or to the Ecological Site Type description (NRCS 2009).

In 2005, BLM conducted ecological site inventories in the Duck Creek Allotment to use in BLM's rangeland health assessments (BLM 2001a). See figure 5. BLM's purpose in using the ecological site inventory was to compare the composition and production of plant communities found today with the appropriate ecological site at its potential. This survey method, which involves estimating the amount of annual production (air dry weight) for each species observed along sample transects, is used to calculate a similarity index. The species production is used to calculate the similarity of the sample site with the plant community for this ecological site in climax condition. The annual production for the species identified is summed and compared with a similar sum for the climax community.

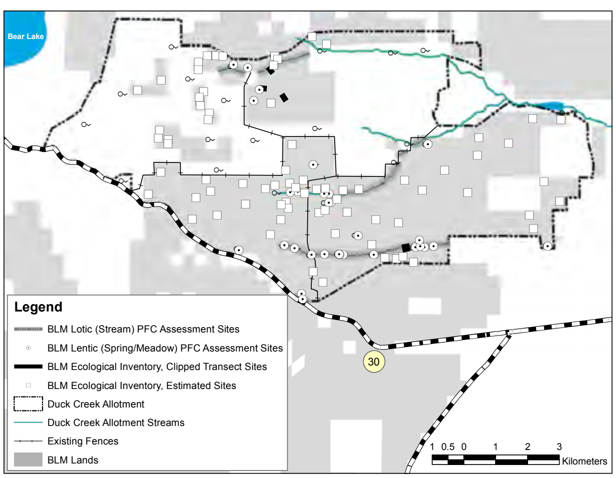

Figure 5. Location of BLM rangeland health and riparian properly functioning condition assessment sites.

BLM used double sampling (BLM 2001a) to collect data at four transects on the Duck Creek Allotment. Each transect had 20 plots where annual production by species was estimated. Two plots on each transect were clipped and weighed wet and then compared to an estimate for annual production that BLM made on the same transect for that plot. Comparison of clipped and estimated values led to a correction factor, which was then applied to the 20 estimated plots on the transect. Assumed corrections were then applied to the field data to: 1) convert the weight of green clipped plants to air dried weight; 2) adjust for the amount of utilization that occurred prior to sampling; and 3) adjust for the percent growth when sampling early or midway through the growing season. The corrected data for all species BLM sampled were then totaled and that total compared against a total for a climax community. The resulting similarity index, expressed as a percent, was then ranked in one of four successional stages: 0-25 percent early; 25-50 percent mid; 51-76 percent late; and 77-100 percent potential natural (climax) community (BLM 2001a).

For the Duck Creek Allotment, BLM concludes that a similarity index of 50 percent or better is ranked as "functional" and meets rangeland health standards (BLM 2008b). BLM used the similarity index results as a key factor to assess whether rangeland health standards were met on the allotment.

Trend Data Collection

Collection of trend data as practiced by BLM (BLM 1996b) typically includes measuring the frequency of key plant species along a transect. Holechek and others (2004) recommend measuring trend at intervals of ≤ 5 years. In the case of Duck Creek BLM has measured trend at intervals between 2 and 12 years, using different locations; this makes analysis of trends at a site impossible. Trend data are considered inadequate to assess whether rangeland health standards are being met (Pellant and others 2000).

From 1962 to 2007, trend data were collected by the BLM at a number of sites using different methods (Figure 4). From 1962 to 1979, the photo plot method (BLM 1985) was used at two sites; from 1982 to 1992, the nested frequency sampling method (BLM 1985) was used at five sites; in 2004, an unknown method was used at a new site; and from 2005 to 2007, the line point intercept method (BLM 1985, Herrick and others 2009) was used at ten new sites.

Rangeland Health Assessments

BLM assessed rangeland health in 2005 at 34 sites. At each of these 34 sites, BLM scored 17 qualitative indicators of soil stability, hydrologic function, and the integrity of the biotic community at an ecological site level (Pellant et al 2000).

Riparian/Wetland Assessments

BLM's rangeland health assessments for riparian areas were based primarily on Properly Functioning Condition assessments for lotic and lentic areas (Prichard 2003a, Prichard 2003b). A properly functioning stream, or lotic area, has stabilized banks to dissipate high water flows in a manner that prevents unwanted erosion, traps sediment, and supports floodplains (BLM 1998). A properly functioning lentic area (springs, ponds, and meadows) has stability due to plants, which prevent excessive erosion, trap sediment, and support ground water recharge (Prichard 2003). The Duck Creek Allotment has more than 13 km of streams and 29 springs and wet meadows. Beginning in 2001, BLM assessed 29 lentic sites and 14 stream segments for properly functioning condition (figure 5).

RESULTS

Herbaceous Plant Annual Production and Utilization

From 2005 through 2009, each year the authors collected paired plot samples of herbaceous residual vegetation in 670 sample plots for a total of over 1,300 samples for grasses and forbs. The residual vegetation found inside the utilization cages represents growing season production protected from grazing for both upland (table 3) and riparian areas (table 4). In 2005 seven upland sites were surveyed. From 2006 to 2009, twelve upland sites were surveyed. Table 5 compares measured upland grass production to the production predicted to occur on specific range sites, as described by the Rich County Soil Survey (SCS 1982; NRCS 2009). Values ranged from 25 to 76 percent of potential.

Upland grazing utilization measured by paired plots from 2005 to 2009 (based on grass and forb residual weights in grazed areas compared to ungrazed utilization cages) is described in table 6. Utilization ranged from 0 to 87 percent. In 2007, BLM personnel visited seven of the authors' upland sites where they measured utilization using the key species method. BLM's and the authors' results are compared in table 6. BLM's utilization results were consistently lower than the authors'.

Table 3. Duck Creek allotment herbaceous plant production in kg/ha in upland areas, based on the Authors' paired plot data.

Site	2005 Grass	2005 Forb	2006 Grass	2006 Forb	2007 Grass	2007 Forb	2008 Grass	2008 Forb	2009 Grass	2009 Forb	Averages Grass	Averages Forb
U1	48	275	99	173	304	38	272	201	175	114	180	160
U2	307	188	232	19	288	2	132	115	153	109	223	87
U3	112	229	135	37	226	0	86	82	87.1	104	129	91
U4	213	302	169	42	168	78	278	148	150	62	196	126
U6	304	417	350	145	190	62	208	242	186	238	248	221
U8	218	100	210	102	345	84	445	117	301	358	304	152
U9	207	130	191	6	135	1	323	25			215	41
U11			59	36	363	4	801	121	739	28	492	47
U12			183	169	353	146	411	285	350	205	325	202
U13			198	507	132	26	445	84	124	293	226	228
U14			67	165	174	6	87	177	108	134	109	121
U15			44	7	150	2	125	85	242	26	141	30
Average	202	234	161	117	236	38	302	140	238	152	232	126
SD	95	109	87	139	89	46	206	74	185	108		

Note: all data collected underneath grazing utilization cages thus protected from grazing.

Table 4. Duck Creek allotment herbaceous plant production in kg/ha for riparian areas, based on the authors' paired plot data.

Riparian Site	2005	2006	2007	2008	2009
U5	1,883	955	1,264	1,263	1,988
U7	1,013	419	900	1,667	482
U10	1,975	404[a]	2,038	1,684	N/A[b]

[a]Utilization cage U10 damaged, clipped small area remaining. [b]Utilization cage U10 damaged and no ungrazed residual vegetation to clip. Note: all data collected underneath grazing utilization cages protected from grazing.

Table 5. Grass annual production by range site based on authors' data for the Duck Creek Allotment.

range site[a]	ha	% of area	ha <50 % slope	authors' sites	grass production avg. of authors' sites kg/ha	grass production potential by range site, at normal precip. year[b] kg/ha	area accessible to livestock in the interspace between shrubs ha	total accessible grass production, authors' 2006-2009 data kg	total accessible grass production at potential for a normal year kg
Mountain Loam	14	(<1%)	12						
Semidesert Loam	2591	28%	2584	U2, U3	167	428	1,731	289,077	740,868
Semidesert Stony Loam	932	10%	929	U4	158	423	622	98,898	263,106
Upland Loam	2016	22%	1986	U1, U6 U13, U14	195	792	1,331	259,545	1,054,152
Upland Shallow Loam	2353	26%	2314	U8, U9 U11, U15	293	856	1,576	461,768	1,349.056
Upland Shallow Loam (Juniper)	132	1%	95			720			
Upland Stony Loam	1157	13%	1099	U12	324	428	736	238,464	354.752
Woodland	0	(<1%)	0						
Not Identified	4	(<1%)	0						
Totals	9199	100%	9018					1,347,752	3,761,934

[a]BLM 2004 Duck Creek Project EA UT-020-2004-0030
[b]SCS 1982 Rich County Soil Survey

We assessed grazing utilization in three riparian sites on the Duck Creek allotment using paired plots (table 7). At each site stubble height of Nebraska sedge was measured. Table 7 reflects the relationship between Nebraska sedge stubble height and grazing utilization at these sites. Stubble heights were measured at 7 additional sites to determine if the stubble height data at the three sites were comparable to other grazed riparian areas (table 8). The BLM requires that stubble heights be more than 12.7cm at the end of the grazing season. Data in table 8 reports that stubble heights of Nebraska sedge were less than 12.7 cm with utilization ranging from 85.7 to 97.4 percent. During August 2005, one month prior to the end of cattle grazing season, stubble height of grasses at two sites in meadows adjacent to Duck Creek and along the greenline were measured and compared. Meadow stubble heights at two different sites (RS1 and RS2) were 3.4 cm and 4 cm compared to greenline stubble heights of 8.1 cm and 6.1 cm respectively. Riparian utilization away from a stream was found to be higher than that measured along the greenline.

Canopy and Ground Cover

Table 9 provides a summary of the mean canopy cover for 10 sites located in BLM ecological sites used in rangeland health assessments in the south half of the allotment. Means were calculated across all sites within each month. Total shrub canopy (sagebrush, rabbitbrush, snowberry and others) averaged 33.3 percent. Shrub canopy other than sagebrush varied from 0.5 to 9.5 percent and averaged 5.1 percent. The overall sagebrush canopy averaged 28.2 percent. BLM estimated sagebrush canopy for the allotment as 38 percent.

Table 6. Upland percent grazing utilization, Duck Creek allotment, authors' and BLM data, 2005-2009.

BLM Site	Author Site	Separation Meters	BLM Sites Species Assessed	Author Sites	2007 BLM Assessment at Authors Sites, Species Assessed
DC 1	U8	133m	**2005:STLE 11%*** 2007:STLE 37%, POA 36% 2008:STLE 42%, POA 44%	**2005:10%*** 2006:71% 2007:61% 2008:81% 2009:87%	
DC 2	U6	256m	**2005:STLE 16%, POA 12%*** 2007:STLE 26%, POA 25% 2008:STLE 42%, POA 37%	**2005:53%*** 2006:65% 2007:67% 2008:71% 2009:81%	
DC 3	U9	487m	**2005:STLE 12%*** 2007:STLE 11%, PONE 8%, AGSP 12% 2008:STLE 29%, PONE 33%, AGSP 27%	**2005:27%*** 2006:20% 2007:0% 2008:49% 2009:na	STLE 21 % POFE 22%
DC 4		na	2005:STLE 13%, POA 17% 2007:STLE 34%, POA 32% 2008:STLE 28%, POA 20%		
DC 5	U1	134m	2005:AGSM 18%, AGSP 21% 2007:AGSM 19%, AGSP 21%, POA 17% 2008:AGSM 24%, AGSP 27%, POA 23%	2005:54% 2006:71% 2007:80% 2008:54% 2009:63%	STLE 20% POFE 30%
DC 7	U2	256m	2005:PSSP 17%, POA 23% 2007:POFE 32%, AGSM 30% 2008:POFE 9%, AGSM 8%, AGSP 10%	2005:75% 2006:73% 2007:84% 2008:0% 2009:56%	STLE 23% POFE 30%
DC 8		na	2005:POA 31%, PSSP 30% 2007:POA 29%, PSSP 25% 2008:POA 15%, PSSP 18%		
DC10		na	2005:STLE 30%, POA 40% 2007:STLE 27%, POA 30% 2008:STLE 6%, POA 6%		
	U3	na		2005:68% 2006:51% 2007:80% 2008:23% 2009:27%	STLE 26% AGSP 15%
	U4	na		2005:40% 2006:10% 2007:54% 2008:57% 2009:44%	STLE 18% AGSP 13%
	U11	na		2006:3% 2007:63% 2008:78% 2009:87%	POFE 40% AGSP 26%
	U12	na		2006:62% 2007:79% 2008:77% 2009:77%	STLE 37% PONE 32%
	U13	na		2006:76% 2007:0% 2008:71% 2009:75%	
	U14	an		2006:76% 2007:71% 2008:38% 2009:52%	
	U15	na		2006:10% 2007:78% 2008:46% 2009:80%	

***Bolded** text means that the site was rested from grazing during that year.

Table 7. Stubble height of Nebraska sedge compared to percent utilization in Duck Creek allotment riparian sites.

