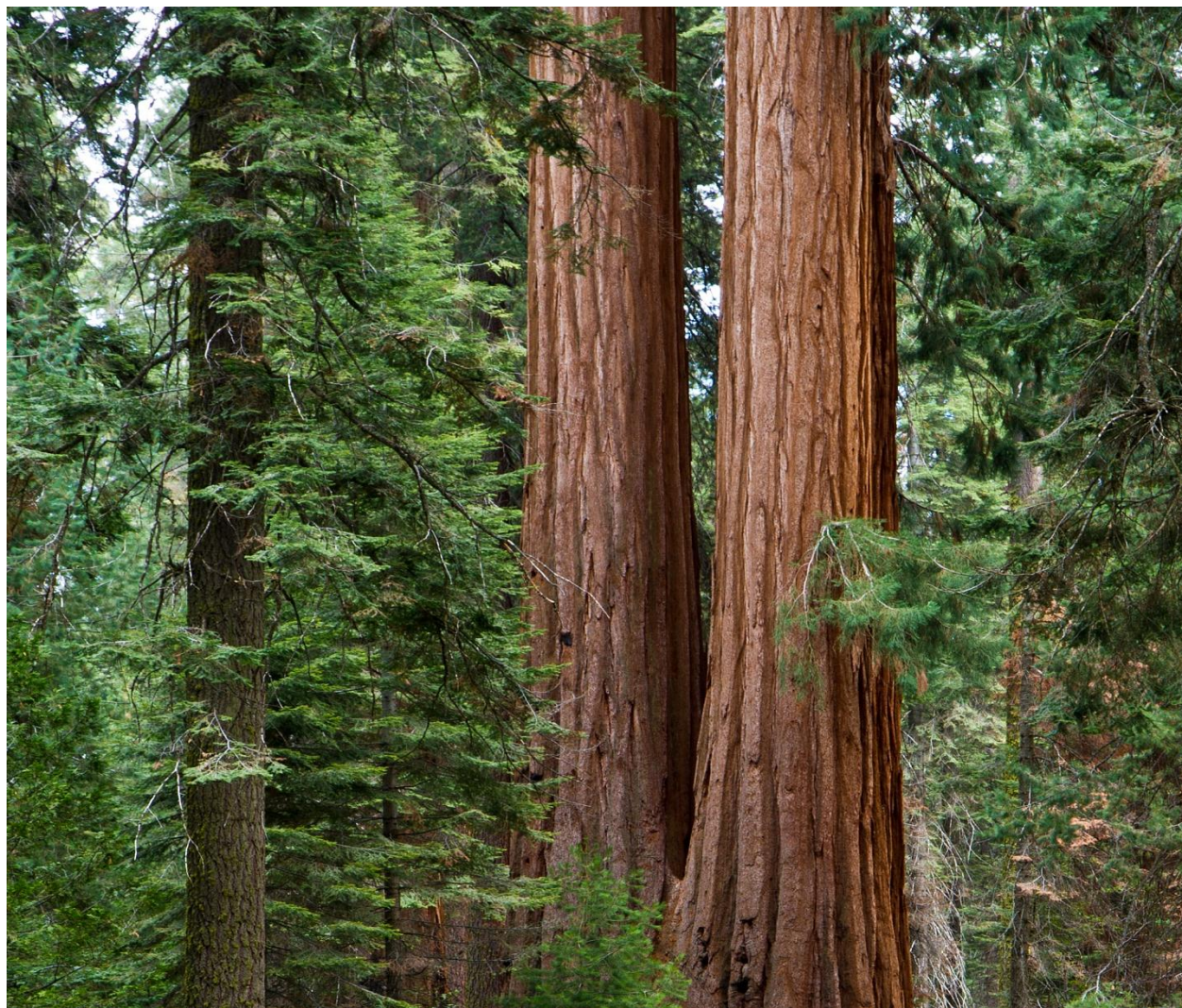




A Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks

Appendix 13 - Meadows

Natural Resource Report NPS/SEKI/ NRR—2013/665.13



ON THE COVER

Giant Forest, Sequoia National Park
Photography by: Brent Paull

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Appendix 13 - Meadows

Natural Resource Report NPS/SEKI/ NRR—2013/665.13

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Natural Resource Stewardship and Science
Fort Collins, Colorado

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Scope of analysis

Although relatively rare features of the Sierran landscape (Davis and Stoms 1996), meadows and wetlands provide critical habitat for a wide array of plants and animals (Kattelman and Embury 1996) and support disproportionately high levels of biodiversity relative to their extent (Ratliff 1982). Meadows play an important role in the life cycle of many invertebrate and amphibian species, and provide a wide variety of ecosystem services such as nutrient retention, flood control, and sediment storage (Johnston 1991, Richardson 1994, Smith et al. 1995, Semlitsch and Bodie 1998, Zedler and Kercher 2005). Meadows also serve as destinations for the many visitors who are attracted by their aesthetic qualities and also for those travelling with pack stock, which rely on meadows for forage for their animals. As such meadows have become focal points of social and legal conflict regarding land management policy in the Sierra Nevada. For these reasons, meadows were selected as a focal resource in the context of the Natural Resource Condition process.

Meadows occur primarily throughout the montane and subalpine zones of Sequoia and Kings Canyon National Parks. For the purposes of this chapter, meadows include dry, moist, and wet meadows, fens, and low-gradient riparian complexes. The vegetation in these systems is dominated by perennial grasses and sedges, but can also support a fairly diverse assemblage of dicots, and frequently includes a significant non-vascular component. Woody species (e.g., willow or emergent conifers) may be locally dominant. Emergent trees generally reflect the composition of the surrounding upland vegetation. Moist and wet meadows are characterized by a palustrine hydrologic regime, and have standing water present for at least part of the growing season. Dry meadows occupy upland habitats and are often characterized by thread leaf sedge (*Carex filifolia*), which forms extensive stands in the subalpine and alpine of the two parks.

Meadows form on gentle to moderately sloping surfaces primarily in canyon bottoms; although they are also found on low, mid and high slopes. The 2007 SEKI vegetation map documents a total of 6,371 ha (15,744 acres) of meadow vegetation between the elevations of 575 and 3940 m (1888 and 12,925 feet).

Meadows are subject to both annual and episodic flooding events and occasional fires. Meadow vegetation composition is strongly correlated with various metrics of water availability (e.g., seasonal water table dynamics and surface soil moisture patterns) and thus may be very sensitive to changes in the timing and amount of water delivery, largely driven by snowpack dynamics.

Due to their ecological importance and as one of the few habitats subject to consumptive use in the Sierran national parks, meadows have long been the focus of both academic and management interest. Specific guidance for managing pack stock in Sequoia and Kings Canyon is provided by the 1986 Stock Use and Meadow Management Plan (NPS 1986) which established which meadows would be open to grazing by pack stock, and also identified a network of meadows that would remain closed to such use. The plan also established the framework for a long term monitoring program to assess the impacts of pack stock use on mountain meadow ecosystems. More recently, the Sierra Nevada Inventory & Monitoring program selected wet meadows and fens (peat accumulating wetlands) as a key vital sign for long term monitoring. Implementation of these programs has resulted in the availability of several monitoring datasets to inform the condition assessment process, including spatially and temporally explicit stock use and grazing records for

park meadows from 1986 through 2009, species composition from five pairs of grazed and ungrazed meadows over a 25+ year period, residual biomass estimates for grazed and ungrazed reference areas within 25 meadows, and a spatial layer linking regulatory status ecological attributes to named park meadows. At the same time, the condition assessment provided an opportunity to summarize these long term data sets in order to inform future planning efforts, such as the revision of the Stock Use and Meadow Management Plan (underway as part of Wilderness Stewardship planning process) and the anticipated Resource Stewardship Plan.

This meadows chapter will be divided into three parts. The first part discusses SEKI meadow spatial distribution, attributes and connectivity (Brooks, Berlow, Matchet, Klinger, Soulard, Joppa, Williams, Alvarez, Guo). The second part analyzes pack stock grazing effects on meadow integrity (Hopkinson, Hammond, Bartolome). The third will describe the process of reconciling the historic meadows layer attributes and regulatory attributes with the current GIS vegetation layer: meadows classification to create a coverage including all of the recognized meadow vegetation polygons and their status with regard to grazing regulations and use levels (Frenzel, Saah and Haultain).

Critical Questions

Meadow Attributes

- What are the general patterns across all ~5000 SEKI meadows with respect to spatial and annual variation in hydro-climatic conditions?
- Do deviations from these broad trends in hydro-climatic conditions indicate groups of meadows that are particularly vulnerable?
- Are there groups of meadows that serve as important spatial ‘hubs’ for potentially connecting meta-populations of meadow-dependent species?

Packstock Grazing

- How is pack stock use distributed across the landscape, and how do use patterns relate to meadow type?
- Is the species composition of selected park meadows that are grazed changing relative to comparable ungrazed meadows? Is species composition changing in individual selected meadows independently of grazing pressure?
- Are residual biomass (end of season standing crop), bare ground, or litter cover changing in paired grazed and ungrazed meadows in SEKI? How are changes in these variables correlated with grazing pressure or snowpack? Are there other factors that are correlated with trends in these variables?

Other

- To what degree are park meadows invaded by non-native plant taxa? What non-native plant taxa are established in park meadows, and what is their distribution?(**See Invasive Plants chapter**)
- How are special status plant taxa distributed relative to SEKI meadows? What regionally endemic and/or sensitive taxa, including bryophytes, are known or expected to occur in SEKI meadows? Which meadow types require special management protection due to the presence of special status or sensitive plants? (**See Special Status Plants chapter**)

Section 1. Sequoia and Kings Canyon Meadow Attributes

Authors: Eric L. Berlow, Matt Brooks, Rob Klinger, J.R. Matchet, Peggy Moore, Steven Ostoja, Christopher Soulard, Lucas Joppa, Rich Williams, Otto Alvarez and Qinghua Guo

Meadow attributes are environmental and spatial features of individual meadows relative to their environment and to each other. We gathered a suite of environmental and spatial attributes for SEKI meadows at the ‘contiguous meadow’ scale, using the SEKI meadow layer that was derived for this report (see final section of meadows chapter). ‘Contiguous meadows’ are defined here as areas that comprise one or more meadow vegetation polygons that are either touching or separated only by a mapped stream. The value of attributing meadows includes:

- Attributes provide a suite of fundamental environmental and spatial information about each meadow that helps to define classes of meadow ‘type’. Meadow typing is beyond the scope of this report, however meadow attribution is a data-driven way of defining groups of meadows with similar hydro-climatic conditions “from the ground up”, and can also provide a foundation for meadow typing.
- Attribute data allow managers to determine whether the population of meadows receiving some management (e.g., grazing) is significantly different, with regard to derived physical attributes, from the population as a whole. In other words, individual meadows of interest can be placed into a broader context of other similar meadows to evaluate whether the patterns observed in one place are unique.
- Meadow attribute data allow for targeted sampling of meadows across specific environmental gradients to explore, for example, how meadow vegetation varies with snow melt date separate from elevation.
- Meadow attribute data allow one to compare, for example, vegetation conditions in a grazed meadow to a suite of multivariate matched ‘control’ meadows that are as similar as possible based on all available environmental and other attributes.
- Outliers from general trends across all meadows provide insights into vulnerabilities or inconsistencies within and between sub-populations of meadows.

The purpose of this section is to introduce these attributes as a tool, first to describe spatially the SEKI meadow population and to set the stage for the stock-grazing section of the chapter. But more importantly, this section will illustrate the utility of this attribute dataset for question-driven exploration of vulnerable or outlier populations, and to address questions of concern to managers and researchers. Much of this utility is gained by plotting attributes against each other to identify consistencies/inconsistencies in meadow relationships. Their application as a management tool is shown in the pack stock grazing section of the chapter, where attributes from pack stock-grazed meadows are compared to the entire meadow population.

Attributes that have been defined spatially for SEKI meadows are described in Table 1.1, as well as data sources and spatial resolution used to determine attributes.

Table 1.1. Meadow attribute spatial layers derived for Sequoia and Kings Canyon NRCA.

Contiguous meadow attributes	Description of layer	Data Source, Spatial Resolution
Basic GIS Attributes	Centroid elevation (m), Contiguous meadow area (ha)	Digital Elevation Model, 10m
Nearest Meadow Distances	Metrics include the horizontal distance, distance along path, cumulative elevation change along path, maximum slope along path, and elevation difference between start and end points	Digital Elevation Model, 10m
Meadow Connectivity	Meadow network metrics include generality, vulnerability	Digital Elevation Model, 10m
Meadow Vegetation Composition	Percentage of total meadow area comprised by a given vegetation type	SEKI 2001 Vegetation Map, 0.5 ha minimum mapping unit
Modeled Climate	18-year average/SD of month T and precipitation (1980-1997) using Daymet http://www.daymet.org/	www.daymet.org , 1km
MODIS Snow Covered Area (SCA)	For each pixel in a given water year 2002-2007, SCA summary value were computed: 1) proportion of year with daily SCA values >25% cover 2) proportion of year with daily SCA values >50% cover 3) the first day after 1 March that daily SCA was <25% cover 4) the first day after 1 April that daily SCA was <25% cover	MODIS, 500m
Landsat Bands 1-3 and NDVI	1985-2006 Landsat 30m zonal statistics for each contiguous meadow, for July, aug, and Sept scenes in each year: Band 1 = Tassele Cap Brightness Band 2 = Tasseled Cap Greenness Band 3 = Tasseled Cap Wetness NDVI = Normalized Difference Vegetation Index	Landsat, 30m
Stock Grazing	1985-2009 reported stock use, tagged to the contiguous meadow scale	SEKI annual stock use reports, reported at forage code scale

Defining 'contiguous meadows'

We derived a suite of environmental and spatial attributes for SEKI meadows at the 'contiguous meadow' scale. Contiguous meadow polygons may be composed of multiple meadow vegetation polygons that are either touching or separated only by a mapped stream (Figure 1.1). This level of aggregation was used to delineate a consistently defined meadow unit that best matches a functional definition of a meadow on the ground: an ecosystem type dominated by a variety of herbaceous species that use surface water and/or shallow ground water (generally at depths of

less than one meter), and where woody vegetation like trees or shrubs, may occur and be locally dense but not dominant at the scale of the entire meadow. Thus, a contiguous meadow polygon could contain a mosaic of different adjacent meadow vegetation types. The contiguous meadow layer was derived from the "SEKI_MeadowRegStatus_20101018" GIS coverage which attributes meadow vegetation mapped as part of the Vegetation Mapping Project with regulatory status from the 1986 Stock Use and Meadow Management Plan. The meadow vegetation polygons from that coverage were derived from the most recent vegetation coverage map using color infrared photography and professional photo-interpretation to assign empirically derived vegetation mapping units to all vegetation in the parks.

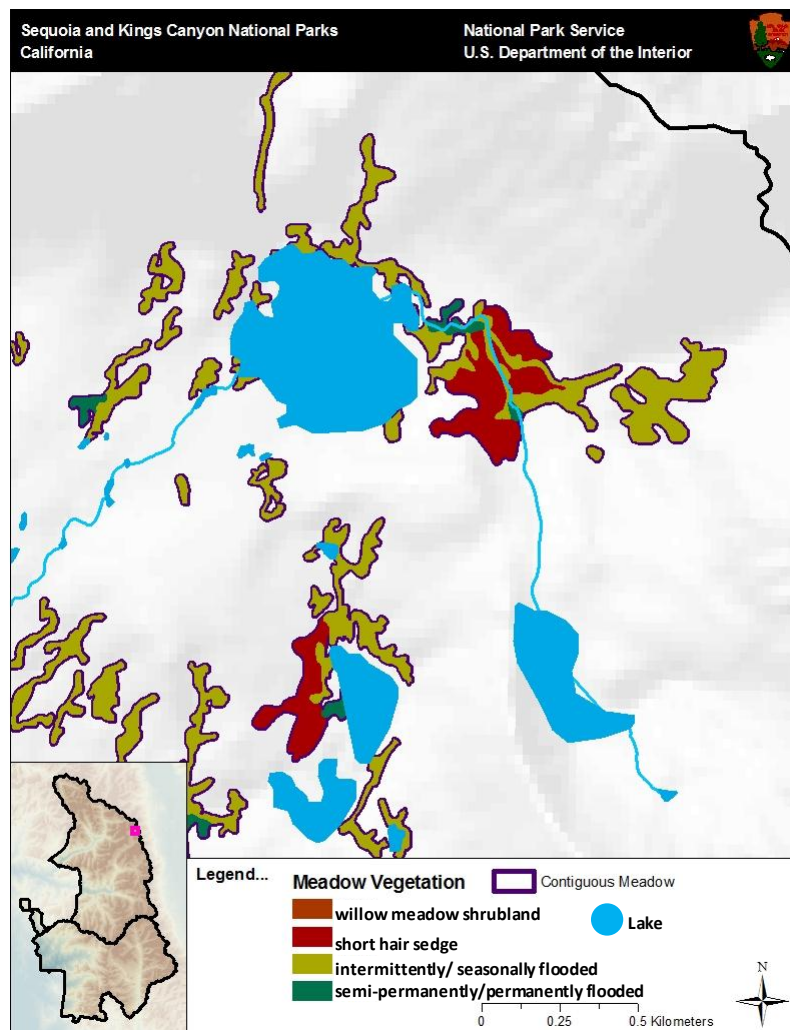


Figure 1.1. Example of how 'contiguous meadows' were delineated from multiple vegetation polygons of the "SEKI_MeadowRegStatus_20101018 GIS Coverage.

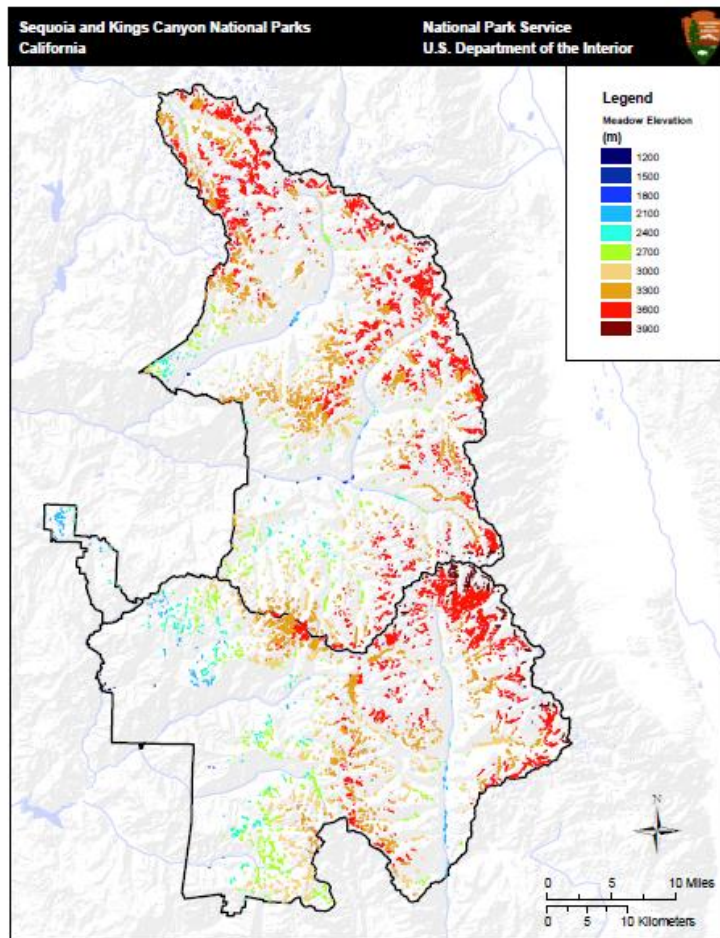


Figure 1.2. Distribution of meadows in Sequoia and Kings Canyon with respect to elevation. Elevation color designations match colors in Figures 4 through 8.

Attributes of SEKI meadows

Elevation

Although SEKI meadows span a range of elevations from 575m to almost 4,000m (Figure 1.2), the bulk of the meadows lie above 2,000m and the greatest extent of meadow – in both area and number – is in the 3,400 to 3,600 m bands (Figure 1.3). Most meadows are a hectare or less in area, but a few are larger than 100 ha. The largest meadows are found between 3,000 and 3,700m.

Snow cover

Climate – specifically temperature and precipitation – drive important processes in meadows. At higher elevations where the majority of meadows are located, temperatures are cool, the growing season is short, and the most precipitation falls as snow. Timing and amount of snowmelt, are important for key meadow processes including growing season length, groundwater recharge, plant emergence, and meadow hydrology. The latter is one of the most important drivers of meadow function, but is difficult to characterize directly.

Significant variation exists in climate and snowmelt from meadow to meadow, and other key factors play a role. Water table depth, slope, aspect, shading, soils are all important in determining the meadow environment. And all of these elements are factors in how meadows will respond to management and to temperature-related stress such as climate change. Of the anthropogenic stressors that are addressed in the NRCA, climate change has the greatest potential impact on meadows due to the importance of hydrology as a system driver.

The utility of physical attributes to show patterns that lead to insights in meadow response to climate variables can be seen with the snow cover area data. We used available estimates of daily fractional Snow Covered Area (SCA) that were derived from 500 m NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery (Dozier et al. 2008, Painter et al. 2009). This time period spanned a range of dry and wet years from 2002-2007. For every meadow centroid we calculated the proportion of each water year that the meadow was greater than 25% SCA. We compared these estimates with those from clipping MODIS pixels to each meadow polygon and the results were similar even for large meadows.

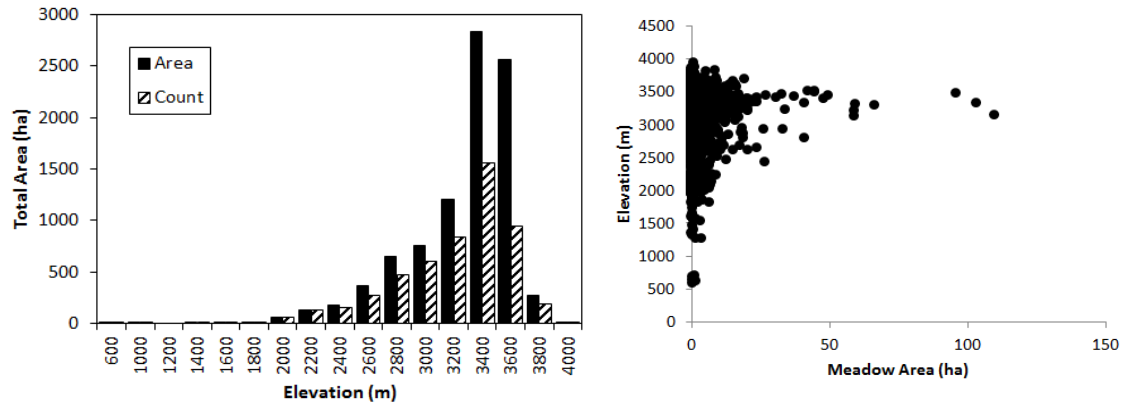


Figure1. 3. Distribution of contiguous meadows across elevations. a) the greatest number and total area of contiguous meadows is between 3,400 and 3,600 m. b) the largest meadows are above 3,000 m. Two larger meadows are not shown, at 200 and 400 ha respectively, around 3,500m.

Even though total precipitation and snow cover can vary dramatically among years, meadow rank with respect to proportion of days in the water year $>25\%$ SCA is highly correlated among years. These trends suggest that meadows can be categorized by their overall relative differences in snow cover despite large annual differences in snowfall (Fig 1.4a). Shown here is a comparison of meadow rankings for the wettest year of the time series (2005) with those of one of the driest years (2004). Mean correlation coefficient for all combinations of pairwise comparisons between years (2002-2007) was 0.95, however intermediate to high elevation meadows experience larger variation in rank than lower meadows. Note an outlier group of high elevation meadows that had unusually large differences in snow cover between a wet and dry year. These meadows, highlighted in the map in blue (Fig 1.4b) either received anomalously less snow or melted out faster in 2004 than in 2005.

Figure 1.5 shows the 6-year average proportion of days in the water year that the meadow snow covered area was $>25\%$ and 50% , respectively. Note that with a 25% cutoff, there is a tighter relationship between snow covered days and elevation. Rather than observing a simple shift to the left (fewer days of $>50\%$ snow cover than days $>25\%$ snow cover), there is a zone between about 2,600-3,200 m with wide spatial variation in snow cover among meadows of similar elevation (blue rectangle). These patterns could be used to identify and sample meadows that vary in snowpack to explore potential impacts of changes in snowpack independent of elevation. Furthermore, it's possible to tease out lower elevation meadows (from 2,000-2,400 m) that retain more snow though the year on average than the rest (red circle).

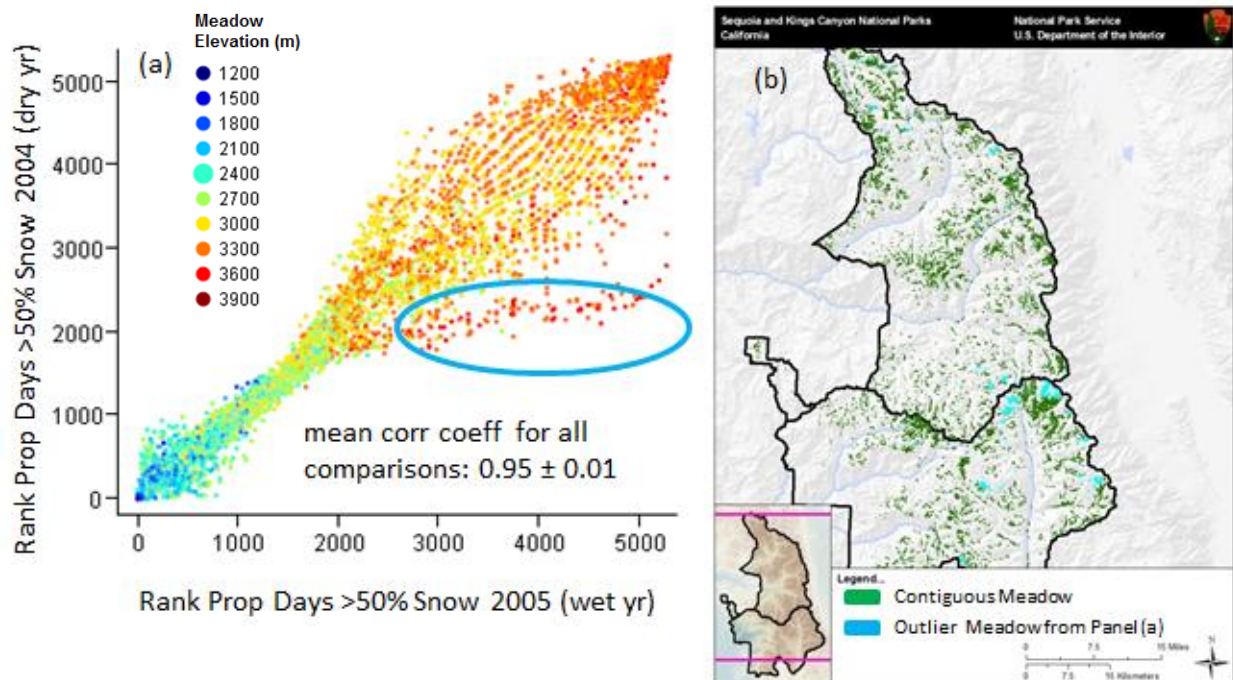


Figure 1.4. Patterns of MODIS-derived snow covered area (SCA) and snow melt-out dates for 5,311 Contiguous Meadows of SEKI. Each point represents one Contiguous Meadow from the SEKI meadow layer derived from the 2000 Vegetation Map. 2005 was the wettest year in the 2002-2007 time series, while 2004 was a relatively dry year. The black line is the one-to-one line indicating identical rankings among years. Note an outlier group of high elevation meadows that had unusually large differences in relative snow cover between a wet and dry year. These meadows are highlighted in the map in blue.

Wetness and Normalized Difference Vegetation Index (NDVI)

The 30m Landsat data provide estimates of meadow ‘wetness’ (e.g., Tasseled Cap Band 3) and aboveground biomass (e.g., NDVI, Normalized difference Vegetation Index). These estimates are at a finer resolution than the 500m MODIS estimates of snow cover, however they corroborate the general MODIS snow trends that, despite large variation among years in precipitation, the vast majority of meadows show very similar TC Wetness and NDVI rankings between years. Figure 1.6 shows these trends for 2005, one of the wettest years in the decade, with 2004, one of the drier years. Note that NDVI rankings are more similar among years than the TC Wetness. These trends are qualitatively identical when means across all years available are examined. Scattered outliers suggest meadows that are potentially more sensitive to annual variation in climate. Outliers in TC Wetness were not the same as NDVI outliers or of meadows that had anomalous snow conditions in Figure 1.4 above. Note that these trends are preliminary results from recently compiled Landsat data and are meant to illustrate 1) that the data are now available for all meadows, and 2) broad trends in these data can help identify the subset of outlier meadows that potentially merit further investigation on the ground.

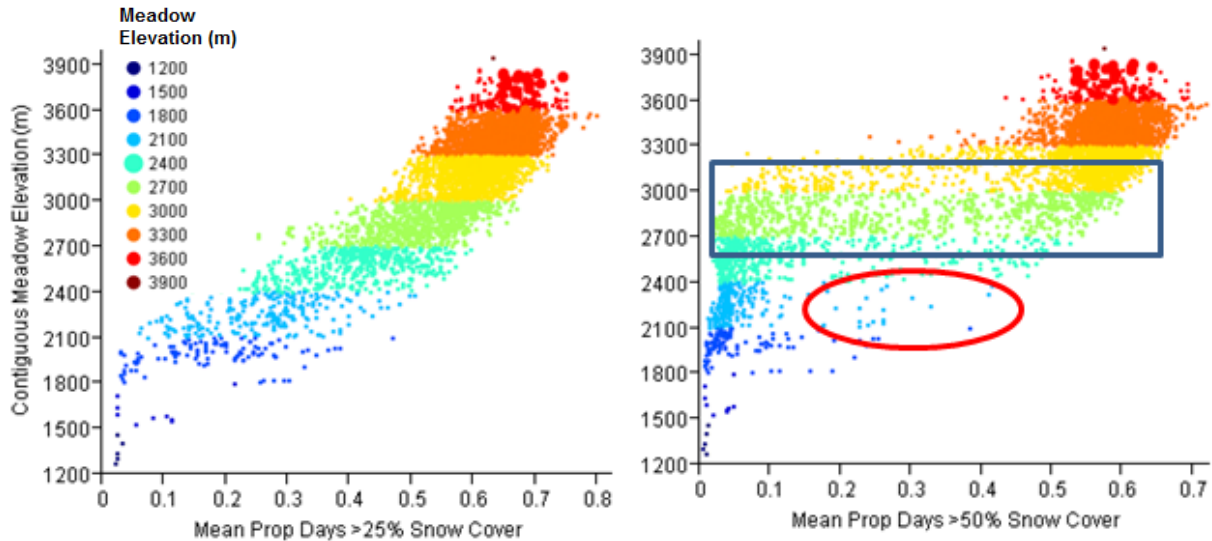


Figure 1.5. The 6-year average proportion of days in the water year that the meadow snow covered area was >25% or 50%, respectively. a) Note that with a 25% cutoff, there is a tighter relationship between snow covered days and elevation. b) At the 50% cutoff, note the zone between 2600 and 3200 m with wide spatial variation in snow cover. The red circle shows low elevation meadows that retain a larger amount of snow though the year on average than the rest.

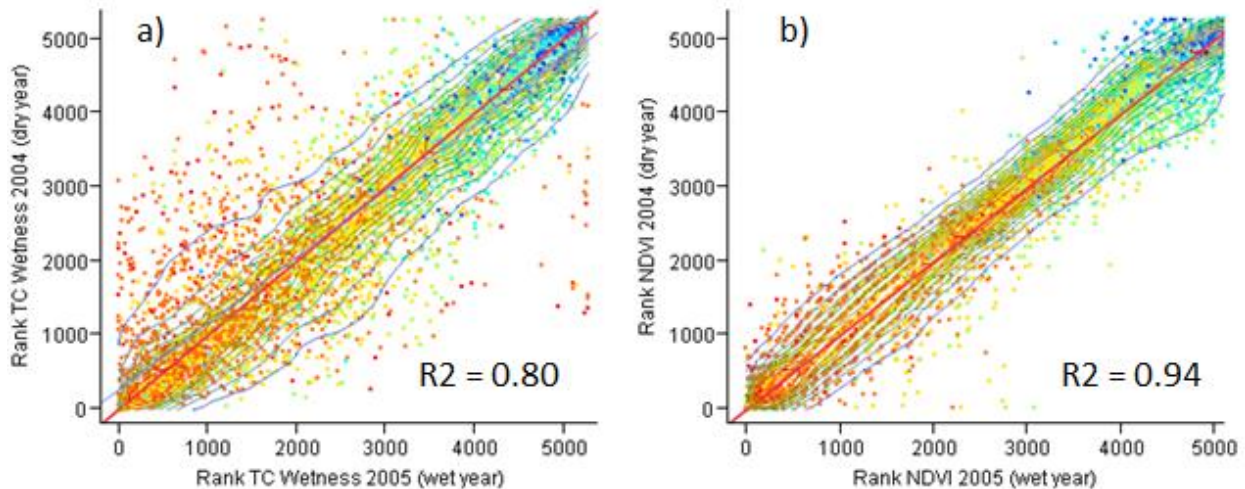


Figure 1.6. Mean August and September meadow wetness estimated from the 30m Landsat (a) Band 3, Tasseled Cap Wetness, and (b) Normalized Difference Vegetation Index (NDVI) for a wet year (2005) and a dry year (2004). The red line is the one-to-one line indicating meadows that have identical wetness rankings in the two years. The contour lines indicate density quantiles for the data points (each point is one meadow). NDVI rankings appear to exhibit less variation among years than the TC Wetness. Points that deviate strongly from the trend point to meadows that may exhibit higher sensitivity to annual variation in moisture or productivity.



While water from snowmelt is known to be an important driver of water availability, the relationship between meadow snow cover and meadow wetness is more complex. Figure 1.7 shows the relationship between mean meadow snow covered days, as estimated from daily MODIS for water years 2002-2007, and mean late summer meadow wetness, as estimated from Landsat Band 3 for August and September from 2001-2006. Low elevation meadows do not depend on local snowmelt for moisture, and they are wetter on average than high elevation meadows. On the other hand, many high elevation meadows (orange to red) are dry despite receiving a lot of snow, but maximum wetness of higher elevation meadows tends to increase with the proportion of days >25% snow cover (red triangle). Maximum wetness tends to decrease with elevation (orange line). These patterns suggest that other factors that determine water *retention* in the soil at high elevations play a key role in determining whether meadows with a lot of snow (i.e., water *supply*) are also wet.

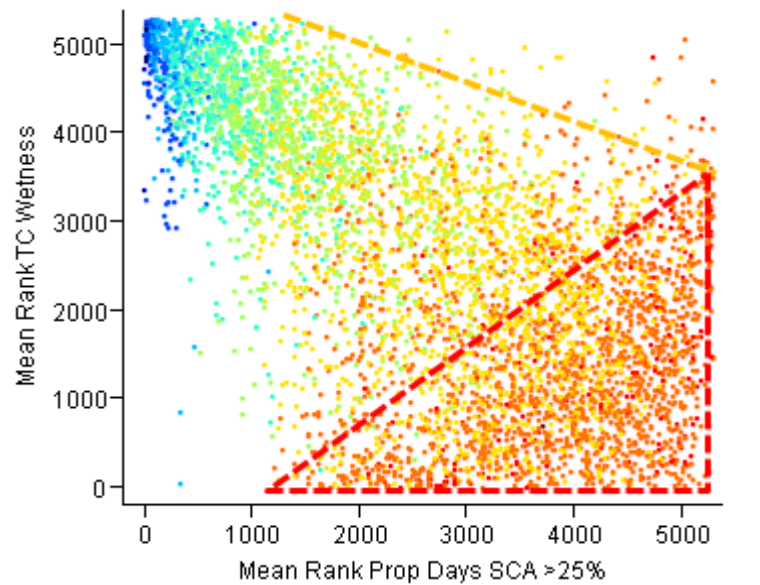


Figure 1.7. The relationship between mean meadow snow covered days (MODIS 2002-2007) and Wetness (Landsat 2001-2006) for all 5,113 contiguous meadows. Many low elevation meadows (blue to green) are wet, independent of snow covered days. Maximum wetness of high elevation meadows (orange-red) tends to increase with the proportion of days >25% cover (red triangle), but many high elevation meadows are dry despite receiving a lot of snow due to poor water retention. There also appears to be an inverse relationship between maximum wetness and snow cover (orange line).

