National Park Service
U.S. Department of the Interior
Yosemite National Park
Yosemite, California

2008 Pack Stock Use Assessment in Subalpine Meadows of the Tuolumne River Watershed

Resources Management and Science

November 2010

2008 Pack Stock Use Assessment in Subalpine Meadows of the Tuolumne River Watershed

November 2010

Resources Management and Science, Yosemite National Park

Written by Elizabeth Ballenger, Joy Baccei, and Lisa Acree

Reviewers: Mark Fincher, Yosemite National Park; Sylvia Haultain, Sequoia and Kings Canyon National Parks; Mark Marschall, Yosemite National Park; Peggy Moore, U.S. Geological Survey; Steve Ostoja, U.S. Geological Survey; Aimee Smith, U.S. Forest Service; N.S. Nicholas, Yosemite National Park; Judi Weaser, Yosemite National Park, Dave Weixelman, U.S. Forest Service

Acknowledgements: Funding from The City of San Francisco Public Utilities Commission made this project possible. We thank Erin Lutrick from Inyo National Forest for feedback on our field methods. We appreciate the hard work of field staff Katherine Wilkin and Heather Leach, whose thoroughness and attention to detail resulted in a high quality dataset for all meadows surveyed. We thank Eric Berlow from University of California, Merced for his invaluable help with initial data summaries and analyses. We thank Leigh Ann Starcevich from Oregon State University for her expertise in statistical analyses. Finally, thanks to Jeff Holmquist from the University of California White Mountain Research Station and Marie Denn from the National Park Service, Pacific West Region, for valuable feedback throughout the duration of the project.

Table of Contents

Summary

In 2008, NPS field staff surveyed twenty-six subalpine meadows (half of which receive high levels of pack stock use) in the Tuolumne River watershed of Yosemite National Park to evaluate existing conditions and inform management strategies for wilderness meadows. Field staff collected information on vegetation, substrate, small mammal sign (e.g. burrows), and stock impacts in 5x5m plots along 20-30m spaced grids in each meadow. Staff also collected information on streambank stability and the potential for streambank erosion due to lack of "armorment" (natural streambank stabilizing materials, such as vegetative cover, rocks, and woody debris). Field staff mapped concentrated areas of stock evidence (trampling, grazing, manure, roll pits, and informal stock use trails) in each meadow. This information provides a baseline for future monitoring of pack stock use and will be integrated into a broader planning context (e.g., socioeconomic, wilderness, biological, legal, policy, etc.) to manage pack stock use in Yosemite.

Analyses of plot data revealed significantly higher levels of bare ground in the high use meadows. The proportion of erosion features was greater in the high use meadows. There were few differences between high and low-no use meadows in streambank armorment. Differences in vegetation cover were not significant. Stock evidence was present in all high use meadows, including those that had not received pack stock use in 2008 prior to the survey, indicating that pack stock impacts can remain visible beyond one year. Stock evidence was greatest in meadows that received the highest use in 2008 (per unit area) prior to the survey, particularly for grazed vegetation and manure. Hoofpunching was highest in meadows with more area dominated by wetland species, indicating that wet meadows may be more susceptible to trampling impacts because of their high proportion of perennially wet soils. This study highlights the importance of regular monitoring in meadow areas receiving high levels of stock use to track changes in meadow conditions and effects of management actions. This study also draws attention to three key components of a strategy to mitigate meadow impacts:

- Identification of appropriate levels of pack stock use in site-specific meadows (both intensity and frequency)
- Identification of best opening dates for stock use at the start of the season (range-readiness dates)
- Consideration for resources of special concern such as Yosemite toad and archeological resources

Introduction

Meadow ecosystems serve important ecological roles in Yosemite National Park and throughout the Sierra Nevada. Although they occupy a small fraction of the landscape, meadows are centers of high biological productivity, providing critical breeding and foraging habitat for a wide suite of animal species (Goldin Rose 2008, Mitsch and Gosselink 1993). Healthy meadow systems enhance water quality, filtering runoff from steep uplands and slowing sediment release rates to adjacent watersheds. Meadows attract a disproportionate amount of human visitation relative to other areas, due to their scenic vistas, recreational fishing opportunities in adjacent lakes and streams, and availability of forage for pack stock. Pack stock grazing is a common practice in high country meadows of Yosemite and the Sierra Nevada. Grazing minimizes the number of stock needed to carry feed and reduces the chances of weed infestations from imported feed (Wells and Lauenroth 2007). However, the trampling, grazing, and manure resulting from pack stock use can affect the biological integrity of meadows in a variety of ways.

Trampling can lead to a variety of negative effects including reduction in vegetation cover, increases in bare soil, and changes in species composition, soil compaction, and impacts to stream morphology. For example, Cole (1987) found that decreases in vegetation cover, species loss, and soil compaction occur at low levels of trampling. Soil compaction, which occurs through trampling, may increase soil erosion through decreased infiltration rates and dislodging soil particles (McClaran and Cole 1993). Wet meadow soils are more susceptible to soil shearing and root severing caused by trampling than drier soils (Vallentine 1990). Disruption of the root mat of perennial grasses and sedges in meadows may also lead to a shift toward communities dominated by tap rooted forb species, further altering meadow function (Cooper *et al.* 2006). Kauffman and Krueger (1984) reviewed studies showing that impacts resulting from bank trampling and shearing influences stream channel morphology and function of riparian systems. Stream banks are particularly susceptible to trampling when soils are wet (Trimble and Mendel 1995). As riparian systems degrade, channel incision can cause the lowering of water tables with severe detrimental effects to the surrounding meadows (Odion *et al.* 1988).

Although it is difficult to separate the effects of grazing and trampling in meadows since they occur simultaneously, concerns about grazing center on the effects of vegetation removal. Defoliation of plants can have direct effects on fitness such as reductions in biomass production, plant size, seed output, and plant vigor (Briske 1991). Studies of common Sierra subalpine meadow vegetation found that frequent, long term herbage removal leads to reduced productivity, and that effects are most severe in moist communities compared to xeric sites (Stohlgren *et al.* 1989, Cole et *al.* 2004). In addition, Cole et *al.* (2004) found that modest grazing levels (25-35% utilization) caused reduction in vegetative cover, increases in bare ground, and shifts in species composition for common subalpine meadow communities at Yosemite. Changes in species composition can occur through competitive release, since un-grazed plants will have an advantage over those that are grazed (Briske 1991). Pack stock selectively graze on preferred forage species (Olson-Rutz et *al.* 1996), and they frequently return to preferred locations, even if that area has already been grazed, rather than graze uniformly in a meadow (Ring et *al.* 1985, Vallentine 1990). This can lead to grazing impacts occurring in localized areas of meadows, even if use rates are low. Cole *et al.* (2004) made specific recommendations that grazing levels in meadows dominated by Brewer's reed grass (*Calamagrostis breweri*) or tufted hair grass (*Deschampsia cespitosa*) do not exceed 25% biomass utilization. Cole et *al.* also recommended that biomass utilization of short-hair sedge (*Carex filifolia*) not exceed 35% to avoid declines in productivity, changes in vegetation and bare ground cover, and shifts in species composition.

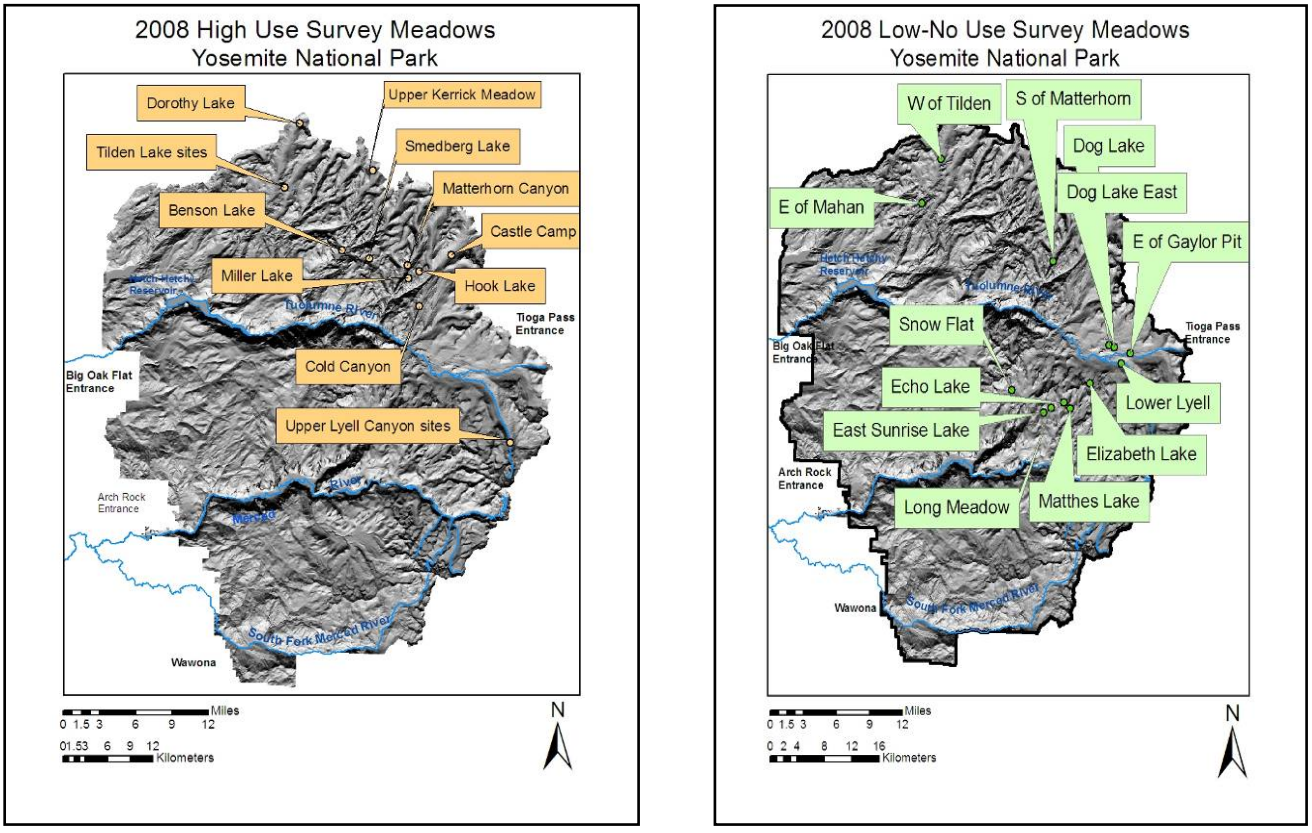
Manure left in meadows and adjacent campsites after pack stock use can influence soil nutrients, and may affect plant vigor and defoliation patterns due to increased levels of nitrogen in the soil (Jamarillo and Detling 1992). In addition, odor and the presence of flies may increase in areas where manure is concentrated (McClaran and Cole 1993). The potential for bacterial and protozoic pathogens to enter the water from pack stock manure is another concern, as runoff could transport manure into streams.