Location	2005	2006	2007	2008	2009
Duck Creek (U5)	8.1 cm (85.7%)	8.3 cm (79.1%)	9.0 cm (96.4%)	7.9 cm (94.8%)	6.7 cm (97.4%)
Six Mile Creek (U7)[c]		9.1 cm (87.2%)	7.6 cm (90.8%)	<10 cm (95.3%)	5.0 cm (96.9%)
S. Fork Six Mile Creek (U10)[c]		7.5 cm (93.7%)	8.0 cm (96.6%)	<10 cm[a] (97.3%)	5.4 cm[b]

[a]Authors' observations for stubble height. [b]The two cages at site U10 in 2008 and 2009 were turned over and utilization could not be measured. [c]In 2005 sites U7 and U10 were no grazed.

Table 8. Nebraska sedge stubble height (cm) measurements taken at authors' Duck Creek Allotment riparian monitoring sites (U5, U7, and U10) at the end of grazing season, along with seven other sites in watershed, 2005 – 2009.

Location	2005	2006	2007	2008	2009
Duck Creek (U5) (RS1)	8.1 (2.5)[a]	8.3 (3.0)	9.0 (3.6)	7.9 (2.4)	6.7 (3.3)
Duck Creek (RS2)	6.1 (1.6)[a]		5.0 (1.6)	5.5(1.8)	4.1 (1.7)
Duck Creek Red Spring			7.6 (2.1)	6.7 (2.1)	4.0 (1.4)
Duck Creek Rich Spring				9.7 (0.7)	6.3 (2.5)
Six Mile Creek (U7)		9.1 (2.7)	7.6 (3.8)	<10[b]	5.0 (1.5)
S. Fk Six Mile Creek (WP123)				7.8 (2.9)	6.1 (2.6)
S. Fk Six Mile Creek (WP124)				5.8 (1.7)	6.8 (2.4)
S. Fk Six Mile Creek (WP125)				5.8 (1.9)	4.8 (1.6)
S. Fk Six Mile Creek (WP126)				7.6 (2.3)	6.6 (1.9)
S. Fk Six Mile Creek (U10)		7.5 (2.7)	8.0 (2.3)	<10[b]	5.4 (2.2)

[a]Measured one month prior to the end of the grazing season. [b]Authors' observation. Parenthesis denote standard deviations.

Table 9. Average canopy cover percent measured by authors at BLM Ecological Sites in Duck Creek Allotment.

Month	Total Shrub	Total Grass	Total Forb	Grass >18cm high	Forb >18cm high
May	31.7 (4.1)[a]	7.2 (4.1)	3.1 (1.6)	0.0 (0)	0.0 (0)
June	34.8 (6.4)	17.6 (3.7)	15.0 (4.1)	4.5 (2.5)	1.2 (2.1)
July	33.6 (5.3)	18.7 (3.2)	12.4 (4.9)	5.7 (2.7)	2.2 (1.6)
September	33.4 (5.1)	17.4 (3.0)	9.1 (4.7)	2.9 (1.6)	1.2 (1.0)
October	33.1 (6.0)	19.0 (3.4)	9.2 (4.7)	2.1 (1.2)	0.6 (0.5)
Overall	33.3 (5.3)	16.0 (5.6)	9.7 (5.7)	3.0 (2.7)	1.0 (1.4)

[a]Numbers in parenthesis are the standard deviation.

Table 10. Average ground cover percent for ten BLM Ecological Sites on Duck Creek allotment.

Month	Bare Ground	Rock	Crust	Grass*	Forb[a]	Shrub*	Litter
May	25.6 (6.6)[b]	4.1 (2.9)	2.8 (1.5)	4.5 (1.6)	9.0 (3.9)	0.8 (0.9)	53.3 (7.7)
June	23.2 (5.8)	3.8 (3.3)	1.8 (1.2)	3.6 (1.3)	6.1 (4.9)	1.3 (0.9)	60.4 (6.8)
July	23.9 (5.5)	4.2 (3.8)	0.9 (0.9)	3.3 (1.0)	4.8 (2.9)	2.5 (1.0)	60.4 (6.2)
Sept	22.8 (7.0)	4.3 (3.0)	0.9 (0.9)	3.4 (0.9)	2.4 (1.6)	3.5 (1.0)	62.8 (7.9)
October	23.6 (9.3)	2.4 (2.4)	1.1 (0.7)	3.1 (0.5)	1.1 (0.7)	3.4 (0.6)	65.4 (10.4)
Overall	23.8 (6.7)	3.7 (3.1)	1.5 (1.3)	3.6 (1.2)	4.7 (4.1)	2.3 (1.4)	60.5 (8.6)

[a]Includes basal hits on shrubs at ground level. [b]Number in parenthesis are the standard deviation.

The authors found that shrub canopy remained consistent through the seasons. Total canopy of grasses and forbs increased from spring into summer to a maximum of 19 and 15 percent, respectively. Grasses and forbs >18 cm in height increased from spring to summer and then decreased into fall with maximum grass canopy of 5.7 and forb of 2.2 percent. The authors' ground cover measurements at different times of the year are summarized across these ten ecological site locations in table 10. Average ground cover values for the five sample periods were: bare ground (23.8 percent); rock (3.7

percent); crust (1.5 percent); grass (3.6 percent); forbs (4.7 percent); shrubs (2.3 percent); and litter (60.5 percent). These averages remained consistent over the months with only the forbs showing a gradual decline from the spring through the fall.

Comparisons of BLM canopy and ground cover estimates (BLM 2008b) with the authors' 2008 data are shown in tables 11, 12 and 16. Authors' measurements of canopy cover (table 11) showed variation within sites for shrubs and forbs, with BLM reporting higher canopy cover of shrubs by 3 percent, grasses by up to 9 percent more, and forbs less by 1 percent. Table 12 shows BLM survey estimates for litter, bare soil, and rock which BLM combined together. If the authors' bare ground, rock and litter data are combined, on average the authors found this total to be three times more than BLM reported. The differences in methods (BLM's subjective estimate versus the authors' line point intercept data) may explain why more bare ground and litter amounts were measured by the authors. Table 16 presents the authors' ground cover data in two categories, under shrubs and between shrubs where we summarize the fraction of ground cover for bare ground, rock, biotic crust and plants that were under shrubs or in the inner space between shrubs.

Table 11. Comparison of BLM canopy estimate and authors' data at 10 BLM ecological inventory sites in the Duck Creek Allotment.

	Shrub %		**Forb %**		**Grass %**	
BLM Site	**BLM**	**Authors**	**BLM**	**Authors**	**BLM**	**Authors**
DC7	30	38.4	10	9.6	30	9.6
DC8	30	37.7	10	12.6	30	18.3
DC9	30	37	10	11.7	35	13.9
DC10	45	27.1	10	11.2	20	15.8
DC11	45	30.2	5	7.0	20	14.9
DC11(a)	45	35	5	4.1	20	17.2
DC17	40	31.1	5	9.2	25	12.9
DC19	15	24.8	10	5.8	35	18.9
DC25	40	36.5	6	12.4	18	18.9
DC26	45	35.5	10	13.9	20	19.6
Average	36.5	33.3	8.1	9.75	25.3	16.0

Table 12. Comparison of BLM ground cover percent estimates and authors' ground cover data at ten BLM Ecological Sites in Duck Creek allotment.

	BLM Data	Authors Data						
BLM Site	**Litter, Bare, Rock %**	**Bare**	**Rock**	**Crust**	**Grass**	**Forb**	**Shrub**	**Litter**
DC7	L+B+R = 30	27.1	2.6	1.6	2.7	3.4	2.1	60.5
DC8	L+B+R = 30	20.6	2.4	5.5	3.7	7.3	2.6	63.0
DC9	L+B+R = 25	17.8	0.2	0.8	4.0	5.4	2.8	69.0
DC10	L+B+R = 25	28.1	2.0	3.2	4.2	3.4	2.3	57.1
DC11	L+B+R = 30	20.5	4.4	2.1	4.7	3.5	2.5	62.4
DC11(a)	L+B+G = 30	35.9	9.0	1.9	3.6	1.4	2.3	46.0
DC17	L+B+R = 30	22.2	1.0	1.8	3.7	3.3	2.1	66.0
DC19	L+B=40	29.2	8.5	1.5	3.1	3.2	2.0	52.7
DC25	L+14B=36	17.8	2.4	0.5	3.6	7.0	2.1	66.8
DC26	B+R=25	18.7	5.2	1.0	2.5	9.2	2.4	61.3

L liter, B bare ground, R rock

Table 16. Comparison of ground cover percent total, beneath under shrubs and inter space between shrubs.

	Bare Ground	Rock	Crust	Grass, basal	Forb, basal	Shrub	Litter
Total	23.8 (6.7)[a]	3.7 (3.1)	1.5 (1.3)	3.6 (1.2)	4.7 (4.1)	2.3 (1.4)	60.5 (8.6)
Beneath shrub	3.1 (2.0)	0.3 (0.4)	0.7 (0.9)	1.1 (0.7)	1.7 (1.8)	0.0 (0.0)	26.3 (5.1)
Inner space	20.7 (5.9)	3.4 (2.8)	0.8 (0.9)	2.4 (0.8)	3.0 (2.6)	2.3 (1.4)	34.1 (6.5)
Shrub/Total %	13.0	9.0	45.8	31.6	36.9	0.0	43.6

[a]Stand deviation is shown in parenthesis.

BLM Ecological Site Inventory and Rangeland Health Assessments

In 2005, BLM collected field data using the ecological site inventory (ESI) method for use in determining whether rangeland health standards are being met on the Duck Creek allotment (figure 5). The ratings on the 28 sites in The Duck Creek Allotment for ESI indicators are displayed in Appendix A along with the ESI Similarity Index for that site for average and wet precipitation years. BLM also assessed the condition of seven stream segments and 28 springs and meadows in Duck Creek. The results of these Properly Functioning Condition (PFC) assessments are included in Appendix B (streams) and Appendix C (springs).

Water Quality Data

Rangeland health standards require that a stream meet state water quality standards (BLM 1997). The results of data collection by the authors in 2009 for six criteria for Utah water quality standards are described in table 13. Water temperature exceeded state criteria in Duck, North Fork Sage, Sage, and South Fork Six Mile Creeks, while it remained below criteria in Big, Otter, and Randolph Creeks. Measured pH at each sampled stream was generally within the criteria range, although small exceedances were found in North Fork Sage Creek and Sage Creek. Dissolved oxygen in all streams met criteria. While industrial emissions need to meet turbidity requirements, nonpoint sources which cover agricultural practices such as domestic livestock grazing do not have a turbidity standard. However, the authors did measure turbidity in the field. Turbidity values in all streams experienced highs that were several times higher than their lows, or background levels, during the five sampling episodes. Observations during sampling showed that instream disturbance and bank trampling of eroding stream banks by cattle lead to increases in sediment and turbidity. The *E. coli* geometric mean concentrations at the sampled sites exceeded the Utah water quality standard in Big, Duck, North Fork Sage, Randolph, Sage, and South Fork Six Mile Creeks. The Otter Creek geometric mean (195 MPN/100 ml) was near the state criterion of 206 MPN/100 ml. Maximum *E. coli* levels found in all streams exceeded the Utah maximum criterion of 668 MNP/100 ml for single readings.