Meadow Elevation (m)

- 1200
- 1500
- 1800
- 2100
- 2400
- 2700
- 3000
- 3300
- 3600
- 3900

Neither NDVI nor Tasseled Cap Wetness (Band 3) was successful in identifying contiguous meadows with a high proportional area of vegetation classified as being very wet (PI code 9000: ‘semi-permanently to permanently flooded meadow’) based on the park vegetation map (Figure 1.8a, c). However, NDVI was a better predictor of the proportion of dry meadow vegetation (PI code 7120: ‘shorthair sedge’), primarily in higher elevation meadows (Fig 1.8b). Note that the minimum mapping unit of the vegetation map is 0.5 ha, while the Landsat imagery is 30m. This preliminary analysis does not evaluate the consequences of different scales of spatial uncertainty. For example, dry ‘Short-Hair Sedge’ polygons may include very wet areas and ponds that are smaller than the minimum mapping unit.

Looking at a suite of attribute data has painted a picture of broad trends in meadow hydro-climate attributes. In some cases these patterns may help identify which meadows are most vulnerably to climate change (e.g., where meadow wetness or vegetation shows a strong response to annual variation in snow). These hydro-climate also may help identify specific outliers of the trends that perhaps merit special attention. It is only by describing general relationships across all meadows that one has a framework to identify key outliers that may indicate anomalous changes to meadow resources. Snow cover is an important driver of potentially available water, and it is an excellent indicator of climatic variability because it integrates both precipitation and temperature. At the same time, other processes on the ground, such as groundwater input and meadow water retention interact with available snowmelt to ultimately determine meadow wetness and vegetation. To better predict meadow wetness would require more data on geologic, topographic, and soil patterns that drive the interaction between local meadow hydrology interacts and larger scale hydro-climatic conditions.

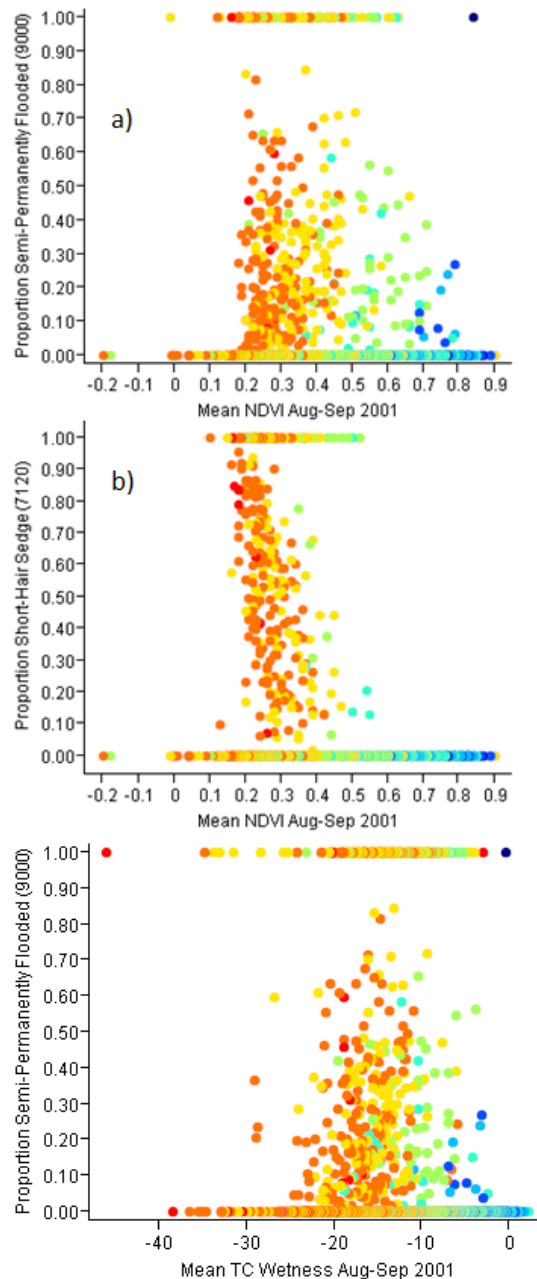


Figure 1.8. The proportion of the contiguous meadow that is (a) wet “Semi-permanently to permanently flooded (PI code 9000) or (b) dry “Shorthair Sedge” (PI code 7120) as a function of mean August and September NDVI from Landsat for the same year that the vegetation map imagery was derived (2001). (c) Mean August and September “Wetness” (Tasseled Cap Band 3) was not a very good predictor of the proportion of wet meadow vegetation.

Connectivity

Meadow flora and fauna response to imposed perturbations and stresses, particularly changing climate, depends not only on which meadows are experiencing more stress, but also on the spatial distribution and connectivity of meadow habitat. The meadows between 2,600 and 3,200 m have the greatest variability in current snow cover (Figure 1.5) and thus provide the greatest range of suitability for species dependent on this attribute, but species must be able to migrate between meadows to find their optimal habitat. The connectivity of meadows within this elevation zone is critical. We created a map of meadow connectivity where links from one meadow ('source meadow') to another meadow ('destination meadow') were created using an exponential dispersal kernel weighted by the sizes of the two meadows. The threshold for drawing a link was a link weight of 0.2:

Link weight = $A_s \cdot A_d \cdot K(d)$, where

$k(d) = \exp(-d/d_0)$;

d_0 is the threshold distance (here = 1000m)

d is the actual Euclidean distance between meadows.

A_s = scaled area of the 'source' meadow

A_d = scaled area of the 'destination' meadow

Figure 1.9a shows the contiguous meadow network map, with the most connected nodes ordered so they rise to the surface. The 25 highest-ranking connected meadows are highlighted in the GIS layer (Figure 1.9b) to show areas that may serve as potentially important meta-population 'hubs' for meadow dependent species such as the Yosemite toad or Belding ground squirrel. Note that these hubs are defined by a dispersal kernel of 1000m based on pure Euclidean distances between contiguous meadow centroids. Other distance thresholds could be used to represent meadow connectivity for species with different dispersal ranges. Similarly, other distance measures that incorporate barriers like terrain and vegetation type could be used. Additionally, these network metrics could change for species with different habitat needs and dispersal ability, for example, species which only occupy wet meadows or those that are non-motile. In other words, the spatial network graph of meadows is meant to illustrate the potential for this new meadow database to better understand how the the distribution of species that are dependent on meadow patches on a landscape scale (Joppa et al. in review).

The broad patterns of meadow hydro-climatic attributes shown here are preliminary and meant to illustrate the potential for blending multiple data sources as the meadow scale to evaluate landscape scale trends. Some interesting preliminary patterns include: 1) Despite known large annual variation in precipitation and snow, the vast majority of meadows appear to exhibit remarkably consistent conditions with respect to one another. In other words, relatively wet (or productive) meadows in one year are typically consistently wetter (or more productive) than other meadows in another year. 2) Strong outliers from these trends point to meadows that may be particularly sensitive to annual variation in climate. Further analyses of the entire time series of available data are necessary to more fully identify groups of meadows that are experiencing important changes in moisture or productivity. 3) Meadows are organized in the landscape such that some are more isolated or connected than others, and some may serve as dispersal hubs. It is critical to understand which meadows among these are currently experiencing the most dramatic changes in hydro-climatic conditions. Again, this will require further analyses of multiple

attributes over multiple years to target any vulnerable meadows among the group of the most highly connected meadows (Joppa et al. in review).

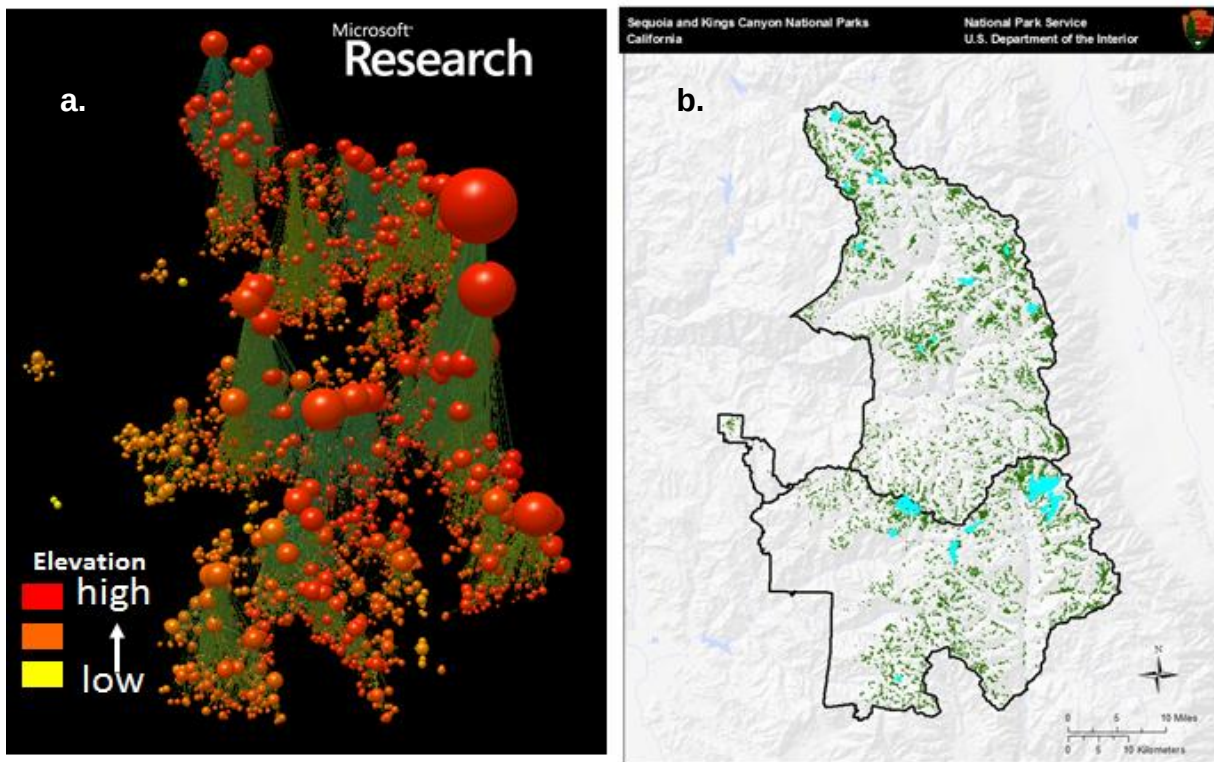


Figure 1.9 (a) Meadow network map for all contiguous meadows in SEKI. Each node is a meadow centroid and is sized by meadow area. Links connecting meadows are based on a 1000 m dispersal kernel and are weighted by meadow size. The node layout is in meadow centroid X-Y space, but is tilted to show the most connected meadows in the third dimension. Nodes are colored by meadow elevation. Most meadows are orange-red because that elevation band has the most meadows. (b) A traditional map of the same meadows with the highest-ranking connected meadows highlighted in blue. These meadows may serve as critical meta-population hubs for meadow-dependent species.

Recommendations for future research

Recommendations for further research include a rigorous evaluation of the spatial distribution of error and uncertainty for meadow scale estimates of both vegetation and hydro-climate attributes. The hydro-climate data have inherently different scales of accuracy, and the meadow layer should be evaluated for any systematic uncertainty in delineation of different vegetation types at different elevations or terrain conditions. Given the spatial network structure of meadow patches in the landscape, it would be useful to better understand the attributes of the most central and highly connected meadow clusters as they may play a critical role in supporting healthy meta-populations of meadow-dependent species. Finally further investigation is warranted into factors that might buffer some meadows against annual changes in snowpack/precipitation. In other words, are there classes of meadows that are less hydrologically vulnerable to changes in climate? What is the spatial patterning of those meadows, and might they play critical roles in creating dry year refugia for species that depend on wet meadow habitat?

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Section 2. SEKI meadows and the impacts of packstock grazing

The potential impact of packstock grazing on meadows in Sequoia and Kings Canyon National Parks (SEKI) is an issue of considerable concern to Park staff, Park users, environmental organizations, and commercial packstation operators. Packstock grazing could affect many ecosystem functions, such as biomass production, hydrology, wildlife habitat, nutrient cycling, invasion dynamics, and plant species composition. Abbott et al. (2003) provide a thorough review of much of the literature examining packstock effects on California meadows.

The following three subsections comprise analyses of three distinct long-term datasets relating to packstock grazing in SEKI meadows:

- 1) packstock use of SEKI meadows,
- 2) residual biomass in meadows with grazed and ungrazed plots, and
- 3) species composition in paired grazed-ungrazed meadows.

Section 2.1. SEKI meadows: Distribution and analysis of packstock use

Authors: Michele Hammond, Peter Hopkinson, and James Bartolome

Introduction

This section provides maps and summary statistics that show the spatial and temporal distribution of current packstock use of SEKI meadows. The National Park Service collects data from all overnight packstock trips, including administrative, commercial and private users (Haultain 2010). A standardized methodology for packstock use reporting was introduced in 1986 and continues on an annual basis. Specified by the forage code for that area, all packstock users report the number of packstock animals, type of animal, and number of nights spent in each meadow area. There are possible inconsistencies between actual packstock use and this summary analysis due to user reporting error and/or lack of reporting. Packstock user reporting errors have been largely taken care of through confirmation of user reported numbers or lack of reporting by annual checks against ranger observation logs (Haultain 2010). All areas with reported stock use have been assigned a forage code. This section will only include an analysis of meadow areas with forage codes and their corresponding reported packstock use.

Packstock use is interpreted with standard range management terminology, animal unit nights (AUN), which are calculated based on the type of animal and the number of nights spent grazing in a meadow. One AUN is equal to approximately 26 lbs. of forage use or grazing by one cow in one “night” or 24 hour period. Other types of packstock are rated higher or lower AUN numbers based on the amount of forage required to sustain them for one night. A horse or mule is defined as 1.25 AUN while burros and llamas are less than one AUN. 30 AUNs are equal to one animal unit month (AUM) (Haultain 2010, SRM 1998).

Because the size of a grazed area is typically used to determine stocking rates, for this analysis we summarize packstock density by AUNs per meadow area (AUN/acre). This also allows comparison with past analyses (e.g., Abbott et al. 2003).

Reporting of packstock grazing use is directly tied to forage codes for each meadow area. SEKI_MeadowRegStatus_20101018 is the GIS layer used to map the spatial distribution of packstock use, calculate the acreage of grazed meadow areas, and to attribute the meadows regulatory status of open or closed to grazing.

Summary SEKI meadow regulatory status statistics

Summary meadow packstock use statistics (Table 2.1.1) in this section are based on the GIS layer, SEKI_MeadowRegStatus_20101018. Regulatory status of meadow areas in this GIS layer is defined in the 1986 Stock Use and Meadow Management Plan. The regulatory status of the meadow areas shows “open grazing” allowed on only 49% of the total meadow area although half of this area (24%) has no historic or current grazing (no forage code). Areas without a forage code, that have the status of open to grazing, have no reported packstock grazing use. The rest of the total meadow area (51%) is permanently restricted by various degrees to packstock use. Of the total meadow area within SEKI, only 25% has current packstock grazing.

Table 2.1.1. Area of meadows in hectares and acres by regulatory status of packstock grazing use; GIS layer used SEKI_MeadowRegStatus_20101018

Regulatory Status	Total Area (hectares)	Total Area (acres)	Percent of total
Administrative use only	5.87	14.50	< 1
Closed to all stock access	67.79	167.43	1
Closed to all stock use by virtue of the half mile rule	3106.87	7673.98	34
Closed to grazing by horses and mules, burros and llamas allowed	229.70	567.35	3
Closed to grazing, day rides and pass-through allowed	881.38	2177.02	10
Closed to grazing, overnight use allowed	309.72	765.02	3
<i>Total area meadows open to grazing</i>	<i>4450.20</i>	<i>10991.98</i>	<i>49</i>
Total area of meadows	9051.53	22357.28	100
<i>Open to grazing, current/historic grazing, with forage code</i>	<i>2238.43</i>	<i>5528.92</i>	<i>25</i>
<i>Open to grazing, no current/historic grazing, no forage code</i>	<i>2211.77</i>	<i>5463.06</i>	<i>24</i>

Packstock grazing use

Reported overall packstock grazing use in Sequoia and Kings Canyon National Parks has a downward trend over the time period 1985-2009 (Figure 2.1.1). Given potentially different reporting regimens over the 25 year period, in 2009 packstock grazing totals approximately 1300 AUN/acre compared with a 1985 annual total of 1800 AUN/acre. Packstock grazing appears to peak in the late 1980's with a high of 2900 total AUN/acre. Packstock use for the last 25 years also appears lower than overall use reported in the 1970's and 80's (Haultain 2010).

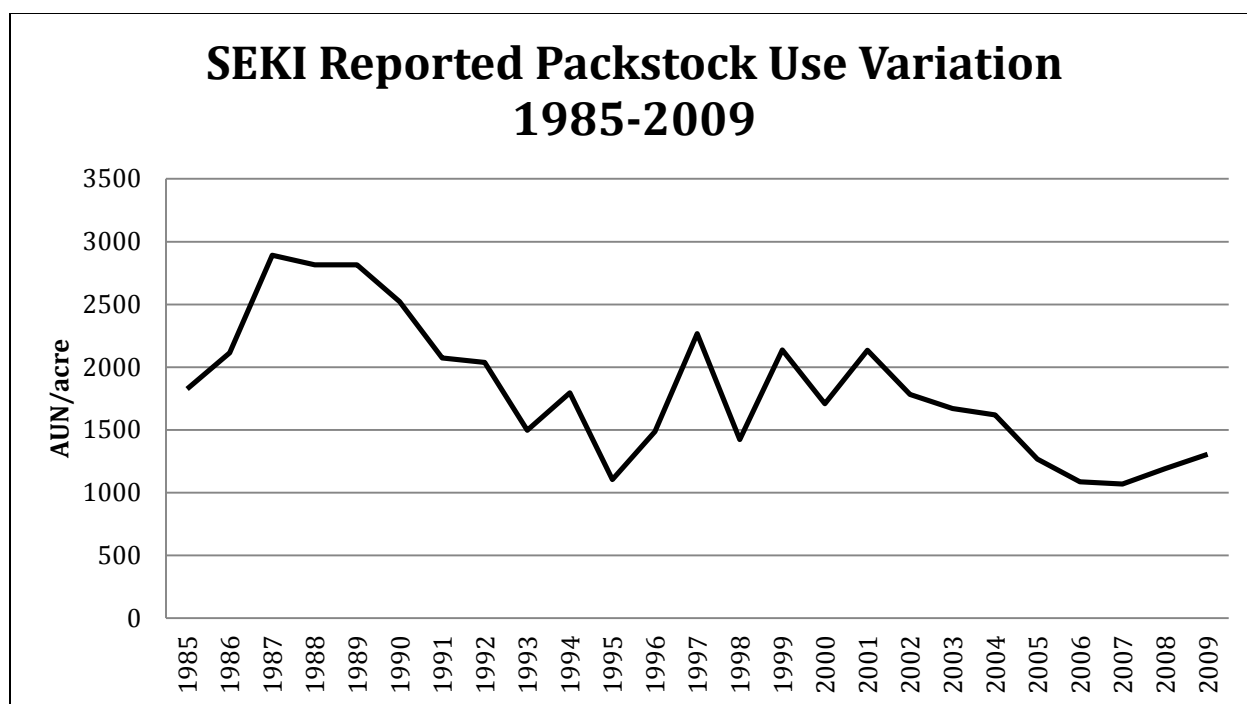


Figure 2.1.1. 1985-2009 annual variation in reported packstock use in SEKI

Packstock user reported data are analyzed in two time periods: 1985-1997 and 1998-2009. Reported packstock use numbers before 1998 are less consistently accurate due to changes in reporting methodology and reliability (Haultain 2010). Average meadow use is calculated for this analysis to get at decadal trends in meadow use as well as allowing a comparison of year to year or interannual variability. Standard deviation and coefficient of variation (CV is the standard deviation/mean) are included for comparison between the two time periods. Coefficient of variation can be used to compare the variation between two different datasets (annual averages from 1985-1997 and 1998-2009) because it is a dimensionless number and is not related to the size of the mean.

The majority of meadows within this analysis have very little packstock use. In both time periods analyzed, almost 50% of meadows had less than one average AUN/acre. Meadows with the highest packstock use become smaller in number over the span of the last three decades. In 1985-1997, 9% of meadows have greater than 30 average AUN/acre or one average animal unit month (AUM) per acre which decreases to 3% of meadows with this heavier average utilization in the following time period. When not looking at the average values, in 1985-1997 there were 17 (7%) meadows that had at least one packstock grazing season (year) that went over a total of 90 AUN/acre or 3 AUM/acre but in the next time period, 1998-2009, there were only 7 (3%) meadows that experienced at least one season with the same level of utilization.

Packstock use on individual meadows was extremely variable with some meadows having significant use in one year and none in the next. Another way to look at interannual variation in meadow use is to compare the coefficients of variation for the averages calculated in a given time period (Figure 2.1.2). Meadows with less than 10 average AUN/acre are removed from

Figure 2.1.2 to better illustrate the variability between time periods. A comparison of 1985-1997 and 1998-2009 packstock use meadow averages plotted against their coefficients of variation (CV) shows approximately the same range of average packstock use for both time periods but more variation between years or a greater range of CVs in the later time period.

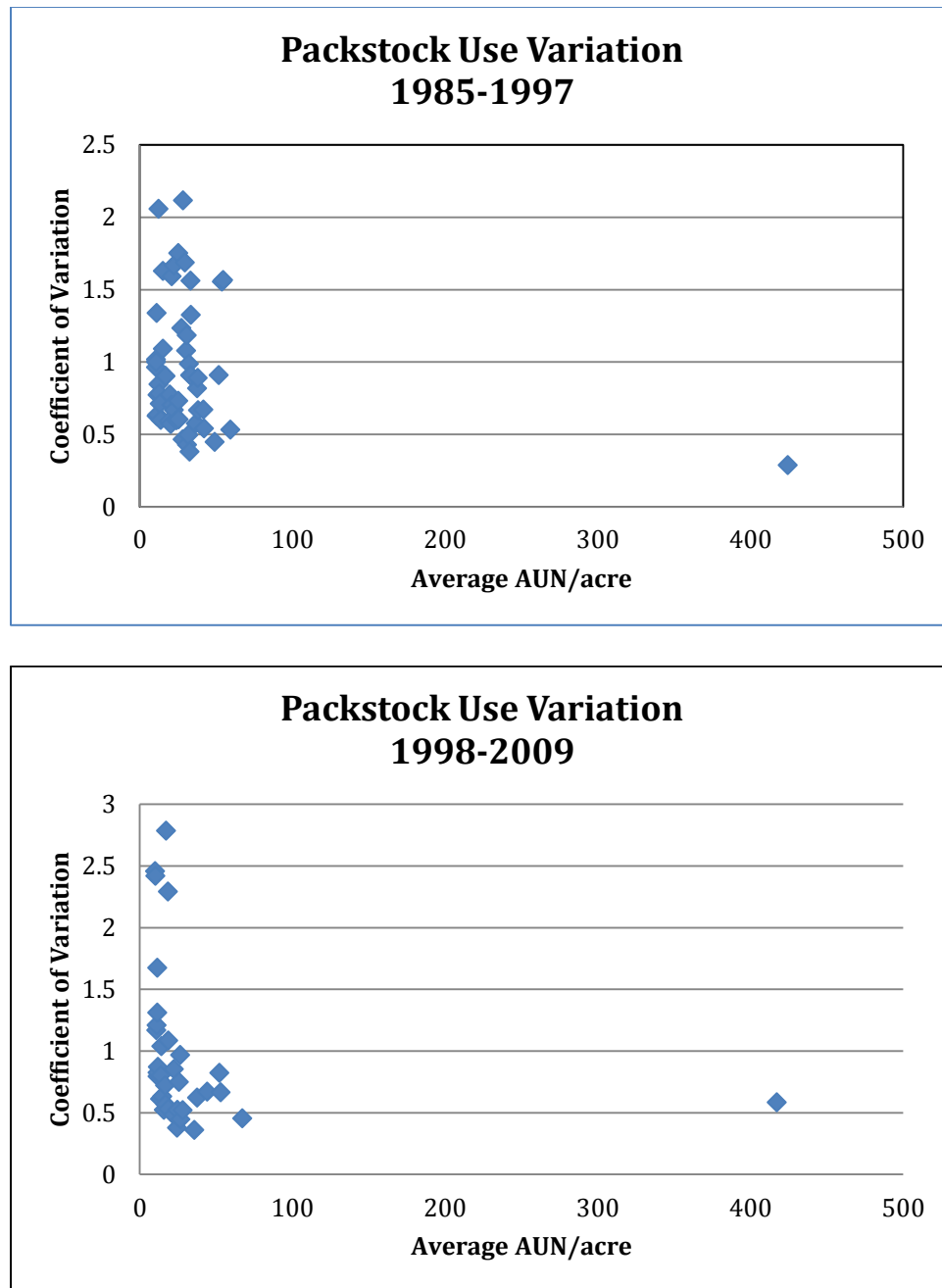


Figure 2.1. 2. 1985-1997 and 1998-2009 meadow average AUN/acre plotted against coefficient of variation; meadows with less than 10 average AUN/acre removed from dataset

Lewis Camp Large Pasture (86-7) has the heaviest packstock grazing use in both time periods but shows more variation in the amount of utilization in 1998-2009 or a larger coefficient of variation (CV 0.29 and 0.58 respectively) (Figure 2.1.2 and Tables 2.1.3 and 2.1.4).

The maps of SEKI, with meadows represented by proportional circles based on average AUN/acre values (Figures 2.1.3 and 2.1.4), give a representation of the change in location and intensity of packstock grazing use throughout both Sequoia and Kings Canyon NP over the last 24 years. In 1985-1997, meadows with greater than 30 average AUN/acre packstock grazing were spread throughout SEKI (range 30-60 average AUN/acre) (Figure 3). In 1998-2009, this class of meadow use moved to fewer locations overall, with the highest concentration along the Kern River in the southern end of Sequoia NP, and with a slightly higher range (30-70) of meadow average AUN/acre (Figures 2.1. 3 and 2.1.4).

Average packstock use along the Kern River (travel zone 86) shifted and became more concentrated in the Lewis Camp area and the Kern Bridge Camp area (86-1) in the years after 1998. Lewis Camp Large Pasture is the meadow area with the highest average grazing intensity for both time periods; 425 AUN/acre in 1985-1997 and 417 AUN/acre in 1998-2009. Lewis Camp had a slight decline (-1.7%) in grazing use between the two time periods (Table 2.1.2). Other meadow areas within this travel zone, Kern Bridge Camp (86-1) and Kern Station Small Pasture (86-8) experienced an increase in average packstock grazing use (+42% and +62%) while average use in Rattlesnake Camp, River Pasture (86-6) and Lower Funston (86-5) declined by more than 60% (Table 2.1.2). The intensity of grazing use in Lewis Camp Large Pasture also declined during this time period from an annual high in 1999 of 848 total AUN/acre to only 204 total AUN/acre in 2009 (Table 2.1.6).

East Vidette (65-2) is the meadow area with the largest decline in average packstock grazing use with the highest negative percent change (-98%). East Lake (67-1) meadow, in the same general area, also experienced a decline of 33% use (Table 2.1.2).

Meadows along the Roaring River area (travel zones 69 and 71) experienced a concentration of average packstock use similar to the Kern River area where 7 different meadow areas, above 30 average AUN/acre in 1985-1997, moved to only 2 meadows above 30 in the later time period (Scaffold Meadow Tourist Pasture (69-5.1) and JR Pasture, Allen Camp (69-3)). JR Pasture had the largest percent increase (78%) in average packstock use over all meadows between the two time periods (Table 2.1.2).

In a previous analysis done for the parks, Abbott et al. (2003) also found that annual packstock use for individual meadows was widely variable. Abbott et al.'s analysis of a subset of meadows (only meadows with residual biomass monitoring) found no consistent trends in packstock use from 1995-2000. The longer term analysis (1985-2009) explored in this section shows different trends for many of the meadows analyzed in the Abbott et al. study. For the five years analyzed in Abbott et al., Lewis Camp Large Pasture had an upward trend in packstock use that is not reflected in our longer time period discussion. Lewis Camp Large Pasture shows a slight decline in average packstock grazing use over 1985-2009. Another meadow from the Abbott et al. study subset, Junction Meadow (Bubbs Creek) (66-3) showed an upward trend in both Abbott et al.'s smaller time period, 1995-2000, and had a 20% increase in average AUN/acre packstock use between 1985-2009 (Table 2.1.2). Other meadows with upward trends in Abbott et al., experienced declines in average AUN/acre during our longer time period 1985-2009 (eg. Little Pete Meadow, 39-3 and Upper Vidette Meadows, 65-3).

Table 2.1.2. Percent change in increasing order for highest use meadows 1985-2009; using the difference between average AUN/acre values from 1985-1997 and 1998-2009; reported for meadows with greater than 20 average AUN/acre in either time period

Forage code (MDWNUM)	Named meadow areas (Forg_name)	1985-1997 Average AUN/acre	1998-2009 Average AUN/acre	Percent Change
65-2	East Vidette Meadow	53.9	1.1	-98.0
86-6	Rattlesnake Camp, River Pasture	54.7	17.2	-68.6
86-5	Lower Funston Meadow	59.3	22.4	-62.2
69-2.2	Upper West Side Roaring River	51.8	24.7	-52.3
67-1	East Lake Meadow	42.1	28.2	-33.1
69-5.1	Scaffold Meadow Tourist Pasture	49.2	35.8	-27.3
28-3	Cony Camp	33.5	26.6	-20.6
58-3	Baxter Creek Drift Fence Meadow	30.7	26.6	-13.3
39-2	Big Pete Meadow	41.7	37.7	-9.8
86-7	Lewis Camp Large Pasture	424.5	417.2	-1.7
66-3	Junction Meadow (Bubbs Creek)	20.4	24.4	19.7
58-1	Castle Domes Meadow	19.7	25.8	30.8
69-4	Lackey Pasture, Scaffold Meadow	16.9	22.2	31.0
58-2	Woods Creek Crossing	38.3	53.1	38.9
86-1	Kern Bridge Camp	31.0	44.2	42.4
86-8	Kern Station Small Pasture	32.3	52.2	61.6
69-3	JR Pasture, Allen Camp	37.7	67.1	78.3

Discussion and recommendations

Of the total meadow area in SEKI, approximately half of the meadows are “open” to packstock grazing but only 25% of these meadows have historic and current reported grazing use. Over all grazed meadows, park total packstock grazing use has declined generally since the 1960’s. Between 1985-1997, levels of packstock grazing were more consistent from year to year and more spread throughout both parks then in the following time period, 1998-2009.

The highest annual levels of consistent packstock use, for the time period 1985-2009, are along the Kern River drainage in the southern end of SEKI and along the Roaring River drainage. More recent packstock use trends (1998-2009) show a concentration of use on a smaller number of meadows in both of these areas. The highest overall average annual levels of packstock use, for both of the parks from 1998-2009, are Lewis Camp Large Pasture (Kern River drainage) and JR Pasture, Allen Camp (Roaring River drainage). JR Pasture, Allen Camp experienced the highest percent increase in average packstock grazing use from 1985-2009. East Vidette Meadow experienced the steepest decline in average packstock grazing use over this time period.

The current methodology for reporting, data checking and analysis of packstock use gives a good description of the spatial and temporal distribution for existing packstock grazing information.

Recommendations for future monitoring and research

Residual biomass monitoring should be consistent and comprehensive in areas with the current highest levels of usage by packstock. A good example is JR Pasture, Allen Camp (69-3) which has the second highest average AUN/acre for 1998-2009 and is currently monitored for residual biomass. All of the meadow areas that experienced the highest percent change increase between 1985-2009 have at least one meadow that is currently being monitored in the residual biomass regimen. Residual biomass or other meadow monitoring should be adjusted to reflect new packstock use patterns found with any future analyses.

Care should be taken when attributing historic packstock use numbers to the various new meadow polygon identifiers within the GIS layers and Access databases included in this report; the forage codes for meadow areas can have multiple associated polygons based on the new vegetation mapping (MID-xx) and contiguous meadow mapping (meadowID).

Recommendations for further analysis using this dataset would be a meadow level breakdown of AUN/acre by the type of user to assess which users are driving the change in packstock use and an assessment of the effect of supplemental feeding on the intensity of grazing use.

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Table 2.1.3. 1985-1997 meadow areas with average, standard deviation and coefficient of variation of annual packstock use; meadows with above 30 average AUN/acre or one average AUM.

Forage code (MDWNUM)	Named meadow areas (Forg_name)	Area (acre)	1985-1997 Average AUN/acre	1985-1997 Standard Deviation AUN/acre	1985-1997 Coefficient of Variation
86-7	Lewis Camp Large Pasture	1.19	424.49	121.59	0.29
86-5	Lower Funston Meadow	4.43	59.34	31.55	0.53
86-6	Rattlesnake Camp, River Pasture	1.11	54.74	85.68	1.57
65-2	East Vidette Meadow	2.40	53.89	83.78	1.55
69-2.2	Upper West Side Roaring River	1.53	51.78	47.12	0.91
69-5.1	Scaffold Meadow Tourist Pasture	9.49	49.21	22.05	0.45
67-1	East Lake Meadow	4.85	42.14	22.82	0.54
39-2	Big Pete Meadow	3.16	41.75	28.01	0.67
58-2	Woods Creek Crossing	3.71	38.25	25.49	0.67
82-1	Junction Meadow (Kern River)	1.72	38.11	33.87	0.89
69-3	JR Pasture, Allen Camp	0.85	37.65	30.77	0.82
90-5.2	Hockett Pasture	8.27	36.82	21.17	0.57
71-1.3	Austin Camp (Trail Crew Camp)	2.33	33.53	44.39	1.32
28-3	Cony Camp	1.79	33.51	30.34	0.91
88-5	Big Five Lakes Upper Stringer Meadow	2.53	33.21	51.85	1.56
69-2.1	Lower West Side Roaring River	2.39	33.12	30.14	0.91
77-7	Pinto Lake Meadow	5.59	32.67	12.42	0.38
86-8	Kern Station Small Pasture	1.50	32.27	31.88	0.99
71-2	Grave Meadow	5.08	31.86	15.79	0.50
86-1	Kern Bridge Camp	6.08	30.99	13.23	0.43
58-3	Baxter Creek Drift Fence Meadow	2.28	30.74	36.42	1.18
89-5.2	Forester Lake Meadows	3.76	30.42	32.77	1.08

Table 2.1.4. 1998-2009 meadow areas with average, standard deviation and coefficient of variation of annual packstock use; meadows with above 30 average AUN/acre or one average AUM.