Meadows in Yosemite wilderness areas receive varying amounts of overnight pack stock use from commercial packers, administrative personnel, and private users. Studies to characterize meadow resources (e.g. vegetation, soils and stream condition, amphibian populations, archeological resources) and assess their existing condition and effects from pack stock use are ongoing. In 2008, field staff from the Division of Resources Management and Science at Yosemite National Park assessed the vegetation communities, stream banks, and pack stock use evidence (mainly trampling, grazing, and manure) in 13 wilderness meadows of the Tuolumne watershed receiving frequent overnight pack stock use. Field staff also collected quantitative data to describe plant communities and substrates, evaluate stream bank erosion and vulnerability to erosion, and quantify pack stock use evidence (such as trampled areas/hoofpunching, manure, grazed areas). The same suite of data were collected from 13 meadows receiving little to no overnight use by pack stock, to compare high use meadows and low-no use meadows. Differences between meadows with high use and little to no use would suggest further investigation into the causation and ecological significance of these differences.

Methods

Study meadows were selected using data and observations about usage patterns provided by the Yosemite Wilderness Office. Meadows with frequent overnight use by pack stock were selected as "high use meadows." "Low-no use meadows" experience little to no known use by pack stock, occur in the same elevation range as high use meadows, and are located within day hiking distance of either Tuolumne Meadows or the high use meadows., Current use by hikers/backpackers or pack stock use that occurred more than 30 years ago was not considered when selecting meadows. Meadow selection was not randomized; consequently, this research represents an observational study by which no inferences can be made about meadows outside this study.

The 26 meadows surveyed from July 8, 2008 to October 1, 2008 included 13 meadows designated as "high use meadows." Thirteen "low-no use" meadows which received little to no stock use were also surveyed. High use meadows received greater than 75 stock nights in at least one year since 2004, and had five-year averages of greater than 15 stock nights. Pack stock use is quantified in 'stock nights,' where one stock night is equal to one horse or mule turned out for overnight grazing. Map 1 displays the general locations of meadows surveyed, and Table 2 (under Results) shows usage statistics for meadows in this study from 2004 to 2008.



Map 1. 2008 Meadow survey locations in Yosemite National Park

Data collection consisted of three major components: gridpoint plots, streambank surveys, and mapping/quantification of pack stock evidence (see subsections below). Coarse descriptive information was also collected during each meadow survey, including slope/aspect, vegetation phenology of dominant species at the time of survey, wildlife sightings, estimates of conifer encroachment, estimates of percent

saturated soil area for each meadow, stream channel description, and comments relevant to stock use (e.g. forage available, avoidability of wet areas, etc.). Shallow ponds (i.e. amphibian habitat) were mapped with global positioning systems (GPS) at each meadow, and tadpole presence or absence in these ponds was noted for most meadows. Formal amphibian surveys were not performed, but observations of Yosemite toads (*Bufo canorus*), mountain yellow legged frog (*Rana muscosa*), and tree frogs (*Pseudacris regilla*) during the course of the meadow surveys were documented. The boundaries of selected wetland plant communities not captured in gridpoint plots (mainly willow and some sedge communities) were mapped as time allowed.

Gridpoint plots

Boundaries for each meadow survey area were defined using a geographic information system (GIS) based on meadow polygons from the 1997 Yosemite vegetation map. Using ArcMap 9.2 software, random survey points were generated on a grid across each meadow. Grid spacing was either 20m, 25m, or 30m depending on meadow size, producing 70-100 evenly-spaced gridpoint plots for most meadows. Field staff located each survey point with Trimble Juno ST GPS units, and recorded all data in the unit's data dictionary. At each point, a temporary 5x5m square plot was established and cover class data were collected to assess vegetation cover of dominant species, substrate characteristics, and pack stock impacts. Small mammal burrow holes and burrow tailings within the plot boundaries were quantified, and litter depth and vegetation canopy height were measured.

Cover class data were collected in the following categories:

Cover Class	Percent Cover
T	Trace (<1%)
P	Present 1-5%
1a	6-10%
1b	11-15%
02	16-25%
03	26-35%
04	36-45%
5a	46-50%
5b	51-55%
06	56-65%
07	66-75%
08	76-85%
09	86-95%
10	96-100%

To ensure consistency of the data, field staff were carefully trained in cover estimations and calibrated at the start of each work week and/or meadow. In addition, the same staff collected data throughout the summer, minimizing differences among observer estimates.

The following data were collected at each 5x5m plot:

- **Total vegetation cover:** Ocular estimate total vascular vegetation cover in the plot (could not exceed 100%, does not account for layered vegetation).
- **Dominant species cover:** The species with the greatest cover was listed as Dominant Species 1 and its cover class was estimated. Two other species (subdominant species) and their cover) were recorded

if they had at least half the relative cover of the most dominant species. (For example, if Dominant Species 1 had a cover class of 06, up to two subdominant species with a cover class of 03 or higher would be recorded.)

- **Association name:** The vegetation community of the plot and area surrounding it (usually >10m in all directions) was assigned a name from the 1997 Yosemite floristic classification (Natureserve 2007). This field characterized a larger area than the 5x5m plot, to minimize the effect of plots falling on an anomalous point.
- **Association comments:** If the community was a mix of different associations, or if it did not fit any of the association names, information was recorded in this field.
- **Moss cover:** Cover of all moss species in the plot. Cover for dormant moss was estimated as if it were in a fully green condition.
- **Bare ground cover:** Cover of all bare ground (including that created by rodent burrowing activity) was included in this estimate. Rocks were only included in this estimate if they were smaller than a quarter (coin less than 1 inch diameter).
- **Litter cover:** Litter was defined as plant material that was dead before the current year's growing season, that was either detached or present in the form of thatch (as in perennial graminoid communities). In *Ptilagrostis kingii*, the curly dead blades attached to the culms which give this species its characteristic look were counted as litter.
- **Water cover:** Standing or flowing water (regardless of depth) at the time of plot collection.
- **Burrow cover:** All burrow holes and excavation tailings were included in this estimate.
- **# Burrow holes:** All small mammal burrow entrances (recent or old), were counted in the plot.
- **Manure cover:** Estimated cover of pack stock manure (fresh or old) present in the plot
- **Hoofpunch cover:** Any distinguishable hoof marks >1cm deep. Hoofpunches break through the root mat in vegetated areas.
- **Hoofprint cover:** Any distinguishable hoof prints <1cm deep that do not break through the root mat were estimated
- **Grazed vegetation cover:** Estimated cover of vegetation that had been grazed, regardless of residual height.
- **Litter depth:** Depth from the soil surface to the surface of the litter/thatch, measured at two randomly-selected locations in the plot.
- **Vegetation height:** Height of the tallest structure (vegetative, reproductive, or dead) of one of the three dominant species listed for the plot was measured within a one meter radius of the two randomly-selected litter depth locations in the plot.
- **Gridpoint comments:** Any supplemental information about the plot was recorded in this field. If field staff rejected a plot for any reason (described below), that information was recorded here.

Cover was estimated for vegetation that was alive during the current growing season. Vegetation late in the growing season that was shriveled and dried was visualized in its fully alive condition for cover estimates.

If a gridpoint fell on an area considered to be anomalous according to the protocols (in a creek, on the transition between two distinct plant communities, on rocks that were greater than 10% cover, in an area of thick conifer encroachment, or on a meadow border with significant needle cast from surrounding forest), the data collector would either reject the plot or move the plot by pacing 5m directly away from the anomalous location.

Gridpoint plot data were downloaded from the GPS units, differentially corrected in Pathfinder Office, then exported to ArcMap, MS Access, JMP 5.1 and MS Excel for summary and analysis. Cover class data were converted to continuous data by using the midpoint of each cover class. In summarizing data, mean percent cover was calculated at the meadow level and all means for "high use meadows" or "low-no use meadows" were calculated by averaging the meadow level means. Because certain plant communities (such as *Carex filifolia*) naturally have higher levels of bare ground and may respond differently to pressure from stock use, plots were grouped for analyses according to dominant species.

Statistical analyses were conducted to detect significant differences between high use and low-no use meadows in bare ground and total vegetation cover (Starcevich 2009). Residual analyses from ANOVA results indicated that residuals for the outcomes in many species groups were not normally-distributed. To provide a unified analysis for all subpopulations of interest, a bootstrapping technique was used to test a null hypothesis of equal means (Manly 2007). A one-sided bootstrap t-test was applied to an alternative hypothesis in this study, because negative effects of pack stock (increased bare ground, decreased vegetation cover) are primarily of interest, and a positive effect of pack stock use was not expected.

Streambank surveys

Streambank surveys were performed in meadows with a distinguishable stream channel where water flows at least part of the year. Streambank surveys consisted of two protocols, *features mapping* and *streambank characterization,* that were performed simultaneously as the surveyor walked along each side of the channel. The survey was performed for both banks of the stream, with endpoints located where the stream enters and leaves the meadow. Endpoints were mapped using GPS, and photos were taken at these points to illustrate streambank condition at each end of the survey.

Erosion features

Using Juno GPS units, the following erosional features were mapped on each streambank as line features in the data dictionary (See Photo 1 for illustration). The presence of pack stock impacts (hoofprints, hoofpunching, manure, or informal trail with hoofprints) within 2m of erosion features was documented.