Table 13. Water quality data in Duck Creek Allotment streams and other nearby streams.

Location	Mean Water Temp °C[1]	Mean pH Units[2]	Mean Dissolved Oxygen[3] mg/l	Nonpoint Source Mean Turbidity[4] NTU	E.coli Range[5] MPN	Geometric Mean E.coli[6] MPN/100 ml
Big Creek	11.5	8.4	10.4	4.9	**119-1,203***	**360***
Duck Creek	**22.3***	8.0	7.0	49.3	**2,481-12,997***	**2,719***
N. Fork Sage Creek	20.0	8.3	7.1	588.4	**14,136->24,196***	**5,103***
Otter Creek	15.2	8.4	8.0	2.7	**81.6-727***	195
Randolf Creek	13.8	8.4	8.8	5.4	**1,046-2,420***	**1,600***
Sage Creek	**21.0***	8.5	7.4	317.6	**3,654-19,863***	**2,974***
S. Fork 6 Mile Creek	**23.0***	8.1	7.1	**69.5***	**998-3,076***	**239***

Utah water quality standards: [1]Temperature C maximum 20, [2]pH range units 6.5-9.0, [3]Dissolved oxygen minimum 30 day average mg/1<6.5, [4]Turbidity increase NTU for point sources [10] - (there is no nonpoint source standard for turbidity), [5]E. coli maximum number / 100 ml <668, [6]E. coli geometric mean, number /100 ml<206. * Values where Utah water quality standards were not met.

Table 14. Number of cattle surveyed on allotment compared to the number reported by rancher and number permitted on Duck Creek and other BLM allotments.

BLM allotment	Year Surveyed	Field survey (# cattle)	Reported use (# cattle)	Permitted (# cattle)	% of reported	% of permitted
Upper Cattle, GSENM[f], UT[a]	2007	222	774[c]	1093	29%	20%
Alvey Wash, GSENM[f], UT[a]	2009	65	295[e]	252	22%	26%
Lower Cattle, GSENM[f], UT[a]	2009	364	614[d]	1284	59%	28%
Vermillion, GSENM[f], UT[b]	2007	33	140[c]	281	24%	12%
40 Mile Ridge[b], GSENM[f]	2008	183	480[e]	570	38%	32%
Smiths Fork, WYO[a]	2008	439	1449[d]	2146	30%	20%
Duck Creek, UT[a]	2006	450	641[c, d]	641	70%	70%
Duck Creek, UT[a]	2008	304	641[c, d]	641	47%	47%
Duck Creek, UT June 25[a]	2010	570	641[d]	641	89%	89%
Duck Creek, UT Sept 4[a]	2010	148	641[d]	641	23%	23%

[a]Aerial survey, [b]Ground survey, [c]From permittee supplied "Actual Use Reports", [d]From billing statements, [e]BLM estimated average over 10 years, [f]GSENM–Grand Staircase-Escalante National Monument.

Livestock Census and Distribution
Aerial surveys were conducted in 2006 and 2008 to determine the distribution and number of cattle within the Duck Creek Allotment (table 14). In 2006, 450 mature cattle were counted, 85 percent of which were in the northwest pasture on June 26. In 2008, 304 were counted, 95 percent of which were located in the northeast pasture on June 24. In 2006, 2008, and 2010 BLM reported grazing billing for 641 cow-calf pairs to graze in the Duck Creek Allotment. The permit holder's actual use reports for 2006 and 2008 reported the same numbers.

DISCUSSION

Ecological Indicators, Policy Assessment, and Determination of Whether Standards Met
This discussion reviews the relationships among ecological condition indicators, ecological goals, standards, and assessment methods in the context of data collected for the Duck Creek Allotment. Our independent assessment of the ecological conditions on the Allotment is discussed in terms of causal factors of specific habitat conditions and potential management changes to reduce undesirable stressors.

Ecological condition indicators include species composition and diversity, biomass (or net primary production), nutrient stock, and ecosystem structure and processes (Westman 1978). The number of trophic levels and whether species are genetically linked through habitat connectivity are also included as indicators of ecosystem conditions (Montoya and others 2006). Conditions measured by each of these indicators are important over time (Soulé 1985) and at different geographic and spatial scales (Scott and others 1999). When habitat resilience is diminished, disturbance can cause the system to cross a threshold to a new ecological state from which recovery is sometimes not possible (Groffman and others 2006). To prevent a transition to an undesired state, land managers must know where state change threshold occurs, what stressors will cause the system to cross the threshold, and the kind of control of stressors needed to prevent crossing the threshold (Thrush and others 2009, Miller2005). The concept of states and thresholds is largely conceptual and has yet to be defined empirically, and so is difficult to integrate into land management. In the meantime, management that insures resiliency and ecological capacity (e.g., managing for protected core areas, landscape connectivity, key species viability, and biodiversity) is recommended (Cumming and others 2005). Inherent to this process is restoring and sustaining the productivity of native ecosystems.

BLM's range management program makes ecological assessments to determine whether standards for habitat are met. A number of field assessment methods have been developed by BLM. Do these assessment methods provide the kind and quality of information needed to assess ecological indicators? Table 15 compares this simplified set of ecological indicators to the methods used by BLM: trend, utilization, Ecological Site Inventory, upland rangeland health assessments, and riparian ecological health assessments. We reviewed each of these methods, their application, and their utility in assessing resilient habitat. Using the criteria described in BLM's Handbook 4180, we reviewed the primary assessment methods BLM uses to determine whether they: 1) are relevant to the specific standard(s); 2) manage for responses that are detectable; 3) describe the minimum suite of indicators needed; 4) provide results that are credible among a diverse audience; 5) use methods that are standardized and accepted; and 6) can distinguish between whether an indicator does or does not meet standards (BLM 2001b). The ecological indictors (rows in table 15) reflect vital signs of ecosystems that are practical to measure (Kurtz and others 2001). These vital signs are chosen to reflect the key natural elements and processes (primary production, trophic transfer, nutrient cycling, water dynamics, and energy transfer) in ecosystems (Miller 2005). Table 15's ecological indictors for biological processes emphasize measures for biodiversity such as species richness, evenness, disparity, rarity, and genetic variability. This indicator is further broken down into additional important biological processes. Each assessment method in table 15 was evaluated on how completely its use would assess the ecological indicators. The results (yes, limited, no) indicate how comprehensive the assessment method is to evaluating ecological health. A majority of the ecological indicators in table 15 are not assessed by the current assessment methods assigned by BLM for this task. Many of the assessment methods offer limited ability to measure the ecological indicator. Only two of the assessment methods seem adequate for two ecological indicators.

Rangeland Evaluations

Trend

Trend and similarity index data were used by BLM to assess whether rangeland health standards are being met in the Duck Creek Allotment (BLM 2008b). Trend data from the earliest monitoring (1969 to 1979) in the Allotment has been lost. Based on data collected at five sites in the Allotment from 1982 to 1992, BLM concluded that the trend was up at four sites and static-to-down at the fifth site (BLM 2008b). The data from this period (1982-92) show significant increases in western yarrow, rabbitbrush, sagebrush, and spiny phlox, all of which are grazing tolerant species that increase with livestock grazing. During this same period, declines were seen in western wheatgrass and clover. A number of grass species persisted in trace amounts, including bluebunch wheatgrass and Sandberg's bluegrass. BLM data show that the trend is down for species livestock prefer and up for species livestock do not prefer. For instance, these data indicate low amounts of bunchgrass species such as bluebunch wheatgrass and Indian ricegrass, which should dominate these range sites but which are favored by livestock. Ecological condition assessments indicate that the trend is moving further away from potential native climax communities.

Because BLM has lost knowledge for the locations of these earlier trend sites (BLM 2008b), BLM established 10 trend sites at new locations in 2004.

Table 15. Evaluation of BLM range management policies and ecological assessment methods that represent ecological indicators.

		Assessment methods				
Ecological indicators	**BLM rangeland health standards**	**Trend**	**Utilization**	**Ecological site inventory**	**Interpreting indicators for rangeland health**	**Lotic / lentic PFC**
Soil nutrient processes	Std 1	No	No	No	Yes	No
Hydrological processes	Std 2,4	No	No	No	Limited[c]	Yes
Biological processes	Std 2,3	Limited[a]	No	Limited[e]	Limited[c]	No[d]
Plant community composition	Std 3	No	No	No	No	No[d]
Habitat structure	Std 2,3	No	No	Limited[b]	Limited[c]	Limited[d]
Habitat connectivity	Std 3	No	No	No	No	No[d]
Wildlife populations	Std 3	No	No	No	No	No
Are the above indicators considered in appropriate spatial scale?	n/a	No	No	No	Limited[c]	Limited[d]
Are the above indicators considered in appropriate temporal scale?	n/a	Yes	No	No	No	No

[a]Trend data collection, as normally practiced by BLM, is limited to the frequency of a few key plant species at sample intervals sometimes a decade long. [b]Ecological Site Inventories focus on generating a similarity index which is outside common ecosystem metrics. [c]Interpreting Indicators for Rangeland Health uses measures of ecologically concepts that have not been independently validated. In practice, only the survey-site scale and not watershed or regional scales are normally considered. Other key factors, such habitat needs for avian and terrestrial wildlife are not adequately assessed. [d]Lotic and Lentic PFC assessments focus on site stability and erosion. Similarly, other key factors such habitat needs for aquatic, avian, and terrestrial wildlife are not adequately assessed.

Using line point intersect transects, BLM collected canopy, ground cover, and species frequency data in 2004 and 2005 at these new sites. From these two years of data, BLM concluded that the trend was upward (improving) based on "canopy cover and species richness." Yet, the line point intersect data did not show significant changes in this one-year period for canopy cover or the number of species. BLM did not analyze the effect on these attributes of higher precipitation in 2005 compared to 2004. BLM's trend data fail to support the conclusions BLM made that the trend is static or upward on most monitoring sites.

Ecological Site Inventory

BLM calculated the ESI similarity index for 34 sites in the Duck Creek Allotment (Appendix A). Of 28 sites assessed, BLM found that 23 sites had a similarity index of 50 percent or more, reflecting what BLM describes as a good, or late seral, ecological condition; nine were classified as mid-seral, one as climax, and one was not determined (BLM 2008b). These results were based on data collected in 2005, which was an above average precipitation year and consequently an above average production year.

Conversion of field production data on species involves applying a number of correction factors to convert collected samples into adjusted production for an average year. There is a clear indication that validation in the field is needed. Calculations based on these combined correction factors lead to a total production for sites in the Duck Creek Allotment that is two times higher than predicted by the ecological site descriptions.

Additional problems exist with BLM's similarity calculations. Using BLM's data, similarity of grasses to the potential natural community was 39 percent, with many sites below 25 percent or in poor condition, while forb similarity was 37 percent, and shrubs were 80 percent of the production of expected native species. By design, the way the BLM calculates the similarity index masks the fact that herbaceous species are often depleted. In shrub dominated communities, the high annual production of shrubs is averaged with those for the grasses and forbs in calculating the similarity index. As a result, the depletion of the native herbaceous community is masked by averaging its production with woody plant production.