Forage code (MDWNUM)	Named meadow areas (Forg_name)	Area (acre)	1998-2009 Average AUN/acre	1998-2009 Standard Deviation AUN/acre	1998-2009 Coefficient of Variation
86-7	Lewis Camp Large Pasture	1.19	417.24	243.87	0.58
69-3	JR Pasture, Allen Camp	0.85	67.14	30.57	0.46
58-2	Woods Creek Crossing	3.71	53.11	35.31	0.66
86-8	Kern Station Small Pasture	1.51	52.17	42.98	0.82
86-1	Kern Bridge Camp	6.08	44.15	29.61	0.67
39-2	Big Pete Meadow	3.17	37.67	23.40	0.62
69-5.1	Scaffold Meadow Tourist Pasture	9.50	35.76	12.87	0.36

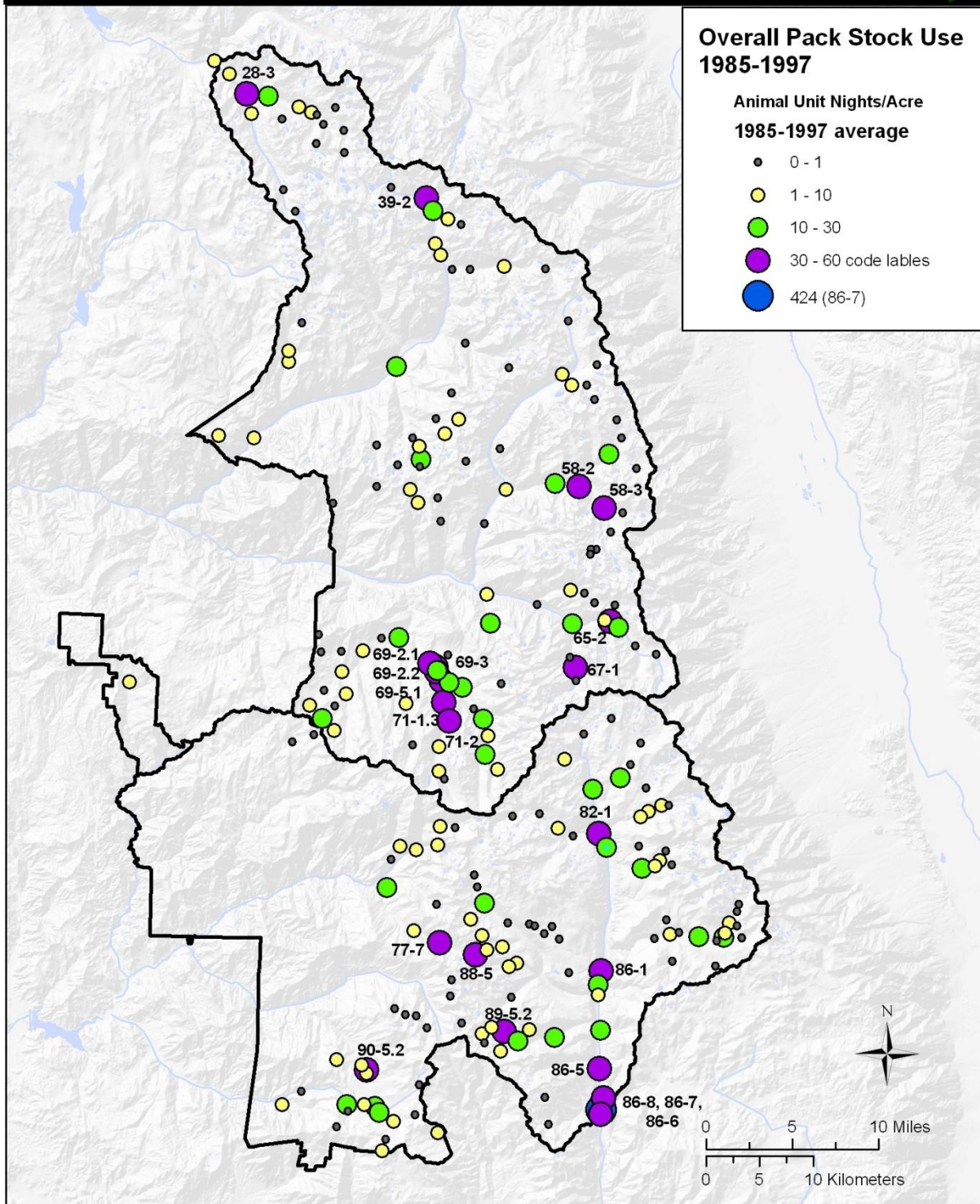


Figure 2.1. 3. Overall packstock use 1985-1997; meadows with forage code labels have greater than 30 average AUN/acre

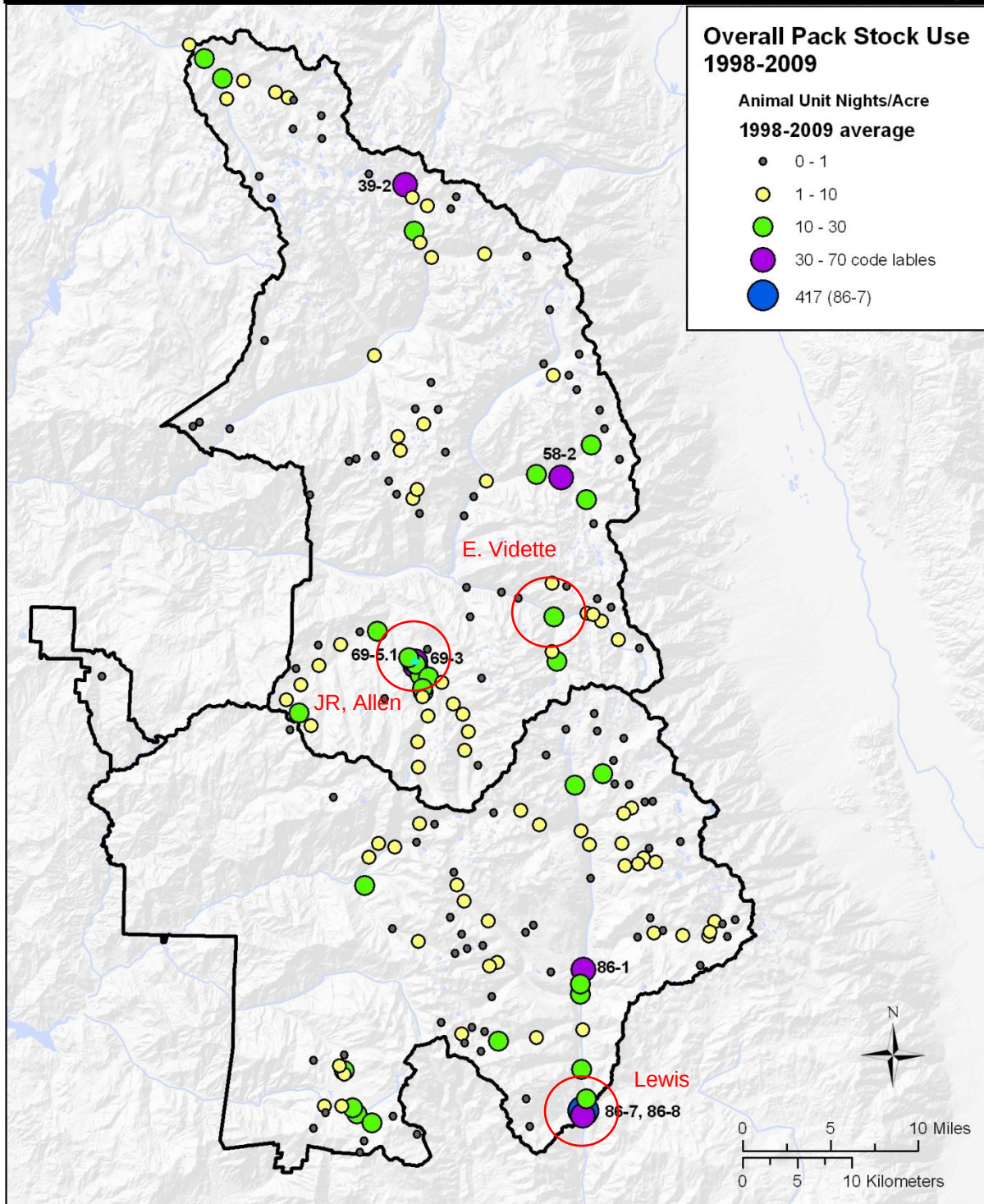


Figure 2.1.4. Overall packstock use 1998-2009; meadows with forage code lables have greater than 30 average AUN/acre

Table 2.1.5. Meadows with forage code; Animal Unit Nights per acre (AUN/acre) for the years 1985-1997; **red** indicates meadows (17) with at least one year of AUN/acre >=90 or the equivalent of 3 Animal Unit Months

Forage Code	Area (acre)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg 85-97	StdDev 85-97	CoefVar 85-97
28-1	0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.38	5.36	0.00	0.00	5.42	0.00	1.01	2.05	2.03
28-2	0.5	0.00	20.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05	0.00	17.86	7.90	3.72	7.23	1.94
28-3	1.8	61.49	89.44	0.00	2.10	18.17	33.79	85.64	6.71	23.17	3.07	49.19	37.03	25.85	33.51	30.34	0.91
28-4	7.7	0.00	0.16	14.36	6.53	3.43	2.61	10.77	2.35	4.77	1.04	0.98	2.45	0.91	3.87	4.33	1.12
28-6	32.8	0.15	0.08	0.38	0.34	0.38	0.00	0.03	0.12	0.85	0.15	0.00	0.34	0.27	0.24	0.23	0.98
28-7	151.4	0.00	0.04	0.02	0.00	0.03	0.28	0.05	0.06	0.00	0.03	0.00	0.00	0.11	0.05	0.08	1.59
33-1	13.4	9.62	8.50	6.54	27.57	22.39	15.89	16.78	62.70	33.09	13.23	24.15	19.90	12.42	20.98	14.76	0.70
33-2	21.3	3.65	5.23	5.59	2.70	9.49	2.61	6.64	5.07	2.23	1.29	0.00	1.00	3.84	3.80	2.60	0.68
33-3	9.6	2.22	0.00	5.74	8.22	8.48	22.19	44.89	6.03	1.64	5.66	9.14	5.22	8.48	9.84	11.83	1.20
33-4.1	3.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.13	0.00	0.00	0.00	0.32	1.15	3.61
33-4.3	8.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.44	0.00	0.00	0.00	0.26	0.95	3.61
33-6	24.3	0.00	0.00	1.23	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.34	3.54
33-8	92.6	0.67	0.00	0.00	0.00	0.13	0.02	0.00	0.57	0.00	0.03	0.00	0.00	0.00	0.11	0.23	2.10
33-9	14.7	0.00	0.00	0.00	0.00	0.08	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	2.52
34-1	60.4	0.00	0.00	0.00	0.00	0.08	0.00	0.11	0.05	0.00	0.08	0.00	0.00	0.00	0.03	0.04	1.64
34-2	36.7	0.00	0.00	0.00	0.00	0.10	0.08	0.02	0.00	0.00	0.07	0.00	0.00	0.00	0.02	0.04	1.78
38-1	14.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.75	0.52	1.87	3.61
38-2	28.9	1.12	5.97	4.33	0.26	1.04	0.17	0.95	1.99	0.43	0.61	1.30	0.00	0.00	1.40	1.79	1.28
38-3	0.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.22	0.00	0.00	0.00	2.63	9.49	3.61
39-1	30.4	0.00	0.00	0.41	0.00	0.00	3.29	0.00	0.00	0.00	0.00	0.49	0.00	0.12	0.33	0.91	2.72
39-2	3.2	39.89	14.22	36.33	85.31	76.38	56.08	35.94	26.86	7.90	17.77	4.74	82.94	58.39	41.75	28.01	0.67
39-3	10.3	6.16	0.24	10.03	35.29	25.62	14.26	18.37	13.17	11.72	2.78	0.36	0.24	1.81	10.77	10.78	1.00
39-4	3.5	8.25	0.00	0.00	38.74	0.00	0.00	0.00	11.48	0.00	0.00	30.13	7.53	0.00	7.39	12.76	1.73
39-5	25.9	0.63	0.00	0.58	4.45	2.37	0.58	1.40	4.01	0.00	3.24	0.00	5.85	13.67	2.83	3.79	1.34
39-6	1.4	0.00	0.00	0.00	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.75	3.61
39-7	5.8	0.65	0.00	0.00	5.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	1.44	3.20
39-8	15.4	6.32	1.46	10.21	20.82	8.83	1.94	2.43	4.70	9.56	3.16	2.92	2.51	4.78	6.12	5.33	0.87
42-1	1.2	6.17	0.00	0.00	0.00	2.47	0.00	0.00	0.00	39.09	0.00	5.14	0.00	31.89	6.52	13.11	2.01
42-4	1.8	11.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	3.16	3.61
45-1	26.7	2.30	0.00	0.56	0.94	0.00	0.00	0.56	0.00	0.89	0.00	0.00	0.70	1.35	0.56	0.69	1.24
46-1	203.9	0.77	0.32	0.07	1.15	0.90	0.02	0.00	0.12	0.09	0.00	0.00	0.03	0.01	0.27	0.40	1.50
46-2	51.3	0.00	0.00	0.00	1.24	0.00	2.51	0.37	3.02	1.02	2.56	0.29	1.88	0.90	1.06	1.10	1.04
46-3	50.5	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	2.08	0.00	0.00	0.96	0.00	0.24	0.61	2.50
46-4	4.6	0.00	0.00	9.74	3.25	0.00	2.98	0.00	0.00	0.00	11.64	0.00	0.00	26.52	4.16	7.79	1.87
46-5	102.1	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.20	0.00	0.00	0.03	0.06	2.20
46-6	14.9	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.09	0.28	3.16
47-1	1.3	0.00	0.00	0.00	0.00	0.00	5.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	1.60	3.61
47-3	75.9	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	3.61
47-7	90.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.21	0.00	0.00	0.69	0.22	0.63	2.81
47-8	9.0	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	3.61
51-1	22.8	0.88	9.54	9.10	9.59	24.39	10.74	15.95	19.07	18.85	14.03	2.47	6.14	4.44	11.17	7.01	0.63

Forage Code	Area (acre)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg 85-97	StdDev 85-97	CoefVar 85-97
51-2	13.0	1.54	0.00	3.56	0.00	0.29	6.45	1.54	1.06	7.31	0.48	0.00	3.08	1.35	2.05	2.42	1.18
51-3	5.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.10	0.00	9.56	1.05	2.80	2.66
52-1	46.4	0.00	0.00	0.00	1.27	0.00	1.37	0.30	0.43	0.00	0.83	1.62	0.00	0.02	0.45	0.61	1.36
52-2	32.3	0.00	0.00	0.00	1.82	1.31	1.00	0.08	0.00	0.00	0.50	0.00	0.00	0.12	0.37	0.61	1.65
52-6	5.8	0.00	0.00	0.00	4.77	0.00	1.30	0.43	0.00	2.60	0.00	0.00	0.00	0.00	0.70	1.44	2.06
52-9	14.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.02	3.61
53-1	25.1	0.00	0.90	1.79	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	2.24	0.00	0.43	0.77	1.79
53-3	39.6	0.00	1.14	0.06	1.80	0.00	0.00	2.18	1.52	1.45	4.33	2.40	3.54	3.65	1.70	1.49	0.88
53-4.1	7.1	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	7.04	0.00	0.00	0.00	0.00	0.60	1.95	3.27
53-4.2	25.7	0.00	4.53	1.95	2.48	8.47	5.99	7.74	4.23	2.87	1.70	1.61	10.46	0.22	4.02	3.28	0.82
53-5	18.8	0.00	4.92	0.00	2.46	6.19	24.81	0.00	9.78	1.33	4.59	6.78	0.27	2.66	4.91	6.72	1.37
53-6	2.3	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.30	3.61
53-7	7.8	0.00	3.86	14.32	10.30	19.46	22.84	22.04	26.06	10.62	8.85	23.16	7.56	9.49	13.74	8.23	0.60
53-8	9.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.00	0.00	0.16	0.59	3.61
54-1	7.3	0.00	0.00	0.00	0.00	0.00	0.69	0.69	0.00	0.00	14.24	0.00	1.03	0.10	1.29	3.91	3.03
54-2	109.4	0.00	1.68	0.78	1.29	1.17	0.40	0.78	2.00	2.59	2.17	0.95	0.50	0.89	1.17	0.75	0.65
54-3	11.4	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.06	0.07	0.16	2.26
54-5.1	2.9	0.00	0.00	0.87	0.00	0.00	3.05	0.00	0.00	0.00	2.18	0.00	0.00	0.00	0.47	1.00	2.13
55-1	3.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.63	1.59	5.72	3.61
55-3	3.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.15	0.17	0.60	3.61
56-1	157.0	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.06	0.18	2.93
56-2	89.6	2.64	0.00	0.00	0.00	0.00	0.73	0.00	0.00	1.09	1.17	0.13	0.20	0.26	0.48	0.77	1.62
56-3	1.0	0.00	0.00	0.00	0.00	51.98	0.00	0.00	69.73	50.71	0.00	15.21	11.41	0.00	15.31	24.92	1.63
57-1	117.3	0.86	0.17	0.21	0.68	0.35	0.75	0.43	0.00	0.53	0.04	0.06	0.14	0.16	0.34	0.29	0.85
58-1	4.4	5.12	29.32	29.89	22.49	49.25	29.61	1.14	19.36	18.50	37.86	0.32	8.26	4.84	19.69	15.25	0.77
58-2	3.7	0.00	62.07	68.81	50.94	53.63	65.78	70.16	22.94	42.50	23.28	5.06	9.15	22.94	38.25	25.49	0.67
58-3	2.3	20.80	0.00	8.76	3.28	136.83	45.32	8.21	16.97	36.12	42.69	0.00	31.20	49.48	30.74	36.42	1.18
59-1	8.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.71	0.00	0.09	0.22	2.53
61-1	3.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.59	0.00	0.00	6.66	2.59	0.91	1.98	2.17
61-2	2.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.31	1.12	3.61
61-3	12.2	0.00	0.00	0.00	0.00	0.00	0.62	4.72	0.62	0.00	6.77	0.00	0.00	0.00	0.98	2.17	2.22
62-1.1	2.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.26	0.00	0.00	0.00	0.17	0.63	3.61
63-1	30.0	3.54	0.00	0.00	0.79	0.87	3.99	1.25	2.25	2.83	0.25	1.87	4.62	0.64	1.76	1.56	0.89
63-2	14.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.96	1.03	0.00	5.39	0.88	1.93	2.21
63-3	4.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.78	4.05	0.00	1.62	0.73	1.48	2.04
64-2	19.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.08	0.28	3.61
65-1	8.2	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.35	14.34	0.17	0.60	2.35	4.97	2.12
65-2	2.4	0.00	35.44	99.03	228.30	0.00	228.82	0.00	0.00	0.00	0.00	20.33	76.62	11.99	53.89	83.78	1.55
65-3	5.7	79.49	10.09	3.93	68.79	60.27	0.00	88.79	15.72	15.94	3.28	0.00	4.80	3.06	27.24	33.64	1.23
65-4	39.3	0.00	0.00	0.00	0.00	0.06	0.47	0.18	3.97	0.22	0.00	0.00	2.77	0.54	0.63	1.25	1.98
65-5	33.3	0.00	0.15	1.35	0.00	0.83	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.11	0.22	0.42	1.93
66-1.1	2.5	0.00	4.96	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	7.44	0.00	0.00	1.03	2.37	2.30
66-2	18.5	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.20	0.06	0.14	2.25

Forage Code	Area (acre)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg 85-97	StdDev 85-97	CoefVar 85-97
66-3	7.0	4.66	27.96	10.04	5.02	17.74	26.85	25.99	23.30	36.56	27.06	18.68	3.58	37.64	20.39	11.64	0.57
67-1	4.8	5.16	51.83	41.26	61.63	71.43	86.38	46.67	46.67	21.14	15.99	23.47	33.26	42.91	42.14	22.82	0.54
67-2	1.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.49	0.00	0.00	0.00	0.00	0.00	0.96	3.47	3.61
67-3	1.0	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.35	3.61
68-1	2.4	1.06	18.57	0.00	0.00	0.00	44.31	16.88	0.53	0.00	24.27	31.65	0.59	5.93	11.06	14.81	1.34
69-2.1	2.4	31.58	85.43	81.92	53.26	68.41	23.23	17.50	0.00	7.81	0.00	14.62	8.88	37.93	33.12	30.14	0.91
69-2.2	1.5	49.37	133.56	128.07	83.27	106.94	36.31	27.36	0.00	12.21	0.00	22.86	13.88	59.30	51.78	47.12	0.91
69-3	0.9	48.36	58.62	76.20	79.13	63.01	51.29	14.65	0.00	0.00	0.00	0.00	36.64	61.55	37.65	30.77	0.82
69-4	1.9	22.46	26.31	41.07	27.59	35.30	24.39	0.00	0.00	0.00	9.63	0.00	30.80	2.57	16.93	15.29	0.90
69-5.1	9.5	54.64	31.20	58.59	36.73	101.38	69.57	33.15	19.46	39.02	50.80	32.65	71.75	40.83	49.21	22.05	0.45
69-5.2	3.1	42.18	65.07	109.26	4.42	33.34	2.41	0.00	0.00	8.03	0.00	2.41	0.00	6.43	21.04	33.47	1.59
69-6.1	6.0	0.00	0.00	0.00	0.00	0.00	4.99	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.43	1.38	3.20
70-1.1	1.4	0.00	39.67	0.00	191.12	0.00	123.51	8.11	5.41	0.00	0.00	0.00	0.00	0.00	28.29	59.89	2.12
70-1.2	4.2	0.00	12.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	3.46	3.61
70-3	3.6	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	11.75	0.00	0.00	0.00	0.00	0.98	3.25	3.30
70-4	5.9	22.77	43.68	46.80	49.96	26.77	27.62	16.65	38.37	22.18	18.97	7.59	7.38	2.95	25.51	15.41	0.60
70-5	29.4	1.36	3.44	8.15	6.75	3.70	4.16	5.22	5.90	0.70	1.23	0.76	0.17	0.72	3.25	2.65	0.82
70-6	5.7	7.69	17.58	38.23	7.56	24.39	3.96	6.59	14.94	2.64	6.15	0.00	8.79	0.00	10.66	10.84	1.02
70-7	4.4	1.70	3.40	0.00	6.24	5.67	0.85	5.67	0.00	0.32	2.27	0.00	0.00	0.00	2.01	2.44	1.21
71-1.3	2.3	70.85	18.79	101.45	128.29	71.39	19.32	0.00	0.00	0.00	0.00	0.00	25.77	0.00	33.53	44.39	1.32
71-2	5.1	35.93	47.50	45.53	50.70	45.04	38.15	35.69	25.35	18.71	5.91	27.57	38.15	0.00	31.86	15.79	0.50
71-3	49.5	3.01	3.26	6.22	7.18	7.05	2.93	8.22	6.34	3.21	1.72	0.00	0.83	0.28	3.87	2.82	0.73
71-4	11.7	5.87	7.41	13.35	3.74	1.92	4.27	9.40	1.28	0.00	18.37	0.00	0.00	16.13	6.29	6.31	1.00
71-5	35.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	0.04	0.12	0.43	3.51
72-10	0.7	5.58	26.04	156.23	44.64	5.58	22.32	0.00	0.00	0.00	0.00	63.24	0.00	3.94	25.20	44.16	1.75
72-13.2	1.1	41.78	0.00	3.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.48	11.55	3.32
72-18	9.4	9.01	0.00	0.00	0.00	3.44	0.00	3.44	0.00	5.30	0.00	0.00	9.27	0.00	2.34	3.51	1.50
72-19	66.1	0.11	0.11	0.40	0.23	0.61	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.15	0.22	1.44
72-3	9.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	0.10	0.35	3.61
72-4	25.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.02	0.05	3.61
72-6	31.8	0.00	0.00	0.20	0.00	0.00	0.31	0.24	1.42	0.47	1.02	0.47	0.16	0.00	0.33	0.44	1.33
72-7	4.3	6.39	1.22	0.00	2.03	0.87	0.00	0.00	1.16	0.12	6.06	3.25	1.16	11.91	2.63	3.53	1.34
72-8	23.2	8.93	14.53	14.04	12.37	11.41	6.24	9.03	8.98	9.68	3.98	5.97	6.45	9.26	9.30	3.18	0.34
72-9	3.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.83	0.00	0.45	1.62	3.61
73-1	2.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	1.01	0.00	0.00	0.00	0.17	0.41	2.45
73-2	1.8	0.00	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41	6.20	0.00	31.18	3.09	8.61	2.79
73-3	2.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75	0.00	0.13	0.49	3.61
73-4	0.8	0.00	1.58	6.33	0.00	0.00	0.00	9.49	7.91	13.03	67.82	9.49	50.61	125.14	22.42	37.35	1.67
73-5	4.0	1.86	1.24	0.00	0.00	0.31	0.00	0.00	0.00	0.52	10.20	2.48	0.00	8.41	1.92	3.39	1.76
74-1	5.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.73	0.13	0.48	3.61
74-3	33.9	0.00	0.04	0.00	0.00	0.00	0.08	0.08	0.08	0.00	0.00	0.00	0.00	0.12	0.03	0.05	1.43
75-1	9.4	25.49	3.88	6.24	9.16	3.58	4.12	0.00	2.79	4.41	17.39	0.00	0.00	2.54	6.12	7.45	1.22
75-2	4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40	0.00	0.00	0.00	0.00	5.87	0.71	1.81	2.54

Forage Code	Area (acre)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg 85-97	StdDev 85-97	CoefVar 85-97
77-1	1.3	0.00	0.00	5.93	0.00	0.00	1.98	4.75	0.00	15.83	0.00	1.98	10.88	3.96	3.48	4.93	1.42
77-2	9.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00	0.00	0.00	0.11	0.38	3.61
77-3	0.7	0.00	66.98	0.00	0.00	0.00	0.00	0.00	0.00	36.06	17.17	0.00	0.00	0.00	9.25	20.35	2.20
77-4	14.3	2.45	0.00	1.22	0.00	0.52	0.79	0.00	1.31	0.00	0.00	0.00	0.00	0.00	0.48	0.77	1.58
77-5	10.0	20.13	21.75	22.00	16.25	28.13	5.25	6.88	11.25	8.38	10.13	1.00	0.00	2.04	11.78	9.09	0.77
77-6	4.6	0.54	0.00	1.62	0.00	0.23	0.00	0.54	0.00	0.45	0.54	0.00	0.00	9.44	1.03	2.57	2.50
77-7	5.6	29.29	34.88	35.78	48.53	37.57	54.97	33.72	44.95	27.21	27.06	24.82	12.52	13.42	32.67	12.42	0.38
78-1	3.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.69	3.44	12.40	3.61
79-1	8.4	7.16	8.65	9.40	30.74	18.50	27.75	15.37	15.93	12.83	19.69	0.00	0.00	0.00	12.77	9.97	0.78
79-2	43.7	4.69	0.98	3.12	4.58	3.98	5.08	0.65	0.16	0.00	2.65	0.00	0.00	0.04	1.99	2.06	1.03
79-3	12.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.05	0.17	3.61
79-4	12.2	0.00	0.65	10.33	2.05	5.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	3.11	2.17
79-5	33.2	0.00	0.00	0.00	0.30	0.00	4.71	1.84	0.00	0.00	0.00	0.00	0.00	0.45	0.56	1.35	2.40
79-6	146.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.03	0.09	3.61
80-2	29.2	0.00	0.00	1.54	0.64	0.00	10.73	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.99	2.96	2.98
80-3	14.6	3.77	7.38	4.12	10.03	2.57	9.35	39.95	23.41	9.26	18.35	4.29	10.12	17.82	12.34	10.43	0.85
80-4	796.0	0.15	0.00	0.00	0.11	0.16	0.08	0.00	0.07	0.00	0.00	0.03	0.11	0.00	0.05	0.06	1.12
80-5.1	22.8	0.00	0.00	0.00	0.00	0.00	0.00	1.20	1.53	0.16	0.70	0.00	0.00	0.00	0.28	0.53	1.90
80-6	201.7	0.63	0.10	0.24	0.07	0.75	1.87	0.35	0.09	0.00	0.48	0.37	0.00	0.01	0.38	0.51	1.34
81-1	506.8	0.03	0.05	0.00	0.01	0.04	0.03	0.00	0.02	0.00	0.01	0.12	0.00	0.09	0.03	0.04	1.20
81-2.1	3.2	0.00	0.00	0.00	0.00	0.00	0.00	4.29	0.00	0.00	0.00	17.27	0.00	1.09	1.74	4.82	2.76
81-2.2	7.3	0.00	0.00	1.02	0.00	0.00	14.69	0.00	3.59	0.48	20.15	0.00	7.17	4.10	3.94	6.47	1.64
81-2.3	9.8	7.13	0.00	7.33	12.99	19.48	4.97	22.39	24.19	5.09	5.09	16.04	5.09	0.00	9.98	8.18	0.82
81-2.4	5.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.89	0.00	2.09	0.00	0.54	1.43	2.66
82-1	1.7	20.17	2.18	24.08	0.00	69.64	37.29	61.51	46.43	3.77	112.73	20.31	20.31	76.98	38.11	33.87	0.89
82-2	0.3	0.00	87.25	0.00	11.90	174.51	35.69	31.73	11.90	0.00	0.00	0.00	23.80	7.93	29.59	49.90	1.69
83-3	24.4	0.00	0.00	0.00	1.53	0.00	0.36	0.52	0.61	0.00	0.00	0.00	0.00	0.00	0.23	0.45	1.93
83-4	38.8	3.77	3.54	7.69	6.63	9.43	6.27	8.71	9.02	3.80	4.69	0.74	3.28	10.46	6.00	2.94	0.49
83-5	29.0	0.00	0.13	0.30	1.21	0.39	3.87	7.88	5.67	3.53	0.26	4.22	5.98	6.33	3.06	2.82	0.92
83-6	9.2	3.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.96	0.00	0.00	0.00	0.81	2.09	2.59
83-7	5.9	20.01	14.05	24.27	18.74	38.11	34.49	34.92	31.72	18.74	53.65	20.23	0.00	4.85	24.14	14.42	0.60
83-8	47.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	5.09	4.62	0.76	1.82	2.39
84-1	42.4	0.00	0.09	0.00	0.18	0.00	0.18	0.00	0.00	0.00	0.44	0.00	0.00	0.12	0.08	0.13	1.69
84-2	47.1	1.51	3.00	0.00	2.92	0.66	5.39	3.95	3.65	2.06	0.00	4.70	0.74	2.92	2.42	1.76	0.73
84-3	32.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	1.13	0.46	1.98	1.90	0.43	0.74	1.74
84-4	17.9	0.00	0.00	0.00	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.02	0.49	0.00	0.15	0.40	2.72
84-5	20.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.02	3.61
84-6	270.5	0.06	0.00	0.00	0.00	0.01	0.04	0.00	0.06	0.05	0.00	0.00	0.00	0.00	0.02	0.03	1.48
85-10	15.7	9.85	9.45	13.26	29.05	29.86	11.28	21.36	20.57	6.91	13.34	0.00	4.53	3.10	13.27	9.44	0.71
85-2	88.3	0.81	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.24	2.66
85-3	15.1	0.00	0.00	0.00	0.00	0.00	0.83	0.23	0.00	0.00	0.23	0.00	0.00	0.00	0.10	0.24	2.37
85-4	10.8	0.00	0.00	10.44	10.44	10.44	28.42	6.84	3.60	0.00	1.97	0.00	0.00	0.00	5.55	8.15	1.47
85-6	25.0	0.00	0.00	0.20	0.20	0.20	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.35	2.43

Forage Code	Area (acre)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg 85-97	StdDev 85-97	CoefVar 85-97
85-7	50.1	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.55	0.07	0.00	0.00	0.00	0.06	0.15	2.68
85-8.1	23.0	4.43	0.00	6.85	7.53	6.85	9.15	12.14	7.76	2.20	0.00	0.00	0.00	0.27	4.40	4.23	0.96
85-8.2	9.5	10.74	0.00	16.60	18.25	16.60	22.19	29.43	18.81	5.33	0.00	0.00	0.00	0.66	10.66	10.26	0.96
85-9	4.0	0.00	0.00	0.00	0.00	0.00	2.48	0.00	0.00	0.00	9.29	0.00	0.00	0.00	0.91	2.61	2.88
86-1	6.1	21.80	52.64	27.14	55.11	35.16	37.14	45.20	28.58	12.78	24.67	21.59	23.03	18.09	30.99	13.23	0.43
86-2	10.3	39.38	14.93	21.91	38.78	37.08	50.07	44.55	29.68	12.00	26.15	20.87	20.96	8.48	28.06	13.04	0.46
86-3	1.6	0.00	0.00	2.33	2.33	2.33	0.00	0.00	0.00	5.43	0.00	4.66	3.11	7.76	2.15	2.54	1.18
86-4	3.1	43.39	0.00	29.52	16.78	4.91	16.78	2.05	48.69	0.00	21.69	0.00	7.78	5.73	15.18	16.55	1.09
86-5	4.4	122.19	38.72	86.40	52.49	46.56	57.51	91.43	55.03	46.05	17.50	16.87	42.05	98.69	59.34	31.55	0.53
86-6	1.1	42.81	85.63	310.47	9.01	75.49	0.00	111.54	54.08	18.03	4.51	0.00	0.00	0.00	54.74	85.68	1.57
86-7	1.2	300.42	290.93	482.77	397.39	385.80	455.37	448.20	616.64	440.61	440.61	234.01	358.39	667.24	424.49	121.59	0.29
86-8	1.5	0.00	2.49	14.95	19.94	30.74	8.31	0.00	72.28	38.22	59.82	26.59	38.22	108.01	32.27	31.88	0.99
87-1	84.9	0.82	0.08	0.38	0.00	0.00	0.06	0.00	0.32	0.15	1.33	0.09	0.00	0.00	0.25	0.40	1.61
87-10	66.2	0.11	0.11	0.25	0.11	0.00	0.24	0.03	0.15	0.11	0.23	0.11	0.00	0.00	0.11	0.09	0.79
87-2	6.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.27	0.00	0.00	0.00	0.17	0.63	3.61
87-3	5.3	20.56	35.22	58.14	20.80	35.45	57.86	5.20	30.02	31.43	8.74	0.00	18.20	7.80	25.34	18.52	0.73
87-4	26.2	0.00	2.62	0.00	0.00	0.00	0.00	2.10	4.15	0.24	0.19	0.00	0.00	0.19	0.73	1.34	1.84
87-5	10.1	0.74	0.00	0.00	0.00	1.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.44	2.60
87-6	8.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.08	0.28	3.61
87-7	24.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.01	0.04	3.61
87-8	14.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.05	0.19	3.61
87-9	14.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.27	0.00	0.00	0.00	0.00	0.08	0.20	2.72
88-1	54.0	0.30	1.00	1.41	0.65	0.69	1.75	2.75	1.48	1.74	2.04	2.29	1.30	1.44	1.45	0.69	0.48
88-2	14.8	6.69	1.10	0.85	6.86	9.23	0.00	3.73	1.69	0.40	0.00	0.00	0.00	0.59	2.39	3.18	1.33
88-3	5.4	0.00	0.00	0.00	0.00	8.27	0.00	0.00	0.00	0.00	8.50	0.00	0.00	4.13	1.61	3.22	2.00
88-4	22.2	0.00	0.00	0.73	0.00	0.00	14.88	5.07	0.56	0.00	2.14	5.58	0.79	0.00	2.29	4.25	1.85
88-5	2.5	47.91	62.23	91.37	167.93	62.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.21	51.85	1.56
89-10	14.4	6.69	4.78	16.51	14.68	16.42	19.67	23.37	16.33	6.62	14.34	1.04	0.26	8.60	11.49	7.27	0.63
89-12	26.0	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.03	0.11	3.36
89-13	36.6	0.27	0.64	0.43	0.00	0.00	0.48	0.00	0.58	0.88	0.75	0.58	0.27	0.00	0.38	0.31	0.82
89-3.1	12.9	1.64	3.20	8.74	2.99	7.00	6.37	0.00	2.90	6.27	0.48	0.00	0.00	4.78	3.41	2.99	0.88
89-3.2	7.2	2.96	5.78	15.78	5.40	12.64	11.51	0.00	5.23	11.33	11.51	0.00	0.00	8.63	6.98	5.33	0.76
89-4	23.8	0.00	2.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.80	3.61
89-5.1	29.3	0.00	0.00	0.00	0.00	0.00	1.32	0.60	0.00	1.45	5.92	3.96	1.49	0.00	1.13	1.84	1.62
89-5.2	3.8	96.70	35.89	40.21	53.50	90.71	13.56	1.66	0.65	0.74	25.25	7.97	2.66	25.92	30.42	32.77	1.08
89-5.3	6.3	0.00	0.00	0.00	0.00	0.00	6.73	0.00	0.00	6.33	0.00	0.00	0.00	0.00	1.00	2.45	2.44
89-6	6.4	5.88	0.00	4.03	1.18	13.52	2.94	16.42	11.16	3.37	12.74	2.74	8.43	0.00	6.34	5.54	0.87
89-7	20.5	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.08	0.22	2.60
89-8	20.9	0.00	0.00	0.00	0.00	0.00	14.03	16.42	10.87	8.48	9.55	0.00	6.75	0.00	5.08	6.17	1.21
89-9	7.2	24.98	32.62	21.17	38.00	40.77	21.65	10.93	47.71	6.25	6.94	9.02	30.36	0.69	22.39	14.94	0.67
90-10	13.2	13.41	14.92	17.28	0.17	13.31	23.79	33.90	28.61	10.29	42.49	13.69	25.68	11.52	19.16	11.30	0.59
90-11	9.3	2.69	27.60	19.25	58.97	13.06	18.71	24.23	9.42	2.83	3.23	7.67	9.69	21.27	16.82	15.17	0.90
90-12	5.9	0.00	0.00	0.00	0.00	0.00	0.00	9.40	0.00	0.00	0.00	0.00	0.00	0.00	0.72	2.61	3.61