- **Slumping:** Streambank which is undercut and slumping into the river, but no fractures apparent.
- **Fracturing:** Cracks in the streambank, usually parallel with the flow, but bank is otherwise intact. Banks are often slumping toward the channel.
- **Blocking:** Bank collapse where blocks of often-vegetated bank materials slough into the stream channel.
- **Headcuts:** The uppermost edge of a forming stream channel (often branching off the main channel) where sheet flow across the meadow is occurring above, but flow is becoming channeled below. Soils above the headcut support more hydric vegetation due to the well-distributed flow, while below the headcut, vegetation communities are generally more xeric due to channelization of the runoff.
- **Scalloping:** Streambank section which has been scoured out to form a distinct curve. This feature may sometimes appear similar to a shallow headcut, but differs in the way that it forms. Scallops are likely formed by either the velocity of streamflow, or streamflow backwatering effects, that cause the streambank to be scoured into a distinct curved shape.
- **Stream crossings:** The location where a trail of any type (formal or informal trail) crosses a stream.

Fracturing in Matterhorn Canyon (note informal trail parallel to stream).

Blocking in Upper Lyell Canyon

Scalloping in Castle Camp, Virginia Canyon

Headcut at Miller Lake

Photo 1. Selected streambank erosion features

Streambank characterization (Adapted from Frazier et al. 2005)

Along the main stream channel in each meadow, data were collected to determine the proportions of different bank stabilizing materials (or "armorment") by performing step transects along each streambank. Footsteps, when evenly paced, have been found to be as reliable as measuring tapes for determining percent composition transects (Winward 2000). Each bank was paced using slow, even steps and the area created by the length of each step and the width 0.5m from the bankful line inland was assigned to one of the following categories:

Rs= Soil/sand
R1= Gravel 1-5cm
R2= Cobbles 6-10cm
R3= Boulders >10cm
R4= Bedrock
L= Litter (or wood <20cm width)
W=Wood >20cm (logs)
T1= Tree <10cm dbh,
T2= Tree > 20cm dbh
V1= 10-25% herbaceous plant cover
V2= 26-50% herbaceous plant cover
V3= >50% herbaceous plant cover
Sc= Clonal shrub (i.e. *Salix* sp.)
Sn= Non-clonal shrub (i.e. *Vaccinium caespitosum*)

If obstacles were encountered (e.g., tree trunks, boulders, large shrubs, etc.), the surveyor would sidestep the obstacle and pace the transect while remaining parallel with the stream. If a step encompassed the transition between two different substrate categories, that step would be counted towards the next category along the streambank. Categories that encompassed less than ½ step were not recorded.

Only stream reaches encompassed by meadow area were surveyed. If a survey stream entered a patch of forested or extremely rocky area, the survey would terminate on one side of the patch and begin again on the other side, cutting out the length of stream not flowing through meadow terrain.

Stream survey data were summarized for each meadow by determining the proportion of each survey length with erosion features and proportions of stream banks in each armorment category. For erosion features data, streambank survey length was determined in ArcMap by overlaying survey endpoint coordinates on Digital Orthophoto Quarter Quadrangle(DOQQ) imagery and digitizing the survey reach between endpoints. Length was multiplied by 2 to calculate total survey length, since both banks of the stream were surveyed. For streambank characterization (armorment) data, the unit of survey length was number of steps on both banks. Once data were summarized for each meadow, they were averaged among meadows within use level groups to compare between high use and low-no use meadows.

Mapping and Quantifying Evidence of Pack stock Use

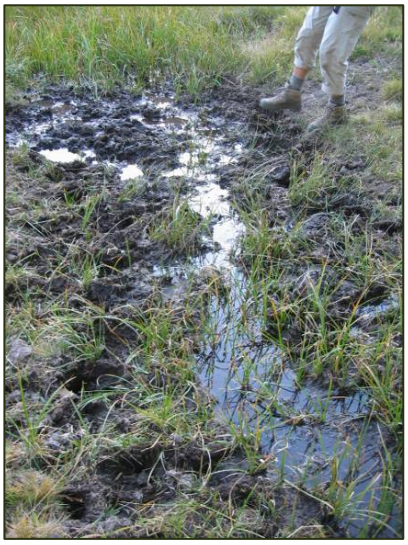
Meadows were systematically surveyed (by walking the entire meadow area) for the following pack stock disturbance features, and mapped using GPS units, where A=Area, L=Line, P= Point. See Photo 2 for illustrations of these features.

- **Roll pits (A):** a defined area of disturbed, bare ground at least 10m^2 and 4cm deep (at the deepest point) created by pack stock taking "dirt baths."
- **Heavily grazed areas (A):** Areas (at least 20m^2) that have vegetation continuously grazed to <5cm in height. If vegetation was taller than 5cm but had obviously been heavily grazed (such as *Carex vesicaria / Carex utriculata* communities in Upper Lyell canyon), they were mapped. Areas that had patchy/ light grazing or were smaller than 20m^2 were captured in the gridpoint plots.
- **Trampled areas/ dense hoofpunching (A):** Areas of hoof-punches that are less than 0.5m apart. Soils usually have a churned appearance. Scattered hoofpunches were captured in the gridpoint plots
- **Informal trails (L):** All social trails (not formal hiking trails) at least 7m long were mapped with line features according to the YOSE (2007) *Field Monitoring Guide: Visitor Experience and Resource Protection Program* (Yosemite National Park 2007). Each feature was attributed as follows:
    - Stunted vegetation- vegetation is crushed or stunted
    - Some barren ground- scattered bare spots, but trail >50% vegetated
    - Barren- scattered plants may be present, but trail >50% bare
    - Rutted (plus average rutting depth)
    - Braided (plus number of braids and average width of braids)
    - Trail width (average, in cm)
    - Rutting depth (average, in cm)- for rutted trails only
- **Dense manure piles (P):** GPS points were created were where there were more than two piles within 2m of each other, and attributed as follows: Low- two manure piles, Moderate- three to four manure piles, High- five or more manure piles.

GPS data were differentially corrected in Pathfinder and exported as shapefiles to ArcMap, where features were edited using a standardized method to correct for outlying points. Data were summarized by each feature type for each meadow, so that comparisons across meadows could be made.

Low-density manure point at Benson Lake

Grazed area of *Deschampsia cespitosa* at Benson Lake. Ungrazed plants nearly the height of the pin flag



Trampled area in Upper Lyell

Roll pit in Upper Lyell

Photo 2. Selected pack stock evidence features

Levels of Overnight Pack Stock Use

The Yosemite Wilderness Office provided numbers for commercial and administrative pack stock use for 2004 to 2008, including the number of stock nights for 2008 that occurred before and after surveys. Usage statistics from private parties was not available. To determine a standardized estimate of use regardless of meadow size, the stock nights per acre were calculated by dividing the five year average of stock nights (from 2004-2008) by the meadow acreage. This was problematic for certain sites where stock spend a large proportion of time grazing outside the meadows (Benson Lake), or where use numbers for a specific location could not be determined because packers report a more general location (Tilden and Lyell sites). Therefore, this number is not exact, but provides some basis for comparison for levels of stock use among meadows.

Results

Field staff surveyed twenty-six meadows from July 8, 2008 to October 1, 2008. Half of the meadows were in the high-use category and half were in the low-no use category. All meadows in the study had low gradient slopes (one to four degrees). Most meadows had south-facing aspects and occurred at elevations between 8800 to 9200 feet. Meadow size varied from approximately three to 63 acres (Table 1). Benson Lake was more than 1,000ft lower (at 7,600 feet elevation) than most of the high use meadows, so a similar elevation low-no use meadow was also surveyed (E of Mahan, 7720 ft). Although field staff did not conduct formal surveys for Yosemite toads, toads were noted when they were observed during the course of fieldwork. Field staff sighted adult Yosemite toads in three high use meadows and one low-no use meadow.

Table 1. High use and low-no use meadows surveyed in 2008

Meadow Name (High use)	Survey date	Size acres	Elev. (ft)	Slope/ Aspect (°)	# Plots (grid spacing)	Yosemite toad sighted	Comments
Benson Lake	8/10/2008	3.0	7600	2.5/ 215	29 (20m)	N	Meadow size does not include approximately 45 acres of wooded area where stock graze in the understory.
Castle Camp	7/10/2008	7.2	8770	2/ 239	44 (20m)	N	
Cold Canyon	7/14-15/08	39.2	8680	3/ 149	97 (30m)	N	Collected full plots at every other gridpoint due to time constraints
Dorothy Lake	8/21-22/08	26.6	9400	2.5/ 237	68 (25m)	Y	Added meadow acreage(several gridpoints) on SE side of lake where most recent stock use is occurring.
Hook Lake	7/13/2008	8.3	9400	3/ 208	48 (25m)	Y	
Kerrick Canyon	7/27-28/08	63.0	9300	2/ 185	171 (30m)	Y	Also found Mtn. yellow-legged frogs. Collected full plots at 75% of gridpoints due to time constraints
Matterhorn Canyon	8/7-8/08	25.3	8460	1/ 193	78 (30m)	N	
Miller Lake	7/11-12/08	18.3	9300	2.5/ 200	93 (25m)	N	Survey area composed of three small meadows
Smedberg Lake	8/8/2008	11.4	9220	2.5/ 309	50 (25m)	Y	
Tilden- north	8/24/2008	11.9	8960	2/ 222	57 (30m)	N	Survey area composed of two long, narrow meadows; upper meadow does not receive use (?)
Tilden- south	8/23/2008	8.0	8900	4/ 127	26 (25m)	N	Survey area composed of three small meadows
Uppermost Lyell	9/8-9/08	36.3	8970	2/ 350	123 (30m)	N	Stock may utilize both Upper Lyell meadows in one visit.
Lower-Upper Lyell	9/10-11/08	20.1	8970	2.5/ 318	99 (25m)	N	Stock may utilize both Upper Lyell meadows in one visit.
Dog Lake	9/23/2008	7.9	9170	2/ 240	65 (20m)	N	
Dog Lake East	9/29/2008	4.8	9240	2/ 119	35 (20m)	N	
East of Gaylor Pit	10/1-2/08	7.0	9320	2/ 190	60 (20m)	N	
East of Mahan	8/25/2008	7.1	7720	1/ 184	32 (20m)	N	Only surveyed east section of meadow, to increase certainty of low-no stock use (evidence of use near trail on west side of creek)
Echo Lake	9/4/2008	17.0	9356	1.5/ 176	51 (30m)	N	
Elizabeth Lake	9/22-24/08	28.2	9480	4/ 160	74 (30m)	Y	
Long Meadow	9/2-3/08	46.1	9500	3/ 180	122 (30m)	N	Collected full plots at every other gridpoint due to time constraints
Lower Lyell Canyon	7/22/2008	16.4	8720	3/ 129	77 (25m)	N	
Matthes Lake	9/17-18/08	31.9	9640	4/ 188	107 (30m)	N	