Further analysis of BLM's ESI data reveals problems with native bunchgrasses such as bluebunch wheatgrass, which is a preferred livestock forage and the key species for the allotment. Bluebunch wheatgrass was found mostly in trace amounts at 13 of 28 BLM ESI sites. The Rich County Soil Survey (SCS 1982) indicates that this grass species should be dominant on the allotment. BLM data show that bluebunch wheatgrass annual plant production is present at 28 percent of the potential amount described in BLM's revised ecological site descriptions (NRCS 2005a, 2005b) or 12 percent of potential predicted in relevant soil-survey rangeland characteristics (SCS 1982). Indian ricegrass in 2005 was found at 10 of 28 sites and was present at 22 percent of potential described in the relevant ecological site description or 12 percent of potential described in the Soil Survey (SCS 1982). Because BLM's ESI data were collected in a wet year (2005), if adjusted for precipitation, the resulting percent of these species relative to their potential would be even lower. By any measure, because these dominant native bunchgrasses exist today at a fraction of their potential, this represents significant ecological deterioration.

The rhizomatous western wheatgrass, a grazing tolerant species, was present at 24 of 28 sites; the Soil Survey does not include it as an expected species present on this allotment for habitat conditions at ecological potential. Sandberg's bluegrass was present at 23 of 24 ESI sites and had the highest biomass of any grass on the allotment. Sandberg's bluegrass is grazing tolerant due to early maturation and short growth form. According to the Soil Survey, it should be present at only 11 of 28 ESI sites. It was present at 219 percent of potential. The plant community composition for the Duck Creek Allotment has shifted away from the potential plant community towards a community dominated by grazing tolerant species.

BLM has moved away from using the similarity index in assessing whether rangeland health standards are met. Interpreting Indicators of Rangeland Health, Technical Reference 1734-06 (Pellant and others 2000, Pierson and others 2002), is the primary method that BLM uses for rangeland health assessments in upland areas. The reference describes the problem with the similarity index and recommends not using it in determining if rangeland health standards are met.

The ESI procedure collects data on plant species and these species' estimated annual production at a site. While this is helpful, because it considers only plant taxa, it offers limited information on the wider array of animal and soil biota and we opine that it is not an appropriate method to use in order to assess ecological conditions and whether rangeland health standards are met. However, in the grazing renewal decision for the Duck Creek Allotment, BLM uses trend and similarity indices in making rangeland health determinations. As a result, those Duck Creek Allotment habitat areas with ecological problems were under reported by the BLM.

Upland Rangeland Health Assessments

The primary assessment method used by BLM to assess whether rangeland health standards are met is "Interpreting Indicators for Rangeland Health" (Pellant and others 2005, Pyke and others 2002). It's technical reference (TR1734-6) uses qualitative rankings of 17 indicators, which compare the survey site against a reference site that resembles the historic climax plant community for that ecological site type. The observer assigns one of five ratings to describe the deviation of the survey site from reference conditions. These rankings have limited relevance to ecological theory and, because they are subjective, are problematic to apply in the field.

Qualitative terms are linked to ecological condition in a way that makes it difficult to assess whether standards are met. The resulting determination of whether standards are met depends on a preponderance-of-evidence. In Utah, scores that are moderate in departure, slight to moderate, or slight to none are assumed to meet rangeland health standards (BLM 2008c). Only in cases where most of the indicators indicate extreme departure will the site be evaluated as not meeting rangeland health standards.

The results of the rangeland health assessments conducted by BLM found that 25 of the 28 upland sites evaluated in Duck Creek were "functioning" and therefore met standards, while 3 sites were functioning at risk.

One example of these indicators, that for bare ground, demonstrates the nature and limitations found with the other 17 indicators. The evaluation matrix for the bare ground indicator describes the departures from reference conditions for five rankings or scores: 1) Extreme to total –"much higher than expected for site. Bare areas are large and generally connected." 2) Moderate to extreme – "moderate to much higher than expected for the site. Bare areas are large and occasionally connected." 3) Moderate – "moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected." 4) Slight to moderate – "slightly to moderately higher than expected for the site. Bare areas are small and rarely connected." and 5) None to slight – "Amount and size of bare areas match that expected for the site."

Comparison of the survey site with a reference area is necessary to infer what is "expected for the site." Representative ecological sites that reflect ecological conditions at their potential are exceedingly rare on BLM lands. Without a representative reference area, there is a strong tendency to accept observed conditions as normal, therefore scoring them higher than they might deserve. For the surveys and assessments that BLM conducted in the Duck Creek Allotment in 2005 (sites 6, 7, and 8) no reference areas were used.

Indicators should predict biological community state transitions, particularly transition to a degraded state. Likewise, to document recovery, indicators should identify conditions that signal a positive change in state. TR 1734-6 cites numerous studies (Anderson 1974, Benkobi and others 1993, Cerda 1999, Gould 1982, Gutierrez and Hernandez 1996, Morgan 1986, Weltz and others 1998) which, while adequately describing ecological principles relating to bare ground, do not support the specific rankings used in TR 1734-6. Erosion that exceeds rates of tolerable soil loss over time will lead to state changes (NRCS 2010). The rangeland health standards call for soil stability that maintains soils at their ecological potential (BLM 1997). For the bare ground indicator, TR 1734-6 does not link the amount of bare ground for a survey site to the specific standard required for making an assessment. The assessment method fails to clearly link the relevant rangeland health standard to the assessment ranking and then support this with scientific studies.

As applied in the field, the amount of bare ground for the Duck Creek Allotment was not ranked as an ecological problem by BLM even though the authors' data showed otherwise. As described below, the authors' measurements of bare ground in the Duck Creek Allotment compared to reference areas show significant departures from potential. Bare ground that the authors' measured in ungrazed reference habitat was extremely low. This suggests that the ranking for bare ground at most Duck Creek Allotment sites should have been "extreme to moderate" rather than "slight to none" departure from reference conditions.

The range site descriptions for the dominant soil types in the Duck Creek allotment identify cool season bunchgrasses as the dominant plant group for the allotment. Bluebunch wheatgrass, Nevada blue grass, needle and thread grass, and Indian rice grass should comprise about half of the annual plant production in these range sites. As described above, these cool season grasses are either absent or found in trace amounts in most range sites in the allotment today. Similarly, cryptobiotic crusts should be prevalent, particularly in the shrub interspace areas, but are rarely found in the line point transect data. The loss of this ecosystem component has far reaching ecological consequences in terms of wildlife support, nutrient flow, soil stability, and biodiversity. TR 1734-6 indicator 12 for functional and structural groups was rated "slight to none" or "slight to moderate" departure from reference conditions. The authors argue that the loss of key groups like cryptobiotic soils may justify a score of "moderate to extreme" departure. Similar arguments can be made for many other indicator ratings.

Spring and Riparian PFC Assessments

BLM relied primarily on lentic and lotic properly functioning condition assessments for evaluating health of riparian areas on the Duck Creek allotment. Of the 6 lotic and 29 lentic assessments, BLM found that 4 stream segments and 6 lentic sites are functioning at risk and thus not meeting rangeland health standards. The stream segments assessed in the Duck Creek Allotment are contained in narrow channels which have become incised or down cut by several feet and now are disconnected from their original, wide floodplains and riparian meadows. BLM's (1993) TR 1737-9 states that, "The absence of certain physical attributes such as a floodplain where one should be are indicators of nonfunctioning condition." This criterion does not appear in the later technical references used by BLM today (Prichard 2003b), and is no longer required in determining whether the streams are properly functioning.

Not all of the rangeland health standards are covered by the proper functioning condition assessments. For example, Standard 2 requires that riparian areas have vegetation that provides "food, cover and other habitat needs of dependent animal species" such as fish. TR 1734-15 and TR 1734-16, which assess properly functioning condition of streams and springs, do not account for these requirements. Stevens and others (2002) describe some of the ecological shortcomings of TR 1734-15 and 1734-16.

For the Duck Creek Allotment, BLM determined that one of the six streams doesn't meet rangeland health standards and that livestock grazing is a factor (BLM 2008b). Additionally BLM reported that six of the 29 lentic locations surveys were functioning at risk and not meeting BLM's rangeland health standards. Based on a single assessment, BLM further noted that the trend for the riparian areas was "static or no apparent trend" toward potential.

Water Quality Assessments

BLM relied on Utah's 303d list of impaired waters to assert that water quality standards were met on the Duck Creek Allotment (BLM 2008b). However, these streams are not monitored by the State, and BLM did not conduct or have others conduct water quality surveys for the Allotment (BLM 2008b). Water quality data collected by the authors show that the sites sampled in Duck Creek fail to meet state temperature and *E. coli* standards (table 13). The elevated levels of water temperature, turbidity (sediment) and *E. coli* found in these streams are influenced by the presence of cattle in the streams and watershed. Activities affecting watersheds or riparian zones also affect stream ecosystems directly, indirectly, and cumulatively. Several reviews of livestock impacts on stream and riparian ecosystems have covered this topic in detail, using hundreds of government documents and peer-reviewed scientific articles. These include Kauffmann and Kreuger (1984), Armour and others (1991), Gregory and others (1991), Platts (1991), Fleischner (1994), and Belsky and others (1999). Livestock in the Duck Creek Allotment regularly trample, wade, defecate, and urinate directly in these streams causing fecal pollution, increased nutrient levels, algae blooms, increased sedimentation, and reduced dissolved oxygen, which impair habitat for native cutthroat trout and other native aquatic organisms. These conditions violate Utah's standards for water quality (Utah Administrative Code R317-2-7.2). These violations of Utah's water quality regulations would cause the streams on the Duck Creek Allotment to fail Standard

4 of the Utah Standards and Guidelines (BLM 1997) and, therefore, the fundamentals of rangeland health. BLM assumed that waters in the Duck Creek Allotment met rangeland health standards for water quality in the absence of water quality monitoring data.

Canopy Cover, Ground Cover and Sage Grouse Guidelines

While the standards and guidelines require vegetation necessary to ensure that native wildlife species populations are at their potential, the methods BLM uses for ecological assessments lack indicators for wildlife. Sage grouse is one of many "special status" species found in the Duck Creek Allotment, which BLM is obligated to consider in management decisions (BLM, 2008b). BLM (2008b) compared its estimates of cover by sagebrush, grasses, and forbs to the Connelly at al. (2000) guidelines for sage grouse habitat. The guidelines for spring nesting and early brood-rearing habitats are: sagebrush canopy of 15 – 25 percent; perennial grass canopy >15 percent for grasses >18 cm height; and forb canopy >10 percent for forbs >18 cm height. For summer brood rearing habitat, sagebrush canopy should be 10 – 25 percent with grasses and forbs >18cm height having a total canopy of >15 percent. Canopy of sagebrush in winter should range from 10 – 30 percent. Authors data (table 11) show that Connelly and others's criteria for grass canopy cover are met. However, the canopy for forbs, and the height required for grass and forbs was not met (table 7 and 9).

As reported above, the authors surveyed 10 of BLM's ESI sites during the spring nesting and early brood rearing period (May and June). None met the minimum sage grouse criteria for grasses and forbs >18cm in height. Of the 160 transects measured by the authors during the summer (July) and fall (September, October), 13 (8 percent) met the 15 percent total forb and grass cover with >18cm height. Eleven of these 13 transects were on steep slopes seldom grazed by cattle. The maximum canopy cover of grasses on these steep sites was 48 percent. 40 percent of sample points had grass over 18 cm in height. This high grass canopy on lightly grazed sites suggests potential for much higher canopy than that measured in most grazed sites and compares favorably with data from ungrazed kipukas in Wyoming big sagebrush communities in southern Idaho. In these kipukas, grass canopy ranged from 29 – 58 percent with an average canopy of 43.5 percent (Welch and Criddle 2003).