Forage Code	Area (acre)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg 85-97	StdDev 85-97	CoefVar 85-97
90-13	8.0	0.00	0.00	11.34	12.58	13.98	13.05	0.00	2.18	0.00	0.00	0.00	0.00	0.00	4.09	6.06	1.48
90-14	44.1	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	3.12	1.70	0.42	0.00	1.42	0.59	0.97	1.64
90-15	5.8	0.00	0.00	6.43	0.00	0.00	0.00	0.00	0.00	0.47	3.00	1.29	0.00	0.00	0.86	1.88	2.19
90-16	13.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.01	0.39	1.39	3.61
90-17	31.4	0.00	0.84	0.00	0.24	1.15	0.00	0.48	0.00	0.00	0.00	0.40	0.00	0.48	0.28	0.38	1.37
90-18	3.9	0.00	0.00	0.00	0.00	1.90	4.76	6.98	0.00	0.00	1.59	19.99	0.00	19.99	4.25	7.32	1.72
90-19	23.8	3.10	1.26	7.20	2.26	1.10	0.84	0.47	1.68	0.55	0.00	0.37	0.00	1.00	1.53	1.92	1.26
90-3	0.8	48.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.51	0.00	0.00	0.00	7.19	17.57	2.44
90-4	5.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.38	0.00	0.00	0.00	1.80	6.48	3.61
90-5.1	42.1	3.77	3.15	3.24	8.68	3.95	13.19	8.50	20.34	9.81	14.83	7.16	8.35	0.64	8.12	5.51	0.68
90-5.2	8.3	21.48	63.07	33.12	63.22	63.52	15.58	45.22	20.57	42.20	0.00	60.80	24.20	25.71	36.82	21.17	0.57
90-8	3.2	6.25	0.00	4.69	0.00	2.74	26.96	0.78	26.96	0.00	1.17	0.00	0.00	89.87	12.26	25.24	2.06
90-9	18.2	0.00	6.33	2.13	0.00	3.30	0.69	0.00	1.44	4.54	3.44	0.00	0.00	3.09	1.92	2.08	1.09
91-1	0.4	0.00	0.00	0.00	0.00	0.00	11.87	2.37	6.33	6.33	4.75	0.00	0.00	0.00	2.43	3.79	1.56
91-2	0.4	0.00	0.00	0.00	0.00	0.00	0.00	3.64	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.01	3.61
92-1	5.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.02	0.07	3.61
92-2	7.3	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	3.61
92-3	18.7	0.47	0.00	0.04	0.20	0.00	0.98	0.00	0.13	0.09	1.40	0.00	0.27	0.00	0.28	0.44	1.59
93-1	29.5	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.61
93-2	17.7	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.15	3.61
93-3	16.0	0.23	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.06	0.12	1.93
94-1	8.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.04	0.16	3.61
95-1	2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.65	0.00	0.00	6.92	1.20	2.94	2.46

Table 2.1.6. Meadows with forage code; Animal Unit Nights per acre (AUN/acre) for the years 1998-2009; red indicates meadows (7) with at least one year of AUN/acre >=90 or the equivalent of 3 Animal Unit Months

Forage Code	Area (acre)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg 98-09	StdDev 98-09	CoefVar 98-09
28-1	0.8	0.00	1.25	0.00	44.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.83	12.87	3.36
28-2	0.5	42.37	25.03	0.00	6.16	12.11	0.00	25.65	12.82	35.91	0.00	7.69	2.05	14.15	14.71	1.04
28-3	1.8	2.24	2.10	83.34	17.60	21.65	2.79	51.38	20.95	2.79	55.88	37.72	20.95	26.62	25.78	0.97
28-4	7.7	1.11	3.75	1.47	4.11	1.96	0.00	3.91	3.43	1.63	24.47	22.84	0.00	5.72	8.50	1.49
28-6	32.8	0.29	1.03	0.11	1.16	0.82	0.00	0.61	0.11	0.00	0.30	0.30	0.38	0.43	0.39	0.92
28-7	151.4	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.09	0.00	0.00	0.02	0.05	2.24
33-1	13.4	11.27	12.92	12.87	12.44	18.26	10.93	0.00	0.00	4.11	9.53	2.99	6.07	8.45	5.75	0.68
33-2	21.3	1.05	4.09	5.10	4.46	2.23	4.35	2.24	6.64	0.00	1.27	4.41	3.62	3.29	1.93	0.59
33-3	9.6	1.23	5.64	6.42	4.64	5.50	0.78	19.96	22.57	8.74	8.09	19.05	0.00	8.55	7.76	0.91
33-4.1	3.6	0.00	0.00	0.00	0.00	4.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	1.19	3.46
33-8	92.6	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.49
34-1	60.4	0.00	0.07	0.00	0.00	0.02	0.29	0.10	0.00	0.00	0.25	0.00	0.00	0.06	0.10	1.68
34-2	36.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.02	0.08	3.46
38-2	28.9	0.00	0.22	0.00	0.00	0.91	0.35	0.00	0.00	0.00	1.30	0.00	1.21	0.33	0.51	1.53
39-1	30.4	0.00	0.36	0.05	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.07	0.07	0.14	1.98
39-2	3.2	14.21	11.45	7.90	33.16	54.08	37.90	55.27	29.21	17.76	40.66	73.82	76.59	37.67	23.40	0.62
39-3	10.3	0.48	20.70	15.58	5.80	7.25	1.69	5.90	3.14	1.93	6.23	10.15	5.44	7.02	5.94	0.85
39-4	3.5	0.00	0.00	7.17	1.43	9.68	5.74	7.53	9.32	48.76	17.57	5.74	19.72	11.05	13.37	1.21
39-5	25.9	0.19	5.26	0.88	1.50	1.35	0.92	0.29	0.00	0.68	5.79	1.84	0.00	1.56	1.95	1.25
39-6	1.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.09	0.00	5.40	1.12	2.69	2.39
39-8	15.4	0.00	3.01	1.87	2.59	1.21	1.54	4.86	4.70	0.57	0.49	2.11	1.86	2.07	1.54	0.74
42-1	1.2	0.00	28.13	5.14	0.00	11.31	17.48	5.14	0.00	7.20	0.00	12.34	3.08	7.49	8.63	1.15
42-2	26.8	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.93	0.65	1.03	0.05	0.56	0.31	0.40	1.30
42-3	86.1	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.29	0.00	0.17	0.00	0.00	0.06	0.10	1.87
45-1	26.7	0.00	1.03	0.05	0.00	0.00	0.00	0.66	3.09	0.00	3.28	0.23	0.42	0.73	1.19	1.63
46-1	204.0	0.00	0.12	0.12	0.81	0.00	0.13	0.00	0.49	0.03	0.30	0.12	0.00	0.18	0.25	1.41
46-2	51.3	0.54	0.29	0.42	1.05	0.51	0.97	0.29	1.78	0.61	1.48	0.51	1.00	0.79	0.47	0.60
46-3	50.6	0.10	0.35	0.37	0.91	0.42	0.77	0.57	0.10	0.00	2.04	0.00	0.00	0.47	0.58	1.24
46-4	4.6	0.00	13.26	0.30	1.89	0.00	1.35	0.00	0.00	0.00	0.00	0.00	1.89	1.56	3.76	2.41
46-5	102.2	0.07	0.00	0.00	0.07	0.00	0.21	0.06	0.00	0.00	0.29	0.25	0.15	0.09	0.11	1.16
46-6	14.9	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.22	3.46
47-7	90.5	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	3.46
51-1	22.8	2.74	7.50	14.52	10.02	20.87	5.81	12.00	8.11	4.22	11.50	7.72	9.48	9.54	4.87	0.51
51-2	13.0	0.00	1.15	0.77	0.00	0.77	0.00	0.00	0.00	2.69	0.00	0.38	3.27	0.75	1.12	1.49
51-3	5.5	0.00	0.00	1.82	0.00	0.00	2.28	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.80	2.35
51-4	5.0	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.00	0.00	0.00	0.00	0.00	0.17	0.58	3.46
52-1	46.5	0.00	0.00	1.61	0.00	0.00	0.43	0.13	0.00	0.00	0.00	0.32	0.51	0.25	0.47	1.87
52-3	15.3	0.00	0.00	0.00	1.47	0.00	0.00	0.00	1.96	0.00	0.00	0.00	0.00	0.29	0.68	2.36
52-4	19.1	0.00	0.00	0.00	0.00	0.00	0.00	6.08	0.00	0.00	0.00	0.00	0.00	0.51	1.75	3.46
52-6	5.8	0.00	0.00	0.00	0.00	0.00	3.04	0.00	0.00	0.43	0.00	0.00	0.00	0.29	0.87	3.02
53-1	25.1	0.00	10.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	3.15	3.46

Forage Code	Area (acre)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg 98-09	StdDev 98-09	CoefVar 98-09
53-3	39.6	0.00	0.00	0.25	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.16	0.00	0.12	0.31	2.51
53-4.1	7.1	0.00	0.00	0.00	0.00	0.35	0.00	0.00	1.06	0.00	4.58	0.00	0.00	0.50	1.32	2.65
53-4.2	25.7	1.95	0.00	1.46	5.16	3.31	7.59	0.63	1.36	2.72	0.00	2.19	0.49	2.24	2.25	1.01
53-5	18.8	2.66	7.11	0.00	7.58	6.85	5.09	4.12	2.39	1.86	0.00	0.00	0.00	3.14	2.95	0.94
53-7	7.8	0.96	23.80	7.08	15.60	11.26	8.44	10.45	15.76	0.00	10.45	2.57	10.93	9.78	6.78	0.69
54-1	7.3	5.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.71	0.00	0.61	1.66	2.71
54-2	109.5	0.00	0.26	0.23	0.24	0.53	0.72	0.49	0.80	0.09	0.53	0.49	0.08	0.37	0.26	0.69
54-3	11.4	0.00	2.96	0.00	1.20	4.82	0.00	0.00	3.28	0.00	0.66	0.44	0.00	1.11	1.65	1.48
54-4	6.1	0.00	0.00	0.00	3.70	0.00	9.87	0.00	0.00	2.88	0.00	1.23	3.08	1.73	2.93	1.69
54-5.1	2.9	0.00	0.00	0.00	0.00	0.00	2.61	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.75	3.46
55-1	3.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.62	8.23	16.46	2.28	5.08	2.23
55-2	4.2	1.50	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.67	0.30	0.00	0.00	0.24	0.45	1.89
55-3	3.8	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	3.46
56-1	157.1	0.00	0.00	0.22	0.10	0.25	0.00	0.43	0.00	0.00	0.29	0.17	0.00	0.12	0.15	1.21
56-2	89.7	1.87	0.00	0.11	1.38	0.07	0.24	0.25	0.11	0.61	0.57	0.54	0.13	0.49	0.58	1.18
56-3	1.0	86.18	0.00	0.00	16.47	0.00	0.00	0.00	0.00	0.00	21.34	0.00	0.00	10.33	24.99	2.42
57-1	117.3	0.29	0.21	0.00	0.19	0.38	0.62	0.32	0.21	0.00	0.41	0.15	0.13	0.24	0.18	0.72
58-1	4.4	64.88	22.20	0.32	36.14	9.45	5.98	33.01	22.20	18.78	20.77	56.63	18.78	25.76	19.30	0.75
58-2	3.7	36.42	41.81	15.17	132.17	51.59	70.79	69.12	95.76	50.66	42.15	28.66	3.03	53.11	35.31	0.66
58-3	2.3	41.58	34.47	11.71	26.26	45.19	16.08	30.09	32.82	14.77	30.64	28.99	7.11	26.64	11.90	0.45
62-1.1	2.8	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.20	3.46
63-1	30.1	1.50	2.79	1.25	1.21	2.11	3.94	1.66	0.58	0.00	7.03	2.36	4.77	2.43	1.97	0.81
63-2	14.6	2.05	0.00	0.60	2.90	0.00	0.00	0.00	3.16	0.60	0.00	0.00	0.00	0.78	1.21	1.56
64-1	16.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.47	0.00	0.00	0.21	0.71	3.46
64-2	19.5	0.00	0.00	0.00	0.09	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.06	0.18	3.03
65-1	8.2	11.59	0.00	0.00	0.15	0.00	0.00	1.22	7.01	1.37	0.00	0.09	0.00	1.79	3.67	2.06
65-2	2.4	0.00	0.00	6.25	6.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	2.54	2.34
65-3	5.7	16.76	45.84	12.66	7.20	0.00	10.17	2.62	13.97	0.00	0.00	3.27	1.31	9.48	12.91	1.36
65-4	39.3	0.10	0.38	0.90	0.35	2.14	6.08	6.10	0.49	1.88	5.69	1.49	8.24	2.82	2.87	1.02
65-5	33.3	0.00	0.00	0.00	0.45	0.00	0.00	0.04	0.00	0.00	0.00	0.49	0.67	0.14	0.25	1.80
66-1.1	2.5	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	3.97	0.00	0.00	0.00	0.39	1.15	2.95
66-1.2	0.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.44	1.54	3.46
66-2	18.5	0.99	0.00	0.00	0.00	0.00	0.20	0.00	0.06	0.00	0.00	0.00	0.00	0.10	0.28	2.75
66-3	7.0	13.84	11.47	31.89	33.18	23.65	38.97	29.20	29.53	31.71	13.26	15.76	20.42	24.41	9.25	0.38
67-1	4.8	35.31	26.03	27.32	28.35	33.51	32.37	57.22	1.03	24.49	43.30	8.25	20.88	28.17	14.70	0.52
67-2	1.8	74.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.19	21.43	3.46
68-1	2.4	1.77	0.00	0.30	0.00	0.00	0.00	2.11	0.00	0.00	0.00	0.00	0.00	0.35	0.75	2.16
69-2.1	2.4	22.17	4.44	7.05	5.74	19.58	25.32	4.18	24.80	19.05	14.09	22.97	20.36	15.81	8.28	0.52
69-2.2	1.5	34.66	6.94	11.02	8.98	30.60	39.58	6.53	38.76	29.78	22.03	35.90	31.82	24.72	12.94	0.52
69-3	0.9	33.69	68.85	71.78	42.48	36.62	27.83	90.82	92.28	84.96	49.80	131.83	74.71	67.14	30.57	0.46
69-4	1.9	36.56	26.30	30.15	12.83	6.41	13.47	35.28	16.04	15.40	38.49	16.68	18.60	22.18	10.72	0.48
69-5.1	9.5	25.14	49.74	46.59	42.64	14.90	11.32	35.80	40.66	35.14	36.45	38.16	52.64	35.76	12.87	0.36
69-5.2	3.1	0.00	0.00	16.86	22.48	8.03	2.41	36.54	43.36	9.64	0.00	0.00	0.00	11.61	15.23	1.31

Forage Code	Area (acre)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg 98-09	StdDev 98-09	CoefVar 98-09
69-6.1	6.0	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	3.46
70-1.1	1.4	16.98	0.00	24.33	19.83	0.00	5.41	0.00	0.00	0.00	0.00	0.00	0.00	5.55	9.21	1.66
70-1.2	4.2	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.76	0.00	0.00	0.00	0.69	1.64	2.36
70-3	3.6	0.00	0.00	9.10	0.00	7.00	4.90	0.00	0.00	0.00	0.00	0.00	0.00	1.75	3.29	1.88
70-4	5.9	6.74	7.16	36.24	13.70	2.53	0.84	4.64	10.11	9.48	2.53	0.00	3.79	8.15	9.74	1.20
70-5	29.4	0.25	3.52	0.89	11.67	15.03	4.47	2.21	0.34	7.64	1.02	8.32	3.99	4.95	4.78	0.97
70-6	5.7	0.88	9.66	9.36	4.39	12.74	16.91	15.81	4.39	9.66	1.98	1.54	7.91	7.94	5.44	0.68
70-7	4.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.07	0.25	3.46
71-1.1	1.6	3.07	0.00	8.45	18.44	19.46	5.13	46.61	4.35	12.55	0.00	5.38	8.71	11.01	12.88	1.17
71-1.2	1.1	4.67	0.00	33.85	28.01	31.44	7.79	70.81	6.61	19.07	0.00	8.17	13.23	18.64	20.22	1.08
71-1.3	2.3	2.15	0.00	9.12	12.88	16.17	3.58	32.55	3.04	8.77	0.00	3.76	6.08	8.17	9.16	1.12
71-2	5.1	11.28	5.17	16.48	4.92	0.00	18.21	5.90	0.00	0.00	4.92	3.44	9.59	6.66	6.12	0.92
71-3	49.5	0.61	5.26	2.32	4.47	3.79	7.44	2.15	3.03	4.95	0.63	3.79	5.96	3.70	2.08	0.56
71-4	11.7	0.00	0.00	0.32	0.64	2.78	0.85	0.00	4.48	1.71	7.47	0.53	1.39	1.68	2.26	1.34
72-10	0.7	1.56	0.00	39.04	79.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.05	24.69	2.46
72-18	9.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.12	0.18	0.61	3.46
72-2	2.9	0.00	2.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.69	3.46
72-6	31.8	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.09	3.46
72-7	4.3	1.74	1.74	0.00	0.00	0.00	0.00	5.23	0.70	1.74	0.00	1.16	0.58	1.07	1.50	1.40
72-8	23.2	4.57	11.59	10.76	6.88	8.55	6.61	2.74	1.94	10.43	5.65	3.93	3.76	6.45	3.27	0.51
72-9	3.6	0.00	0.00	0.00	0.00	0.00	0.00	2.06	0.00	0.00	0.00	0.00	0.00	0.17	0.59	3.46
73-1	2.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.04	0.00	1.59	5.50	3.46
73-2	1.8	2.82	3.95	0.00	0.00	1.18	0.00	0.00	3.95	4.93	0.00	7.05	23.96	3.99	6.73	1.69
73-4	0.8	0.00	0.00	0.00	0.00	5.31	61.66	6.32	0.00	11.07	0.00	15.81	37.94	11.51	19.29	1.68
73-5	4.0	0.00	0.00	3.10	13.02	3.42	6.82	6.20	4.09	4.96	1.55	0.00	2.79	3.83	3.71	0.97
74-1	5.7	0.00	0.00	0.00	0.00	1.32	0.00	0.44	0.00	0.00	0.00	1.10	0.00	0.24	0.47	1.99
75-1	9.4	0.00	0.00	0.00	0.66	8.76	0.19	0.80	5.31	0.00	0.00	0.00	2.79	1.54	2.78	1.81
75-2	4.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76-2	1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.18	0.43	1.50	3.46
77-1	1.3	0.00	0.00	0.00	0.00	26.69	0.00	24.72	1.98	0.00	0.00	0.00	22.74	6.34	11.13	1.75
77-2	9.1	0.00	0.00	0.00	0.00	0.00	11.38	0.00	3.02	0.00	0.00	0.00	0.00	1.20	3.32	2.77
77-3	0.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	70.38	0.00	0.00	0.00	5.87	20.32	3.46
77-5	10.0	5.00	14.50	12.50	8.00	39.36	9.13	16.24	11.12	26.62	15.12	20.37	24.49	16.87	9.59	0.57
77-6	4.6	4.58	0.00	0.00	0.81	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	1.32	2.81
77-7	5.6	0.00	1.34	6.61	3.58	6.93	6.53	0.00	0.00	0.00	0.00	0.00	25.48	4.21	7.30	1.74
78-1	3.6	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.30	3.46
79-1	8.4	13.12	0.00	10.74	22.52	13.57	15.15	13.72	17.90	36.24	26.55	23.27	31.62	18.70	9.91	0.53
79-2	43.7	0.07	0.00	0.00	0.00	0.63	0.08	0.09	0.21	0.16	0.00	0.00	0.00	0.10	0.18	1.76
79-4	12.2	0.00	0.00	23.30	0.65	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.82	2.17	6.67	3.08
79-5	33.2	0.00	0.00	0.34	0.00	0.00	0.00	6.63	0.00	0.68	4.07	0.49	0.00	1.02	2.11	2.07
79-6	146.9	0.00	0.00	0.00	0.44	0.00	0.71	0.00	0.00	0.00	0.31	0.00	0.00	0.12	0.24	1.95
80-1	100.9	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	3.46
80-2	29.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.10	1.37	0.40	1.00	2.51

Forage Code	Area (acre)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg 98-09	StdDev 98-09	CoefVar 98-09
80-3	14.6	7.32	24.52	9.69	30.98	16.25	19.85	12.04	6.88	4.68	14.32	7.54	6.52	13.38	8.18	0.61
80-4	796.4	0.00	0.00	0.00	0.03	0.02	0.11	0.06	0.02	0.00	0.00	0.01	0.03	0.02	0.03	1.45
80-5.1	22.8	0.00	0.00	0.33	0.00	1.05	0.60	0.00	0.00	0.00	0.00	0.40	0.00	0.20	0.34	1.71
80-5.2	173.9	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.46
80-6	201.8	0.00	0.00	0.18	0.07	0.07	0.35	0.00	0.43	0.00	0.00	0.00	0.35	0.12	0.16	1.36
81-1	507.0	0.01	0.08	0.02	0.26	0.16	0.31	0.20	0.12	0.31	0.11	0.22	0.21	0.17	0.10	0.61
81-2.1	3.2	0.00	0.00	0.00	2.34	0.00	0.00	4.68	4.68	0.00	0.33	0.22	0.94	1.10	1.80	1.64
81-2.2	7.3	0.00	19.46	0.00	2.39	3.41	0.00	0.00	18.78	9.90	2.39	3.76	6.14	5.52	7.00	1.27
81-2.3	9.8	0.00	1.91	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.76	0.21	0.00	0.31	0.59	1.90
81-2.4	5.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.68	0.00	0.00	0.78	0.00	0.70	2.21	3.13
82-1	1.7	0.00	13.78	5.80	0.00	5.08	5.95	26.51	18.85	4.35	24.42	0.00	9.43	9.51	9.35	0.98
82-2	0.3	11.89	7.93	11.89	7.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30	5.02	1.52
82-3	1.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.36	0.00	0.00	0.00	0.00	0.86	2.99	3.46
83-1	25.9	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.04	0.04	0.19	0.03	0.05	2.03
83-3	24.4	0.36	0.61	0.00	0.36	0.00	1.89	0.00	0.00	0.00	0.15	0.00	0.00	0.28	0.55	1.94
83-4	38.9	0.15	9.30	4.09	9.63	7.37	8.32	7.17	1.87	4.95	9.33	6.68	7.30	6.35	3.02	0.48
83-5	29.0	6.08	3.06	6.09	4.82	5.92	1.42	1.51	16.21	6.67	3.82	0.22	0.00	4.65	4.35	0.94
83-6	9.2	0.82	0.00	3.82	0.00	0.00	0.00	4.77	0.00	0.00	0.00	3.00	0.00	1.03	1.76	1.71
83-7	5.9	3.40	0.00	0.00	0.00	2.55	0.00	0.00	13.83	12.98	0.00	0.72	9.58	3.59	5.36	1.49
83-8	47.9	3.73	2.82	3.86	3.42	5.09	2.61	3.49	4.17	5.19	1.33	8.97	6.10	4.23	1.96	0.46
84-1	42.4	0.53	0.00	0.00	0.15	1.45	0.27	0.02	0.00	0.00	0.02	0.00	0.00	0.20	0.42	2.09
84-2	47.1	3.53	3.47	0.74	0.29	5.38	5.73	2.73	9.00	9.21	3.95	6.60	10.32	5.08	3.25	0.64
84-3	32.9	0.00	0.00	3.80	1.48	0.00	0.00	0.00	0.87	0.00	0.00	3.49	0.00	0.80	1.41	1.75
84-5	20.0	0.00	0.00	0.00	0.25	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.07	3.01
84-6	270.6	0.03	0.00	0.00	0.00	0.07	0.03	0.03	0.12	0.07	0.00	0.00	0.00	0.03	0.04	1.34
85-10	15.7	6.67	4.37	11.48	15.80	3.71	5.16	5.32	9.29	5.40	3.65	8.94	9.37	7.43	3.66	0.49
85-4	10.8	0.00	0.00	0.00	8.23	10.69	4.41	3.71	9.51	4.87	8.93	0.81	3.25	4.53	3.97	0.88
85-5	27.0	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	3.46
85-6	25.0	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.01	0.20	0.63	0.10	0.11	0.20	1.82
85-7	50.1	0.00	0.00	0.00	0.47	0.00	0.51	0.08	0.00	0.00	0.00	0.02	0.00	0.09	0.19	2.09
85-8.1	23.0	1.41	6.09	0.58	1.71	0.00	1.16	4.12	1.60	0.33	0.57	0.46	0.54	1.55	1.79	1.16
85-8.2	9.5	3.42	14.75	1.40	4.15	0.00	2.81	10.00	3.89	0.81	1.37	1.12	3.75	3.96	4.28	1.08
86-1	6.1	13.98	34.53	9.25	52.82	65.48	77.20	53.97	27.13	0.00	37.61	56.52	101.33	44.15	29.61	0.67
86-2	10.3	8.12	39.00	8.72	13.81	19.74	6.18	21.15	19.87	14.66	11.00	6.54	8.36	14.76	9.33	0.63
86-3	1.6	0.00	83.82	3.10	130.38	0.00	0.00	5.43	0.00	0.00	0.00	0.00	0.00	18.56	42.57	2.29
86-4	3.1	0.82	13.09	12.27	3.68	27.82	19.23	5.73	2.86	0.00	0.00	4.50	7.77	8.15	8.55	1.05
86-5	4.4	10.72	61.21	8.46	24.86	46.13	22.00	15.96	42.31	28.77	5.64	3.10	0.00	22.43	19.16	0.85
86-6	1.1	0.00	167.81	20.27	0.00	0.00	0.00	10.27	0.00	7.88	0.00	0.00	0.00	17.19	47.86	2.78
86-7	1.2	464.66	848.18	615.33	710.16	544.73	558.43	390.90	229.69	118.01	201.25	121.17	204.41	417.24	243.87	0.58
86-8	1.5	66.44	83.88	88.03	111.28	76.40	115.44	9.14	21.59	39.86	0.70	4.98	8.30	52.17	42.98	0.82
87-1	84.9	0.00	0.00	1.27	0.00	0.10	0.04	0.21	1.13	2.12	0.00	1.10	0.96	0.58	0.71	1.23
87-10	66.2	0.00	0.00	0.00	0.00	0.84	0.03	0.38	1.10	0.00	0.00	0.00	0.94	0.27	0.43	1.57
87-2	6.6	2.64	0.00	1.32	0.00	0.00	20.77	0.00	0.00	0.00	0.00	14.16	0.00	3.24	6.84	2.11

Forage Code	Area (acre)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg 98-09	StdDev 98-09	CoefVar 98-09
87-3	5.3	5.67	0.00	0.00	0.00	40.16	10.73	3.31	0.00	9.69	5.43	17.72	15.83	9.04	11.59	1.28
87-4	26.2	0.48	0.00	7.72	0.00	0.24	0.27	10.29	0.57	0.00	0.00	0.00	3.10	1.89	3.48	1.84
87-7	24.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	0.00	0.00	0.09	0.30	3.46
87-9	14.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.03	0.10	3.46
88-1	54.0	0.00	0.00	0.16	0.23	1.34	0.64	0.00	0.00	0.00	0.25	0.00	0.00	0.22	0.40	1.83
88-2	14.8	0.00	0.00	0.09	0.93	0.75	0.00	0.25	0.00	0.00	0.00	0.85	0.00	0.24	0.37	1.56
88-3	5.4	0.00	0.00	1.63	0.69	1.76	0.00	0.00	0.00	0.00	0.00	0.00	2.75	0.57	0.95	1.67
88-4	22.2	0.00	0.00	1.24	0.90	0.90	0.05	0.00	1.35	0.00	0.00	0.00	0.68	0.43	0.54	1.28
88-5	2.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48	0.12	0.43	3.46
89-10	14.4	0.00	10.77	8.08	0.00	0.00	0.26	0.00	0.52	0.00	0.00	0.00	0.00	1.64	3.69	2.25
89-12	26.0	0.00	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.44	3.46
89-13	36.6	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.07	0.16	2.34
89-3.1	13.0	0.00	0.00	4.83	8.74	0.00	3.60	0.00	3.47	0.00	7.38	6.52	6.71	3.44	3.37	0.98
89-3.2	7.2	0.00	0.00	8.71	15.77	14.44	6.50	0.00	6.27	0.00	13.33	11.77	12.11	7.41	6.17	0.83
89-4	23.8	0.00	0.00	0.58	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.20	2.37
89-5.1	29.4	0.00	0.04	0.94	0.13	0.11	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.12	0.27	2.24
89-5.2	3.8	0.00	0.00	0.19	0.00	2.99	0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.40	0.94	2.34
89-6	6.4	0.00	33.11	1.37	0.00	6.86	8.23	1.57	5.09	2.35	0.00	0.00	13.32	5.99	9.50	1.59
89-7	20.5	0.00	0.00	0.37	0.88	1.28	0.27	0.00	0.00	0.00	0.00	0.00	0.12	0.24	0.42	1.72
89-8	20.9	0.00	0.00	0.00	1.67	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.48	3.12
89-9	7.2	24.80	0.87	10.41	26.36	25.23	22.20	23.59	28.10	3.47	31.22	3.12	0.00	16.61	11.98	0.72
90-1	1.8	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.22	3.46
90-10	13.2	2.83	5.66	13.21	13.02	30.49	27.28	9.63	11.23	10.95	14.35	0.94	1.13	11.73	9.31	0.79
90-11	9.3	0.00	11.30	13.46	14.40	24.22	14.80	3.77	0.00	2.83	3.23	26.91	29.34	12.02	10.47	0.87
90-13	8.0	17.08	0.00	21.43	0.00	13.82	27.95	10.41	0.00	13.67	0.00	17.55	19.57	11.79	9.73	0.83
90-14	44.1	0.68	0.00	0.00	0.00	0.00	0.00	0.03	0.00	1.70	0.00	1.59	0.00	0.33	0.64	1.93
90-15	5.8	0.00	0.00	0.00	7.07	0.00	2.14	0.00	0.00	0.00	0.00	0.00	0.00	0.77	2.08	2.71
90-16	13.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.11	0.37	3.46
90-17	31.4	0.00	0.00	0.00	0.00	0.16	0.00	0.56	0.00	0.00	1.91	0.00	1.43	0.34	0.65	1.92
90-18	3.9	0.00	0.00	0.00	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.92	3.46
90-19	23.8	0.00	0.79	0.37	0.11	2.10	1.63	0.26	0.42	0.16	0.32	0.16	0.00	0.53	0.67	1.27
90-3	0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-4	5.3	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.94	64.45	29.51	7.92	19.71	2.49
90-5.1	42.1	7.93	11.16	2.36	10.16	10.84	9.59	10.51	3.92	3.59	3.62	10.54	12.68	8.08	3.65	0.45
90-5.2	8.3	15.12	14.81	46.56	3.63	15.72	9.98	11.49	8.92	11.79	12.85	2.42	12.85	13.84	11.13	0.80
90-8	3.2	0.00	0.00	2.34	11.72	20.70	1.56	0.00	0.00	0.00	0.00	0.00	0.00	3.03	6.49	2.15
90-9	18.2	9.62	0.00	1.37	0.21	4.12	5.71	2.06	0.00	8.59	0.82	8.46	10.72	4.31	4.12	0.96
92-3	18.7	0.15	0.07	0.00	0.39	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.14	1.79
95-1	2.0	5.53	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.59	3.15

Section 2.2 SEKI meadows: residual biomass monitoring

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Introduction and methodology

Measuring residual biomass, the live and dead aboveground plant material remaining after a grazing season, is a widely accepted and frequently employed method for monitoring livestock grazing utilization in California (Holechek et al. 2011; Heady and Child 1994). Commonly, the residual biomass is then compared to a standard (see for example, Bartolome et al. 2006) to assess whether changes should be made in grazing management to ensure optimal forage productivity and resource protection. Although residual dry matter (RDM) standards are designed to inform a wider array of practices, they are focused on the issues of livestock utilization and best developed for that purpose (Bartolome et al. 2006). Prior to 1993, no residual biomass standards existed that were directly applicable to SEKI meadows. In the absence of minimum residual biomass standards, residual biomass data from paired grazed and ungrazed plots can be compared to ascertain whether grazed residual biomass is substantially lower than ungrazed residual biomass.

In 1991, SEKI ecologists began testing a residual biomass monitoring program, which eventually grew to include 38 packstock grazed meadows, to evaluate the impact of packstock use on meadows and to inform packstock and meadow management decisions (Abbott et al. 2003; Haultain 2008). The use and advantages of residual biomass monitoring methodology using comparative yield for packstock grazed meadows is reviewed in a publication by McClaran and Cole (1993), described in detail by Haultain (2008) and Abbott et al. (2003), follows the comparative yield approach of Haydock and Shaw (1975) and is recommended by McClaran and Cole (1993). Briefly, each monitored meadow has a designated “core” (grazed) area and a “reference” (ungrazed) area (4 of the 38 meadows have another meadow as its ungrazed reference). Within each area, quadrats are established that represent five levels of residual biomass, encompassing the range of residual biomass found in the area. These quadrats then serve as the standard against which a further 150-200 quadrats are assigned by visual assessment to one of the five levels of residual biomass. Representative quadrats for each of the five levels are clipped and weighed to provide an average biomass weight for each level. From these data, an estimate of lbs/acre of residual biomass is calculated for the core and reference area of each meadow.

Not all 38 meadows in the residual biomass monitoring program are sampled every year. Additionally, data may not be collected in both core and reference areas in a sampled meadow within any given year. Because this analysis was undertaken specifically to evaluate the effect of the intensity of packstock grazing on meadows as a difference between core (grazed) and reference (ungrazed), we needed to use data from meadows in which both the core and reference areas were sampled in the same year. Abbott et al. (2003) analyzed the residual biomass data from 1995-2000; this report provides analysis of residual biomass data from 2001-2009 to extend the data set and provide material for further discussion.

Neuman (1993) initiated development of minimum residual biomass recommended guidelines for SEKI meadows from a method proposed by Ratliff et al. (1987) based on annual decomposition rates for Sierran meadows in 3 moisture classes. Ratliff et al.'s method also assigns a condition class to each meadow, assuming that condition affects production. Reflecting the philosophy and objectives of National Park Service wilderness management, Neuman added a margin of an additional 10% residual biomass over and above the Ratliff standards. Ratliff's exhaustive, descriptive vegetation study for southern Sierras preceded more recent studies showing that physical factors may be critical for determining meadow temporal and spatial patterns (Benedict 1982, Allen-Diaz 1991) and emphasizing the need to utilize more sophisticated ecological site descriptions in classification (Brown 2010). For SEKI meadows, initial condition class assignments were based on estimated historic use levels. It is important to note that such substitution of recent grazing intensity (very light, light, moderate, and heavy) for Ratliff's assessment of meadow condition, although a common management practice, is not proven to be related to the RDM method for developing standards. Current U.S. Forest Service methodology for assessing meadows for wildlife habitat employs stubble height, which has its own problems, including measurement errors, lack of good ties to habitat requirements, and frequent inability of meadow systems to reach recommended stubble height standards even when ungrazed (Lile et al. 2003). For this analysis, we used the SEKI residual biomass recommended guidelines listed in Haultain 2008.

To evaluate which factors are important in explaining the amount of residual biomass, we used a classification and regression tree (CART) analysis (De'Ath and Fabricius 2000; S-Plus 7.0 for Windows, Insightful Corp.). CART analysis was carried out for combined core (grazed) and reference (ungrazed) plots in 2002-2007, the years for which snow covered area data were available. Nodes were pruned based on length of twig (i.e., amount of variance explained (De'Ath and Fabricius 2000)). Potential explanatory variables include presence or absence of packstock grazing, year, elevation, annual moisture level (for which we used the variable "snow covered area," generated by Matchett, and which were available for 2002-2007 only; Table 2.2.2), and for core areas only, annual packstock use, estimated as annual Animal Unit Nights (AUN) per acre (Table 2.2.2). Annual averages for AUN/acre and snow covered area are presented in Table 2.2.3. Some explanatory variables include missing data, which CART robustly accommodates. Because AUN/acre was only recorded for core areas, we did an additional CART on core areas only to see where that variable entered the model. For selected paired comparisons, we used simple regression to establish significance of relationships.

Results

Twenty-five meadows (Table 2.2.1) had at least one year of sampling in both core and reference areas, for a total of 131 meadow-years (Table 2.2.2). Seventy-six of these 131 meadow-years met or exceeded the SEKI minimum residual biomass recommended guidelines. Fifty-five meadow-years fell below the recommended guidelines, although in 5 of the 55 meadow-years that fell below guidelines, residual biomass in the core area was not significantly different from residual biomass in the reference area so these meadow-years are considered to have met the guidelines (Haultain 2008). In sum then, 62% of the meadow-years met or exceeded the SEKI minimum residual biomass recommended guidelines, while 38% fell below guidelines.

Fifteen meadows met the recommended guidelines in at least 50% of the years reported for that meadow (Table 2.2.2). The other 10 meadows (40%), McClure, Little Pete, Junction/Bubb's Creek, Austin Camp Creek Crossing/Trail Crew Camp, Lake South America, Upper Crabtree, Lower Funston, Forester Lake, South Fork Meadow, and South Fork Pasture, fell below the recommended guidelines in 50% or more of the years reported for that meadow (although 2 of these meadows were only sampled in 1 year but fell below the guidelines in that year). South Fork Meadow fell below the guidelines in every year reported.