Meadow Name (High use)	Survey date	Size acres	Elev. (ft)	Slope/ Aspect (°)	# Plots (grid spacing)	Yosemite toad sighted	Comments
Snow Flat	9/15, 23/08	9.7	8760	2/ 206	82 (20m)	N	
South of Matterhorn	8/8/2008	5.5	8440	1/ 182	58 (20m)	N	Meadow only partially surveyed due to time constraints
Sunrise Lake (east)	9/2/2008	11.9	9427	1/ 322	78 (25m)	N	
West of Tilden	8/22/2008	14.472	8340	2/ 200	99 (25m)	N	

Overnight pack stock use was reported in 2008 for all high use meadows and one low-no use meadow (Table 2). No use was reported in 2008 for any other low-no use meadow, though meadows may have received occasional undocumented day use or private party overnight use. Pack stock use in the high-use meadows varied widely by year and by meadow. Some meadows had consistent high use each year (Benson, Castle Camp, Matterhorn Canyon, Lyell Canyon sites), whereas other meadows had sporadic high use (2008 Hook Lake and Cold Canyon, 2007-2008 Smedberg Lake). Castle Camp's average per acre use is five times higher than any other site, though grazing of understory vegetation in the surrounding wooded areas takes place once the preferred meadow vegetation has been grazed (Mark Fincher, Wilderness Specialist at Yosemite National Park, personal communication). Stock use per acre at Benson Lake is likely much higher in the meadows than the calculated value, since this value was diluted by including 45 acres of open wooded area where pack stock reportedly graze for a large proportion of their time (Mark Fincher, personal communication).

Appendix C contains detailed results on each of the high-use meadows surveyed, including results for streambank surveys and a site map showing vegetation communities and stock evidence. Appendix D contains a summary table of findings from high-use meadows surveyed. The following sections in this portion of the report summarize results from surveys, to characterize meadow conditions and make comparisons across groups of high use and low-no use meadows.

Table 2. Pack stock use levels in all high use and one low-no use meadow. The column for each year indicates total usage over the course of the season, in stock nights (For example, 120 stock nights could be a party of 12 stock for 10 nights). The last column indicates the amount of usage that took place in 2008 prior to the date the site was surveyed. Table 2 is continued on the next page.

Meadow Name	Total Stock Use Nights					Average	Average stock nights/ acre	2008 pre-survey stock nights
	2004	2005	2006	2007	2008			
Benson Lake (includes forest)	120	190	118	201	173	140	3.1	70
Castle Camp	72	57	409	239	576	270.6	37.7	0
Cold Canyon	26	22	22	0	85	31	0.8	0
Dorothy Lake	73	54	35	0	52	43	1.6	35
E. Sunrise Lake (low-no use site)	0	25	0	0	0	5	0.42	0
Hook Lake	8	0	0	0	76	17	2.0	0
Kerrick Canyon	91	53	73	106	0	65	1.0	0
Matterhorn Canyon	92	49	102	262	238	149	5.9	72
Miller Lake	123	0	0	11	20	31	1.7	0
Smedberg Lake	68	11	0	52	90	44	3.9	40

Meadow Name	Total Stock Use Nights					Average	Average stock nights/ acre	2008 pre-survey stock nights
	2004	2005	2006	2007	2008			
Tilden- north	163	128	75	0	21	77	3.9	21
Tilden- south	163	128	75	0	21	77	3.9	21
Uppermost Lyell	440	219	487	564	326	407	7.2	326
Lower-Upper Lyell	440	219	487	564	326	407	7.2	326

Vegetation communities

Field staff identified plant communities at over 2,500 gridpoint plots, and collected full plot data (as outlined under the Gridpoint Plot Data" subsection of Methods) at 1,805 of these plots. Staff identified twenty herbaceous meadow communities and five willow shrubland communities from the Yosemite floristic classification (Natureserve 2007) in the meadows surveyed. Figure 1 illustrates the proportions of plant communities in each meadow, with the least-encountered associations grouped into "other associations," and all willow communities merged into "*Salix* association." "Other associations" also represents those gridpoint areas which did not fit the Yosemite Floristic Classification. "Other Carex alliance" represents gridpoint areas dominated by sedge species that did not fit the Yosemite Floristic Classification. *Carex vesicaria* and *Carex utriculata* were not distinguished as separate species during the fieldwork, since they are difficult to tell apart in the field and are functionally very similar in their habitat requirements.

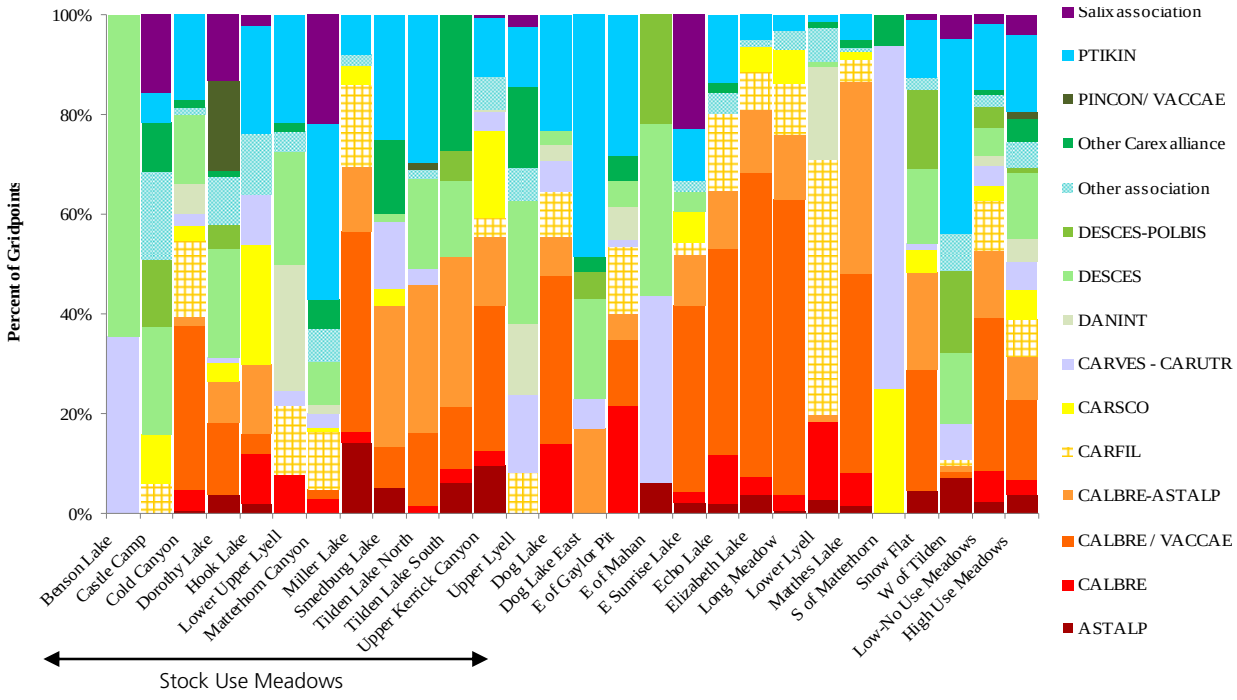


Figure 1. Plant community composition for all meadows. The last two bars represent a summary of high use and low-no use meadows. The location and legend are listed in alphabetical order (meadows grouped by high use and low-no use.) Plant associations in the legend are abbreviated with 6-letter codes first three letters of the genus and species.) See Appendix A for a crosswalk of association names to 6-letter codes and common names.

Several communities were dominant consistently throughout the meadows surveyed. *Calamagrostis breweri* / *Vaccinium cespitosum* comprised 22% of all gridpoints surveyed, and *Ptilagrostis kingii*

communities comprised 15%. *Calamagrostis breweri* / *Aster alpigenus*, *Deschampsia caespitosa*, and *Carex filifolia* each comprised 9-10% of the gridpoints surveyed. *Carex vesicaria- utriculata*, *Calamagrostis breweri*, *Danthonia intermedia*, *Carex scopulorum*, and *Aster alpigenus* comprised 3-5% of the gridpoints surveyed. At least two of these ten communities dominated over 90% of the vegetation surveyed in each meadow. High use and low-no use meadows did not differ greatly in the proportions of their plant communities when looking at them as groups; however, individual meadows did vary greatly in terms of which communities were most dominant.

The most dominant species from gridpoint plots were correlated to the regional wetland indicator species list (available at http://www.fws.gov/nwi/Plants/list88.html) to determine the proportion of gridpoints with wetland indicator species. Wetland vegetation was grouped into the following categories: obligate wetland species (OBL) occur in wetlands greater than 99% of the time, facultative wetland species (FACW) occur in wetlands greater than 67% of time), facultative species (FAC) equally occur in wetlands and non-wetlands, facultative upland species (FACU) usually occur in non-wetlands, and obligate upland species (UPL) almost never occur in wetlands. After determining the proportion of vegetation dominated by species from each category, inferences were made about the wetness of each meadow.