For most sites in the Duck Creek Allotment, BLM estimated the combined ground cover for bare ground, rock and litter at these sites, while not considering ground cover beneath shrub, forb and grass canopies (table 12). As a result BLM's data could not provide information which is important for erosion assessments and comparison to potential. Precipitation on the Duck Creek Allotment occurs mostly during the October – March period as snowfall. Summer rains are a small contribution to the total. Erosion is, therefore, mostly driven by overland flow from snowmelt, which is affected by overall ground cover rather than raindrop impact which is influenced by canopy cover. Bare ground under a shrub may be prone to water erosion while classified as covered by canopy cover. BLM did not measure ground cover beneath grass, forb, and shrub canopy, based on the assumption that canopy cover-intercepted rainfall is the most significant factor protecting the soil from erosion. West and Gifford (1976) found that shrub canopy cover intercepted about 1 percent of precipitation, refuting that canopy cover acts to protect ground cover from erosion. The authors argue that ground cover should be measured independently of canopy cover. When combined, bare ground under shrubs may be missed. For this reason, BLM's ground cover surveys are likely to under report the amount of bare ground.

By assessing what contacts the ground and not counting foliar or canopy cover as ground cover, the authors found that the average bare ground at surveyed locations was 25.3 percent (table 12), with most bare ground occurring in shrub interspaces where livestock access is not restricted (table 16). The authors surveyed an ungrazed highway right of way on the south side of the Duck Creek Allotment that had not been grazed by livestock for 30 years (UDOT 2009) and found that bare ground was 1 percent for this upland loam range site type, which is a dominant range site on the allotment. A study in the nearby Uinta-Wasatch-Cache National Forest in big sagebrush habitats where livestock had been excluded for decades measured 5.6 percent bare ground and 38.8 percent basal cover of grasses (Carter 2003). Thus these sites serve as reference areas. The Uinta-Wasatch-Cache National Forest provides ground cover values for various habitat types. In big sagebrush communities, the potential ground cover is 89 – 93 percent with a maximum of 96 percent (USDA Forest Service 2005).

The canopy and ground cover data just summarized provide yet another check in the overall ecological evaluation process. BLM did not consistently assess bare ground, which our data show is far from potential. The result is excessive erosion and the related rangeland health standard not being met. Sage grouse habitat needs are not built into the standard agency assessment process when determining whether rangeland health standards are met. Herbaceous habitat conditions required by sage grouse appear not to be met in Duck Creek during much of the growing season. This may explain why, in the past several decades, the number of active leks has declined from three to one in the Duck Creek Allotment (BLM 1979; BLM 2004b). The failure to assess these conditions prevented BLM from adequately determining whether the allotment meets rangeland health standards as they apply to sage grouse.

Management Response to Ecological Assessments

Once the ecological condition of the allotment is assessed and it is determined whether standards are being met, then an evaluation of current management guides the next management decisions. Many of the tools for assessing the influence of management and land use require annual surveys. Plant utilization and stubble height monitoring are two typical annual monitoring activities. Coupled with ecological conditions, these annual monitoring data then should guide changes in grazing use. This section discusses the effectiveness of actions taken by BLM in the study area in response to its assessments of rangeland health.

Grazing Utilization Assessments

Forage utilization is “the percentage of the current year’s herbage production consumed or destroyed by herbivores” (Holechek and others 2004). It is a key guide for determining whether current management is setting grazing use levels to move the allotment towards meeting rangeland health standards. Utilization by livestock and wildlife are key inputs in designing a plan to meet standards. Utilization in the upland areas in Duck Creek is summarized in table 6. Based on paired plot sampling conducted by the authors, utilization in most sites for most years exceeded BLM’s 50 percent utilization standard for upland areas (BLM 2008b). On average, BLM’s utilization data, collected using the key species method, were 31 percent lower than that collected by the authors. BLM reported utilization was well within the utilization standard of 50 percent. The results of a paired t test comparing BLM’s utilization estimates to the authors’ reported $t = -5.84$ with 17 degrees of freedom. The probability of the null hypothesis (that BLM data equal the authors) is 0.000 percent.

A number of factors explain this discrepancy. The paired plot method used by the authors is quantitative and relies on collection of the grasses and forbs from plots of a standard area, or quadrats. These samples are dried and weighed to determine biomass. The key species method used by BLM is an ocular estimate of the amount of forage removed from plants either by sampling individual plants along a transect or sampling in quadrats. TR 1734-3 states that the use of quadrats is more reliable than the transect, which BLM used in the Duck Creek Allotment. In addition, the key species method requires ungrazed reference plots for comparison. In some years, BLM did not have ungrazed reference plots and thus had to guess what ungrazed conditions would look like. TR 1734-3 requires that observers are trained to estimate utilization and then compare that estimate to clipped and weighed samples. BLM had no records for the utilization training described in TR 1734-3 for the Duck Creek Allotment.

Little research has been conducted to assess whether the key species method accurately represents forage utilization. We can find no studies that validate the method with more quantitative approaches such as the paired plot method. The study usually cited to support the key species method is Heady (1949). Heady (1949) called for utilization estimates to be based on the volume or mass of the plant removed in a “general reconnaissance.” He admitted that these estimates vary widely among individuals or even for one individual between different hours of a day. Holechek at al. (2004) note that the key species method is subjective and its reliability “cannot be readily quantified with standard statistical procedures”. Lastly, BLM (2008b) used many species that are tolerant of grazing as its key species, which leads to management that promotes overutilization and thus decline of the more palatable and less grazing tolerant native bunchgrasses.

A plot of the grass production (kg/ha) in ungrazed upland plots on the Duck Creek Allotment against the grass utilization for the same locations sampled by the authors over five years (52 locations, 1144 samples) is shown in figure 6. This graph shows that when the grass production drops below 200 kg/ha utilization drops to 60 percent or less. Where there is a range of productivity in the uplands, lower utilization may reflect a degraded site with production much lower than potential. This underscores the importance of knowing the actual production at the site where utilization monitoring occurs and of choosing sites that reflect higher production within the allotment. Pinchak at al. (1991) also found that grazing utilization was related to standing crop.

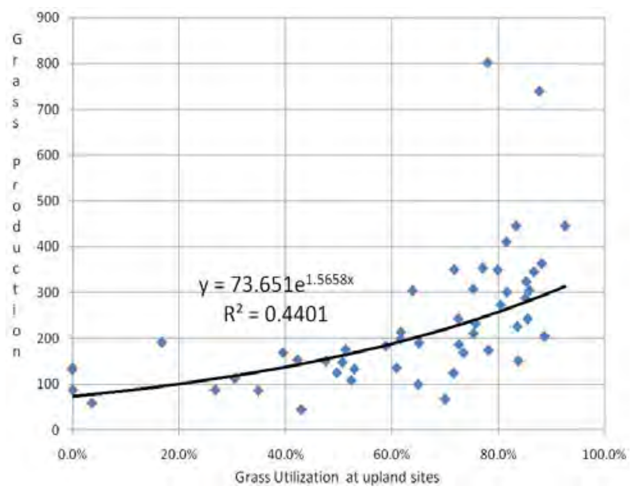

Figure 6. Graph of the correlation of utilization with habitat grass production.

These flaws in the key species method have far reaching consequences. Utilization monitoring provides the key information that BLM uses to change livestock numbers and the duration of grazing. If utilization data are inaccurate or do not represent the desirable forage species, appropriate changes in grazing management are unsupported by this utilization monitoring.

Stubble Height Monitoring

Technical Reference 1734-3 provides BLM with a method to conduct stubble height monitoring (BLM 1996a). A number of assumptions are made when choosing both a key species and a specific height for that species, specifically, that when the stubble height requirement is met: 1) required utilization levels are met; 2) grazing use is moving towards meeting rangeland health standards; and 3) use in the field by agency staff leads to consistent data regardless of the examiner.

For livestock to graze riparian areas without damage, the grazing system must leave adequate residual stubble height to ensure plant vigor, species diversity, stream bank protection, and sediment capture. To achieve this, minimum herbage stubble height of 10 to 15 cm should be present on all streamside areas at the end of the growing season. For spring grazed pastures, livestock should be removed by July 15, or earlier at lower elevations (Clary and Webster, 1989). Clary and Webster (1989) further recommend that utilization levels should not exceed 40 – 50 percent for summer grazed pastures or 30 percent for fall grazed pastures. Clary and Webster (1989) found that: a 15 cm (six-inch) stubble height corresponded to 24 – 32 percent utilization; four-inch stubble height corresponded to 37 - 44 percent utilization; and a 7 cm (three inch) stubble height corresponded to utilization of 47 – 51 percent. The 15 cm stubble heights should apply to streamside and nearby meadow sites.

Stubble height monitoring has not been closely correlated with ecological habitat conditions. Rather, stubble height is most often tied to the amount of utilization that occurs on the sampled species (McDougald and Platt 1976, BLM 1999c). As a result, stubble height monitoring may be of use in judging the intensity of grazing use but fails to provide a measure of achievement of rangeland health standards (BLM 1997) which are ecologically based.

BLM's most common use of stubble height monitoring is in riparian areas. For the Duck Creek Allotment, BLM used Nebraska sedge (Carex nebrascensis *Dewey*) and Baltic rush (*Juncus balticus*)for stubble height monitoring . Both species persist in degraded riparian conditions in this allotment. Out of the 80 sedge species listed in Hurd at al.'s (1998) "Guide to Intermountain Sedges" only one species, Nebraska sedge, is reported to be tolerant of livestock grazing. Because it is rhizomatous and offers poor forage for grazing animals, Baltic rush is also resistant to grazing (Utah State University Cooperative Extension 2010). Choosing a key species that tolerates grazing means that measuring stubble height will be inadequate for monitoring those species sensitive to and likely to decline with standard BLM grazing use. In the Duck Creek Allotment, the absence of woody riparian plants from most riparian areas and the low diversity of riparian plant species may be accounted for in part by using grazing tolerant species for monitoring, which leads to extremely high utilization levels on riparian vegetation, including willows (Clary and Webster 1989).

Studies of the use of stubble height monitoring in riparian areas have raised a number of concerns. The University of Idaho Stubble Height Study Team (2004) found that the linkage between stubble height data and riparian function has not been adequately researched and thus stubble height is likely inappropriate to use as the only monitoring method for riparian condition. In the Duck Creek Allotment up to 2010, stubble height has been BLM's only annual monitoring method in riparian areas. Other appropriate monitoring methods could include vegetation composition along the green line, stream bank stability, and regeneration of woody species. Burton at al. (2008) developed a riparian assessment method that incorporates multiple quantitative and qualitative indicators of riparian area condition to respond to concerns raised by the use of a single indicator, specifically stubble height.

A summary of residual stubble height data in riparian areas measured by the authors in the Duck Creek allotment is provided in table 7. BLM's 5" (12.7 cm) stubble height objective was never met during five years of monitoring. Readings were generally less than 7.6 cm (3 inches). Most readings were taken in October, a month after the grazing season for cattle ends.

In 2006 through 2010, a rotation grazing system was put in place in the Duck Creek Allotment. Cattle spent typically one month in each of four pastures. BLM predicted that in September regrowth might be expected in pastures that cattle left earlier. However, utilization and stubble height monitoring in riparian areas showed no difference between a pasture that had been rested for up to three months and one where the cattle had most recently gazed. Dry conditions later in the growing season are typical for this climate and this supports research that has shown that for conditions typical for Duck Creek, summer regrowth is minimal (Lile et al 2003).

BLM generally found stubble heights to be greater than the authors' data by 2.3 to 6.4 cm. There are several reasons for this. BLM measured *Carex* and *Juncus* species and reported the average height of the combined species. Inspection of BLM data shows that the Baltic rush generally had stubble heights of about 5 cm greater than the sedge species. In addition, the stems of Baltic rush are so tough that they tend to pull free from the rootstocks when grazed by livestock, especially cattle (Utah State University Extension 2010). When stubble height monitoring data are collected using the Baltic rush, the only measurable stems are those that remain largely ungrazed. It is not possible to know how many stems have been pulled free. As a result, stubble height monitoring using this species tends to under report grazing use and over report the actual average height of these plants.