Residual biomass fluctuated annually on both core and reference plots (Table 2.2.2) and variation in residual biomass was about the same for reference and core sites: the coefficient of variation for residual biomass in core areas was 65% and in reference areas 62%. Residual biomass increased significantly by an average of about 500 lbs./acre from 2001-2009 on core (grazed) plots ($r=0.319$, $p<.01$) (Figure 2.2.1); and increased, but not significantly on reference (ungrazed) plots ($r=0.123$) (Figure 2.2.2). AUN/acre over that same period on the core plots remained flat, not differing significantly ($r=0.001$), and averaging just under 5 AUN/acre (Figure 2.2.3).

The CART analysis (Figure 2.2.4) showed that the explanatory power of additional variables, reflected in residual deviance (Figure 2.2.5), was low and stabilized when more than 6 nodes remained in the model. Therefore we pruned the model at 6 nodes, which leaves about 30 percent residual variance. This pruning eliminated low value explanatory variables such as narrower elevational bands and AUN splits. It also does not include year as an explanatory variable because of its very low explanatory power. Elevational splits explained the greatest amount of variance in residual biomass (6 terminal nodes; Figure 2.2.4). Meadows below 7,745 feet had the highest levels of residual biomass. For meadows above 7,745 feet, two other elevation splits show the strong negative effect of higher elevation on biomass. For meadows above 7745 feet, but below 9678 feet, AUN per acre below 2.33 had higher biomass, a category which includes all of the reference plots. Within that elevational group, the last included variable, snow cover more than 44 percent, which is above the average snow cover value (Table 2.2.3), was associated with higher biomass.

Because only core plots had AUN records, we did a separate CART analysis only on those plots (Figure 2.2.6), pruning to five nodes. The major mid-elevation split at about 7500 feet remains the most important explanatory variable, with AUN/acre less than 16.2 below 7662 feet. Some lower residual biomass years (2002, 2003, 2004, and 2005) occurred above 7662 feet, and in the other years, there was more residual biomass at very low AUN levels below 1.8/acre. Variables other than elevation had only a small effect on explaining residual variance.

We looked at several key variables from CART with simple regression, which showed a significant overall negative linear relationship between elevation and core residual biomass (Figure 2.2.1, $r=-0.498$, $p<.01$). The overall simple linear relationship of elevation and reference plot biomass was also negative and significant (Figure 2.2.2, $r=-0.647$, $p<.01$). This approach confirmed the lack of a strong relationship between year and AUN on core plots; overall grazing use did not change among years (Figure 2.2.3, $r=.001$ ns).

Discussion and recommendations

Over 60% of the meadow-years met the SEKI minimum residual biomass recommended guidelines developed for packstock grazed SEKI meadows. However, 38% of the meadow-years did not meet the preliminary standards. In particular, 10 of the meadows, McClure, Little Pete, Junction/Bubb's Creek, Austin Camp Creek Crossing/Trail Crew Camp, Lake South America, Upper Crabtree, Lower Funston, Forester Lake, South Fork Meadow, and South Fork Pasture, fell below their recommended guidelines in 50% or more of the years reported for that meadow. These meadows may be candidates for further evaluation of the relationship between packstock use and residual biomass.

Classification and regression tree (CART) analysis shows that elevation is the primary factor influencing residual biomass for 25 meadows evaluated. Abbott et al. (2003) separated their data into montane (average of 7,600 feet elevation) and subalpine (average of 9,800 feet) categories. CART showed that a separation at 7,745 feet explained most of deviance in residual biomass and that second and third separations at 9,678 feet and 10,559 feet were also useful for better understanding differences in residual biomass when considered along with snow cover and AUN/acre (Figure 2.2.4). For middle elevation meadows below 7,745 feet, low AUN/acre (<2.3; see Table 2.2.3 for annual averages) results in lower levels of core residual biomass, however this is an artifact produced by the influence of ungrazed reference areas. When we analyzed the core (grazed) areas separately, the CART analyses suggest that packstock use plays a fairly small role in annual residual biomass levels, but that AUN/acre may have an influence in certain cases. Because so much of the variance is explained by measured physical factors (Figures 2.2.5 and 2.1.6), there is little likelihood that better condition class assignment criteria or other variables will provide significant additional predictive information.

Residual biomass recommended guidelines are based in part on meadow condition classes as proposed by Ratliff (1987) based on plant composition, but which in this study were estimated by prior grazing use. Because vegetation based range condition classes are primarily determined by physical factors (Brown 2010), a conclusion supported by our results and analysis here, condition either based on vegetation or productivity appears inappropriate for setting residual dry matter standards. Any standard assigned to a meadow may be based on a combination of incorrect condition class information and a lack of correct standards for such meadow; it would be better based on specific management objectives and physical site factors like elevation. Other important site factors, like seasonal water table, strongly influence meadow production (Allen-Diaz 1991) and may vary considerably at very small scales within meadows.

Residual biomass on both core and reference plots have increased over the period examined (Figures 2.2.1 and 2.2.2), suggesting that meadow production has also increased. A previous report by Abbott et al. (2003) reported that core and reference residual biomass did not increase between 1995 and 2000. The significant biomass increase in core areas we reported (Figure 2.2.1) appears to come from three low residual biomass years (2001, 2002, and 2003) followed by a return to the mean seen prior to 2000. The condition classes for SEKI meadows based on residual biomass might therefore be regarded as improving after 2003, although condition is conventionally based on the cover of particular species rather than meadow biomass production. Both Abbott et al. (2003) and our analyses reveal no significant overall yearly trends in AUN since 1995. Caution should be used in deciding whether a meadow has met its minimum

residual biomass recommended guidelines. It should be noted that Cole et al. (2004) have suggested that Ratliff et al.'s (1987) residual biomass recommendations, upon which SEKI's residual biomass recommended guidelines are based, are set too low and that they may result in declines in meadow productivity, if not changes in species composition. Because elevation, very low AUN/acre (probable surrogate for reference sites), and snow cover dominate explanatory variables, it is very unlikely that the AUN and residual biomass recommended guidelines play much of a role in maintaining meadow productivity under currently applied recommended guidelines.

Recommendations for future monitoring and research

That said, the current residual biomass monitoring program collects valuable data that help SEKI staff manage packstock use in meadows. Echoing Abbott et al. (2003), we strongly recommend collecting both core and reference data from a within a single meadow whenever possible, even if it means collecting data for fewer meadows; without comparison plots, annual variation in residual biomass makes packstock impact analysis problematic. Because so much of the variation is tied up in physical factors, especially elevation, any evaluation system that attempted links to condition would need to have much smaller scale measurements. Species composition data associated with the residual biomass plots might improve the assessment of packstock use impact but only with better site specific environmental information (see Cole et al. 2004) and by tying the recommended guidelines more closely to elevation. Because of the significant correlation of ungrazed residual biomass to elevation, it may be better to use that environmental factor directly in establishing any final RDM standards. We recommend re-evaluation of the SEKI residual biomass recommended guidelines for the few meadows consistently falling below the guidelines, taking into consideration Cole et al.'s (2004) statements regarding Ratliff et al.'s (1987) method. Finally, given the high degree of environmental control of biomass on these meadows and the stable residual biomass over nearly two decades, we suggest that despite some limitations, the RDM approach is effectively guiding and monitoring packstock use and is a defensible practice.

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Table 2.2.1. Residual biomass meadows (n=25) with area and elevation of meadow

Meadow no.	Forage area name	Area (acre)	Elevation (feet)
33-1	Evolution Meadow	13.38	9,230
33-2	McClure Meadow	21.27	9,671
33-3	Colby Meadow	9.58	9,700
39-3	Little Pete Meadow	10.35	8,860
51-1	Simpson Meadow	22.82	5,958
58-1	Castle Domes Meadow	4.39	8,130
66-3	Junction Meadow (Bubbs Creek)	6.98	8,130
67-1	East Lake Meadow	4.85	9,550
69-3	JR Pasture, Allen Camp	0.85	7,429
69-5.1	Scaffold Meadow Tourist Pasture	9.50	7,360
71-1.3	Austin Camp (Trail Crew Camp) ¹	1.07	7,940
80-3	Tyndall Creek Meadows	14.58	10,650
80-5.1	Lake South America	22.84	11,950
83-4	Upper Crabtree Meadow	38.86	10,460
83-7	Lower Whitney Creek, Strawberry Meadow	5.87	9,950
83-8	Sandy Meadow	47.93	10,620
84-2	Lower Rock Creek Crossing Meadow	47.14	9,656
85-8.1	Rock Creek Lake Meadow	23.01	10,498
86-2	Upper Funston Meadow	10.32	6,700
86-5	Lower Funston Meadow	4.43	6,480
88-1	Lower Little Five Lakes Meadows	53.99	10,420
89-5.2	Forester Lake Meadows	3.76	10,354
90-10	South Fork Meadow	13.24	8,515
90-11	South Fork Pasture	9.29	8,560
90-5.2	Hockett Pasture ²	8.27	8,500

¹ 71-1.2 Austin Camp (Creek Crossing Meadow) serves as the ungrazed reference area for the 71-1.3 Austin Camp (Trail Crew Camp) core area (Haultain 2008, Table 2.2.3).

² 90-5.1 Hockett Meadow serves as the ungrazed reference area for the 90-5.2 Hockett Pasture core area.

Table 2.2.2. Core and reference residual biomass estimates in lbs/acre; AUN=animal unit night; red indicates that the meadow is below standard in that year

Year	Meadow no.	Meadow name	Core (grazed) biomass	Reference (ungrazed) biomass	% difference (core / reference)	Core and reference significantly different?	Direction of difference	Residual biomass standard	AUN/acre	Snow covered area	elevation (ft)
2001	33-1	Evolution	669	879	76	no diff		75	12.44	NA	9,230
2002	33-1	Evolution	275	739	37	diff	C<R	75	18.26	0.43	9,230
2004	33-1	Evolution	697	442	158	diff	R<C	75	0.00	0.34	9,230
2005	33-1	Evolution	771	783	98	no diff		75	0.00	0.56	9,230
2006	33-1	Evolution	535	1167	46	diff	C<R	75	4.11	0.47	9,230
2007	33-1	Evolution	651	666	98	no diff		75	9.53	0.27	9,230
2008	33-1	Evolution	691	740	93	no diff		75	2.99	NA	9,230
2009	33-1	Evolution	842	893	94	no diff		75	6.07	NA	9,230
2009	33-2	McClure	615	833	74	diff	C<R	75	3.62	NA	9,671
2002	33-3	Colby	331	819	40	diff	C<R	75	5.50	0.24	9,700
2004	33-3	Colby	421	589	71	no diff		75	19.96	0.21	9,700
2005	33-3	Colby	304	317	96	no diff		75	22.57	0.27	9,700
2008	33-3	Colby	453	1089	42	diff	C<R	75	19.05	NA	9,700
2009	33-3	Colby	603	686	88	no diff		75	0.00	NA	9,700
2001	39-3	Little Pete	532	813	65	no diff		75	5.80	NA	8,860
2002	39-3	Little Pete	412	1436	29	diff	C<R	75	7.25	0.46	8,860
2003	39-3	Little Pete	1818	4198	43	diff	C<R	75	1.69	0.54	8,860
2004	39-3	Little Pete	565	1401	40	diff	C<R	75	5.90	0.46	8,860
2005	39-3	Little Pete	1150	1468	78	no diff		75	3.14	0.62	8,860
2006	39-3	Little Pete	1331	2084	64	diff	C<R	75	1.93	0.52	8,860
2007	39-3	Little Pete	751	1649	46	diff	C<R	75	6.23	0.37	8,860
2008	39-3	Little Pete	765	1159	66	diff	C<R	75	10.15	NA	8,860
2009	39-3	Little Pete	932	945	99	no diff		75	5.44	NA	8,860
2009	51-1	Simpson	1295	1573	82	no diff		65	9.48	NA	5,958
2001	58-1	Castle Domes	740	1123	66	diff	C<R	65	36.14	NA	8,130
2002	58-1	Castle Domes	913	1270	72	no diff		65	9.45	0.31	8,130
2002	66-3	Junction - Bubb's Creek	450	1424	32	diff	C<R	75	23.65	0.37	8,130

Year	Meadow no.	Meadow name	Core (grazed) biomass	Reference (ungrazed) biomass	% difference (core / reference)	Core and reference significantly different?	Direction of difference	Residual biomass standard	AUN/acre	Snow covered area	elevation (ft)
2003	66-3	Junction - Bubb's Creek	665	1630	41	diff	C<R	75	38.97	0.32	8,130
2004	66-3	Junction - Bubb's Creek	352	1112	32	diff	C<R	75	29.20	0.28	
2005	66-3	Junction - Bubb's Creek	216	1372	16	diff	C<R	75	29.53	0.55	
2006	66-3	Junction - Bubb's Creek	340	1598	21	diff	C<R	75	31.71	0.47	
2007	66-3	Junction - Bubb's Creek	437	1339	33	diff	C<R	75	13.26	0.27	
2008	66-3	Junction - Bubb's Creek	1363	1516	90	no diff		75	15.76	NA	9,550
2009	66-3	Junction - Bubb's Creek	1493	821	182	diff	R<C	75	20.42	NA	
2007	67-1	East Lake	441	586	75	no diff		75	43.30	0.38	
2008	67-1	East Lake	1977	833	237	no diff		75	8.25	NA	
2009	67-1	East Lake	412	598	69	no diff		75	20.88	NA	
2009	69-3	Scaffold Meadow (JR Pasture, Allen Camp)	533	724	74	no diff		65	74.71	NA	7,429
2004	69-5.1	Scaffold Meadow Tourist Pasture	2558	2487	103	no diff		65	35.80	0.03	7,360
2005	69-5.1	Scaffold Meadow Tourist Pasture	1643	1942	85	no diff		65	40.66	0.08	
2006	69-5.1	Scaffold Meadow Tourist Pasture	2219	2342	95	no diff		65	35.14	0.03	
2007	69-5.1	Scaffold Meadow Tourist Pasture	2240	2385	94	no diff		65	36.45	0.07	
2008	69-5.1	Scaffold Meadow Tourist Pasture	2077	1823	114	no diff		65	38.16	NA	
2009	69-5.1	Scaffold Meadow Tourist Pasture	1523	1870	81	diff	C<R	65	52.64	NA	7,965
2002	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	952	1099	87	no diff		65	16.17	0.15	
2003	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	942	1455	65	diff	C<R	65	3.58	0.04	
2004	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	625	1002	62	diff	C<R	65	32.55	0.15	
2005	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	667	1762	38	diff	C<R	65	3.04	0.21	
2006	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	1036	2214	47	diff	C<R	65	8.77	0.09	10,650
2007	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	1353	1603	84	no diff		65	0.00	0.12	
2008	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	1686	1550	109	no diff		65	3.76	NA	
2009	71-1.2/1.3	Austin Camp Creek Crossing/Trail Crew Camp	756	1636	46	diff	C<R	65	6.08	NA	
2004	80-3	Tyndall Creek	546	846	65	diff	C<R	65	12.04	0.46	
2005	80-3	Tyndall Creek	669	637	105	no diff		65	6.88	0.61	

Year	Meadow no.	Meadow name	Core (grazed) biomass	Reference (ungrazed) biomass	% difference (core / reference)	Core and reference significantly different?	Direction of difference	Residual biomass standard	AUN/acre	Snow covered area	elevation (ft)
2006	80-3	Tyndall Creek	717	744	96	no diff		65	4.68	0.50	
2007	80-3	Tyndall Creek	516	860	60	diff	C<R	65	14.32	0.32	
2008	80-3	Tyndall Creek	1049	1296	81	diff	C<R	65	7.54	NA	
2009	80-3	Tyndall Creek	671	582	115	no diff		65	6.52	NA	
2003	80-5.1	Lake South America	17	307	6	diff	C<R	75	0.60	0.58	11,950
2004	83-4	Upper Crabtree	274	852	32	diff	C<R	75	7.17	0.34	
2005	83-4	Upper Crabtree	542	748	73	diff	C<R	75	1.87	0.46	
2007	83-4	Upper Crabtree	292	954	31	diff	C<R	75	9.33	0.16	10,460
2008	83-4	Upper Crabtree	299	642	47	diff	C<R	75	6.68	NA	
2009	83-4	Upper Crabtree	385	342	113	no diff		75	7.30	NA	
2003	83-7	Lower Whitney Creek	494	572	86	no diff		65	0.00	0.15	9,950
2002	83-8	Sandy	716	576	124	no diff		65	5.09	0.40	
2003	83-8	Sandy	901	745	121	no diff		65	2.61	0.34	
2004	83-8	Sandy	772	1141	68	diff	C<R	65	3.49	0.31	
2005	83-8	Sandy	952	1365	70	diff	C<R	65	4.17	0.46	
2006	83-8	Sandy	1571	1473	107	no diff		65	5.19	0.39	10,620
2007	83-8	Sandy	1805	912	198	diff	R<C	65	1.33	0.17	
2008	83-8	Sandy	814	828	98	no diff		65	8.97	NA	
2009	83-8	Sandy	814	932	87	no diff		65	6.10	NA	
2001	84-2	Lower Rock Creek Crossing	1144	745	153	no diff		65	0.29	NA	
2002	84-2	Lower Rock Creek Crossing	319	964	33	diff	C<R	65	5.38	0.12	
2003	84-2	Lower Rock Creek Crossing	481	901	53	diff	C<R	65	5.73	0.09	
2004	84-2	Lower Rock Creek Crossing	463	1086	43	diff	C<R	65	2.73	0.13	
2005	84-2	Lower Rock Creek Crossing	621	1306	48	diff	C<R	65	9.00	0.13	9,656
2006	84-2	Lower Rock Creek Crossing	1352	1666	81	no diff		65	9.21	0.10	
2007	84-2	Lower Rock Creek Crossing	1278	998	128	no diff		65	3.95	0.10	
2008	84-2	Lower Rock Creek Crossing	922	876	105	no diff		65	6.60	NA	
2009	84-2	Lower Rock Creek Crossing	742	677	110	no diff		65	10.32	NA	
2002	85-8.1	Rock Creek Lake	230	196	118	no diff		75	0.00	0.38	
2003	85-8.1	Rock Creek Lake	236	222	106	no diff		75	1.16	0.37	10,498

Year	Meadow no.	Meadow name	Core (grazed) biomass	Reference (ungrazed) biomass	% difference (core / reference)	Core and reference significantly different?	Direction of difference	Residual biomass standard	AUN/acre	Snow covered area	elevation (ft)
2004	85-8.1	Rock Creek Lake	65	120	54	no diff		75	4.12	0.40	
2005	85-8.1	Rock Creek Lake	263	227	116	no diff		75	1.60	0.51	
2006	85-8.1	Rock Creek Lake	281	357	79	no diff		75	0.33	0.45	
2007	85-8.1	Rock Creek Lake	812	437	186	diff	R<C	75	0.57	0.22	
2008	85-8.1	Rock Creek Lake	910	358	255	diff	R<C	75	0.46	NA	10,498
2009	85-8.1	Rock Creek Lake	769	621	124	no diff		75	0.54	NA	
2004	86-2	Upper Funston	1709	1852	92	no diff		65	21.15	0.17	
2005	86-2	Upper Funston	1324	1559	85	no diff		65	19.87	0.21	
2007	86-2	Upper Funston	1053	1536	69	diff	C<R	65	11.00	0.08	6,700
2008	86-2	Upper Funston	1290	1618	80	no diff		65	6.54	NA	
2009	86-2	Upper Funston	781	808	97	no diff		65	8.36	NA	
2004	86-5	Lower Funston	1450	2279	64	diff	C<R	65	15.96	0.12	
2005	86-5	Lower Funston	1223	3227	38	diff	C<R	65	42.31	0.22	
2006	86-5	Lower Funston	1236	3962	31	diff	C<R	65	28.77	0.18	6,480
2007	86-5	Lower Funston	1621	2293	71	diff	C<R	65	5.64	0.10	
2008	86-5	Lower Funston	1848	2089	88	diff	C<R	65	3.10	NA	
2009	86-5	Lower Funston	2238	3059	73	diff	C<R	65	0.00	NA	
2001	88-1	Lower Little 5 Lakes (Long Lake)	94	174	54	no diff		65	0.23	NA	
2002	88-1	Lower Little 5 Lakes (Long Lake)	325	333	97	no diff		65	1.34	0.61	10,420
2003	88-1	Lower Little 5 Lakes (Long Lake)	172	225	76	no diff		65	0.64	0.60	
2004	88-1	Lower Little 5 Lakes (Long Lake)	185	376	49	diff	C<R	65	0.00	0.58	
2001	89-5.2	Forester Lake	249	600	41	diff	C<R	65	0.00	NA	
2002	89-5.2	Forester Lake	234	440	53	diff	C<R	65	2.99	0.50	10,354
2004	89-5.2	Forester Lake	362	317	114	no diff		65	0.00	0.51	
2005	89-5.2	Forester Lake	356	523	68	no diff		65	0.00	0.60	
2001	90-10	South Fork Meadow	439	1051	42	diff	C<R	75	13.02	NA	
2003	90-10	South Fork Meadow	346	546	63	diff	C<R	75	27.28	0.04	
2004	90-10	South Fork Meadow	600	937	64	diff	C<R	75	9.63	0.08	8,515
2005	90-10	South Fork Meadow	886	1602	55	diff	C<R	75	11.23	0.10	
2008	90-10	South Fork Meadow	1033	1423	73	diff	C<R	75	0.94	NA	

Year	Meadow no.	Meadow name	Core (grazed) biomass	Reference (ungrazed) biomass	% difference (core / reference)	Core and reference significantly different?	Direction of difference	Residual biomass standard	AUN/acre	Snow covered area	elevation (ft)
2009	90-10	South Fork Meadow	507	940	54	diff	C<R	75	1.13	NA	8,560
2001	90-11	South Fork Pasture	719	954	75	no diff		75	14.40	NA	
2002	90-11	South Fork Pasture	441	556	79	no diff		75	24.22	0.07	
2003	90-11	South Fork Pasture	327	836	39	diff	C<R	75	14.80	0.02	
2004	90-11	South Fork Pasture	490	979	50	diff	C<R	75	3.77	0.08	
2006	90-11	South Fork Pasture	1063	1378	77	diff	C<R	75	2.83	0.06	
2008	90-11	South Fork Pasture	683	1225	56	diff	C<R	75	26.91	NA	
2009	90-11	South Fork Pasture	491	795	62	diff	C<R	75	29.34	NA	
2001	90-5.2	Hockett Pasture	427	1262	34	diff	C<R	65	3.63	NA	8,500
2002	90-5.2	Hockett Pasture	550	1117	49	diff	C<R	65	15.72	0.14	
2003	90-5.1	Hockett Meadow	370	529	70	diff	C<R	65	9.59	0.05	
2004	90-5.2	Hockett Pasture	749	808	93	no diff		65	11.49	0.08	
2005	90-5.2	Hockett Pasture	820	1211	68	diff	C<R	65	8.92	0.13	
2006	90-5.2	Hockett Pasture	1072	1186	90	no diff		65	11.79	0.09	
2007	90-5.2	Hockett Pasture	582	852	68	diff	C<R	65	12.85	0.08	
2008	90-5.2	Hockett Pasture	801	1074	75	no diff		65	2.42	NA	
2009	90-5.2	Hockett Pasture	289	771	38	diff	C<R	65	12.85	NA	

Table 2.2.3. Annual averages for the 25 residual biomass meadows: animal unit night (AUN) per acre, 2001-2009, and snow covered area, 2002-2007

Year	Average AUN/acre	Average snow covered area
2001	14.34	unknown
2002	15.15	0.32
2003	10.38	0.26
2004	18.21	0.26
2005	13.31	0.39
2006	13.03	0.28
2007	10.39	0.19
2008	14.46	unknown
2009	12.45	unknown

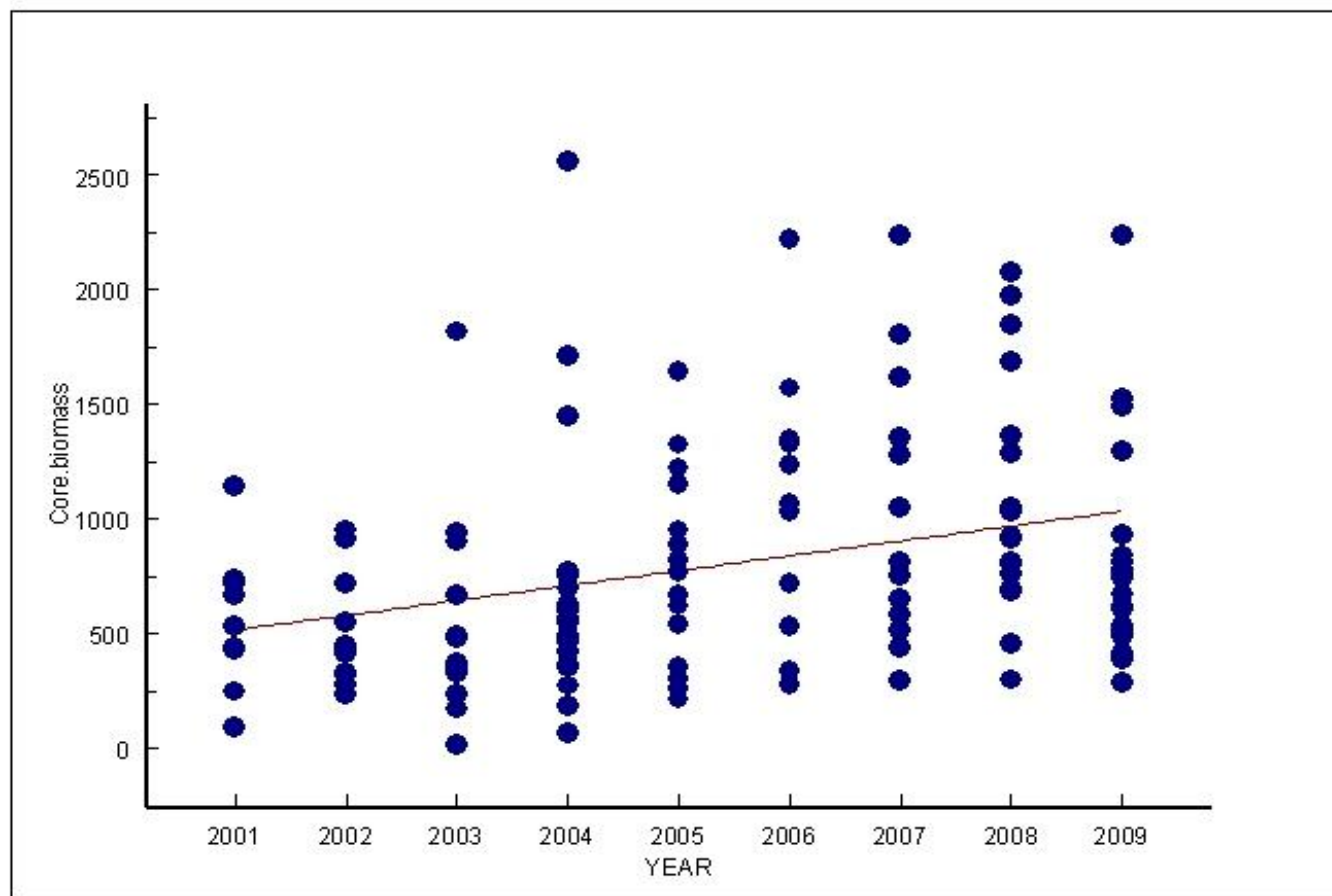


Figure 2.2.1. Residual biomass (lbs/acre) in core plots for 25 residual biomass meadows, 2001-2009, with fitted least-squares trend line ($r=0.319$). The increase in core biomass over time is significant at $p<.01$.

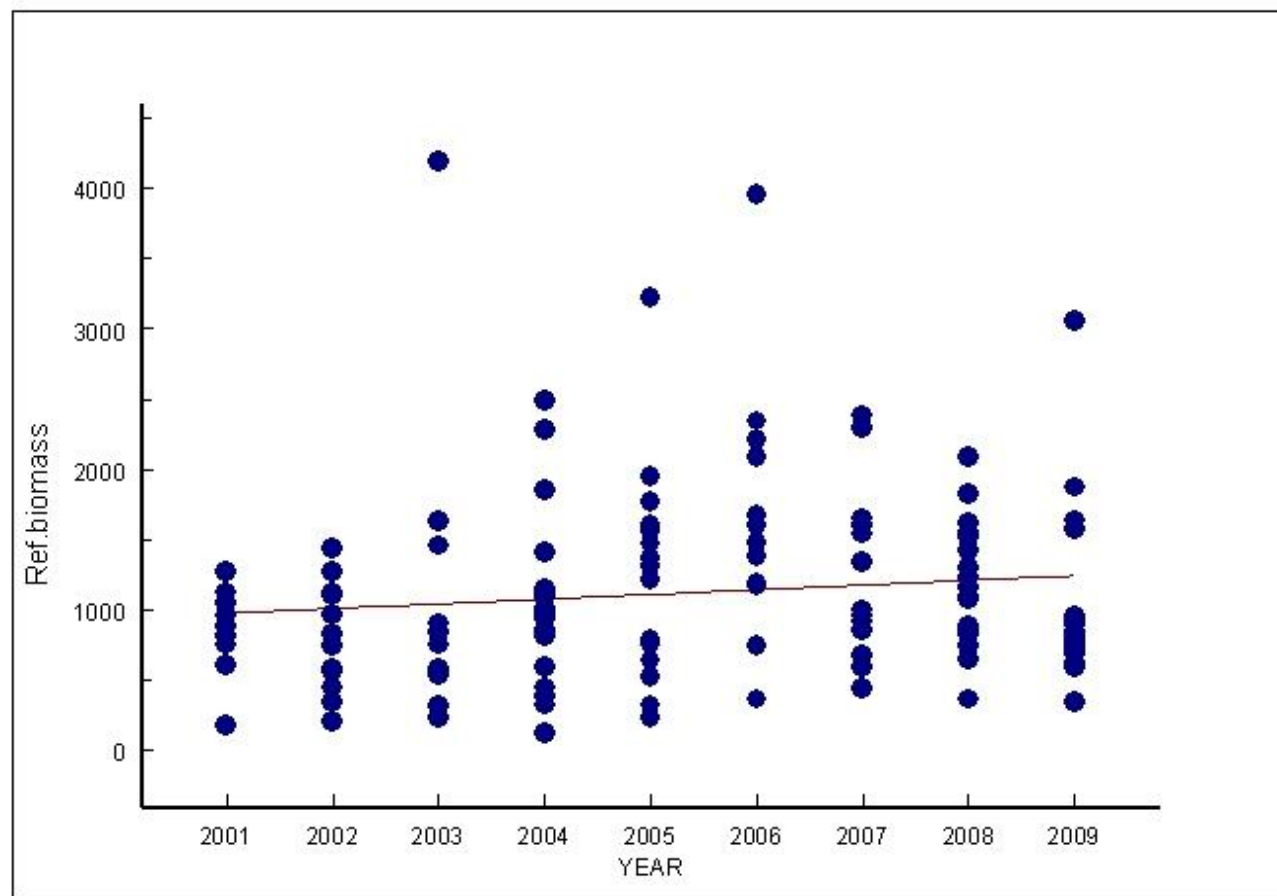


Figure 2.2.2. Residual biomass (lbs/acre) in reference plots for 25 residual biomass meadows, 2001-2009, with fitted least-squares trend line ($r=0.123$). This relationship is not statistically significant.

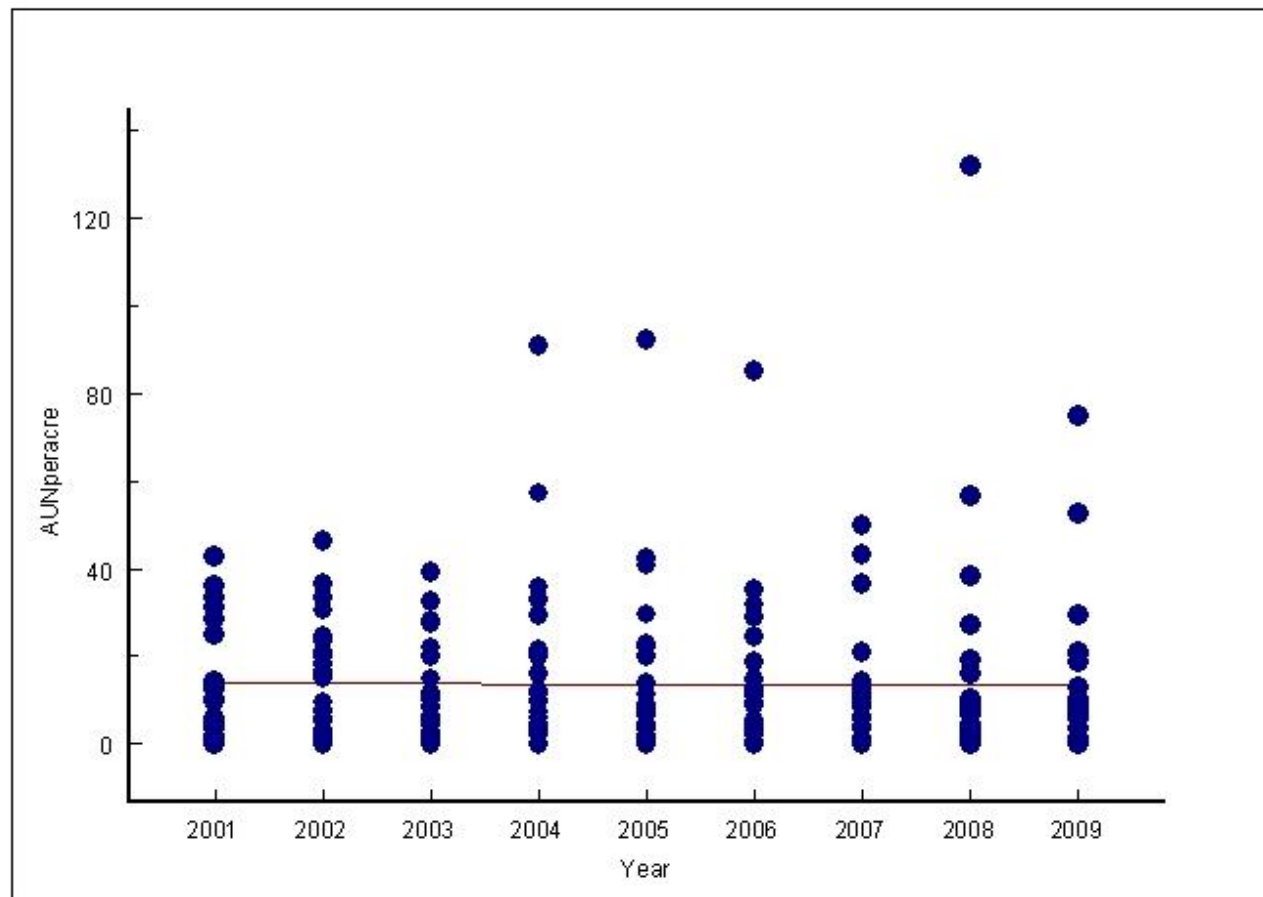


Figure 2.2.3. Animal Unit Nights (AUN) per acre, for 25 residual biomass meadows, 2001-2009, with fitted least-squares trend line ($r=0.001$). This relationship is not statistically significant.