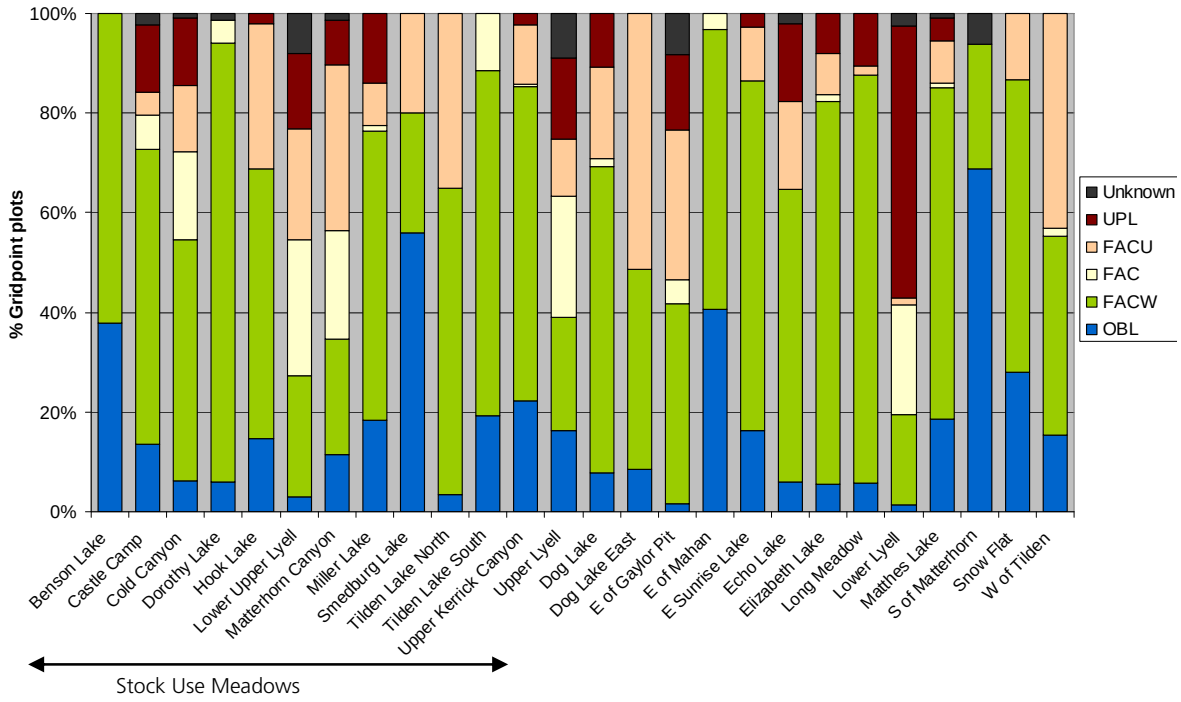


Figure 2. Proportion of regional wetland indicator ratings for most dominant species ("dominant species 1") at meadow gridpoints. "Unknown" portion of bars represents species identified only to genus level, and wetland indicator status was not able to be determined. UPL= upland, FACU= facultative upland, FAC= facultative, FACW= facultative wetland, OBL= obligate wetland.

More than half the vegetation in most meadows was dominated by FACW species (Figure 2). S of Matterhorn and Smedberg Lake had the highest proportion of OBL species and therefore likely had the highest proportion of area saturated for much of the growing season. Benson Lake and E of Mahan were also likely very wet, with all or nearly all of their plots dominated by OBL or FACW species. Lower Lyell was by far the driest meadow, with more than half its vegetation dominated by UPL species. Lower-Upper Lyell, Matterhorn Canyon, and E of Gaylor Pit were relatively dry, with a little over 40% of their vegetation dominated by UPL and FACU species.

Gridpoint plot data analysis

Certain meadow plant communities naturally have more bare ground. The most obvious example of these are *Carex filifolia* communities, which grow in drier, gravelly areas, compared to more mesic communities like *Calamagrostis breweri*, *Deschampsia cespitosa* or *Aster alpigenus* (Cooper *et al.* 2006). If a meadow has more *Carex filifolia* communities, it will naturally have a higher percentage of bare ground. To confirm this in our data, average bare ground was calculated across all plots for the common herbaceous plant communities (listed in Figure 1 above), and only *Carex filifolia* had significantly more bare ground compared to the other communities. Therefore, when graphically comparing attributes (such as bare ground, total vegetation cover, mammal burrowing activity, etc.) across meadows, *Carex filifolia* plots were separated in the analyses (See Figures 3-5 below). Further statistical analyses were conducted by separating non-*Carex filifolia* plots according to dominant plant species, to detect differences in specific plant communities. The number of plots dominated by a particular community of interest varied greatly within each meadow, so meadow-level means were based on a highly-variable number of plots. An additional bootstrapping analysis was conducted on the subset of meadows containing at least five plots in areas dominated by the species of interest (Starcevich 2009). Appendix B contains tables detailing the results of these analyses for percent cover of bare ground and total vegetation cover.

Mean bare ground values were higher in the high use meadows surveyed compared to the low-no use meadows, with the greatest difference in *Carex filifolia* vegetation (Figure 3). On average, high use meadows had 15% more bare ground in *Carex filifolia* communities ($t=1.96$, $p=0.0353$) and 3% more bare ground in other vegetation ($t=2.69$, $p=0.0177$). Significantly more bare ground ($p<0.05$) was found in high-use meadow communities of *Carex scopulorum*, *Carex vesicaria-utriculata*, *Deschampsia cespitosa*, and *Vaccinium caespitosum* when all plots were considered. When meadows with greater than five plots of each dominant species were considered, *Ptilagrostis kingii* and *Aster alpigenus* were also found to have significantly more bare ground. The greatest outlier of the meadows was Lower Lyell, which had much higher levels of bare ground in non-*Carex filifolia* communities than the other low-no use meadows. Lower Lyell meadow was characterized by dry, sandy soil and was the only meadow with a few plots dominated by the shrub *Artemisia tridentata*.

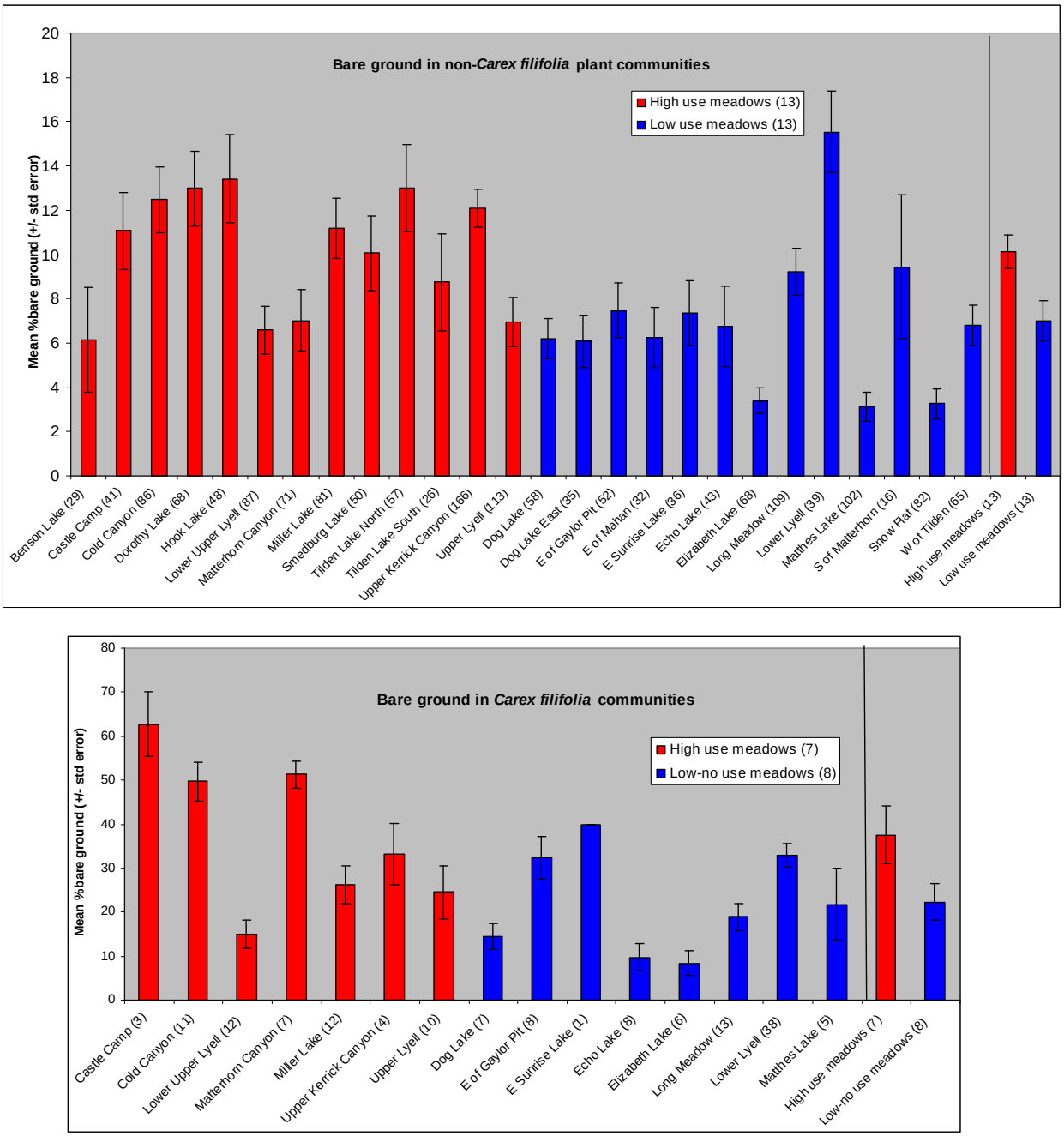


Figure 3. Mean bare ground values. Meadows without *Carex filifolia* communities appear in the lower graph. Sample size is indicated in parentheses after each meadow name.

Low bare ground cover in a meadow does not necessarily imply high vegetation cover, as litter or moss may cover the ground. Therefore total vegetation cover was also compared among meadows (Figure 4). Only *Deschampsia cespitosa* communities demonstrated a significant effect of pack stock use, with total vegetation cover 8% lower in high use meadows (t=1.82, p=0.0372). However, this difference was not statistically significant when the analysis was conducted on meadows with at least five plots of *Deschampsia cespitosa*. No other plant communities had statistically significant differences in total vegetation cover between high use and low-no use meadows.