The differences between BLM's and the authors' data may also be due to BLM's measurement of stubble heights in areas with hummocks, standing water, or hoof shear depressions, where the vegetation is more protected and grazed less or last. Such areas are technically not along the greenline where stubble height is normally measured. Further, BLM measures heights of plants that have been trampled and are flat against the soil surface. These are likely to have much longer leaf lengths than those that remain standing during the grazing season.

Our livestock census in the Duck Creek Allotment showed 450 cow-calf pairs in 2006 and 304 cow-calf pairs in 2008. Riparian area utilization was not reduced due to a lower number grazing. In 2006 riparian utilization was 87 percent at Six Mile Creek and 94 percent in the south fork of the same creek. In 2008 when fewer cattle were present in the allotment, riparian utilization was 95 percent. The preference of cattle for riparian areas leads to riparian utilization exceeding the standard at both stocking levels when grazed for one month. This is consistent with long-standing research showing that cattle heavily graze riparian areas before seeking upland forage (Hormay and Talbot 1961, Pinchak et al, 1991).

Stocking Levels - Animal Unit Month Redefined

In addition to meeting rangeland health standards, grazing management must also be within the carrying capacity of the allotment (BLM 2006). "(T)he most important of all grazing management decisions, carrying capacity analysis involves spatial analysis of the forage production, the capacity of the area to support livestock grazing, and the amount that can be allocated to livestock" (Holecheck and others 2004). A key factor in this analysis is how much forage a typical sized cow consumes. The animal unit month (AUM) is the basis of permits, stocking rates and fees for grazing public lands. The AUM, however, does not represent current livestock weights and forage consumption.

BLM and the Forest Service have defined an AUM as: "The amount of forage needed to sustain one cow, five sheep, or five goats for a month. A full AUM's fee is charged for each month for adult animals if the grazing animal (1) is weaned, (2) is 6 months old or older when entering public land, or (3) will become 12 months old during the period of use. The term AUM is commonly used in three ways: (1) stocking rate, as in X acres per AUM; (b) forage allocation, as in Y AUMs in allotment A; and (3) utilization, as in Z AUMs consumed a calculated amount of forage" (BLM 2004a).

This definition of an AUM does not account for actual weight and forage consumption of the various animals listed, and it ignores forage consumption by calves and lambs. Clarification and updating of these values are needed so that livestock producers are charged for the actual forage consumed by their animals and the carrying capacity of the land is not exceeded. This would insure that the Federal Land Policy and Management Act (FLPMA) requirement to graze within the carrying capacity of the allotment is met, and that the FLPMA requirement of sustainable use without permanent impairment of productivity is achieved.

Natural Resources Conservation Service (NRCS 2003), in its National Range and Pasture Handbook, defines an animal unit (AU) as one mature cow of approximately 1,000 pounds and a calf as old as 6 months, or their equivalent, then states, "An animal unit month (AUM) is the amount of forage required by an animal unit for one month" (USDA 2003). BLM has typically used 800 lbs/month of forage as the consumption rate for a cow/calf pair. This is 12 kg per day (26 lb/day) and is consistent with a long-standing definition by the Society for Range Management that an animal unit is "one mature (1000 lb.) cow or the equivalent based upon average daily forage consumption of 26 lbs. dry matter per day" (SRM 1974). This was later revised to define an animal unit (AU) as the forage consumption of one standard mature 1,000-pound cow (454 kg), either dry or with calf up to 6 months old and consuming 26 pounds (12 kg) of air-dry forage per day or 800 pounds (363 kg) per month (Ortmann and others 2000).

There are conflicts among these different definitions. First, the use of 26 lbs/day represents oven-dry weight instead of air-dry weight, which is more commonly used in assessing forage production. NRCS (2003) further defines the actual forage consumption as 26 pounds of oven-dry weight or 30 pounds of air-dry weight per day as "the standard forage demand for a 1,000 pound cow (one animal unit)". This is 2.6 percent of body weight for oven-dry weight and 3 percent of body weight for air-dry weight of forage. As agencies applied these forage needs in their administrative processes, unfortunately the difference between air and oven dried weights got lost. The resulting process further underestimates forage needs for livestock. Note that there is no forage allowance for the calf even though the definition of an animal unit includes a calf. The same is true for lambs, when considering sheep grazing.

Second, these definitions are outdated in terms of the size of today's cattle based on an analysis of USDA market statistics. The University of Nevada Agricultural Experiment Station published a report on cattle production in 1943. This report analyzed 14 years of ranch operation for 11 ranches in northeastern Nevada. At that time, a mature cow was defined as one unit and a branded calf or weaner as ½ unit, for a combined total of 1.5 units per cow/calf pair. Bulls were considered 1.5 units. For the period 1938 – 1940, the average weight of mature cows when they left the range was 435 kg, calves were 173 kg, and bulls were 554 kg. This means that in the 1930s, a cow/calf pair's weight was 608 kg (1340 lbs). The Forest Service, in its Range Analysis Handbook (USDA 1964) provided a detailed summary of forage consumption for cattle and sheep as air-dry amounts. At that time, an Animal Unit was considered as a 1,000-lb cow, while a cow plus 400-lb calf was considered 1.46 animal units. Air dry forage consumption was 24 lb/day (11 kg/day) for the cow and 33 lb/day (15 kg/day) for the cow/calf pair (USDA 1964).

An analysis of USDA market statistics over time reveals significant increases in live weights of cattle (Uresk 2010). In 1964, live weight of mature cattle averaged 456 kg (1,006 lbs) (USDA 1964). In 1978 when the Federal administration implemented the billing formula, the live weight of slaughter cattle averaged 488 kg (USDA 1979). After this point, cattle weight increases were rapid due to selective breeding and the use of hormones and supplements with the USDA reporting average weight for slaughter cattle at 589 kg (1296 lbs) in 2009 (NASS 2010). This is a 100 kg increase over the USDA reported weights in 1978.

Holechek at al. (2004) summarized the weaning weights of calves grazed on various types of rangelands. The data for the period since 1990 produced an average weaning weight of 195 kg within a range of 173 – 216 kg. Ray and others (2004) gave a weaning weight of 218 kg for calves. Using the current market statistics for slaughter cattle of 589 kg and, in the absence of current data use the average weaning weight of 195 kg provided by Holechek at al. (2004), today's estimated average weight of a cow/calf pair during the grazing season is 784 kg.

NRCS estimated that the daily forage consumption for a grazing animal equals 3 percent of its body weight. Thus the combined cow/calf weight of 784 kg consumes 23.7 kg of air-dry forage each day, or 715 kg (1,573 lb) of forage for a month (30.4 days) per AUM. Today's larger weights for cattle make the BLM and SRM definitions of 12 kg/day (26 lb/day) significant underestimate the forage use of today's cattle(Uresk 2010). Based on all of these factors, today's cattle are likely to consume double the amount of forage currently allocated for one AUM. This means that, based on the forage consumption rate alone, current stocking rates should be significantly reduced in the situation where stocking now equals the allotment carrying capacity.

In 2004, BLM made range capacity estimates for the Duck Creek Allotment based on a forage requirement of 2 percent of body weight for a 1,000 pound cow (BLM 2004b). This equates to a requirement for an AUM of approximately 272 kg (600 lb) of forage for each AUM, or 38 percent of the amount consumed by a cow/calf pair today, grossly underestimating the forage demand. By using the same forage requirement for an AUM that has been in effect since 1961, there is a tendency to overstock an allotment.

Stocking Levels, Carrying Capacity Analysis

Holechek and others (2001) provide a sequence of steps to determine an initial stocking rate for an allotment. This sequence of steps includes determining which lands are capable of supporting livestock grazing: the area must be within two miles of water and have slopes less than 60 percent and produce a minimum amount of forage. When these adjustments are made, most but not all of the Duck Creek Allotment is capable of supporting livestock grazing. The forage available for those lands capable of livestock grazing is determined using reductions for different categories of slope and a reduction in available forage for distances between one and two miles from water. In its 2008 decision (BLM 2008b), BLM did apply these considerations in making a capacity analysis. Based on the updated information that we have assembled, we estimated that the carrying capacity of these lands is actually less than BLM asserts and, thus, the number of livestock that the Duck Creek Allotment might support is also less.

We estimated current forage production in Duck Creek based on the annual production of grasses, since the dominant shrub, sagebrush, and most forbs offer poor forage for cattle. Table 17 presents the dominant forb species identified by BLM and the authors. Species that had annual production of 12 kg/ha or more and were found at a number of sites at that production level are included in table 17.The data indicate that the forbs that dominate the Duck Creek Allotment are not desirable livestock forage species and are not considered in the forage base in this allotment.

Table 17. Palatability of dominate forbs in the Duck Creek Allotment.

Symbol	Common name	Scientific name	Preference
ACNI2	Common yarrow	*Achillea millefolium*	NUUU
ANMI3	Pussy toes, littleleaf	*Antennaria microphylla*	NNNN
ASTRA	Vetch, timber milk	*Astragalus miser*	UDUU
ERCA8	Matted buckwheat	*Eriogonum caespitosum*	UUUU
LIDAD	Toadflax, dalmatian	*Linaria dalmatica*	UUUU
PHHO	Hoods (spiny) phlox	*Plox hoodii*	NNNN
PACA15	Groundsel, wooly	*Packera cana*	NNNN
SYAS3	Aster, western	*Symphyotrichum ascendens*	NNNN
ZIPA2	Deathcamas, foothill	*Zigadenus paniculatus*	TTTT

Cattle grazing preference by quarter of the year: N = not used, D = desirable, P = preferred, T = Toxic, U=undersirable. Species Source: Bureau of Land Management. 2005. Ecological site inventory data at 28 sites in Duck Creek Allotment (species found at 12 kg/ha or more in abundance at several sites). Cattle preference source: Natural Resources Conservation Service. 2005. Ecological site description RO34AY222WY loamy 10-14, animal preferences, quarterly for commonly occurring species. pp 8-9.

Forage production based on current grass production is described in table 5. The range site information comes from the county soil survey (SCS 1982). The authors placed forage production monitoring cages in five of the nine range sites found in the Duck Creek Allotment. The resulting data from our sites represent 98 percent of the area of the allotment. Multiple sample sites were located in most range sites, and the amounts of forage found at these sites were averaged together. Grass production for 2005 was not used because precipitation was above average; other years had average precipitation.

Cattle have access to herbaceous plants that are primarily located in the shrub interspace area. This carrying capacity analysis assumes that grass growing under shrubs is not available as a forage source to cattle. Based on the canopy cover survey the authors conducted, 67 percent of the allotment is interspace area between shrubs (table 9). The available area for forage was determined by multiplying the area in a range site with a slope less than 50 percent (BLM slope criterion) by this interspace factor of 67 percent. The total production for a Duck Creek range site is the result of multiplying the available area times the grass production of that range site.

If we make the standard assumption often used by BLM—that one AUM uses 272 kg (600 lbs)/month, forage under shrubs and in interspaces can be grazed and 50 percent of palatable forage is *allocated to livestock*—we find that the Duck Creek Allotment will support 2,479 AUMS and produc*e* 1,348,681 kg for the allotment based on the authors' forage production data. The Duck Creek Allotment is currently managed to allow 3,320 AUMs of grazing use.

Using data that reflect the weight of today's cows and the light utilization required for impaired lands in this region, one AUM requires 706 kg (1,556 lb)/month and 30 percent of the grass production would be allocated to livestock (Holechek at al. 2004). Based on these assumptions using the authors' forage production data, the current carrying capacity for the Duck Creek Allotment is 581 AUMs or 18 percent of what is now permitted to graze.

A more detailed analysis of forage capacity of this allotment is likely to lead to the conclusion that this allotment will support even fewer livestock. One key consideration, not incorporated in the capacity analysis in the previous paragraph, is the erodibility of soils. Highly erodible soils are unlikely to sustain domestic grazing under traditional grazing practices (USDA 2003). Erodible areas that cannot sustain livestock grazing because of biophysical limitations are classified as not capable or suitable for livestock grazing (USDA 2004, BLM 1979). Areas identified with high to very high potential for erodibility should be classified as unsuitable for livestock grazing and not included in carrying capacity analysis. Based on the Rich County soil survey (SCS 1982), almost half of the allotment has soils with high or very high erodibility. Reducing the amount of land capable and suitable for grazing will further reduce the capacity of the allotment.