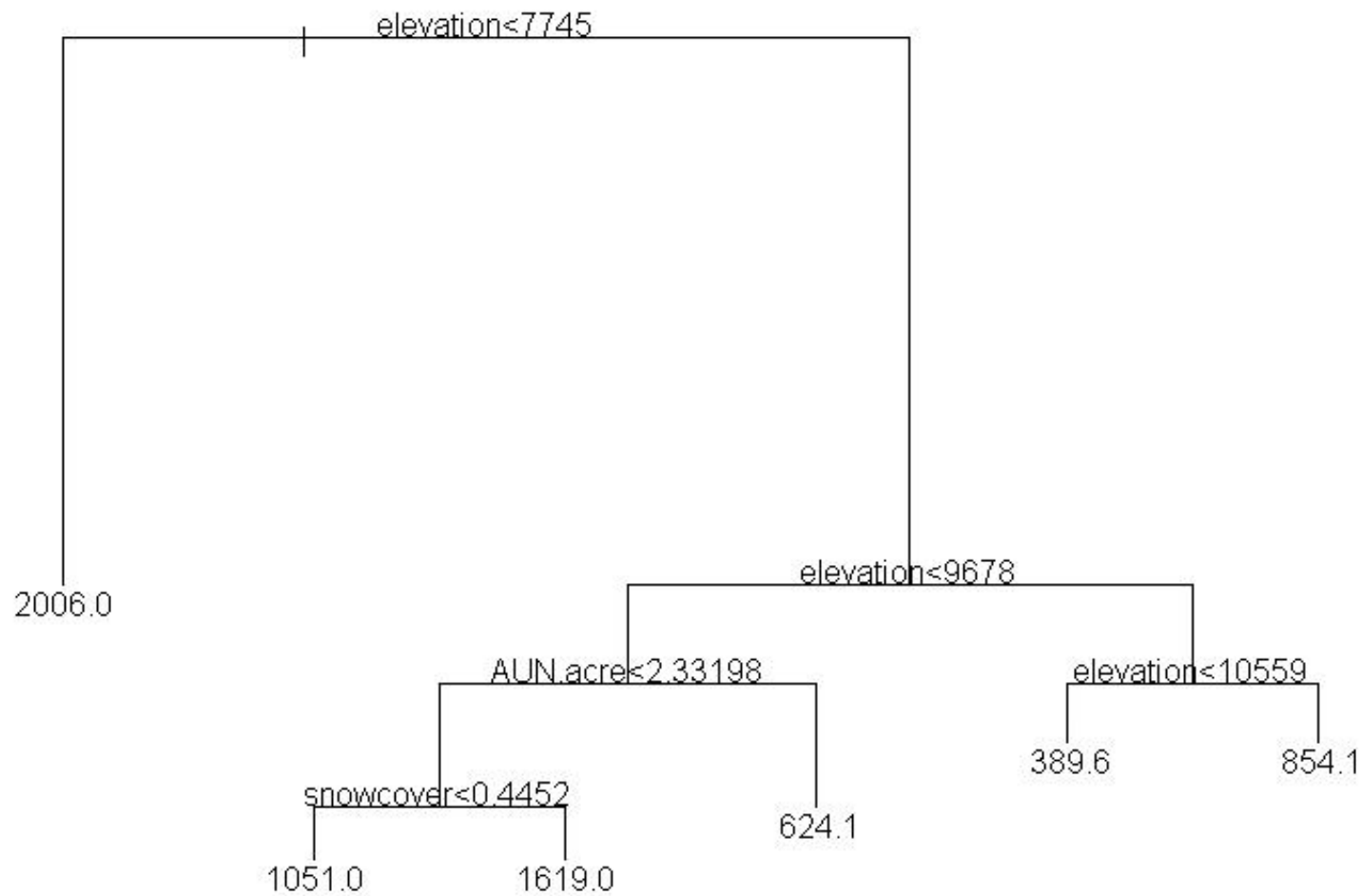


Figure 2.2.4. Six node regression tree for residual biomass (lbs/acre), using explanatory variables of elevation (ft), annual animal unit night (AUN) per acre, and proportion snow cover. Length of branches reflect proportion of total deviance explained by each split. Residual biomass per acre is number at ends of terminal branches.

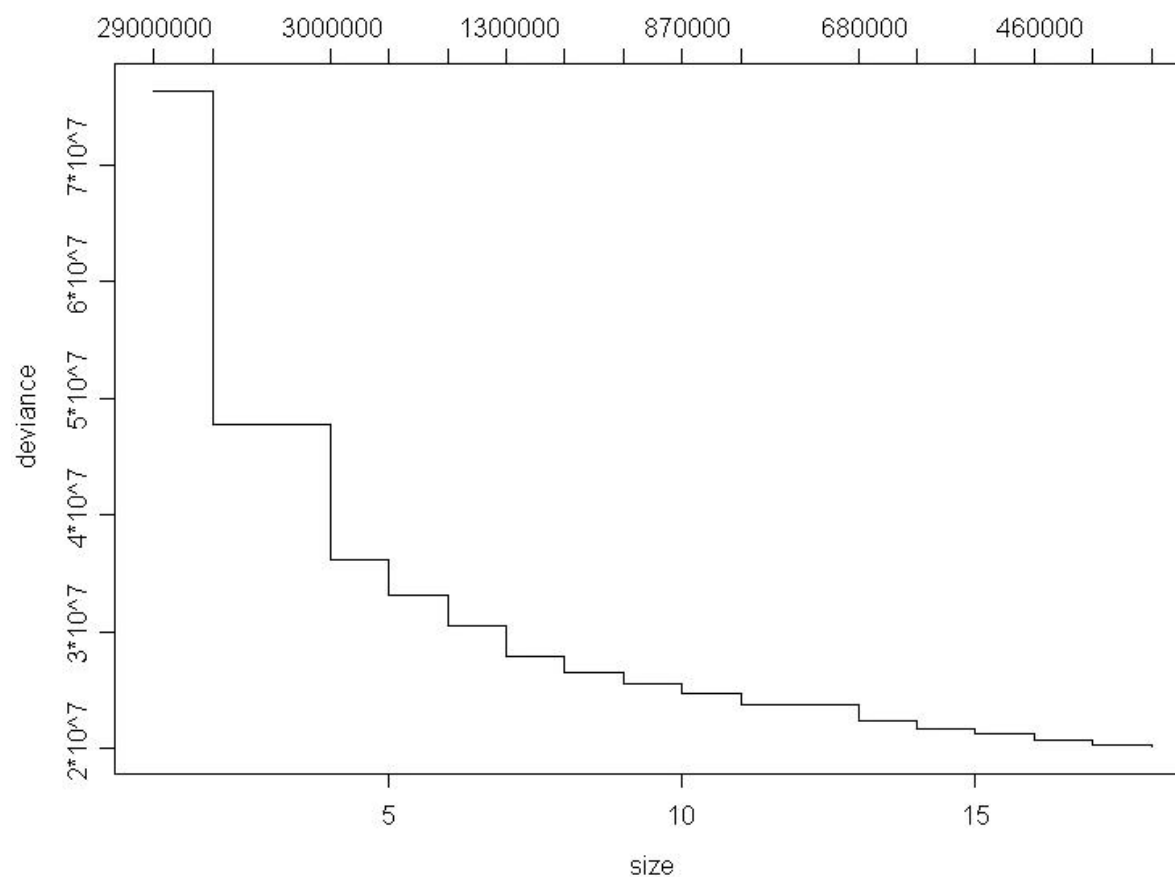


Figure 2.2.5. Residual deviance for residual residual biomass using sixteen nodes. The x-axis is size of the CART tree in number of terminal nodes, the y-axis is percent of the overall deviance remaining $\times 10^6$ (e.g., $3 \times 10^7 = 30$ percent). The values at the top of graph are the total deviance remaining at selected nodes.

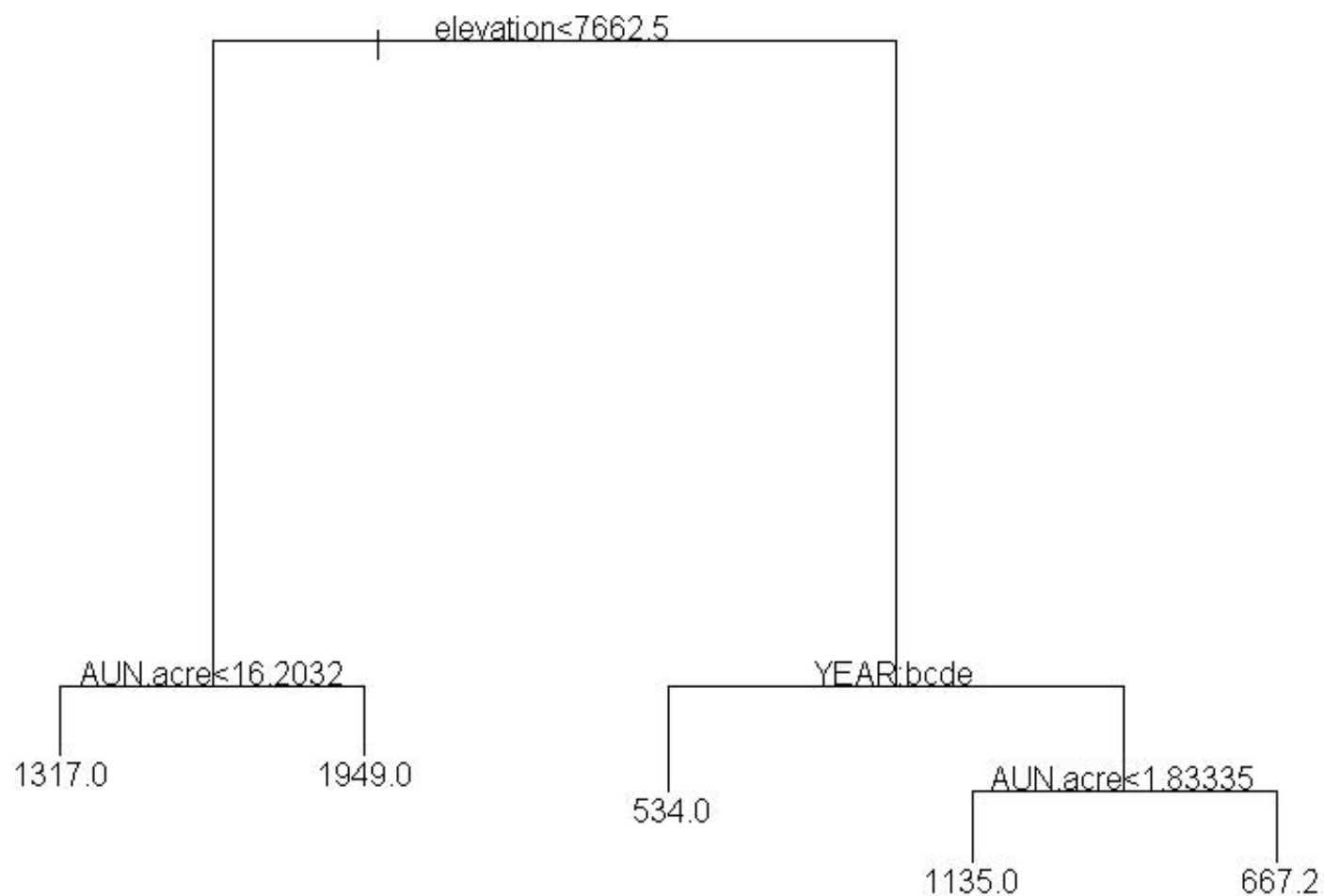


Figure 2.2.6. Regression tree for core residual biomass only (lbs/acre), using explanatory variables of elevation (ft), year, and annual animal unit night (AUN) per acre; year code: b=2002, c=2003, d=2004, e=2005. Length of branches reflect proportion of total deviance explained by each split. Residual biomass per acre is number at ends of terminal branches.

Section 2.3 SEKI meadows: paired grazed/ungrazed meadows species composition

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Introduction and meadow sampling methodology

To evaluate packstock grazing effects on plant species composition, SEKI staff has collected data on a set of five paired grazed-ungrazed meadows over the past twenty-five years (Table 2.3.1, Figure 2.3.1). The monitoring program collected data on the first meadow pair in 1985 and since then has initiated sampling on four other meadow pairs, resampling every pair on an approximately 5-year rotation (Table 2.3.1). Meadows pairs selected for monitoring represent several different meadow types, as described by DeBenedetti (1985: 32-37).

Table 2.3.1. Paired meadow species composition locations, vegetation types, and sampling dates

Meadow Pair	Forage/ meadow code	Vegetation type	Sampling dates
East Lake			
East Lake Above Fence (grazed)	67-1	Medium sedge (<i>Carex scopulorum</i> var. <i>bracteosa</i>)-grass-herb	1991, 1994, 1999, 2004
East Lake Below Fence (ungrazed)	67-1		
Hockett Plateau			
Hockett (grazed)	90-5.1	Fine sedge (<i>Eleocharis pauciflora</i>)	1985, 1988, 1991, 1995, 2000, 2005, 2009
Mitchell (ungrazed)	90-7		
Lower Rock Creek			
Rock Creek Crossing (grazed)	84-2	Tall Grass (<i>Deschampsia cespitosa</i>) & sedge-herb	1987, 1990, 1993, 1998, 2003, 2008
Rock Creek Ranger Station (ungrazed)	84-1		
Upper Rock Creek			
Rock Creek Lake (grazed)	85-8	Fine grass (<i>Calamagrostis breweri</i>) and sedge-herb	1987, 1990, 1993, 1999, 2002, 2007
Rock Creek #2 (ungrazed)	85-9		
Monarch Divide			
Shorty's (grazed)	53-7	Wide sedge (<i>Carex utriculata</i>)- fine grass (<i>Calamagrostis breweri</i>)-herb	1989, 1992, 1996, 2001, 2006
Shorty's Bench (ungrazed)	none		

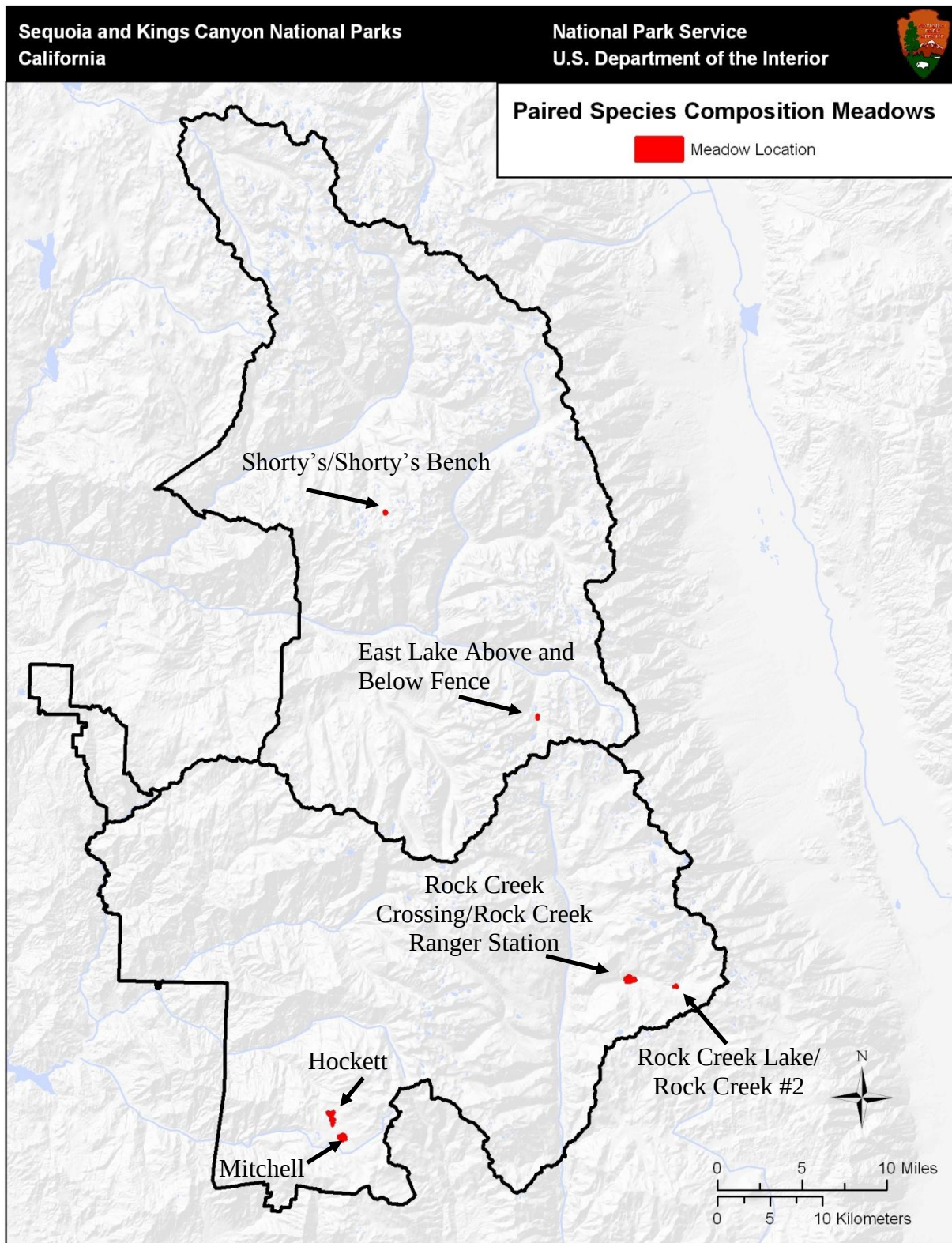


Figure 2.3.1. Paired grazed-ungrazed species composition meadows in Sequoia and Kings Canyon National Parks

The sampling scheme was developed by McClaran and Neuman (1989) and standard operating procedures are described in detail in Frenzel and Haultain (2010a) and McClaran and Neuman (1989). Briefly, a single large plot (approximately 500 to 3,000 m²) has been permanently established in the grazed and ungrazed meadows of each meadow pair. Each plot is divided into 10 to 15 equal subareas; within these 10-15 subareas, 10 to 20 25x25 cm quadrats are haphazardly located during the sampling event, for a total of 100 to 200 quadrats per meadow. The number of quadrats is determined by the vegetation type and is the same for all sampling years for a given meadow. All species rooted within the quadrat are recorded, as are the presence of moss and hoof prints greater than 2.5 cm deep; percentage of bare ground within the quadrat is also recorded. The same data are collected for a 10x10 cm quadrat nested within the 25x25 cm quadrat. The resulting metric is a species' frequency of occurrence in the 100-200 quadrats of each large plot (e.g., in 2008, *Deschampsia cespitosa* occurred in 65 of the 100 quadrats at Rock Creek Crossing so its frequency for that meadow in that year is 0.65).

Analytic techniques

As of 2009, the 10 paired meadow plots have been sampled between 4 and 7 times for a total of 56 plot-years (Table 2.3.1). SEKI staff have exhaustively assessed the dataset and corrected all observed errors when possible (Frenzel and Haultain 2010b). Noting that 2004 and 2005 data were not collected for the 10x10 cm quadrats and following Abbott et al.'s (2003: 45) reasoning about the limited additional data from the smaller quadrat size, we used only the 25x25 cm quadrat data for these analyses. We further trimmed the data by eliminating all unknown taxa from a single sampling event with less than 5% frequency (a total of 37 records) and several moss entries with frequency recorded as 0 or blank cell (a total of 6 records).

Frequency of hoofprints greater than 2.5 cm deep averaged over the entire sampling period was compared for each meadow pair's grazed and ungrazed meadows using 2-tailed t-tests, assuming unequal variances. Percent cover of bare ground within the quadrat averaged over the entire sampling period was compared for each meadow pair's grazed and ungrazed meadows using 2-tailed t-tests, assuming unequal variances.

We checked the meadow pairs' species list for any non-native plant species and evaluated whether non-natives were more frequent in grazed meadows.

To look at community composition patterns and grazing-related patterns in the data, we first turned to the ordination technique, detrended correspondence analysis (DCA), using PC-ORD, version 5 (MjM Software Design, Gleneden Beach, OR). DCA places plots at certain points along undefined axes based on patterns of species composition and frequencies found in those plots (McCune and Grace 2002). Two plots with similar species composition and frequency will be closer to each other than to other plots that are less similar. In other words, DCA separates plots that are different in species composition and species frequency. Each plot can be also coded for treatment type, although this information does not influence the DCA algorithm; DCA graphs may then reveal treatment patterns. DCA is an indirect gradient analysis technique: axes may represent environmental gradients as revealed by species distributions. Our DCA found structure in the data for 3 axes. We report for the first 2 axes, as the 3rd axis explained only a minor percentage of the variance. The r^2 values we report for the first 2 axes may be interpreted as the proportion of variance in the data represented by each axis (McCune and Grace 2002).

We also evaluated individual species' relations to the DCA; those species important in differentiating plot groups were examined. We also used these DCA species-axis correlation graphs to determine whether any species seemed to occur only or primarily in the ungrazed or in the grazed meadows.

Using the DCA axis 1 and axis 2 scores (i.e., the plot/year coordinates in ordination space; scores for each axis were standardized), we analyzed whether there were significant differences in temporal change between the grazed meadows and the ungrazed meadows. For each meadow, we determined the Euclidian distance in ordination space between a plot/year and the following plot/year (e.g., between Hockett 1985 and Hockett 1988, Hockett 1988 and Hockett 1991, Hockett 1991 and Hockett 1995, etc.). This provided 3 to 6 temporal distances for each meadow. The average temporal distance for each meadow was compared to the average temporal distance for its paired meadow, using 2-tailed t-tests, assuming unequal variances. We also determined the temporal distance between a meadow's first plot/year and its last plot/year. The average first to last distance for all grazed meadows was compared to the average first to last distance for all ungrazed meadows, using 2-tailed t-tests, assuming unequal variances.

We also employed another ordination technique, non-metric multidimensional scaling (NMDS), using PRIMER, version 6 (PRIMER-E, Ivybridge, England). Like DCA, NMDS is an indirect gradient analysis technique, but it makes fewer assumptions about data distributions and dissimilarity relationships between samples (Clarke and Warwick 2001). Stress values provide information on the quality of the ordination. We also performed a cluster analysis and an analysis of similarity (ANOSIM), using PRIMER. A cluster analysis provides information complementary to the NMDS results and can help in interpretation of plot groupings (Clarke and Warwick 2001). An ANOSIM tests the null hypothesis that there are no differences between groups; in this case, the two groups that we evaluated were the grazed meadows and the ungrazed meadows. The ANOSIM provides a test statistic, *R*, which is a measure of the degree of separation between groups that generally falls between 0 and 1, along with a significance level for the test statistic (Clarke and Warwick 2001). We ran the ANOSIM for 999 permutations.

Residual biomass data were collected in the grazed meadows of four of the five meadow pairs (all but Shorty's) as part of a separate residual biomass monitoring program. Residual biomass data are collected by SEKI staff in a designated "core" (grazed) area and a "reference" (ungrazed) area in each meadow. Annual estimates of residual biomass are compared for core and reference area of a meadow, based on overlapping 95% confidence intervals. Please see the residual biomass monitoring analysis section for further details on the analytic methods.

Results

The detrended correspondence analysis resolved for 3 axes. The cumulative r^2 value for axes 1 and 2 was 0.64, which is a high value for complex ecological data of this type (Table 2.3.2). Figure 2.3.2 shows the graph for axes 1 and 2; see Table 2.3.3 for meadow codes in the figures. Each meadow is more similar to the other meadow in the pair than to meadows in other pairs. The Hockett/Mitchell meadow pair differs from each other more than other pairs differ from each other.

We hypothesize that axis 1 may represent a moisture gradient, from wet (left) to mesic (i.e., still wet but less so; right). *Mimulus primuloides* ssp. *primuloides*, an indicator of wet meadows (Allen-Diaz 1991), was present in all meadow pairs except Hockett/Mitchell, suggesting all the meadows are at least moderately wet. *Eleocharis pauciflora*, found in wet meadows (Allen-Diaz 1991), pulled plots to axis 1's left (Figure 2.3.3). *Deschampsia cespitosa*, typically found in areas that are only moderately wet (Allen-Diaz 1991), pulled plots to axis 1's right (Figure 2.3.4). *Poa pratensis* and *Potentilla gracilis*, other species associated with drier meadow types (Allen-Diaz 1991), also pulled plots to axis 1's right (Table 2.3. 4). In addition, *Achillea millefolium*, commonly found in upland areas, pulled plots to axis 1's right (Table 2.3.4).

Environmental correlates with axis 2 are unknown but differentiated Hockett/Mitchell at the lower end from Shorty's/Shorty's Bench at the top. *Calamagrostis breweri* pulled axis 2 at the top (Figure 2.3.5), and *Carex illota* and *Carex utriculata* differentiated Shorty's/Shorty's Bench from other plots.

Hockett/Mitchell were differentiated by the presence of the following species:

Antennaria corymbosa

Danthonia intermedia

Ivesia lycopodioides ssp. *megalopectala*

Polygonum bistortoides

Spiranthes romanzoffiana

and the absence of *Mimulus primuloides* ssp. *primuloides*.

Table 2.3.4 presents DCA species-axis correlation coefficients for those species which differentiated meadow pairs or individual meadows; these species' correlation coefficients were generally > 0.5.

Table 2.3.2. r^2 values for SEKI paired meadows species composition detrended correspondence analysis

Axis	Increment	Cumulative
1	.359	.359
2	.282	.641
3	.045	.687

The DCA species-axis correlation graphs did not indicate that any species occurred primarily in the ungrazed or in the grazed meadows. The broad taxon "moss," a potential indicator of grazing use (Dull 1999), was ubiquitous (Figure 2.3.6). The average frequency of "moss" in all grazed plot/years was 0.48 and in all ungrazed plot/years was 0.44; this difference was not statistically significantly different ($p=0.68$; 2-tailed t-test, assuming unequal variances).

Table 2.3.3. Species composition paired meadow figure codes and grazing status

Meadow code in figures	Meadow name	Grazing status
ELA	East Lake Above Fence	grazed
ELB	East Lake Below Fence	ungrazed
HOC	Hockett	grazed
MIT	Mitchell	ungrazed
RCX	Rock Creek Crossing	grazed
RCR	Rock Creek Ranger Station	ungrazed
RCL	Rock Creek Lake	grazed
RC2	Rock Creek #2	ungrazed
SHO	Shorty's	grazed
SHB	Shorty's Bench	ungrazed

Although all the meadow pairs except Shorty's/Shorty's Bench exhibited greater average temporal distance for the grazed meadow than the ungrazed meadow, none of the grazed-ungrazed meadow pairs showed statistically significant differences in average temporal distance (p-values ranged from 0.17 to 0.76; Table 2.3.5). Similarly, average first to last distance for all grazed meadows (16.4) was not statistically significantly different from the average first to last distance for all ungrazed meadows (14.8; p-value = 0.78).

Table 2.3.5. Average temporal distance for meadows, with t-test p-value for each pair (2-tailed, assuming unequal variances)

Meadow name	Grazing status	Average temporal distance	t-test p-value
East Lake Above Fence	grazed	13.1	0.29
East Lake Below Fence	ungrazed	7.3	
Hockett	grazed	19.2	0.48
Mitchell	ungrazed	15.3	
Rock Creek Crossing	grazed	21.0	0.17
Rock Creek Ranger Station	ungrazed	10.8	
Rock Creek Lake	grazed	14.0	0.71
Rock Creek #2	ungrazed	12.3	
Shorty's	grazed	11.7	0.76
Shorty's Bench	ungrazed	13.0	

Non-metric multidimensional scaling produced a stress value of 0.15 for the 2-dimensional ordination; this stress value implies a good to fair ordination (Clarke and Warwick 2001). Like the DCA, the NMDS clustered each meadow in a pair closer to one another than to meadows in other pairs (Figure 2.3.7). Hockett/Mitchell were again the most segregated of the meadow pairs.

The cluster analysis, complementary to the NMDS, also grouped each pair of meadows together, at a similarity of just above 50 (Figure 2.3.8). Interestingly, the cluster analysis separated out the Rock Creek Crossing/Rock Creek Ranger Station pair to a slightly greater extent even than the Hockett/Mitchell pair; this differs from the DCA results. In addition, the cluster analysis differentiates Rock Creek Crossing from Rock Creek Ranger Station and Hockett from Mitchell to a greater extent than any other pair's meadows are differentiated. However, the grazed Rock Creek Crossing meadow and the ungrazed Rock Creek Ranger Station meadow are still more similar to one another than any pair is to any other pair; the same holds true for grazed Hockett and ungrazed Mitchell: they are more similar to one another than any pair is to any other pair (Figure 2.3.8). The cluster analysis overlay on the NMDS graph (Figure 2.3.7) shows that at 50% similarity level, Rock Creek Crossing and Rock Creek Ranger Station do not (quite) cluster, although all other pairs do. Again, the DCA graph does not show this level of differentiation for Rock Creek Crossing and Rock Creek Ranger Station (Figure 2.3.2).

The analysis of similarity (ANOSIM) for the meadows, separated into a grazed group and an ungrazed group, found very little difference between the two groups; the test statistic, $R = 0.024$, with a p -value of 0.155. The null hypothesis that there is no difference between the grazed meadow group and the ungrazed meadow group could not be rejected.

Frequency of hoofprints greater than 2.5 cm deep averaged over the entire sampling period was greater in each meadow pair's grazed meadow than its ungrazed meadow for all five meadow pairs (Table 2.3.6); the difference was only statistically significant (p -value < 0.05 ; 2-tailed t -tests, assuming unequal variances) in two of the meadow pairs, although another two pairs were weakly significant (p -value < 0.11 ; 2-tailed t -tests, assuming unequal variances; Table 2.3.6). Only East Lake Above Fence/East Lake Below Fence did not show a difference. In most years, grazed Rock Creek Crossing and grazed Rock Creek Lake had > 0.10 frequency of hoofprints; the other grazed meadows only exceeded 0.10 frequency in 1 or 2 years (Table 2.3.6). In the 1980s and 1990s, *ungrazed* Rock Creek #2 had hoofprint frequencies between 0.03 and 0.13, suggesting that substantial trespass grazing occurred despite the fact that Rock Creek #2 is closed to grazing; the two 2000s sampling events recorded no hoofprints. The other ungrazed meadows had hoofprint frequencies of 0 to 0.01 (East Lake Below Fence in 1999 had 0.03; Table 2.3.6).

Percent cover of bare ground averaged over the entire sampling period was never statistically significantly different for any of the meadow pairs' grazed and ungrazed meadows (p -values > 0.10 ; 2-tailed t -tests, assuming unequal variances; Table 2.3.7). In two meadow pairs, the grazed meadows had greater cover of bare ground; in two meadows, grazed and ungrazed meadows had about the same cover of bare ground; and in one meadow, the ungrazed meadow had greater cover of bare ground (Table 2.3.7). For the most part, temporal trends in cover were in the same direction for paired grazed and ungrazed meadows (Table 2.3.7).

Only three non-native plant species occurred on the species list from this dataset: *Poa pratensis* ssp. *pratensis*, *Spergularia rubra*, and *Taraxacum officinale* (there were four other potential non-natives: 3 *Agrostis* occurrences and 1 *Poa* occurrence; all four were found in only one year at very low frequencies). A suspect observation (Frenzel and Haultain 2010b), *Spergularia rubra* was noted in only one quadrat in grazed Hockett meadow in 1988. *Taraxacum officinale* was found in 5 of the 6 sample events at grazed Rock Creek Crossing; frequency has remained < 0.05 . *Poa pratensis* ssp. *pratensis* is the most widespread non-native species, found in 4 of the 5 meadow pairs (Table 2.3.8). At East Lake Above Fence/East Lake Below Fence, it occurred at very low frequency in both meadows in 1 or 2 of the most recent sampling events. At grazed Hockett, it has been found at very low frequency in several sampling events; it has not been found at ungrazed Mitchell. At Rock Creek Crossing/Rock Creek Ranger Station, it has occurred in both meadows at frequencies as high as 0.32; the grazed meadow has a slightly higher average frequency (0.13) than the ungrazed meadow (0.09), and no *Poa pratensis* ssp. *pratensis* was recorded in the ungrazed meadow during the most recent sampling event. Frequency of *Poa pratensis* ssp. *pratensis* was very low at Rock Creek Lake/Rock Creek #2, but it was recorded only during the first sampling event in the grazed meadow, while it has been found in 4 of the 6 sampling events in the ungrazed meadow.

Comparing residual biomass estimates for “core” (grazed) areas to those for “reference” (ungrazed) areas of 4 grazed meadows showed that, with one exception, differences tended to be non-significant (Table 2.3.9): East Lake Meadow showed no difference; Rock Creek Lake showed either no difference or higher residual biomass in the grazed area; and Lower Rock Creek Crossing Meadow showed significantly lower residual biomass in the grazed area but only from 2002-2005. The exception to these trends is Hockett Meadow (including Hockett Pasture). In 6 of the 9 years reported, residual biomass was significantly lower in the grazed area than the ungrazed area of Hockett Meadow. Average packstock use at Hockett Meadow was not notably greater than at the other three meadows (Table 2.3.9).

Discussion

The dominant species/functional groups used by Frenzel and Haultain (2010; Table 2.3.1) to classify the meadow pairs are supported by the detrended correspondence analysis (DCA) species-axis correlation graphs and coefficients as generally being important in separating out those meadow pairs (Table 2.3.2). Based on the DCA species-axis correlations, we propose that axis 1, which represents almost 40% of the variation in species composition, represents a moisture gradient, from wet to mesic (i.e., somewhat less wet). Environmental correlates with axis 2, which represents an additional ~30% of the variation in species composition, are unknown. Neither axis, however, appears correlated with grazing status.

Two previous reports have analyzed the species composition dataset for grazing effects: McClaran and Neuman (1989) and Abbott et al. (2003). The former report found no significant differences between the grazed and ungrazed meadows, while the latter found limited evidence for grazing effects in some meadow pairs. McClaran and Neuman (1989) designed the species composition monitoring methodology for SEKI and reported on the first years of data collection in one meadow pair, Hockett/Mitchell. The criterion used by McClaran and Neuman (1989) to determine whether grazing was having a significant effect on meadow vegetation was a 15% or greater change in the frequency of any plant species between sampling dates. McClaran and

Neuman (1989) found that three species had changed by more than 15% in Hockett/Mitchell: one species decreased on both meadows, one species increased on the grazed meadow, and one species decreased on the ungrazed meadow; they concluded that packstock grazing did not appear to cause effects that exceeded the criterion for change.

Although focusing primarily on the residual biomass dataset, Abbott et al. (2003) also analyzed the species composition dataset, 1985-2001. For Hockett/Mitchell, they found no changes of >15% that they could attribute to packstock grazing. They did identify some species that were at consistently higher or lower frequencies on Hockett or Mitchell that they hypothesized might represent grazing effects; however, the differences may also represent underlying spatial variation. They found no significant differences in trends in Rock Creek Lake/Rock Creek #2. At Rock Creek Crossing/Rock Creek Ranger Station, Abbott et al. (2003) suggested grazing may have caused declining trends observed in *Deschampsia cespitosa* and *Carex fissuricola* on the grazed meadow that did not occur on the ungrazed meadow. They also noted several species that were at consistently higher frequencies on the grazed or ungrazed meadow. Again, such differences may represent a grazing effect or underlying spatial variation. The species that were at consistently different frequency levels at Rock Creek Crossing/Rock Creek Ranger Station were not the same as those at Hockett/Mitchell. East Lake Above Fence/East Lake Below Fence exhibited no changes clearly attributable to packstock grazing. Abbott et al. (2003) noted several species that were at consistently higher frequencies on the grazed or the ungrazed meadow, two of which, *Luzula oresteria* and *Eleocharis pauciflora*, exhibited the same characteristic at Rock Creek Crossing/Rock Creek Ranger Station, and one of which, *Aster alpigenus* var. *andersonii*, showed a similar characteristic at Hockett/Mitchell. At Shorty's/Shorty's Bench, Abbott et al. (2003) found that *Eleocharis pauciflora* and *Mimulus primuloides* showed overall trends that appeared to be influenced by grazing status, but variation between each sampling year made the case for grazing influence less clear.

The most suggestive result from Abbott et al. (2003)'s analysis is the apparent preference of *Eleocharis pauciflora* for ungrazed meadows, although interannual trends were not always different between grazed and ungrazed meadows. Although the DCA species-axis correlation graph for *Eleocharis pauciflora* did not appear to differentiate grazed and ungrazed plots (Figure 2.3.3), the frequency data for 1985-2009 showed that Abbott et al. (2003)'s observation about the species remained largely valid in the years following their analysis (Table 2.3.10). Rock Creek Crossing/Rock Creek Ranger Station are an anomaly in that the grazed meadow had higher frequency of *Eleocharis pauciflora* in most years. Also, grazed Shorty's had a very high frequency of the species in 2006. The potential value of *Eleocharis pauciflora* as a grazing indicator species warrants further research.

Abbott et al. (2003) also carried out a successional stage analysis, which took more of a community-level approach to their evaluation of the species composition dataset. They found no changes in seral stage attributable to packstock grazing. Interestingly, almost without exception, all pairs' grazed meadows had a greater percentage of late seral species than their ungrazed meadows (Abbott et al. 2003: 54, Table 2.3.21).

Similar to the previous two reports, we could find very little evidence for grazing-related compositional differences in the 5 paired meadows. In none of the ordination analyses we ran did grazed and ungrazed meadows differentiate into groups (Figures 2.3.2 and 2.3.7). Although

each grazed and ungrazed pair is at least slightly separated, this may result from underlying spatial variation rather than grazing status.

Furthermore, if grazing had a strong effect on species composition, the effect would likely be cumulative, and a temporal directional trend should be evident in the ordination graphs (Figures 2.3.2 and 2.3.7). There is no clear temporal trend, with one possible exception: in the DCA, the grazed meadow East Lake Above Fence moves primarily in a single direction in ordination space, viz. to the right, along axis 1 (Figure 2.3.2); this may represent a drying trend (see discussion of axis 1, above). The other meadows show no such directional trends, and meadows within a pair follow the same general temporal trends in ordination space. The NMDS does not show any clear directional trends in ordination space (Figure 2.3.7).