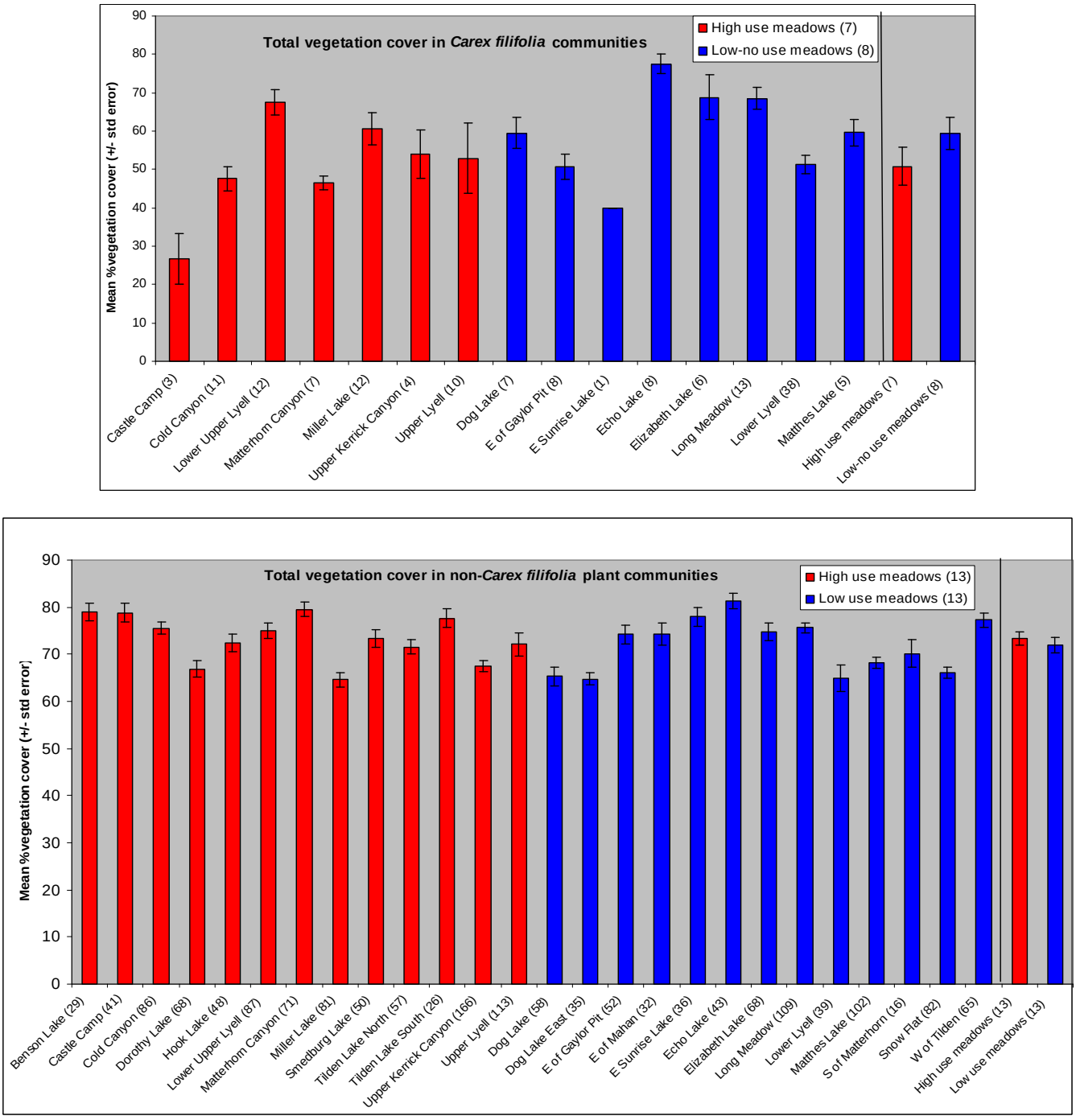
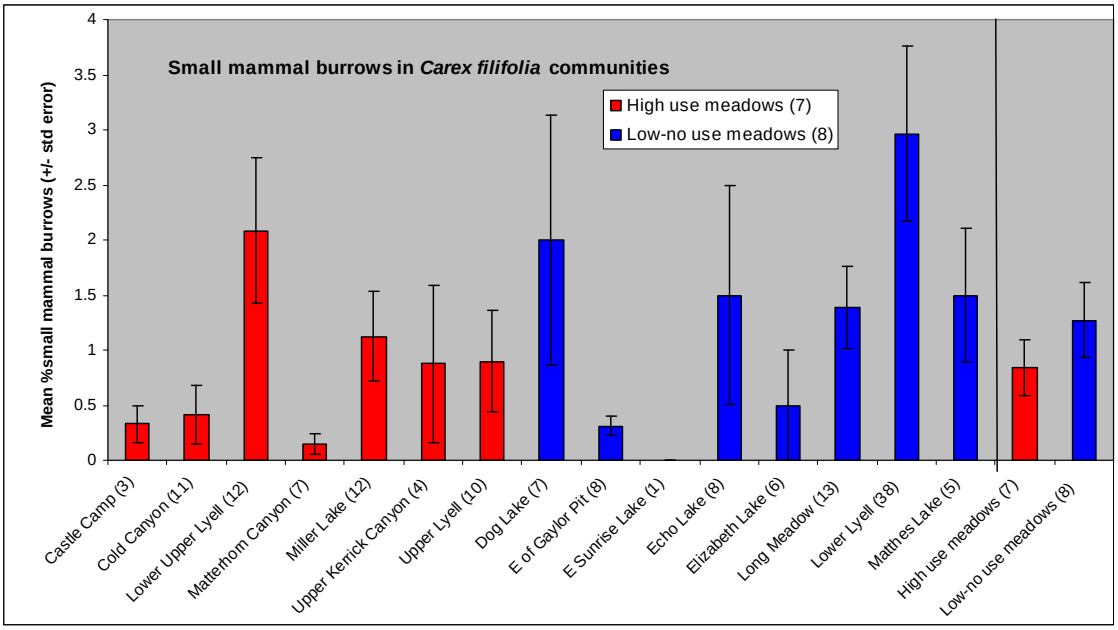


Figure 4. Mean total vegetation cover values for *Carex filifolia* and all other vegetation communities. Meadows without *Carex filifolia* communities do not appear in the upper graph. Sample size is indicated in parentheses after each meadow name.

Small mammal burrows and/or burrow tailings were found in 38% of all plots surveyed. Across all meadows, plots dominated by *Calamagrostis breweri* had the most burrowing evidence (12% of plots), followed by *Ptilagrostis kingii* (10%) and *Carex filifolia* (5%). *Vaccinium caespitosum* and *Deschampsia cespitosa* had burrowing evidence in 4% of all plots. Lower Lyell had the highest levels of small mammal burrows, particularly in non-*Carex filifolia* vegetation (Figure 5). This was also the driest of the meadows surveyed. Meadows which had a high proportion of wet vegetation (such as S of Matterhorn, Benson Lake,

Smedberg Lake) tended to have low levels of small mammal burrowing evidence, since much of the meadow is likely saturated during the growing season. Because of the wide variation among plots within meadows , a consistent difference was not detected in small mammal burrowing between high and low-no use meadows. Data for small mammal burrow cover were not statistically analyzed.



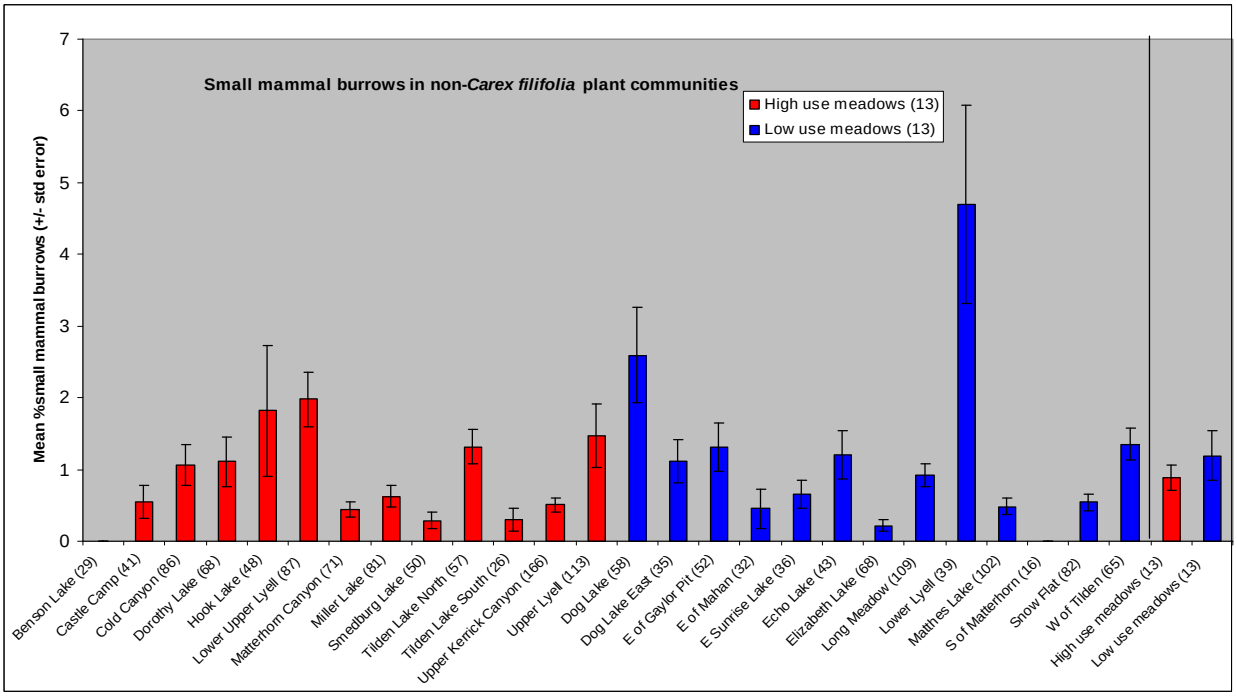


Figure 5. Mean small mammal burrowing cover values for *Carex filifolia* and all other vegetation communities. Meadows without *Carex filifolia* communities do not appear in the upper graph. Sample size is indicated in parentheses after each meadow name.

Other data collected which are not summarized here include moss cover, litter cover, and litter depth. Canopy height data could not be analyzed with confidence because the methodology resulted in the tallest

structure (often the inflorescence) being measured. Therefore, meadows that were visited earlier in the season (before the grass heads had fully bolted) had shorter canopy heights than those visited later in the season, thus confounding the data.