The authors argue that capacity analysis should also account for the amount of herbaceous plant production needed to support wildlife. Except for major game ungulates, range capacity fails to account for this key need. The authors reviewed the forage demands for common mammals that occupy the Duck Creek Allotment, table 18 (Catlin at al. 2003), and found that about 225 kg/ha per year should be allocated to mammalian herbivores in sage steppe. To calculate this allocation, we selected three primary herbivores (or in the case of folivorous/omnivorous rodents, a guild) that fairly represent the mammalian herbivores present in sage steppe: mule deer, jackrabbits, and rodents. More study is needed to validate the estimates in table 18 for this specific locale. Based on wildlife needs in the Duck Creek Allotment, it is probable that 5-30 percent of the annual plant production is needed to support wildlife when making a range capacity analysis. When wildlife forage needs are included into the range capacity analysis, the carrying capacity for livestock will be further reduced.

BLM argues that the current stocking number is well within the forage production capacity of this allotment (BLM 2008b). We argue--based on the best available information concerning forage production, livestock consumption, habitat and wildlife needs--that the livestock number that can be supported in this allotment is substantially lower than what is now permitted. Grazing at levels above the allotment's carrying capacity leads to high utilization levels, shift in the plant community away from potential, and increased degradation of riparian areas.

Table 18. Kg/ha/year of forage (grass and forb) biomass necessary to support typical mammal herbivore populations in arid Utah.

Species	Density *(Individuals per hectare)*	Average total forage per individual *(kg./day/individual)*	Herbaceous forage in diet *(percent)*	Herbaceous forage per individual *(kg./day per individual)*	Herb. forage per population per day *(kg/ha/day)*	Herb forage per population per year *(kg/ha/year)*
Deer	**0.11**	**1.58**	**22.40%**	**0.325**	**0.035**	**12.73**
Deer Lit Citations	*1*,34,42,43,45*	*2,9,11,12,27,29,37*	*4,10,14,27, 29,29*			
Jackrabbits	**2.01**	**0.13**	**74.70%**	**0.097**	**0.199**	**72.66**
Jackrabbit Lit Citations	*5,6,8,20,22, 29,40*	*4,15,15,22,29, 32,33,36*	*3,21,23,24, 32*			
Rodents	**16.3**	**0.056**	**43%**	**0.024**	**0.39**	**142.3**
Rodent Lit Citations	*16,17,18,19,25, 26,28,38, 39,46,47*	*29,30,31,35*	*38,41,44,48*			
Total Herbaceous Forage Allocation For Mammalian Herbivores =					**227.6 kg/ha/yr**	

*References are as follows: 1.Chapman & Feldhamer 1982, 2.Demaras & Krausman 2000, 3. Fagerstone et al. 1980, 4. Krausman 1996, 5. Daniel et al. 1993, 6. Johnson & Anderson 1984, 7. Kufeld 1973, 8. Anderson and Shumar 1986, 9. Smith 1953, 10. Bueker et al. 1972, 11. Aldredge et al. 1974, 12. Smith 1952, 13. Hobbs et al. 1982, 14. Hansen & Clark 1977, 15. Currie and Goodwin 1966, 16. Fautin 1946, 17. Grant et al. 1982, 18. Nelson & Leege 1982, 19. Grant & Birney 1979, 20. Norris 1950, 21. Fagerstone et al. 1980, 22. Arnold 1942, 23. Alipayo 1991, 24. Wansi 1989, 25 WRSOC 1983, 26. Hanley & Page 1981, 27. Urness 1981, 28. Rosenstock 1996, 29. Stoddart et al. 1955, 30. Golley 1960, 31. Kuford 1958, 32. Hoffmeister 1986, 33. McAdoo & Young 1990, 34. UDWR 2003, 35.Detling, in prep, 36. Vorhies 1933, 37. Jensen 1984, 38. Goodwin & Hungerford 1979, 39. Shepard 1972, 40. Stoddart 1938, 41.Black & Frischknecht 1971, 42. Horejsi & Smith 1983, 43. Clegg 1994, 44. BLM 1998, 45. AGFD 2003, 46. West 1983a, 47. West 1983b. 48. Alston 2002.

Drought Management

BLM's drought management policy includes consideration of the U.S. Drought Monitor forecasts, and early assessment of on-the-ground conditions to determine management actions, including possible reductions in grazing to accommodate drought (BLM 2003). The U.S. Drought Monitor has provided assessments of drought since 1999 and shows that for the period 2000 to 2009, drought was experienced on the Duck Creek Allotment 7 out of these 10 years. Except for the above average precipitation year in 2005 when BLM conducted surveys, most years have average or below average precipitation (Fig. 4). BLM sends out drought notices periodically, but no evidence of destocking has been found in billing records or actual use reports. Some notices were sent out near the end of the grazing season, too late for meaningful action, even though drought had been identified months earlier.

Holechek at al. (2004) recognize that livestock stocking rates should be reduced in accordance with forage capacity. Forage production varies with precipitation and can range widely between dry and favorable years (SCS 1982). After drought, the ability of forage plants to recover is directly related to the standing crop levels maintained during the dry period (Holechek at al. 1999b). It has long been recognized that dry years (below average precipitation years) occur about 50 percent of the time (Hutchings and Stewart 1953). These authors suggested that 25 – 30 percent use during average precipitation years of all forage species by livestock is proper. They recommended this level because routinely stocking at capacity will result in overgrazing in half the years and necessitate heavy use of supplemental feed. Even with this system, they recognized that complete destocking would be needed early into, during, and after drought (Thurow and Taylor 1999).

Drought management should reflect the need to restore degraded habitat prior to drought. The Duck Creek Allotment contains degraded native plant communities, soils exposed to accelerated erosion, and degraded riparian systems. These conditions have been exacerbated by BLM management during drought and dry years. BLM has not adequately monitored and managed the public lands for their potential or sustained use. The result is that productivity has been impaired and will be impaired permanently unless management changes are based on science and objective, quantitative assessments.

Discussion of Grazing Practices

Research over the past several decades provides solutions to the livestock induced problems on the Duck Creek Allotment and millions of acres of public lands across the West. Drought has become a persistent condition on the Duck Creek Allotment, and management should accommodate these conditions as they become normal with climate change. Failure to adjust stocking rates within current capacity and reduce stocking to account for lower forage production in dry or drought years has potentially serious negative ecological impacts.

High stocking rates have led to high utilization on the Duck Creek Allotment and to shifts in the native plant community to less desirable species and lowered productivity. The substantial decline of a keystone native bunchgrass, bluebunch wheatgrass, exemplifies the cost of over-utilization. BLM has consistently allowed heavy use (50 percent or more) to occur on the allotment's uplands and 90 percent in riparian areas. Research has shown that utilization levels of 30 percent or lower improve productivity. Holechek at al. (1999, 2004) have found that during drought moderately stocked pastures produce 20 percent more forage than heavily stocked pastures, and lightly stocked pastures produce 49 percent more forage than heavily stocked pastures and 24 percent more forage than moderately stocked pastures.

In 2005, the north half of the Duck Creek Allotment was rested. Monitoring after this rest period showed no measurable herbaceous plant community improvement. From 2006 to 2009, a four pasture deferred system of grazing was followed. Utilization in riparian areas continued to exceed 90 percent and regrowth was not evident in any of the pastures. Deferred grazing systems such as BLM is implementing on the Duck Creek Allotment have shown no advantage over season-long grazing (Briske and others 2008). Stocking rate adjustments have proven effective in increasing forage production if utilization does not exceed 30 percent (Briske at al. 2008, Clary and Webster 1989, Eckert and others 1986, 1987, Holechek at al. 1998, Holechek at al. 2000, Van Poollen at al. 1979).

Except for rest for half of the allotment in 2005, rest has not been provided in the Duck Creek Allotment for other years and pastures. Lack of a full growing season for rest and high utilization may explain the low vigor of the native bunchgrass communities (Anderson 1991, Hormay and Mueggler 1975, Mueggler 1975,Talbot 1961). In studies of long-term rest at Idaho National Engineering Laboratory, the recovery rate of grasses in sagebrush communities was slow but real, progressing from 0.28 percent to 5.8 percent ground cover over 25 years (Anderson and Holte, 1981), and non-natives such as cheatgrass had an inverse relationship to native perennial grasses (Anderson and Inouye 2001).

CONCLUSIONS

On western rangelands, livestock grazing as has been traditionally practiced has significantly reduced wildlife habitat resilience (Belsky and others 1999, Bruan 2006, Fleischner 1994, Fleischner 2010, Jones 2000,). This paper presents a more comprehensive analysis in order to understand the relationship between ecological theory, land management policy, habitat management standards, agency ecological assessment methods, and how these are practiced in the field. As the authors' analysis shows, specific on the ground data gathering was critical in order to link field application with policy and theory.

Secretary of the Interior Salazar has committed his agency to "three new functions: renewable energy production, carbon capture and storage, and climate adaptation" (Salazar 2009). Carbon storage and climate adaptation are both relevant to range management. Through agency-promoted ecosystem restoration, storage of organic carbon in soils and plants could increase according to Salazar. About 13 percent of soil organic carbon is stored in shrublands (Sundquist at al. 2009). We do not know the amount of increase in stored organic carbon that we might see if those lands reached their ecological potential. The ecological assessment methods reviewed in this paper typically don't assess the amount of carbon stored in soils. Correction of this shortcoming is not planned at this time. Failure in the past to accurately assess carbon storage and other ecological indicators is also not recognized as a research need by the federal government (U.S. Global Change Research Program, 2009). However, the need for change in range management has not been articulated in agency responses to climate change up to this point.

The authors argue that promoting resilient habitat is a key part of the adaptation needed to reduce the impacts of climate change in the West. As is detailed in this paper, BLM habitat assessment methods by design often under report habitat that has significantly departed from its ecological potential, and thus has lost its resilience. Based on the ecological assessments that BLM has conducted in Utah, only 1 percent of the assessed allotments require changes in range management in order to meet rangeland health standards. Our research on the Duck Creek Allotment suggests that rangelands have experienced a significant loss of resilience, and that this has not been captured fully by agency monitoring and analysis.

In order to understand what might be the cause of the disconnect between agency ecological assessments and ecosystem condition, several analyses were required. Each element of the research presented here provides needed insight into what causes agency assessments to conflict with measured ecological condition. Part of the problem can be explained in the design of agency ecological assessment methods. A review of BLM policies and assessment methods shows that key ecological indicators are missing from BLM's ecological assessment methods. BLM's rangeland health standards cover many of the required ecological factors, but they do not incorporate these indicators at the spatial and temporal scales needed.

BLM has preferred to use qualitative ecological assessment methods that, judged by the authors' data, fail to meet federal requirements for assessing compliance with BLM's standards. As our critique of these assessment methods shows, independent review and validation of agency assessment methods is seriously needed. The use of these methods in the field, as demonstrated in this study, has under reported ecological problems.

The consequences of BLM's failure to adequately assess habitat conditions on the Duck Creek Allotment are significant. BLM's analysis failed to identify the significant loss of the key dominant bunchgrass community, the loss of overall productivity, the excessive amount of bare ground in most ecological sites, a shift in the plant community towards lower biodiversity dominated by grazing tolerant plants, the almost complete loss of woody riparian plants, and, likely, a reduction in wildlife populations. As a result, today Duck Creek has no ducks.

Likewise, BLM's trend, utilization and stubble height monitoring data are not consistent with the authors' data. BLM's qualitative ocular methods consistently reported utilization levels over 31 percent less than levels determined by quantitative methods. Grazing utilization in upland areas was well above the required management standard of 50 percent and was over 90 percent in riparian areas. BLM claims to rely on its utilization and stubble height data to seasonally adjust the amount of grazing each year. Based on the Duck Creek Allotment data presented in this study, the methods BLM used consistently under reported utilization and are inappropriate for making accurate stocking level decisions.