It should be noted that based on a five year grazing experiment in mountain meadows in Yosemite National Park, Cole et al. (2004) concluded that when grazing impact is light, species composition change is a less sensitive indicator of meadow condition than changes in productivity and ground cover. Therefore, the lack of strong differences in species composition between grazed and ungrazed meadow pairs may not definitively demonstrate that packstock grazing has had no effect on the meadows.

Initial evaluation of the DCA and the NMDS ordination graphs suggested that grazed meadows may show greater temporal variation as measured by a meadow's movement in ordination space from sampling event to sampling event. However, this did not prove to be the case, as none of the paired grazed-ungrazed meadows showed statistically significant differences in average temporal distance nor did average first to last distance differ for all grazed meadows compared to that for all ungrazed meadows.

The DCA revealed no species that appeared to serve as an "indicator" of grazed or ungrazed meadows, i.e., no species appeared only in all or most grazed or ungrazed meadows (though note the above discussion of *Eleocharis pauciflora*). Cryptogamic crusts have been proposed as sensitive indicators of livestock grazing (Jones 2000; Memmott et al. 1998). A local example of this is Dull's work (1999) in a southern Sierra Nevada montane meadow. Dull (1999) evaluated stratigraphic pollen records covering the last 150 years for evidence of vegetation changes following the widespread introduction of livestock to the region. He found that pollen from a liverwort, *Riccia*, decreased dramatically in the period after livestock grazing was initiated and proposed that cryptogamic crusts formed by mosses and liverworts likely disappeared from his site due to the direct (e.g., grazing, trampling) and indirect (e.g., stream incision and lowered water table) effects of livestock. Although the SEKI species composition sampling does not collect data on any specific species of non-vascular plants, frequency of the broad taxon "moss" is collected and may serve as a proxy for cryptogamic crusts generally. In the SEKI paired meadows, "moss" showed no evidence of grazing effects; it was ubiquitous (Figure 2.3.6) and occurred at essentially the same average frequency in grazed and ungrazed meadows.

Perhaps unsurprisingly, frequency of hoofprints greater than 2.5 cm deep tended to be greater in each meadow pair's grazed meadow than its ungrazed meadow for all five meadow pairs, but the difference was only statistically significant in two of the meadow pairs. One of these two pairs, Rock Creek Crossing/Rock Creek Ranger Station, was the pair that the cluster analysis separated

out (although hoofprints were not part of the analysis); however, the cluster analysis did not separate out the other pair, Rock Creek Lake/Rock Creek #2. The presence of deep hoofprints is likely to result from a combination of packstock species and stocking rate, hydrology of the meadow, and actual saturation of the ground at any given point while packstock are present. In any event, regardless of hoofprint frequency, there is little evidence that vegetation is different between paired grazed and ungrazed meadows.

Percent cover of bare ground was never statistically significantly different for any of the meadow pairs' grazed and ungrazed meadows, and temporal trends in bare ground were generally in tandem for paired grazed and ungrazed meadows. Weather patterns and meadow hydrology, among other environmental variables, are likely to play significant roles in level of bare ground (Abbott et al. 2003). Cole et al. (2004) assert that indicators such as cover of bare ground are more sensitive indicators of meadow condition than species composition. If this holds true for SEKI meadows, the similarity in cover of bare ground for grazed and ungrazed meadow pairs suggests that current packstock use in the five meadow pairs is not excessive.

There are very few non-native plant species in the paired meadows, and for the most part they occur at very low frequencies. The exception is *Poa pratensis* ssp. *pratensis* in the Rock Creek Crossing/Rock Creek Ranger Station meadow pair. Most of the occurrences of non-natives occurred in grazed meadows, suggesting a potential link between packstock use and the introduction of non-native species. With the exception of *Poa pratensis* ssp. *pratensis*, once introduced, non-natives do not seem to increase in frequency. The frequency of *Poa pratensis* ssp. *pratensis* is not always higher in grazed meadows. The potential of packstock to serve as vectors for non-native species should be considered in managing packstock use, but given the low incidence of non-native species within the species composition plots despite decades of packstock use and before that livestock use, it seems possible that these five meadow pairs are resistant to non-native species.

Comparison of residual biomass estimates for “core” (grazed) areas to those for “reference” (ungrazed) areas of 4 of the 5 grazed meadows suggest that for East Lake Meadow, Rock Creek Lake, and Lower Rock Creek Crossing Meadow, packstock use levels are not excessive. Cole et al. (2004) found that for at least a year post-grazing, meadow productivity may be reduced. For these three meadows, in the last year for which data are available, 2009, there was no difference in residual biomass on grazed and ungrazed areas of the meadows (it should be noted that residual biomass is not a direct measure of productivity). For Hockett, however, residual biomass was generally significantly lower in the grazed area than the ungrazed area, including in 2009. This suggests that packstock use at Hockett may be excessive in some years, although the meadow has only fallen below the minimum recommended difference between grazed and ungrazed residual biomass (65%; Haultain 2008) in 3 of the 9 years reported (Table 2.3.9). Again, we could find no evidence that the lower residual biomass and higher packstock use at Hockett has caused permanent vegetation change. Both the DCA and the NMDS clustered Hockett vegetation in 1985 and 2008 (the first and most recent sampling events) together; ungrazed Mitchell exhibited a very similar pattern (Figures 2.3.2 and 2.3.7).

Conclusions and recommendations

We could find no strong evidence that current management of packstock use has resulted in vegetation change in the five meadow pairs sampled. The meadows in each meadow pair are more similar to one another than to any other meadow pair; grazed meadows do not cluster into a group, nor do ungrazed meadows. Because of the sampling design, any differences between each pair of grazed and ungrazed meadows could be due to pre-existing spatial variation. Temporal changes in vegetation do not seem to be greater in grazed meadows nor do they appear to be cumulative (with the possible exception of the East Lake Above Fence meadow). No species appears to serve as an “indicator” of grazing, not even the cryptogamic crust proxy, “moss”. Deep hoofprints tended to be more frequent in the grazed meadows, but this does not appear to have translated into large vegetational changes. Cover of bare ground does not differ between paired grazed and ungrazed meadows. Non-native plants are few in number and mostly at very low frequency. *Poa pratensis* ssp. *pratensis* does appear to have established in the Rock Creek Crossing/Rock Creek Ranger Station pair and may be more abundant in the grazed meadow.

Because species composition in the five meadow pairs does not appear to be strongly influenced by contemporary levels of packstock use, current management protocols regarding opening dates for packstock use, packstock numbers permitted, and residual biomass levels remaining at the end of the season could be formalized into packstock use standards for several classes of snowpack year (or some other annual weather-related variable) for the different meadow types these five pairs represent. Indeed, it may be that current management protocols would produce conservative standards. Any standards developed would require careful monitoring if applied to meadows other than the five pairs sampled; the sampling design limits easy extrapolation (McClaran and Neuman 1989: 9).

The sampling design for species composition is adequate for current monitoring purposes. Analysis of the data shows little evidence of packstock-driven change in species composition. As long as this situation continues, the sampling design suffices. The current method allows for feasible, practical data collection, given back-country logistical impediments and limited long-term resources.

For community analysis using ordination, data from the 25x25 cm quadrats are suitable. If, however, SEKI plans to analyze change in frequency of individual species, it is probably necessary to continue sampling both 10x10 cm and 25x25 cm quadrats. Frequency sampling works best when species' frequency values fall between 20% and 80% (Despain et al. 1991). Larger sized quadrats will include most species, including rare ones, but will result in almost 100% frequencies for common species, reducing one's ability to detect change in common species; smaller quadrats solve this problem but can miss rare species (Despain et al. 1991). Therefore, using multiple quadrat sizes will generate informative data for both rare and common species. Analysis of common species should employ data from the smaller quadrats, analysis of rare species the larger quadrats.

Because packstock grazing is not randomly assigned to meadows and because the meadow pairs are likely to be inherently somewhat different, the current sampling design cannot show whether grazing causes differences between grazed and ungrazed meadows. If significant differences

were observed between grazed and ungrazed meadows, a new sampling design would need to be implemented. To reveal causation, adequate sampling design would likely require more plots in individual meadows, with grazing or not grazing assigned to plots randomly. Given the variability in vegetation and environmental factors within a single meadow, determining grazing effects may prove difficult even if SEKI meadow sampling employed an experimental design. We recommend crossing this methodological bridge when (and if) SEKI comes to it.

Recommendations for future monitoring and research

The temporal length of the current dataset is valuable because it helps to control for normal temporal variation (Cole et al. 2004). In addition, it may prove useful in searching for evidence of climate change effects on SEKI meadow vegetation. We recommend continuing species composition sampling on the current meadow pairs. Expanding species composition sampling to other meadow types and other areas of SEKI not currently sampled would make the dataset more representative of SEKI's meadows.

A significant improvement to the species composition sampling effort would be the addition of coordinated residual biomass sampling on the species composition plots (or expanding species composition sampling to the residual biomass plots, as recommended by Abbott et al. (2003: 75)). If carefully planned and implemented, combining residual biomass sampling with species composition data would allow the development of defensible residual biomass standards, a goal of many Sierra Nevada land managers.

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Table 2.3.4. DCA species-axis correlation coefficients for those species which differentiated meadow pairs or individual meadows; Pearson's r is the linear correlation coefficient between axis and species; a negative r value pulls meadows to axis 1's left or down on axis 2; **species had $r < |0.5|$ but appeared important on the graphs

Species	No. of plot/years in which species occurs	Axis 1 r	Axis 2 r	Effect on DCA
<i>Achillea millefolium</i>	12	0.593		pulls axis 1 right, but RCX only
<i>Agrostis idahoensis</i>	39	0.785		pulls axis 1 right
<i>Antennaria corymbosa</i>	13		-0.571	differentiates Hockett/Mitchell
<i>Aster alpigenus</i> var. <i>andersonii</i>	56	-0.637	0.549	ubiquitous
<i>Aster occidentalis</i> var. <i>occidentalis</i>	32		-0.721	bimodal - Hockett and RCX only
** <i>Botrychium simplex</i>	32	-0.451		Mitchell only
<i>Carex athrostachya</i>	8		-0.605	Hockett only
<i>Carex aurea</i>	26	0.502		pulls axis 1 right, but also in Hockett
<i>Calamagrostis breweri</i>	40		0.720	pulls axis 2 up strongly
<i>Carex fissuricola</i>	18	0.579		pulls axis 1 right
<i>Carex illota</i>	10		0.588	differentiates Shorty's/Shorty's Bench
** <i>Carex scopulorum</i> var. <i>bracteosa</i>	18	0.406		differentiates East Lake
<i>Carex utriculata</i>	34		0.676	differentiates Shorty's/Shorty's Bench
<i>Danthonia intermedia</i>	19		-0.703	differentiates Hockett/Mitchell
<i>Deschampsia cespitosa</i>	17	0.736		differentiates RCRS/RCX
<i>Eleocharis pauciflora</i>	54	-0.636		occurs in most plots, but more heavily in Mitchell and Shorty's/Shorty's Bench
<i>Epilobium hallianum</i>	7		-0.536	Hockett only
<i>Epilobium oregonense</i>	16	0.592		pulls axis 1 right, but RCRS only
<i>Gentiana newberryi</i>	36	-0.524		Mitchell, Shorty's, RC2/RCL
** <i>Gnaphalium palustre</i>	4		-0.461	Hockett only but weak
** <i>Hordeum brachyantherum</i>	6	0.458		RCX only but weak

Species	No. of plot/years in which species occurs	Axis 1 r	Axis 2 r	Effect on DCA
<i>**Hypericum anagalloides</i>	14	0.297		differentiates East Lake
<i>Ivesia lycopodioides</i> ssp. <i>megalopetala</i>	14	-0.500	-0.769	differentiates Hockett/Mitchell
<i>Juncus balticus</i>	15	0.603		pulls axis 1 right
<i>Juncus nevadensis</i>	12	0.528		pulls axis 1 right
<i>Juncus orthophyllus</i>	25	0.685		pulls axis 1 right, but also in Hockett
<i>**Lewisia pygmaea</i>	8		-0.463	Hockett only but weak
<i>Mimulus primuloides</i> ssp. <i>primuloides</i>	55		0.566	Everywhere BUT Hockett/Mitchell
MOSS	50		0.445	ubiquitous
<i>Muhlenbergia filiformis</i>	55	0.691		ubiquitous
<i>Muhlenbergia richardsonis</i>	23		-0.603	Hockett only
<i>**Pedicularis attollens</i>	26		-0.480	Hockett/Mitchell and RCLake/RC2
<i>**Pedicularis groenlandica</i>	7	0.326		differentiates East Lake
<i>Perideridia parishii</i> ssp. <i>latifolia</i>	46		-0.825	Everywhere BUT Shorty's/Shorty's Bench
<i>Phleum alpinum</i>	35	0.659		pulls axis 1 right
<i>**Polygonum bistortoides</i>	7		-0.407	differentiates Hockett/Mitchell
<i>**Potentilla diversifolia</i> var. <i>diversifolia</i>	6		0.194	differentiates RC2
<i>Potentilla drummondii</i>	6		-0.583	Hockett only
<i>Potentilla gracilis</i>	12	0.694		pulls axis 1 right, but at low cover
<i>Poa pratensis</i> ssp. <i>pratensis</i>	23	0.609		pulls axis 1 right, but at low cover
<i>**Salix orestera</i>	14	0.313		weakly differentiates East Lake
<i>Spiranthes romanzoffiana</i>	17		-0.674	differentiates Hockett/Mitchell
<i>Stellaria longipes</i> var. <i>longipes</i>	35	0.624		pulls axis 1 right, but at low cover
<i>Trifolium monanthum</i> var. <i>monanthum</i>	34	0.678		pulls axis 1 right
<i>Trisetum spicatum</i>	31	0.602		pulls axis 1 right, but at low cover
<i>**Vaccinium caespitosum</i>	15	0.290		differentiates RCLake

Table 2.3.6. Frequency of hoofprints greater than 2.5 cm deep in species composition meadow pairs, 1985-2009; frequencies in red > 0.1

Meadow pair	Year	Meadow name	Grazing status	Frequency	Meadow name	Grazing status	Frequency	t-test
EastLake	1991	East Lake Above Fence	G	0.07	East Lake Below Fence	U	0.01	0.29
EastLake	1994	East Lake Above Fence	G	0.03	East Lake Below Fence	U	0	
EastLake	1999	East Lake Above Fence	G	0	East Lake Below Fence	U	0.03	
EastLake	2004	East Lake Above Fence	G	0.31	East Lake Below Fence	U	0.01	
Average frequency: grazed				0.10	Average frequency: ungrazed		0.01	
HockettPlateau	1985	Hockett	G	0.03	Mitchell	U	0.01	0.11
HockettPlateau	1988	Hockett	G	0.01	Mitchell	U	0	
HockettPlateau	1991	Hockett	G	0.04	Mitchell	U	0.01	
HockettPlateau	1995	Hockett	G	0	Mitchell	U	0	
HockettPlateau	2000	Hockett	G	0.11	Mitchell	U	0.01	
HockettPlateau	2005	Hockett	G	0.04	Mitchell	U	0.01	
HockettPlateau	2009	Hockett	G	0.24	Mitchell	U	0	
Average frequency: grazed				0.06	Average frequency: ungrazed		0.004	
LowerRockCreek	1987	Rock Creek Crossing	G	0	Rock Creek RS	U	0	0.03
LowerRockCreek	1990	Rock Creek Crossing	G	0	Rock Creek RS	U	0	
LowerRockCreek	1993	Rock Creek Crossing	G	0.16	Rock Creek RS	U	0	
LowerRockCreek	1998	Rock Creek Crossing	G	0.16	Rock Creek RS	U	0	
LowerRockCreek	2003	Rock Creek Crossing	G	0.15	Rock Creek RS	U	0	
LowerRockCreek	2008	Rock Creek Crossing	G	0.24	Rock Creek RS	U	0	
Average frequency: grazed				0.12	Average frequency: ungrazed		0	
MonarchDivide	1989	Shortys	G	0.05	Shortys Bench	U	0	0.05
MonarchDivide	1992	Shortys	G	0.18	Shortys Bench	U	0	
MonarchDivide	1996	Shortys	G	0.03	Shortys Bench	U	0	
MonarchDivide	2001	Shortys	G	0.09	Shortys Bench	U	0	
MonarchDivide	2006	Shortys	G	0.04	Shortys Bench	U	0	
Average frequency: grazed				0.08	Average frequency: ungrazed		0	

Meadow pair	Year	Meadow name	Grazing status	Frequency	Meadow name	Grazing status	Frequency	t-test
UpperRockCreek	1987	Rock Creek Lake	G	0.18	Rock Creek #2	U	0.09	0.10
UpperRockCreek	1990	Rock Creek Lake	G	0.11	Rock Creek #2	U	0.13	
UpperRockCreek	1993	Rock Creek Lake	G	0.27	Rock Creek #2	U	0.03	
UpperRockCreek	1999	Rock Creek Lake	G	0.26	Rock Creek #2	U	0.03	
UpperRockCreek	2002	Rock Creek Lake	G	0.03	Rock Creek #2	U	0	
UpperRockCreek	2007	Rock Creek Lake	G	0.01	Rock Creek #2	U	0	
Average frequency: grazed				0.14	Average frequency: ungrazed		0.05	

Table 2.3.7. Percent cover of bare ground in species composition meadow pairs, 1985-2009

Meadow pair	Year	Meadow name	Grazing status	Mean cover	Meadow name	Grazing status	Mean cover	t-test
LowerRockCreek	1987	Rock Creek Crossing	G	5.5	Rock Creek RS	U	1	0.57
LowerRockCreek	1990	Rock Creek Crossing	G	4.1	Rock Creek RS	U	6.9	
LowerRockCreek	1993	Rock Creek Crossing	G	3.6	Rock Creek RS	U	3.5	
LowerRockCreek	1998	Rock Creek Crossing	G	39.48	Rock Creek RS	U	28.1	
LowerRockCreek	2003	Rock Creek Crossing	G	13.79	Rock Creek RS	U	6.61	
LowerRockCreek	2008	Rock Creek Crossing	G	9.3	Rock Creek RS	U	5.4	
Average cover: grazed				12.6	Average cover: ungrazed			8.6
UpperRockCreek	1987	Rock Creek Lake	G	6.4	Rock Creek #2	U	4.8	0.82
UpperRockCreek	1990	Rock Creek Lake	G	11.7	Rock Creek #2	U	9.7	
UpperRockCreek	1993	Rock Creek Lake	G	8.8	Rock Creek #2	U	10.3	
UpperRockCreek	1999	Rock Creek Lake	G	15.23	Rock Creek #2	U	15.98	
UpperRockCreek	2002	Rock Creek Lake	G	7.02	Rock Creek #2	U	8.51	
UpperRockCreek	2007	Rock Creek Lake	G	15.95	Rock Creek #2	U	12.65	
Average cover: grazed				10.9	Average cover: ungrazed			10.3
MonarchDivide	1989	Shortys	G	3.61	Shortys Bench	U	10.91	0.20
MonarchDivide	1992	Shortys	G	5.71	Shortys Bench	U	16.1	
MonarchDivide	2001	Shortys	G	3	Shortys Bench	U	2.62	
MonarchDivide	2006	Shortys	G	2.45	Shortys Bench	U	5.03	
Average cover: grazed				3.7	Average cover: ungrazed			8.7
EastLake	1991	East Lake Above Fence	G	9.05	East Lake Below Fence	U	3.5	0.98
EastLake	1994	East Lake Above Fence	G	5.32	East Lake Below Fence	U	8.75	
EastLake	1999	East Lake Above Fence	G	9.98	East Lake Below Fence	U	13.94	
EastLake	2004	East Lake Above Fence	G	4.98	East Lake Below Fence	U	2.81	
Average cover: grazed				7.3	Average cover: ungrazed			7.3

Meadow pair	Year	Meadow name	Grazing status	Mean cover	Meadow name	Grazing status	Mean cover	t-test
HockettPlateau	1985	Hockett	G	9.3	Mitchell	U	7.1	0.12
HockettPlateau	1988	Hockett	G	6.6	Mitchell	U	6.9	
HockettPlateau	1991	Hockett	G	6.6	Mitchell	U	5.8	
HockettPlateau	1995	Hockett	G	8.53	Mitchell	U	2.39	
HockettPlateau	2000	Hockett	G	7.53	Mitchell	U	5.95	
HockettPlateau	2005	Hockett	G	1.22	Mitchell	U	1.04	
HockettPlateau	2009	Hockett	G	18.37	Mitchell	U	2.71	
Average cover: grazed				8.3	Average cover: ungrazed		4.6	

Table 2.3.8. Frequency of *Poa pratensis* ssp. *pratensis* in species composition meadow pairs, 1985-2009; frequencies in red > 0.03

Meadow pair	Meadow name	Grazing status	Year	Frequency
EastLake	East Lake above fence	G	1999	0.01
EastLake	East Lake above fence	G	2004	0.03
EastLake	East Lake below fence	U	1999	0.03
HockettPlateau	Hockett	G	1991	0.01
HockettPlateau	Hockett	G	1995	0.01
HockettPlateau	Hockett	G	2000	0.01
HockettPlateau	Hockett	G	2009	0.01
LowerRockCreek	Rock Creek Crossing	G	1987	0.01
LowerRockCreek	Rock Creek Crossing	G	1990	0.11
LowerRockCreek	Rock Creek Crossing	G	1993	0.10
LowerRockCreek	Rock Creek Crossing	G	1998	0.03
LowerRockCreek	Rock Creek Crossing	G	2003	0.32
LowerRockCreek	Rock Creek Crossing	G	2008	0.18
LowerRockCreek	Rock Creek RS	U	1987	0.03
LowerRockCreek	Rock Creek RS	U	1990	0.08
LowerRockCreek	Rock Creek RS	U	1993	0.12
LowerRockCreek	Rock Creek RS	U	1998	0.10
LowerRockCreek	Rock Creek RS	U	2003	0.18
UpperRockCreek	Rock Creek Lake	G	1987	0.01
UpperRockCreek	Rock Creek #2	U	1987	0.01
UpperRockCreek	Rock Creek #2	U	1993	0.02
UpperRockCreek	Rock Creek #2	U	1999	0.01
UpperRockCreek	Rock Creek #2	U	2007	0.03

Table 2.3.9. Residual biomass estimates in lbs/acre for 4 of the 5 grazed meadows; AUN=animal unit night; AUN data for Hockett Meadow from Hockett Pasture (90-5.2)

Year	Meadow no.	Meadow name	Core (grazed) biomass	Reference (ungrazed) biomass	% difference (core / reference)	Difference significant?	Direction of difference	AUN/acre	Average AUN/acre
2007	67-1	East Lake	441	586	75	no diff		43.30	24.1
2008	67-1	East Lake	1977	833	237	no diff		8.25	
2009	67-1	East Lake	412	598	69	no diff		20.88	
2001	84-2	Lower Rock Creek Crossing	1144	745	153	no diff		0.29	5.9
2002	84-2	Lower Rock Creek Crossing	319	964	33	diff	C<R	5.38	
2003	84-2	Lower Rock Creek Crossing	481	901	53	diff	C<R	5.73	
2004	84-2	Lower Rock Creek Crossing	463	1086	43	diff	C<R	2.73	
2005	84-2	Lower Rock Creek Crossing	621	1306	48	diff	C<R	9.00	
2006	84-2	Lower Rock Creek Crossing	1352	1666	81	no diff		9.21	
2007	84-2	Lower Rock Creek Crossing	1278	998	128	no diff		3.95	
2008	84-2	Lower Rock Creek Crossing	922	876	105	no diff		6.60	
2009	84-2	Lower Rock Creek Crossing	742	677	110	no diff		10.32	
2002	85-8.1	Rock Creek Lake	230	196	118	no diff		0.00	1.1
2003	85-8.1	Rock Creek Lake	236	222	106	no diff		1.16	
2004	85-8.1	Rock Creek Lake	65	120	54	no diff		4.12	
2005	85-8.1	Rock Creek Lake	263	227	116	no diff		1.60	
2006	85-8.1	Rock Creek Lake	281	357	79	no diff		0.33	
2007	85-8.1	Rock Creek Lake	812	437	186	diff	R<C	0.57	
2008	85-8.1	Rock Creek Lake	910	358	255	diff	R<C	0.46	
2009	85-8.1	Rock Creek Lake	769	621	124	no diff		0.54	
2001	90-5.2	Hockett Pasture	427	1262	34	diff	C<R	3.63	9.9
2002	90-5.2	Hockett Pasture	550	1117	49	diff	C<R	15.72	
2003	90-5.1	Hockett Meadow	370	529	70	diff	C<R	9.59	
2004	90-5.2	Hockett Pasture	749	808	93	no diff		11.49	
2005	90-5.2	Hockett Pasture	820	1211	68	diff	C<R	8.92	
2006	90-5.2	Hockett Pasture	1072	1186	90	no diff		11.79	
2007	90-5.2	Hockett Pasture	582	852	68	diff	C<R	12.85	

Year	Meadow no.	Meadow name	Core (grazed) biomass	Reference (ungrazed) biomass	% difference (core / reference)	Difference significant?	Direction of difference	AUN/acre	Average AUN/acre
2008	90-5.2	Hockett Pasture	801	1074	75	no diff		2.42	
2009	90-5.2	Hockett Pasture	289	771	38	diff	C<R	12.85	

Table 2.3.10. Frequency of *Eleocharis pauciflora* in species composition meadow pairs, 1985-2009

Meadow pair	Year	Meadow name	Grazing status	Frequency	Meadow name	Grazing status	Frequency
UpperRockCreek	1987	Rock Creek Lake	G	0.10	Rock Creek #2	U	0.11
UpperRockCreek	1990	Rock Creek Lake	G	0.04	Rock Creek #2	U	0.09
UpperRockCreek	1993	Rock Creek Lake	G	0.07	Rock Creek #2	U	0.17
UpperRockCreek	1999	Rock Creek Lake	G	0.19	Rock Creek #2	U	0.39
UpperRockCreek	2002	Rock Creek Lake	G	0.05	Rock Creek #2	U	0.12
UpperRockCreek	2007	Rock Creek Lake	G	0.00	Rock Creek #2	U	0.21
LowerRockCreek	1987	Rock Creek Crossing	G	0.05	Rock Creek RS	U	0.03
LowerRockCreek	1990	Rock Creek Crossing	G	0.04	Rock Creek RS	U	0.00
LowerRockCreek	1993	Rock Creek Crossing	G	0.15	Rock Creek RS	U	0.06
LowerRockCreek	1998	Rock Creek Crossing	G	0.35	Rock Creek RS	U	0.17
LowerRockCreek	2003	Rock Creek Crossing	G	0.04	Rock Creek RS	U	0.14
LowerRockCreek	2008	Rock Creek Crossing	G	0.11	Rock Creek RS	U	0.13
MonarchDivide	1989	Shortys	G	0.23	Shortys Bench	U	0.90
MonarchDivide	1992	Shortys	G	0.39	Shortys Bench	U	0.80
MonarchDivide	1996	Shortys	G	0.37	Shortys Bench	U	0.39
MonarchDivide	2001	Shortys	G	0.15	Shortys Bench	U	0.77
MonarchDivide	2006	Shortys	G	0.75	Shortys Bench	U	0.84
EastLake	1991	East Lake above fence	G	0.31	East Lake below fence	U	0.58
EastLake	1994	East Lake above fence	G	0.21	East Lake below fence	U	0.50
EastLake	1999	East Lake above fence	G	0.15	East Lake below fence	U	0.43
EastLake	2004	East Lake above fence	G	0.21	East Lake below fence	U	0.54
HockettPlateau	1985	Hockett	G	0.33	Mitchell	U	0.83
HockettPlateau	1988	Hockett	G	0.18	Mitchell	U	0.94
HockettPlateau	1991	Hockett	G	0.12	Mitchell	U	0.95
HockettPlateau	1995	Hockett	G	0.53	Mitchell	U	0.73
HockettPlateau	2000	Hockett	G	0.37	Mitchell	U	0.85
HockettPlateau	2005	Hockett	G	0.48	Mitchell	U	0.94

Meadow pair	Year	Meadow name	Grazing status	Frequency	Meadow name	Grazing status	Frequency
HockettPlateau	2009	Hockett	G	0.33	Mitchell	U	0.94

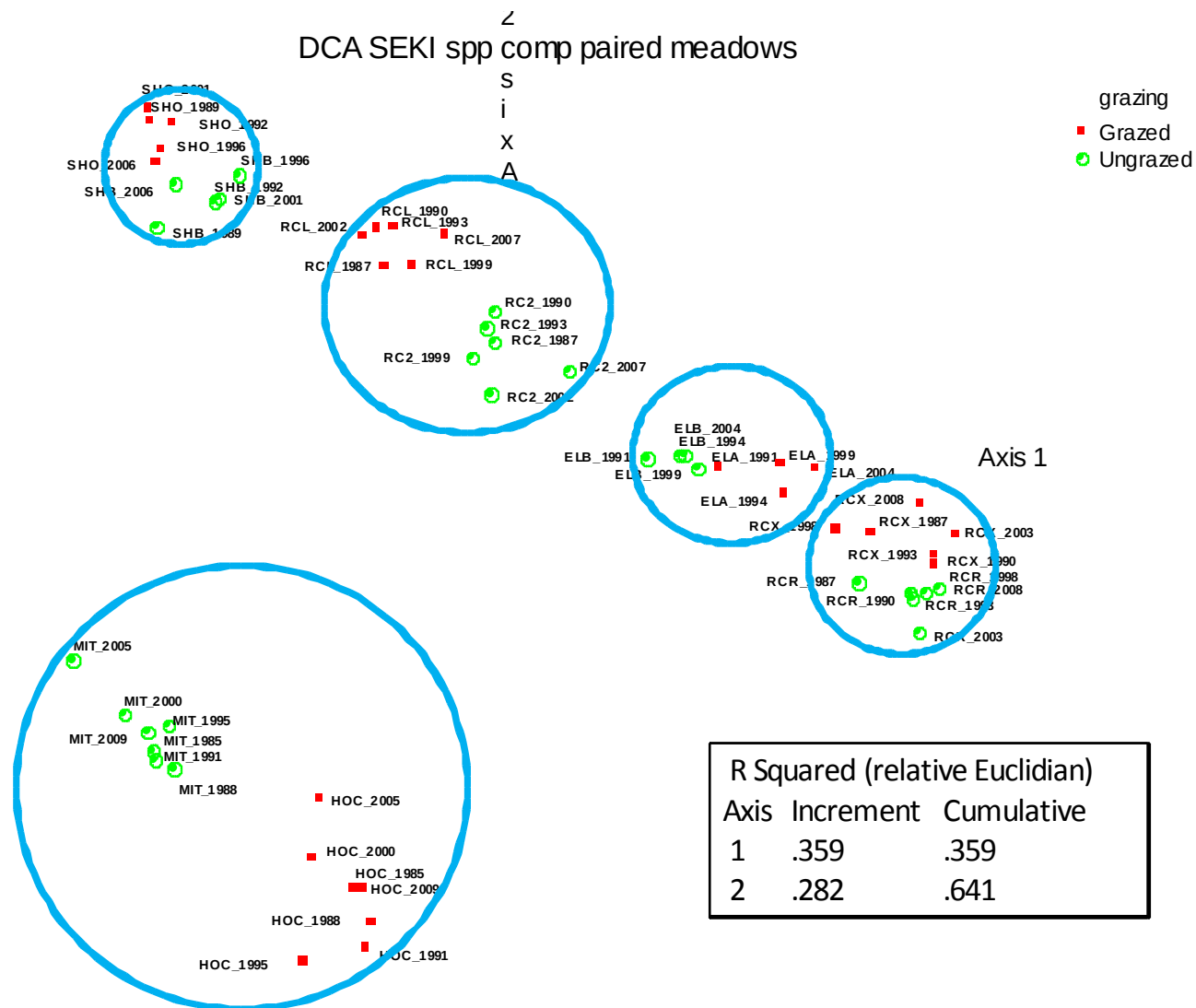


Figure 2.3.2. DCA graph of the species composition meadow pairs, 1985-2009; circles overlaid on graph

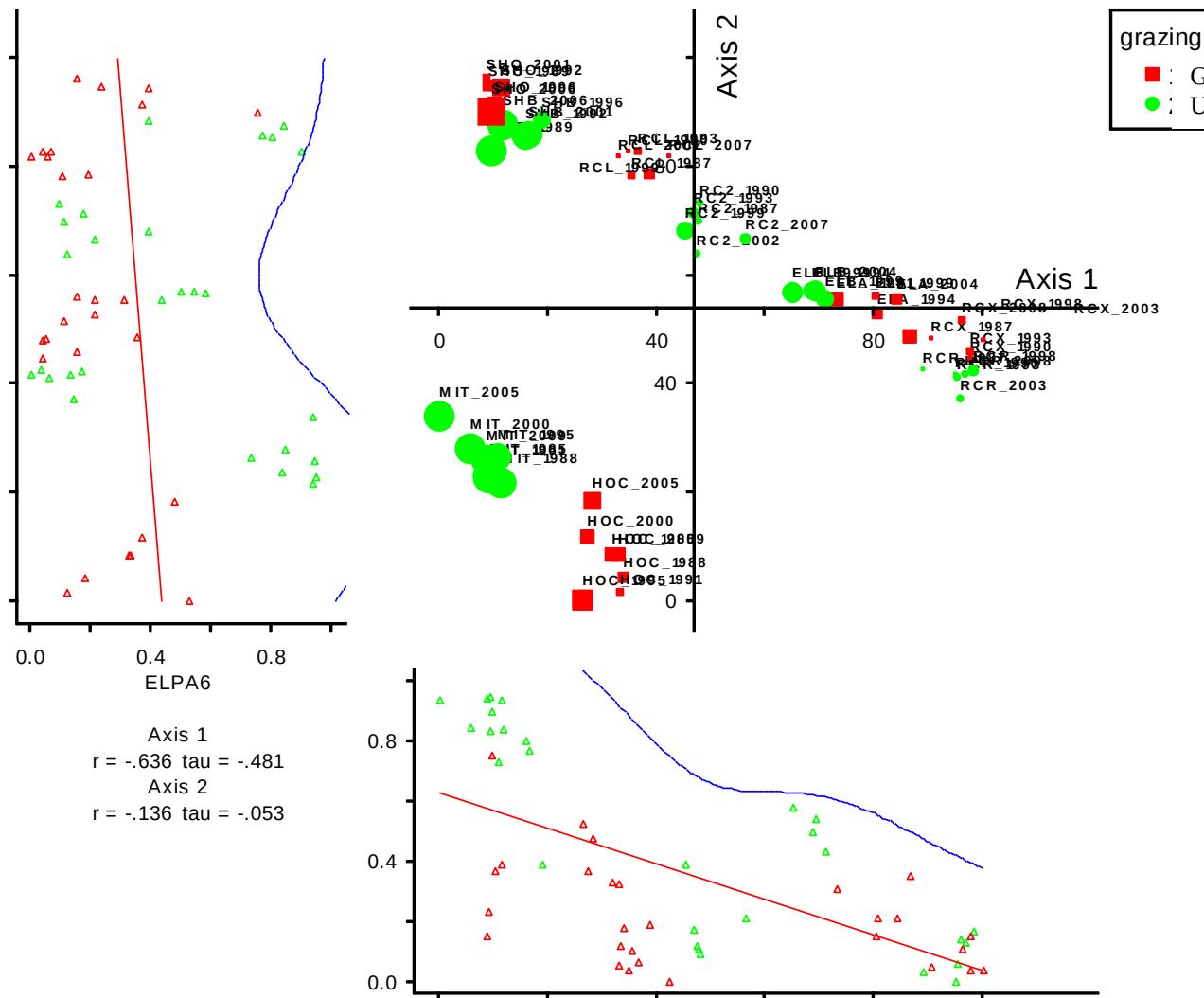


Figure 2.3.3. *Eleocharis pauciflora* DCA species-axis correlation graph for the species composition meadow pairs, 1985-2009; each point represents a plot; upper left graph: scatterplot of species against Axis 1 scores, lower right: Axis 2, with least squares regression line and smoothed envelope; Pearson's r and Kendall's tau for species correlation with axis (McCune and Grace 2002)