Data on pack stock evidence were summarized from gridpoint plots to determine the proportion of plots with any evidence present. Data were also summarized to determine proportion of plots with greater than 10% cover of evidence, in order to determine the proportion of plots that showed more intensive use. Because of the importance of hoofpunches in indicating use when soils are wet, hoofpunches were reported separately for each meadow (Figure 6). Stock use evidence (hoofpunching, hoofprints, manure, or grazed vegetation) was found in gridpoint plots from all high use meadows and seven of the 13 low-no use meadows. Benson Lake and Upper Lyell Canyon showed the highest proportion of plots with any pack stock use evidence and proportion of plots with >10% cover of pack stock use evidence. Smedberg Lake, Tilden South, and Matterhorn Canyon also had very high levels of pack stock use evidence. Most of the low-no use meadows had very little, if any pack stock use evidence.

The meadows with the highest proportion of plots containing hoofpunches were also those meadows with the highest proportions of OBL and FACW wetland species (Benson Lake, Smedburg Lake, Matterhorn Canyon), with the exception of Upper Lyell. Upper Lyell had a first stock use date for 2008 that was earlier than all but one of the high use meadows. First use dates for each meadow are reported in the individual meadow descriptions in Appendix C.

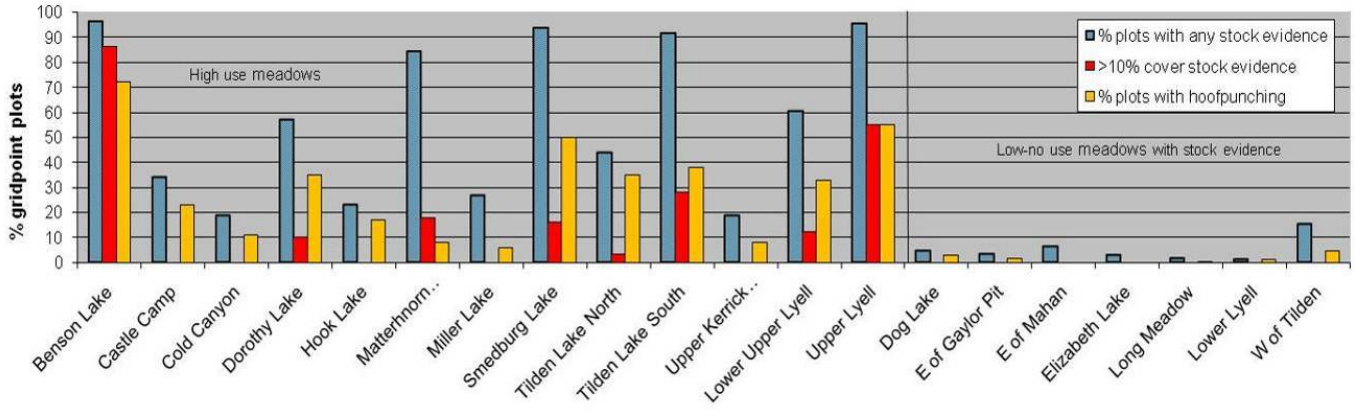


Figure 6. Proportion of plots in each low-use meadow with pack stock use evidence. Stock evidence consists of hoofpunching, hoofprints, manure, or grazing. Hoofpunching is denoted with yellow bars.

Streambank survey data

Streams were surveyed in all meadows except for Benson and Dorothy Lakes (high use) and E of Mahan and S of Matterhorn (low use), since those sites did not have streams running through the survey areas. Total survey length was much greater in high use meadows than low-no use meadows (Table 3).

Table 3. Stream survey lengths for high use and low-no use meadows.

High use meadows	Survey length (m)	Low-no use meadows	Survey length (m)
Castle Camp	868	Dog Lake	332
Cold Canyon	2412	East of Dog Lake	381
Hook Lake	518	East of Gaylor Pit	859
Kerrick Canyon	2114	Echo Lake	1219
Matterhorn Canyon	2728	Elizabeth Lake	307
Miller Lake	1804	Long Meadow	1165
Smedberg Lake	840	Lower Lyell Canyon	987
Tilden- north	1748	Matthes Lake	872
Tilden- south	238	Snow Flat	659
Uppermost Lyell	3310	East Sunrise Lake	155
Lower-Upper Lyell	1421	West of Tilden	1309
Totals:	18372		8249

Erosion features

High use meadows at Upper Lyell, Lower-Upper Lyell, and Castle Camp all had the highest proportions of length with streambank erosion (40-44%), followed by low-no use meadows at East of Dog Lake (38%), Elizabeth Lake (28%) and Matthes Lake (28%, Figure 7). Long Meadow, Cold Canyon, East Sunrise Lake and Snow Flat (all low-no use meadows except for Cold Canyon) had the lowest proportions of erosion features (2-3%).

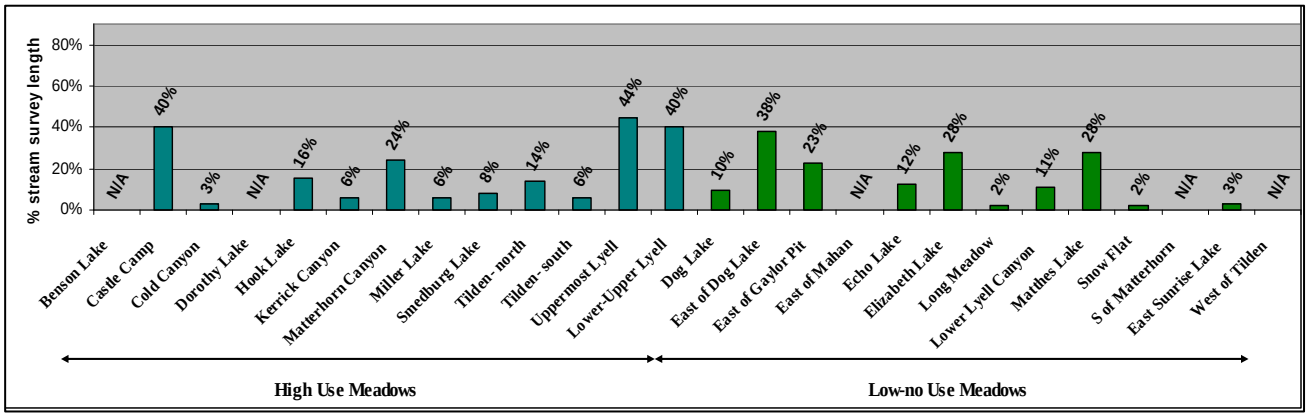


Figure 7. Percent of each stream with erosion features mapped.

Fracturing and blocking were the most common erosion features for all streams, with high use meadows showing slightly higher proportions of these features than low-no use meadows (Figure 8). High use meadows had approximately 5% more total erosion features on average than low-no use meadows, however the variation in data between meadows was so high that this may not be a significant difference. Due to time and budgetary constraints, statistical analyses were not performed on the streambank data. Information on types of erosion features found on streams in each meadow is contained in Appendix C.

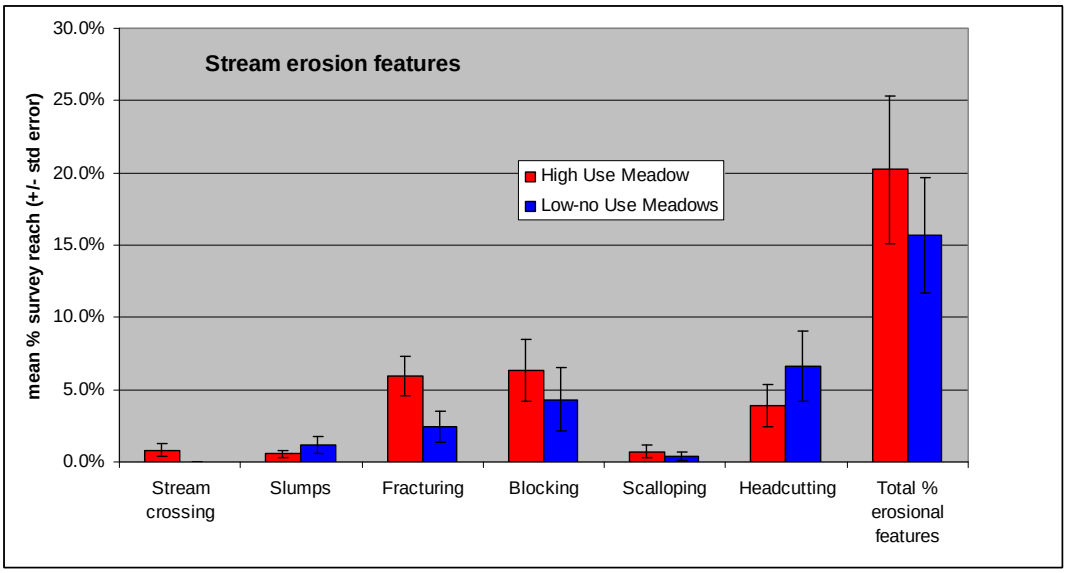


Figure 8. Streambank erosion features for high use vs. low-no use meadows

Streambank characterization

High use and low-no use meadow streams did show obvious differences in streambank composition (Figure 9). The most common streambank category for both high use and low-no use meadows was dense herbaceous vegetation. Willows were also common on stream banks in both meadow types, and a low proportion of stream banks were composed of either bare soil or sparse vegetation. Variability among meadows of both groups was great, however low-no use meadows did have a lower proportion of bare streambanks, no sections of streambank with only bare soil or gravel, and fewer sections of low-moderate herbaceous cover. Information on streambank composition for each meadow is given in Appendix C.