Because of this problem with BLM monitoring, carrying capacity analysis is needed. Unfortunately, BLM has rarely conducted range capacity analyses in the past 25 years (Robinson 2008). To be consistent with today's conditions and the agency's ecological management direction, range capacity analyses needs to be updated West wide. Forage demand by livestock has changed over time and stocking decisions made by BLM fail to address this change. The forage needs of today's livestock are a key input in any carrying capacity analysis. The increase of the weight of cattle today indicates that today's cows consume more than BLM currently allocates. And, the ecological needs of wildlife should also be incorporated into range capacity analysis, with special attention to ecological restoration. This study estimated, based on field data and current recommendations for grazing practices, that BLM had significantly overstocked the Duck Creek Allotment.

Drought will become the norm in the future. Preparation for potential drought conditions requires actions prior to drought to reduce land use impacts, as well as a recovery period after a drought. Based on BLM's record in the Duck Creek Allotment, response to droughts has been minimal and too late to be effective. Rest or stocking reductions of livestock needed for drought management or post drought recovery have not occurred. In 2006, Congress established the National Integrated Drought Information System (NIDIS Act), which incorporated existing and new drought data and prediction analysis into a coordinated program. Based on BLM's records for the Duck Creek Allotment, agency use of these data to predict and respond to drought has not occurred.

BLM did recognize that new management was needed to address problems in some riparian areas in the Duck Creek Allotment. In the first phase of BLM's revised management scheme, the allotment was divided into four pastures, with grazing occurring in each pasture each year for one month on a rotating schedule. Our study for this allotment has field data prior to and for several years during this first phase. Based on comparing pre and post deferment data, conditions in this allotment show almost no improvement in riparian and upland areas. While the number of livestock grazed has often been less than the permitted number, the data show continued degradation. Phase two of the revised management scheme recently placed upland water troughs in these pastures and data are now being collected to identify any resulting changes. It is too early to evaluate this second phase.

Holling and Meffe (1996) provide a model that helps explain the characteristics on the ground of BLM's current range program in the Duck Creek Allotment. Holling (1995) argues that when socioeconomic goals dominate "any attempt to manage ecological variables (e.g. fish, trees, water, cattle) this inexorably leads to less resilient ecosystems, more rigid management institutions, and societies more dependent on resource extraction." Gunderson & Holling (2002) label this as a pathology of resource and ecosystem management.

The refusal by BLM to implement proven solutions to overgrazing illustrates Gunderson and Holling's concept of pathological management. Rest, both growing season long and over many years, is normally required for habitat recovery (Kowalenko and Romo 1996, Thurow and Taylor 1999). Further, once recovery has occurred, stocking levels must be set to ensure that habitat remains at its ecological potential. Changes in grazing systems (deferred, rotational, short duration rotation, rest rotation, etc.) alone do not address the problems caused by overstocking (Briske at al. 2008).
The extent to which habitat condition departs from ecological potential is a significant factor influencing the severity of impacts from drought (Bahre and Shelton 1993). The examples that compare impaired streams and sagebrush habitat with nearby sites that are near ecological potential demonstrate the enormous importance of resilient habitat to ecosystem support in a time of drought. Habitat at its ecological potential is likely to be impacted less from climate change than predicted (West and others 2009). Methods are available for assessing habitat resilience; but as our Duck Creek Allotment study has shown, BLM's current range management program falls far short of identifying loss of habitat resilience and taking action to correct that loss.

We see the new direction of Interior as an opportunity to promote resilient rangelands as a key part of our response to climate change. As this paper shows, significant change in BLM is needed in order to assess the health of ecosystems and manage in deference to habitat health. History has shown that BLM is unlikely to address this need solely through internal means. Engagement of the scientific community is required. Ronald Reagan (1987) advocated a policy of "trust but verify." Clearly the concept of external verification applies to range management as well as to foreign policy.

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Appendix A. BLM Upland Rangeland Health assessment results for Duck Creek allotment, 2005.

Site ID	1 rill	2 water flow	3 pedestals	4 bare ground	5 gullies	6 wind scour	7 litter move	8 resist erosion	9 soil loss	10 plant comp	11 compaction	12 function groups	13 plant mortality	14 litter amount	15 Annual Prod	16 invasive	17 repro perennials	Assessment Results	Similarity Index (Normal Precip.)
DC-1	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	2	5	F	66%
DC-2	4	2	4	5	3	5	4	3	5	3	4	2	4	3	3	2	4	FAR	54%
DC-3	5	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	F	56%
DC-4	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	F	63%
DC-5	5	4	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	F	48%
DC-6	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	2	5	F	68%
DC-7	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	4	5	F	66%
DC-8	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	4	5	F	66%
DC-9	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	3	5	F	68%
DC-10	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	F	68%
DC-11	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	F	56%
DC-12	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	4	5	F	78%
DC-13	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	F	73%
DC-14	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	F	85%
DC-15	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	F	59%
CD-16	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	F	59%
DC-17	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	F	53%
DC-18	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	F	53%
DC-19	5	5	5	5	5	5	4	5	5	5	5	4	5	4	5	3	5	F	49%
DC-20	4	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	F	20%
DC-21	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	F	58%
DC-22	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	F	53%
DC-23	5	5	5	5	5	5	4	5	5	5	5	4	5	4	5	3	5	F	72%
DC-24	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	F	61%
DC-25	5	4	4	5	5	5	5	4	5	4	4	3	4	4	3	3	4	FAR	40%
DC-26	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	F	45%
DC-27	4	3	4	5	3	5	4	3	5	3	5	4	4	4	4	4	5	FAR	50%
DC-28	5	5	5	5	5	5	5	5	5	5		5	5	5	5	4	5	F	64%

Appendix B. Results of BLM lotic (stream) PFC assessments, Duck Creek Allotment, 2005.

Stream Segment	Stream Name	1 flookplain inundation	2 Beaver	3 sinuosity, width, gradient	4 riparian area widening	5 uplands not degrading stream	6 diverse age class	7 diverse composition	8 soil moisture	9 roots withstand floods	10 plants high vigor	11 plants protect banks	12 large woody debris	13 channel dissipates flood	14 point bars reveg.	15 stream lateral migration	16 stream vertically stable	17 sediment/flow in balance.	Function
DC-R1A	Duck Creek	N	NA	YN	N	Y	Y	Y	Y	Y	Y	YN	N	Y	Y	Y	Y	Y	FAR
C- R1B	Duck Creek	Y	NA	Y	Y	Y	Y	Y	Y	Y	Y	YN	NA	Y	Y	Y	Y	Y	FAR
DC-R15	Six Mile Creek	Y	NA	YN	YN	Y	Y	Y	YN	YN	YN	YN	NA	YN	Y	Y	Y	Y	FAR
DC- R21	Six Mile Creek	YN	NA	Y	Y	Y	YN	YN	Y	YN	Y	YN	NA	YN	YN	Y	Y	Y	PFC
DC-R21B	Six Mile Creek	N	NA	YN	Y	Y	YN	YN	YN	YN	YN	YN	NA	YN	N	YN	Y	Y	FAR
DC-R29	Sage Creek, Sec 18 SE/SW	Y	NA	Y	YN	Y	Y	Y	Y	YN	Y	Y	NA	Y	YN	YN	Y	Y	FAR
DC-R31	Reach A, NF 6 mi	Y	NA	YN	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	Y	Y	Y	PFC

YN indicates that the answer was between yes and no.

Appendix C. Results of BLM lentic (Spring) PFC assessments, Duck Creek Allotment, 2005.

Site	Stream Name	1 Wetland saturated frequently	2 fluctuating water level	3 wetland area at potential	4 uplands not degradating wetlands	5 water quality supports plants	6 water flow not disturbed	7 structure not inhibiting flow	8 diverse plant age class	9 diverse plant composition	10 Maintain soil moisture	11 root mass prevents erosion	12 plants have high vigor	13 Plant cover protects soils	14 no frost heaving	15 favorable microsite condition	16 chemicals not affect plants	17 soil soil saturation good	18 impermeable geologic layer	19 water sediment balance	20 shores endure waves	Functional Rating
DC-R2	Duck Creek	y	y	y	y	y	y	na	y	y	y	y	y	yn	y	n	y	y	na	y	na	PFC
DC-R3	Duck Creek	y	y	n	y	y	y	na	y	y	y	y	y	y	y	na	y	y	na	y	na	PFC
DC-R4	(see R3)	y	y	n	y	y	y	na	y	y	y	y	y	y	y	na	y	y	na	y	na	PFC
DC-R5	DC spring 4	y	y	n	y	y	y	na	y	y	y	y	y	y	y	na	y	y	na	y	na	PFC
DC-R6	Spring 5	y	y	n		y	n	na	y	y	y	y	y	y	y	na	y	y	na	y	na	FAR
DC-R7	Rich Spring	y	y	n	y	y	y	na	y	y	y	y	y	yn	y	na	y	y	na	y	na	PFC
DC-R8	Duck Creek	y	y	n	y	y	y	na	y	y	y	y	y	yn	n	na	y	y	na	y	na	PFC
DC-R9	(See R8)	y	y	n	y	y	y	na	y	y	y	y	y	yn	n	na	y	y	na	y	na	PFC
DC-R10	(See R8)	y	y	n	y	y	y	na	y	y	y	y	y	yn	n	na	y	y	na	y	na	PFC
DC-R11	(See R8)	y	y	n	y	y	y	na	y	y	y	y	y	yn	n	na	y	y	na	y	na	PFC
DC-R12	DC spring 14	y	y	y	y	y	y	na	y	y	y	y	y	y	yn	na	y	y	na	y	na	PFC
DC-R13	Red Spring (by highway)	n	n	n	y	na	n	na	y	y	yn	y	y	y	n	na	y	n	na	y	na	FAR
DC-R14	Hidden Spring	n	y	n	y	n	n	na	n	n	n	n	n	y	y	na	y	n	na	y	na	NF
DC-R16	Up stringer meadow	y	y	n	y	y	y	na	y	y	yn	yn	yn	y	n	na	y	y	na	y	na	FAR
DC-R17	(same as R16)	y	y	n	y	y	y	na	y	y	yn	yn	yn	y	n	na	y	y	na	y	na	FAR
DC-R18	North Spring	y	y	y	y	y	y	na	y	y	yn	y	yn	y	y	na	y	y	na	y	na	FAR
DC-R19	Barrel Spring	y	y	y	y	y	y	na	y	y	yn	y	yn	y	y	na	y	y	na	y	na	FAR
DC-R20	Sec 33 spring. S.F 6 mile	y	y	y	y	y	y	na	y	y	y	y	y	y	yn	y	y	y	na	y	na	PFC
DC-R22	Spring 1, N. 6 Mile	y	y	y	y	y	y	na	y	y	y	y	y	y	y	na	y	y	na	y	na	PFC
DC-R23	Rabbit Spring																					
DC-R24	Spring 3, 6 Mile	yn	yn	n	y	y	y	na	yn	yn	yn	yn	yn	y	y	na	y	yn	na	y	na	FAR
DC-R25	Meadow Sec 25 E1/2																					
DC-R26	Spring 2, Sec 25 NW1/4	y	y	y	y	y	y	na	y	y	y	y	yn	y	n	na	y	y	na	y	na	PFC
CD-R27	McKinnon Spring																					
DC-R28	Sec 31 spring	y	y	n	y	y	n	na	n	n	n	yn	n	n	n	na	y	yn	na	y	na	NF
DC-R30	Sage Creek Spring	y	y	yn	y	y	y	na	y	y	y	y	y	yn	yn	na	y	y	y	y	na	PFC

na means that the indicator was not applicable for that site. yn indicates that the answer is in part both yes and no for the indicator