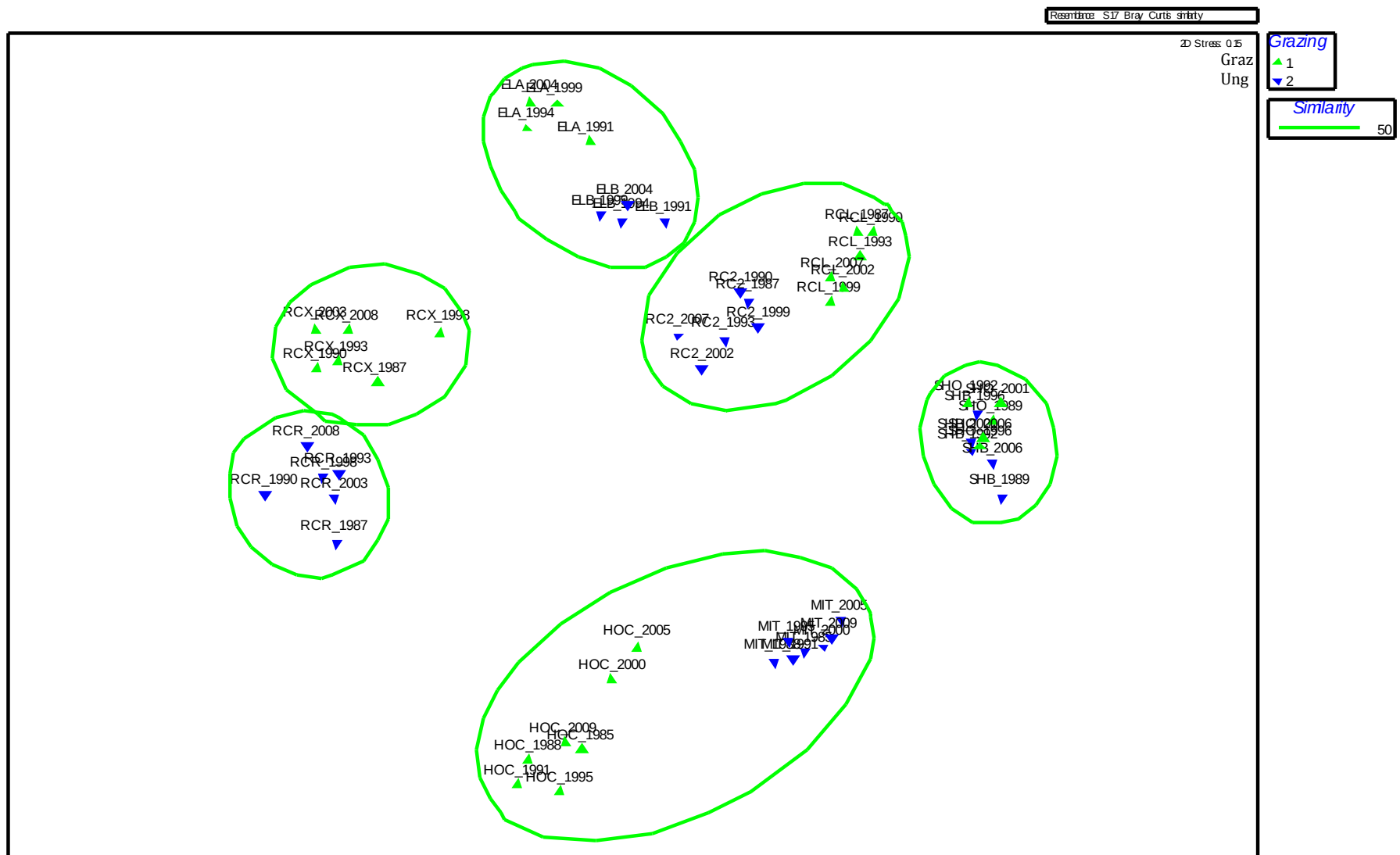


Figure 2.3.7. NMDS graph of the species composition meadow pairs, 1985-2009

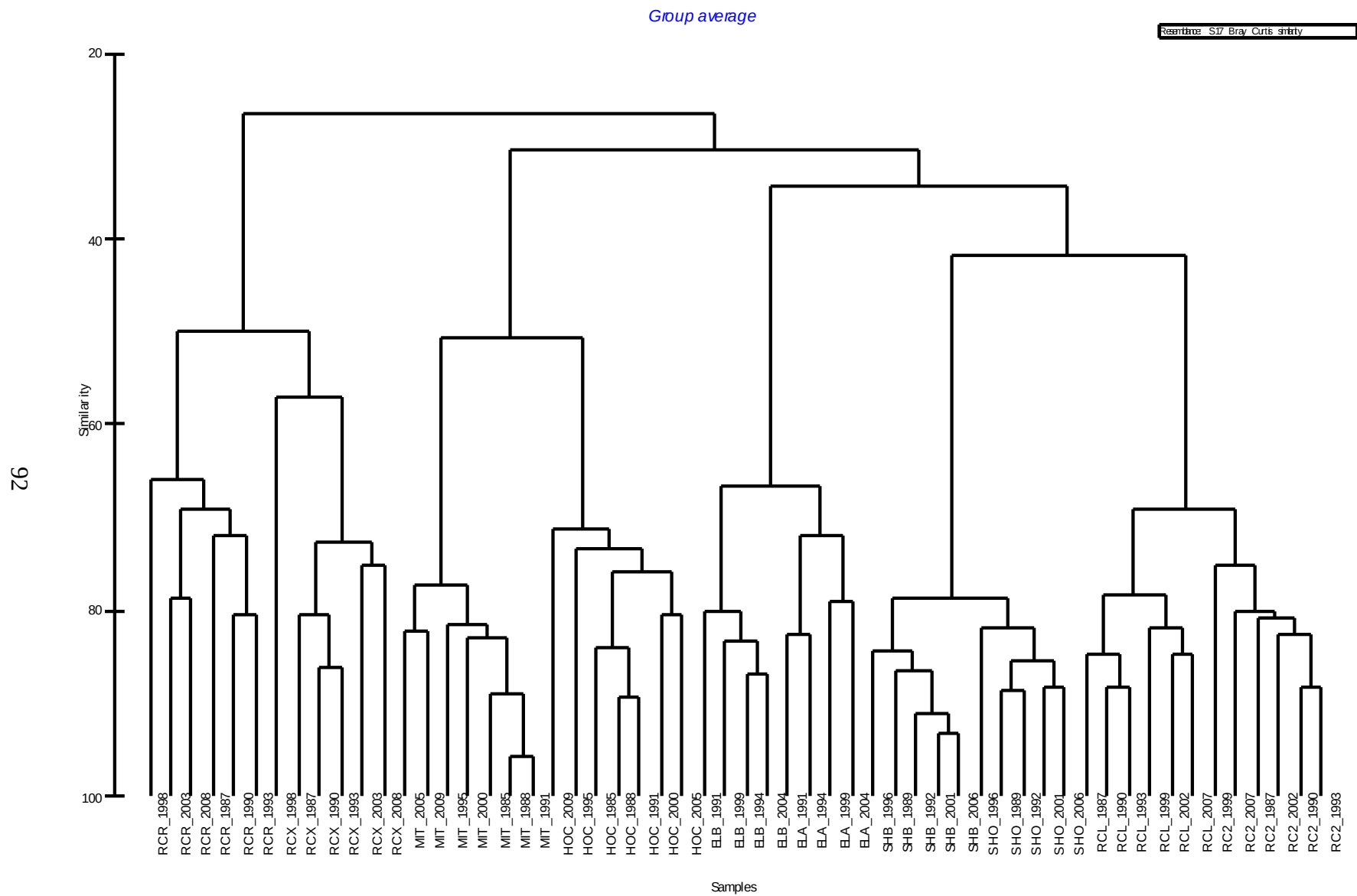


Figure 2.3.8. Cluster analysis of the species composition meadow pairs, 1985-2009

Section 2.4 SEKI meadows: Condition assessment for SEKI packstock-grazed meadows

Authors: Peter Hopkinson, Michele Hammond, and James Bartolome

We based the SEKI packstock-grazed meadows condition assessment on two datasets: the paired grazed/ungrazed meadows species composition dataset and the residual biomass monitoring dataset. It is important to note that these two datasets represent only a small subset (about 26 meadows) of SEKI's packstock-grazed meadows, which themselves are a subset of all meadows in SEKI (Figure 2.4.1). The condition map (Figure 2.4.2) must not be taken to represent all SEKI meadows. Furthermore, the condition map's map units are large watersheds, while the actual condition data come from small meadows; therefore, each large watershed and all the meadows therein are rated based on one to seven small meadows per watershed (Table 2.4.1). Finally, in those watersheds for which watershed status based on the species composition dataset differed from status based on the residual biomass dataset, we conservatively rate the watershed at the lower status.

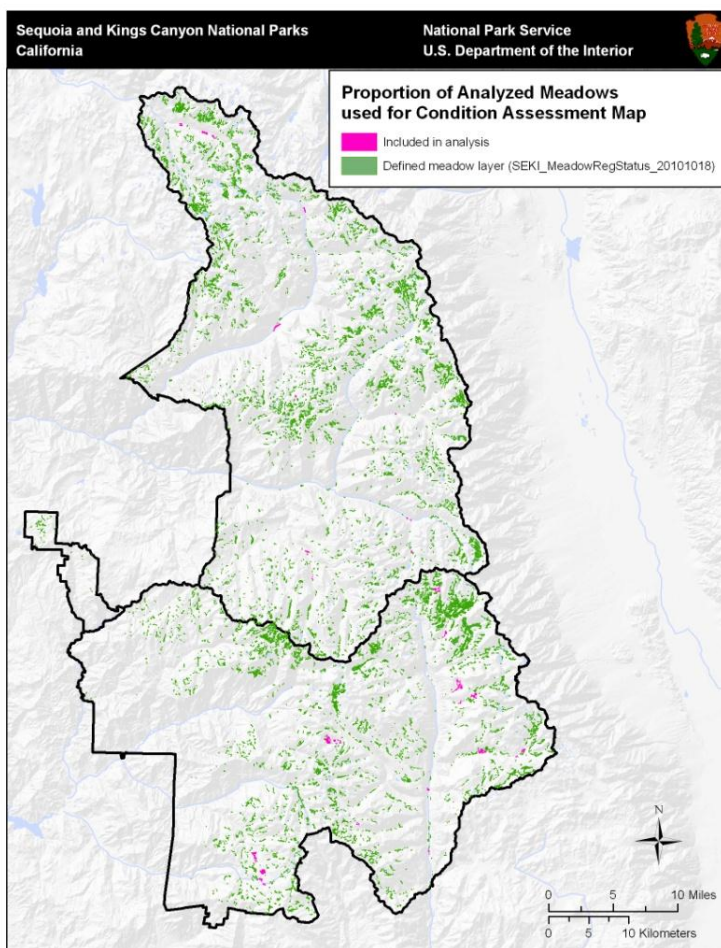


Figure 2.4.1: Meadow coverage in Sequoia and Kings Canyon National Parks; pink polygons represent meadows that were included in the meadow condition assessment analyses, representing only a small subset of total SEKI meadows

As discussed in the species composition section, we could find no strong evidence that current management of packstock use has resulted in vegetation change in the five meadow pairs sampled, with the possible exception of the grazed portion of East Lake meadow. The grazed portion but not the ungrazed portion of this meadow shows some evidence of directional change over the years sampled, potentially a drying trend; this is only an initial evaluation, which requires further field investigation to confirm. Based on the species composition dataset then, we rate 4 of the 5 meadow pairs as good condition and 1 meadow pair, East Lake meadow, as moderate condition (Table 2.4.1). Note that the decision to rate East Lake meadow as moderate rather than poor is arbitrary. No clear trend was observed in the data. Our confidence in the overall condition assessment for the 4 good meadows is medium and the 1 moderate meadow is low.

As noted in the residual biomass section, many of the evaluated meadows met the SEKI residual biomass recommended guidelines in at least 50% of the years reported for that meadow. However, 12 meadows fell below the SEKI residual biomass recommended guidelines in 50% or more of the years reported for that meadow (including 2 meadows only sampled in 1 year). We rate as good the meadows that met the residual biomass recommended guidelines in a majority of sampling years. The 12 meadows (and their watersheds) that fell below their guidelines are rated as moderate: McClure, Colby, Little Pete, Junction/Bubb's Creek, Austin Camp Creek Crossing/Trail Crew Camp, Lake South America, Upper Crabtree, Lower Funston, Forester Lake, South Fork Meadow, and South Fork Pasture (Table 2.4.1). Note that the decision to rate these meadows as moderate rather than poor is arbitrary. Because the overall residual biomass trend on grazed meadows is increasing, we rate the condition map trends as improving. Our confidence in the overall condition assessment for the 25 residual biomass meadows is low because the SEKI residual biomass recommended guidelines are based on meadow condition assessments made 15 years ago. In addition, results of a recent study of packstock grazing in Yosemite National Park meadows suggest that SEKI's residual biomass recommended guidelines might be set too low, making condition assessment based on them uncertain.

Table 2.4.1. Residual biomass monitoring meadows used in developing condition map; **meadows also represented in species composition dataset (note that Shorty's Meadow is not in the residual biomass monitoring program)

Meadow no.	Meadow name	Species comp. packstock grazing effect	Below residual biomass guidelines	HUC watershed
33-1	Evolution Meadow			Upper South Fork San Joaquin River
33-2	McClure Meadow		Yes ¹	Upper South Fork San Joaquin River
33-3	Colby Meadow		Yes	Upper South Fork San Joaquin River
39-3	Little Pete Meadow		Yes	Middle Fork Kings River
51-1	Simpson Meadow			Middle Fork Kings River
53-7	Shorty's Meadow**		NA	Middle Fork Kings River
58-1	Castle Domes Meadow			Upper South Fork Kings River
66-3	Junction Meadow (Bubbs Creek)		Yes	Upper South Fork Kings River
67-1	East Lake Meadow**	Potentially		Upper South Fork Kings River
69-3	JR Pasture, Allen Camp			Roaring River
69-5.1	Scaffold Meadow Tourist Pasture			Roaring River
71-1.2	Austin Camp (Creek Crossing Meadow)		Yes	Roaring River
71-1.3	Austin Camp (Trail Crew Camp)		Yes	Roaring River
80-3	Tyndall Creek Meadows			Rock Creek - Kern River
80-5.1	Lake South America		Yes ¹	Rock Creek - Kern River
83-4	Upper Crabtree Meadow		Yes	Rock Creek - Kern River
83-7	Lower Whitney Creek, Strawberry Meadow			Rock Creek - Kern River
83-8	Sandy Meadow			Rock Creek - Kern River
84-2	Lower Rock Creek Crossing Meadow**			Rock Creek - Kern River
85-8.1	Rock Creek Lake Meadow**			Rock Creek - Kern River
86-2	Upper Funston Meadow			Golden Trout Creek - Kern River
86-5	Lower Funston Meadow		Yes	Golden Trout Creek - Kern River
88-1	Lower Little Five Lakes Meadows			Golden Trout Creek - Kern River
89-5.2	Forester Lake Meadows		Yes	Golden Trout Creek - Kern River
90-10	South Fork Meadow		Yes	South Fork Kaweah River
90-11	South Fork Pasture		Yes	South Fork Kaweah River
90-5.1	Hockett Meadow**			East Fork Kaweah River
90-5.2	Hockett Pasture			East Fork Kaweah River

¹ McClure and Lake South America residual biomass only measured in one year but failed to meet their guidelines in that year.

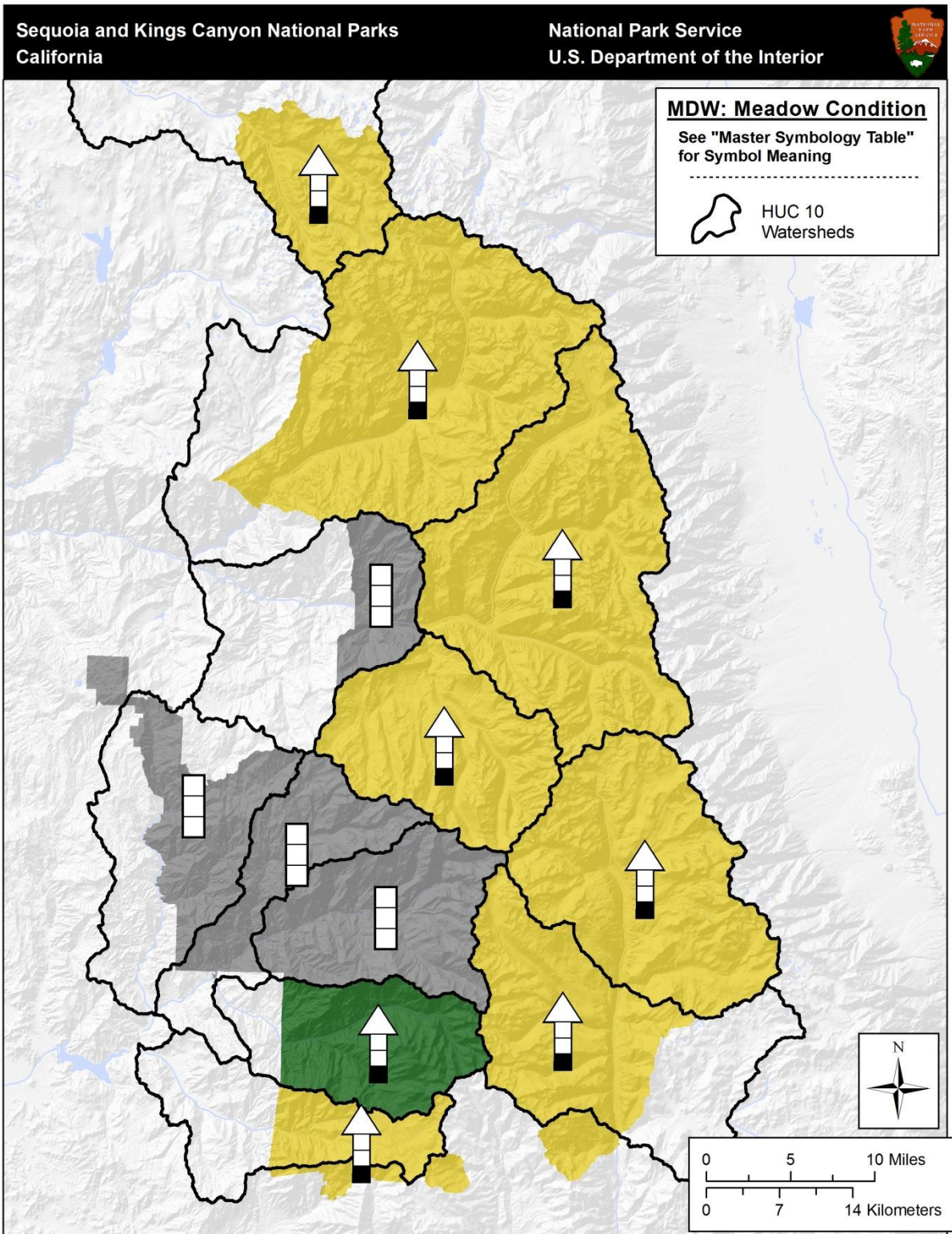


Figure 2.4.2. HUC10 condition map for packstock-grazed meadows

Section 3. A New Meadow GIS Coverage for Sequoia and Kings Canyon National Parks

Authors: Erik Frenzel, David Saah, and Sylvia Haultain

Background and need

As discussed in the introduction to this chapter, meadows are an important resource in Sequoia and Kings Canyon from both an ecological and a cultural standpoint. As the subject of focused study and use over the past sixty years and longer, a great deal of information has been collected on meadows both individually and collectively. With the advent of GIS technology in the 1980s, a spatial layer of meadows from the perspective of managing pack stock use was created to display meadow distribution and regulatory status for both users and managers. This legacy layer was delineated by hand using relatively coarse scale black and white aerial photography. This map was extensively ground truthed and attributed, including the name of the forage area (according to Neuman, 1990), the quantity and quality of the forage, as well as which activities (travel, overnight camping, and grazing) were permissible under the 1986 plans. Perhaps most importantly, this dataset allowed managers to link stock use statistics and ecological attributes (including species composition and wildlife observations) to individual meadows in a spatially explicit manner.

Beginning in 1999, the parks began the process of updating the vegetation map. Aerial photography was obtained in 2001, and the map was completed in 2007. This vegetation map used finer scale color infrared photography and professional photointerpretation to assign empirically derived mapping units to all vegetation in the parks. The spatial accuracy of the resulting map was equivalent to 1:24000 National Map Accuracy Standards, with overall map accuracy of 80% at the association level and 86% at the alliance level (AIS, 2007). This provided park managers and ecologists with a more comprehensive view of the distribution of meadows throughout the two parks, increasing the acreage of mapped meadow vegetation by 60%. However, the introduction of a more explicit data layer also introduced problems of attribution to the dataset, resulting in newly delineated meadow polygons that were not linked to the various attribute datasets.

The purpose of this project was to take advantage of the more accurate mapping of the 2001 vegetation map product (Figure 3.1) and combine it with the stock use attributes of the 1990 legacy meadow map and associated datasets to create a new map product. The new product maintains consistency with naming conventions in the tabular meadow monitoring data sets (e.g. stock use, residual biomass, and species composition) and allows for more accurate analyses of those monitoring data. Most importantly, it allows the meadow polygons to be related to current regulatory status, thus facilitating comparisons between allowed uses and the distribution of meadow vegetation parks wide.

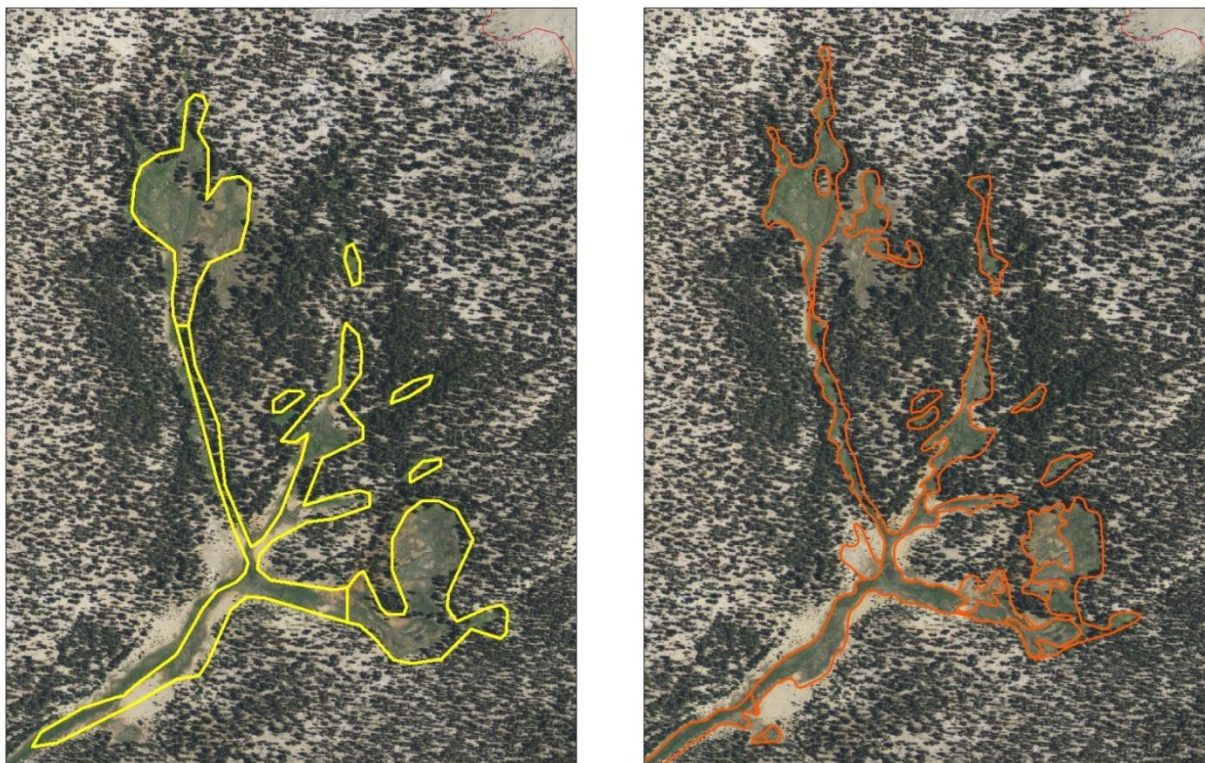


Figure 3.1: Sandy Meadow. Legacy mapping (left) and 2001 mapping (right). In this particular example, the 2001 mapping reduced the estimated acreage of the meadow by 0.9 hectares, and four vegetation types were differentiated.

One of the particular challenges was attributing meadow vegetation with regulatory status under the 1986 Stock Use and Grazing Management Plan (SUMMP) and 1986 Backcountry Management Plan (BCMP). The plans establish, where stock may travel and graze, how many stock per party are allowed to graze and for how long, and also provide for temporary restrictions, drift fences, grazing opening dates, and other tools for managing and monitoring stock use impacts. These regulations are complex and include both general and specific spatial references. Incorrectly assigning regulatory status could result in resource impacts if a sensitive meadow closed under the plan was opened to grazing, and correct interpretation of the regulations is necessary to ensure support for park management efforts.

Methods

A step by step methodology is detailed in the report *A New Meadow Regulatory Status GIS Coverage for Sequoia and Kings Canyon National Parks, CA* (Frenzel et al. 2010). Here we present the rationale for our methodology and some of the challenges of developing the new map.

Rather than migrating regulatory status directly from the legacy map to the new map, a decision was made to build a model from the regulations in the 1986 plans and reattribute all polygons with the regulatory status. The primary reason to do this is that the process used to attribute the legacy map was not documented; by implementing the regulations in a new spatial model, the map would be the product of a transparent, consistent, repeatable and defensible method. We

used an explicitly spatial process. Most of the model inputs were either existing GIS data or were digitized as part of this project. The overall framework was to:

- Select vegetation that represented meadows and forage areas
- Use spatial data to attribute polygons
- Derive the regulatory status from a combinations of attributes

The first step was to identify which vegetation types represented meadow vegetation. This was done using expert knowledge of the characteristics of the vegetation mapping units, each of which is assigned a photointerpreter (PI) code. Two classes of vegetation (*Intermittently to Seasonally Flooded Meadow*, PI code 8000, and *Semi-permanently to Permanently Flooded Meadow*, PI code 9000) were used by photointerpreters to capture wet meadow vegetation. However, the *Willow spp./meadow shrubland mapping unit* (PI code 6500) was also included, as this type is a common component of meadow complexes and riparian meadows, especially on slopes. On the dry end of the herbaceous vegetation spectrum, extensive stands of *Shorthair Sedge Herbaceous Alliance* (PI code 7120) were also included, as they represent a major component of grazed areas in the subalpine zone. Limited acreages of other vegetation mapping types were also included where they represented portions of named forage areas. Full descriptions of the mapping units can be obtained in the final photointerpretation report for the map (AIS, 2007).

The second step required a major effort to error check, update, expand, and create spatial data inputs for the model. This included adding described forage areas from Neuman (1990) to the legacy map using better imagery. In addition, we created spatial representations of the regulations in the 1986 plans, including closures, night limits, and party limits. Many of these came from buffers of linear features (trails) or polygons representing portions of watersheds or travel zones. These spatial data inputs were used to attribute meadow vegetation.

The combination of attributes was used to determine the regulatory status for every polygon in the new map. We used a logic statement to calculate the status of each meadow, with location-specific regulations (e.g. Mitchell Meadow is closed to grazing but open to overnight use) taking precedence over general rules (e.g. The Hockett Plateau is open to off trail stock travel and grazing).

Results and Discussion

In deciding which vegetation types to include, we faced a challenge related to the different purposes of the two maps. While the four vegetation types included from the 2001 map all represent graminoid-dominated vegetation types, stock may or may not graze these preferentially or even primarily. Woodlands, areas of upland herbaceous species, etc may all be grazed. This was partially recognized in the legacy map with an attribute of “associated forage”. Another issue that was addressed was what to do with forage areas defined by the legacy map which were not represented by the primary meadow vegetation types (*Semi-permanently to Permanently Flooded Meadow*, *Intermittently to Seasonally Flooded Meadow*, *Shorthair sedge Alliance*, and *Willow spp./meadow shrubland mapping unit*). These have monitoring data associated with them, but do not overlap any of the meadows types. The decision was made to carry these forward by clipping the underlying 2001 vegetation map polygons regardless of PI code after correcting for any registration errors. As to non-meadow associated forage, users of the map will need to account for the limitations of the map to represent areas which are actually grazed.

Another significant challenge was determining how to apply language in planning documents to determine the regulatory status of each meadow in the park in a defensible and repeatable way. The 1986 plans included text descriptions of regulations but few detailed maps of how these regulations were to be applied on the ground. The legacy map provides insight into the past interpretation of the regulations, but one of the goals of the project was to ensure that these interpretations were accurately represented in the map. This required going back to the language of the 1986 plans and creating features to represent every regulation. While the process of creating these spatial data inputs necessarily involved some subjectivity, the data themselves are open to scrutiny and reinterpretation, as every feature was attributed with the section of the plans upon which they were based. Figure 3.2 illustrates the complex nature of the regulations for a portion of the upper Kern River watershed.

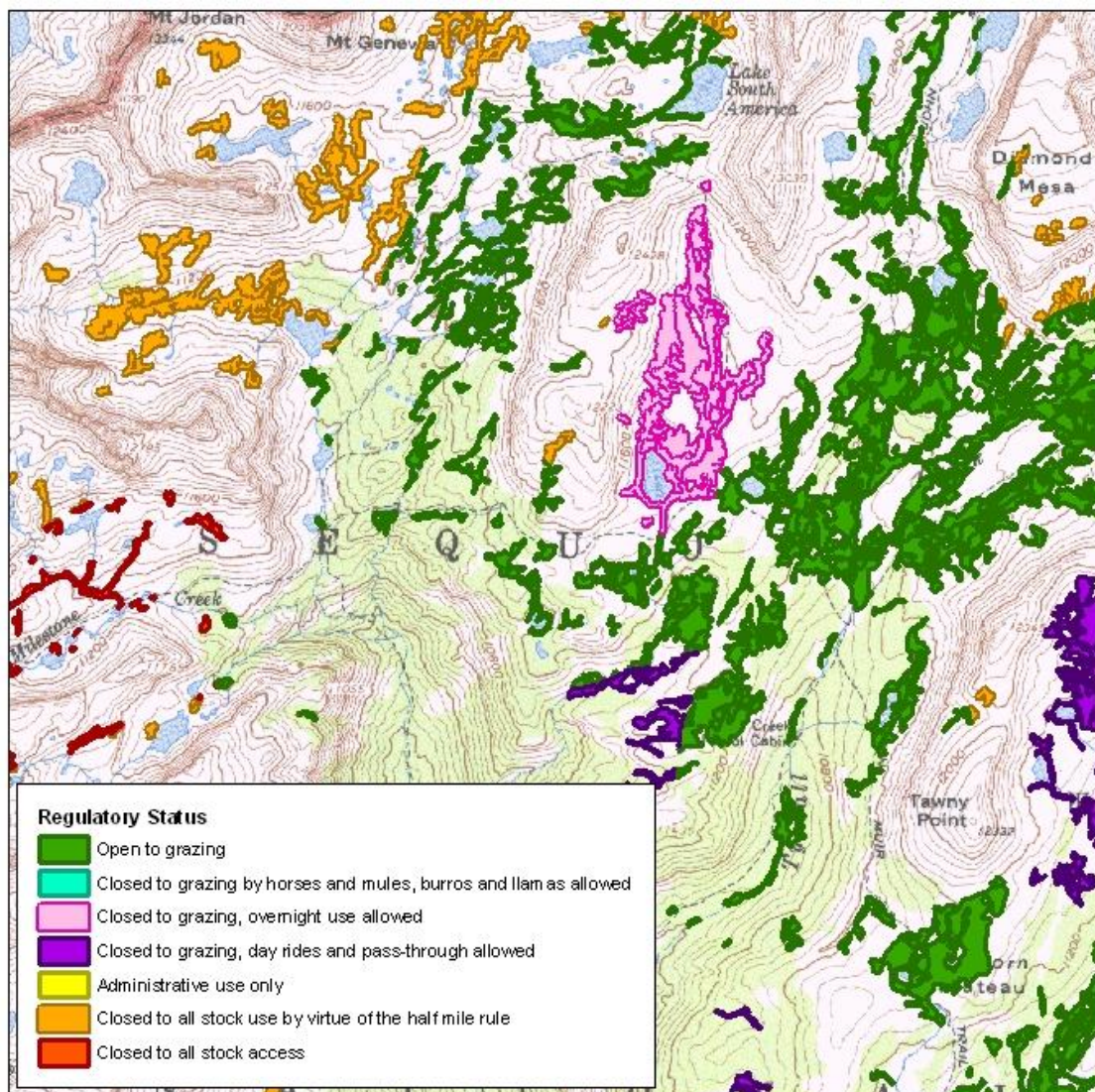


Figure 3.2: A portion of the new meadow map with regulatory status.

One important attribute was the forage area code that links tabular monitoring data to actual locations. The acreage in each forage area is one parameter used to estimate grazing capacity.

Two alternative approaches were evaluated: a spatial join and a convex hull approach. The spatial join only attributed polygons in the new data which touched those in the legacy dataset. The convex hull drew an envelope around all of the polygons which shared a forage code; any polygons in the new data which touched the envelope were attributed with that forage area code. The convex hull approach was ultimately adopted, since it helped capture many of the small patches of vegetation which were unmapped (and therefore unattributed) in the legacy map. However, we found that in a few cases the convex hulls were not accurate representations of the forage area and had to be manually edited.

The map product was verified by individually examining each named forage area, and visually inspecting the rest of the map. We found that the automated process used to assign a regulatory status and forage codes correctly attributed regulatory status to polygons. Automation of the forage area codes provided reasonable results in all but 15 of 341 forage areas (~4%). These cases fell into three broad categories. First, the shape of eight convex hulls had to be modified to reflect topographic features and some of the polygons they affected were reattributed with accurate forage area codes as necessary. Second, five polygons which intersected two or more convex hulls and had to be cut in two in order to be attributed with correct forage area codes. Third, two polygons were reattributed without being cut into two polygons.

The differences between the legacy map and new map reflected their differences in purposes and methods. As expected, the more detailed and comprehensive cartography of the 2001 vegetation map increased the amount of meadow vegetation represented, both in terms of area and number of contiguous meadow units (Table 2.4.2). The relative amount of area in named forage areas was higher for the legacy map (60% vs. 39%); this was despite the addition of 40 additional named forage areas which were not included on the legacy map. We attribute the decreased proportion of named meadows to the management focus of the legacy map. Likewise, the new map included a much larger proportion of meadow vegetation “closed to grazing by virtue of the half mile rule”. Because these meadows were less likely to be impacted by stock use when the legacy map was created, it seems likely that they were not fully represented in the legacy mapping. The new mapping indicates that less than 50% of the area of meadow vegetation is open to grazing by horses and mules, while less than 60% is open to grazing by burros and llamas. A particularly powerful illustration of the increase in resolution and spatial accuracy for the new map is the large area (46%) of the legacy map which was later mapped as non-meadow vegetation. While some of this represents non-meadow forage areas, much of it is the result of legacy polygons having poor registration with meadow features (assuming that the 2001 vegetation map mapped these features more precisely).

Table 2.4.2. Summary of differences between the legacy and new maps

	Legacy	New
Number of contiguous meadows	3053	5311
Total area (ha)	3861	9052
Area in named forage areas (ha)	2287	3571
Number of named forage areas	301	341
Percentage of meadow area in each management status category		
Open to grazing	67.7%	49.2%
Closed to grazing, day rides and pass-through allowed	1.8%	9.7%
Closed to grazing by horses and mules, burros and llamas allowed	5.1%	2.5%
Closed to grazing, overnight use allowed	16.3%	3.4%
Administrative use only	0.1%	0.1%
Closed to all stock use by virtue of the half mile rule	6.4%	34.3%
Closed to all stock access	2.6%	0.7%
Percentage of area in each PI code		
9000 – Semi-permanently to Permanently Flooded Meadow	10.1%	8.0%
8000 – Intermittently to Seasonally Flooded Meadow	36.7%	62.4%
7120 – Shorthair sedge Alliance	2.9%	18.8%
6500 –Willow spp./meadow shrubland mapping unit	4.3%	9.0%
Other	46.0%	1.8%

Conclusions

We found the spatially explicit modeling of meadow regulatory status to be a defensible, transparent, and repeatable method of transferring legacy attributes to a new spatial layer. The resulting data layer brings together spatial and tabular meadow information from a number of key datasets into a single data product based on the most current spatial data inputs. This project thus provided a basis for the analysis of the legacy datasets evaluated in this assessment, and allowed for comparison with the broader extent of meadow vegetation on a landscape scale. In addition to providing more accurate information about the current management of park meadows, the model framework can also be quickly adapted to evaluate the differences between scenarios in parkwide planning efforts such as the Wilderness Stewardship Plan and the anticipated Resource Stewardship Plan. As such, the new meadow GIS layer is one of the most significant data products developed through the Natural Resource Condition Assessment, and will be used extensively by park managers, ecologists, and researchers in the years to come.

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