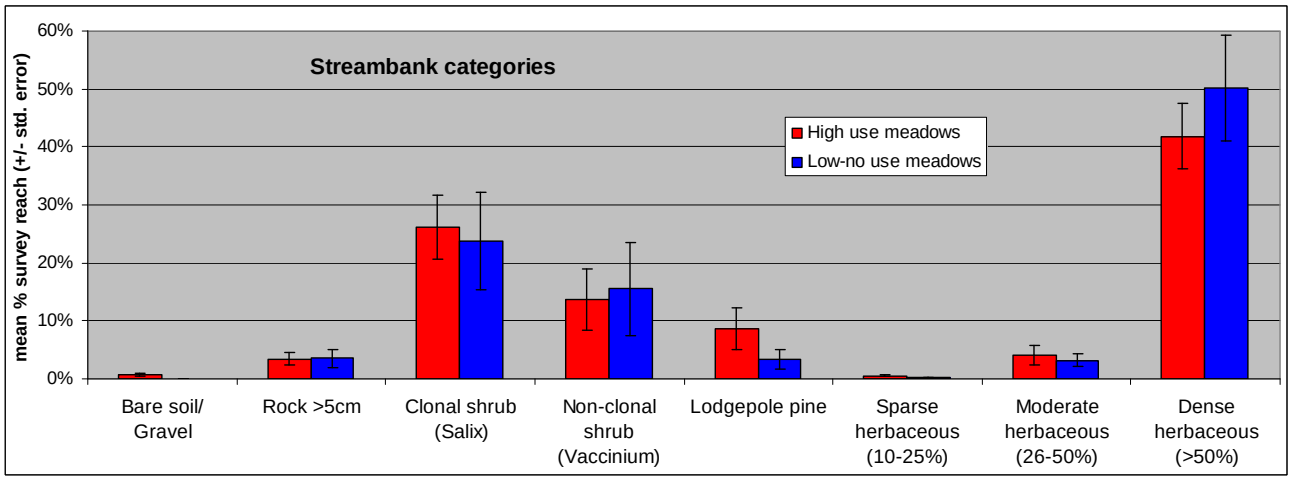


Figure 9. Streambank composition for high use vs. low-no use meadows. Herbaceous vegetation >50% cover has been left off this graph (42.0% for high use, 49.2% for low-no use) for display purposes, so a smaller scale could be used.

Mapping and Quantifying Evidence of Pack stock Use

Stock use evidence mapped within all meadow survey areas (in the form of roll pits, trampled areas, grazed areas, and social trails) totaled 55,111 square meters (13.6 acres). Approximately 56% of this area was classified as trampled, 42% as grazed, 1% as roll pits and 1% as meadow informal trails. Nearly 500 medium to high density manure points (more than three piles less than 2m apart) were also mapped, with many more low-density manure piles. The highest total area of pack stock evidence mapped was in Upper Lyell Canyon. However if meadow size is considered, the highest evidence per square meter of meadow was mapped at Benson Lake (Figure 10, left graph). Castle Camp, Cold Canyon, Hook Lake, Upper Kerrick Meadow, and Miller Lake were surveyed before any overnight pack stock use for 2008 occurred. Therefore, any pack stock evidence mapped was likely residual evidence left from previous years' use. Stock evidence mapped generally increased with the current season's pack stock use numbers (Figure 10, right graph) with the exception of Lower-upper Lyell. Stock nights reported for Lyell Canyon was divided in half to obtain use numbers for Lower-upper Lyell and Upper Lyell, which may not reflect actual use patterns, since pack stock use is known to be more concentrated in Upper Lyell Canyon (Mark Fincher, Yosemite Wilderness Specialist, personal communication).

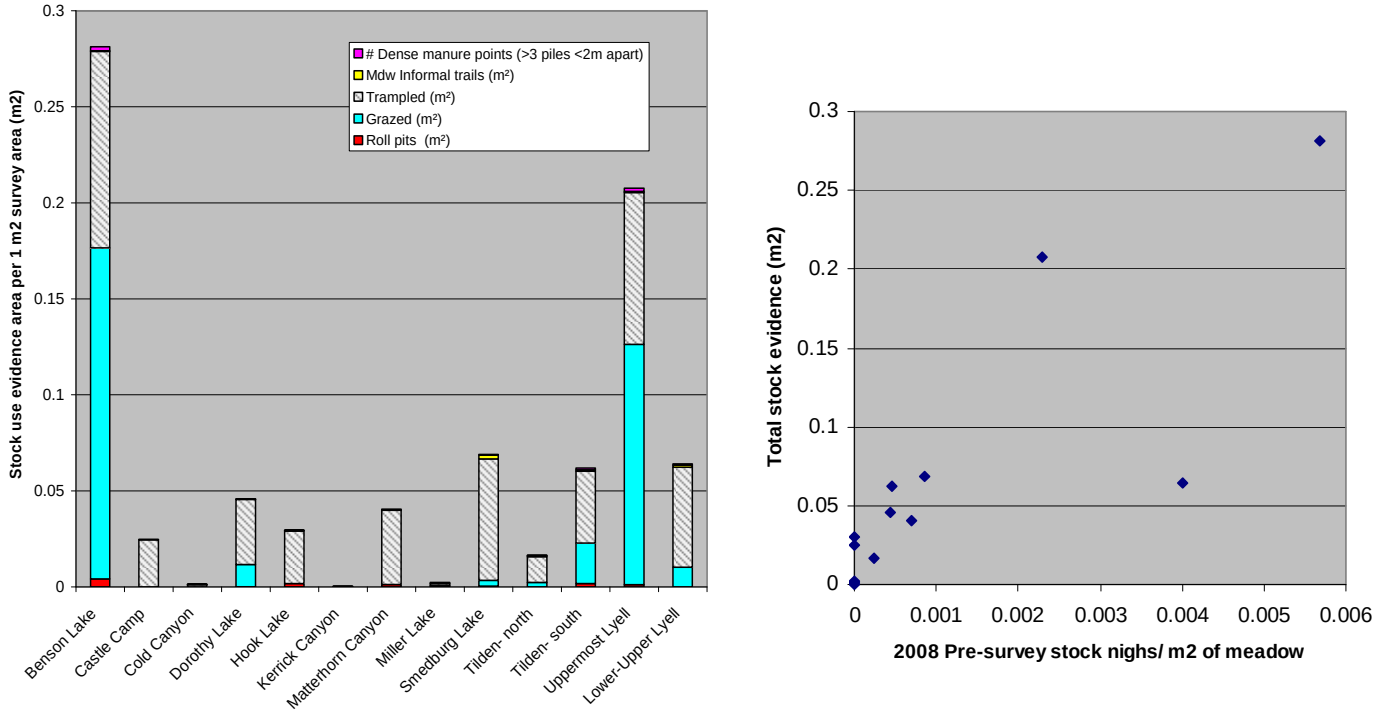


Figure 10. Stock use evidence mapped in high use meadows. Values were calculated by taking the area of polygons mapped and dividing it by meadow area so that graphs would depict evidence relative to meadow size. The second graph depicts all evidence mapped graphed against pre-survey pack stock use for 2008.

Discussion

Vegetation

Plant communities common to Sierra Nevada subalpine meadows dominated the 26 meadows in this survey. The proportions of these communities and dominant species varied among meadows, allowing for characterization of meadows based on vegetation types. Of meadows surveyed with high pack stock use, all had at least a small proportion of obligate wetland species, indicating that each meadow contained areas that are likely saturated long into the growing season. This information is important because the effects of pack stock grazing (mainly hoofpunching or trampling) are severe in moist to hydric communities (Stohlgren *et al.* 1989, Cole *et al.* 2004), and soil shearing and root severing occurs more easily in wet soils (Vallentine 1990). According to vegetation data, the wettest meadows surveyed were Benson Lake, Dorothy Lake, Tilden South and Upper Kerrick, but anecdotal observation of site conditions (saturated soils) during the surveys indicates that Castle Camp, Hook Lake, and Smedberg Lake also have a high proportion of wet areas. In future studies, wetland indicator ratings tailored specifically to conditions in Yosemite could better inform these results, as some species in Yosemite are known to occur in habitats that are wetter or drier than their regional wetland indicator ratings suggest. For example, *Vaccinium caespitosum*, regionally rated as a facultative wetland plant, occurs in drier areas of meadows in Yosemite such as conifer-encroached meadow edges (anecdotal observations).

Gridpoint data analysis

Bare ground and vegetation cover are important indicators of meadow health. Increases in bare ground would be cause for concern since these areas are most susceptible to erosion during spring runoff and storm events. In the 26 meadows surveyed, high use meadows on average had 15% more bare ground in *Carex filifolia* communities and 3% more bare ground in other communities, compared to low use meadows. These were statistically significant differences when the bootstrap t-test was performed. This is consistent with other related studies, which found increased bare ground in grazed meadow communities (Stohlgren *et al.* 1989, Olson-Rutz *et al.* 1996, Cole *et al.* 2004). It should be noted that because selection of meadows in this study was not random, inferences about grazed and ungrazed meadows outside of this study cannot be made.

The difference between high use and low-no use meadows was not apparent in total vegetation cover, where only *Deschampsia cespitosa* communities had significantly lower total vegetation cover in high use meadows. It may seem contradictory that meadows with higher bare ground could have the same total vegetation as meadows with less bare ground, but litter cover could make up the difference in these situations. Due to time and budgetary constraints, litter cover was not analyzed in this study, but if low-no use meadows had higher litter cover, they could exhibit lower bare ground cover while exhibiting the same total vegetative cover as high use meadows. A plausible explanation for higher litter cover in low-no use meadows is that horse traffic may disturb the thatch layer between live vegetation, creating more bare ground in the high use meadows. In addition, grazing removes herbaceous material that might otherwise accumulate as litter. No supporting evidence was found in the published literature to corroborate this theory, however.

Differences between high use and low-no use meadows in this study could be understated, as the low use meadows chosen for this study were not completely pristine and all have sustained some level of anthropogenic impact. Due to time constraints, low-no use meadows were chosen adjacent to trails, and many have heavy traffic from hikers or a history of heavy past grazing. For example, Dog Lake East and

Lower Lyell were used as administrative pastures for decades, possibly until the 1960s. E of Mahan had a trail crew camped on its edge in 1980-1981 and again in the mid 1990s, and their stock support grazed this meadow. Dog Lake, Sunrise Lakes, Elizabeth Lake, and Echo Lake are all popular hiking destinations with heavy day-use traffic. An old road bed is still visible in Snow Flat Meadow, and this may affect hydrologic processes there. The statistical differences between high use and low-no use meadows that were found in this study suggests that further investigation into the relationship between pack stock use and meadow condition would be informative. A future study involving random selection of meadows, a higher sample size of meadows, and a pool of low-no use meadows in more pristine condition would be valuable.

Information from gridpoint plot data provided a way to quantify and characterize distribution and levels of pack stock use evidence across meadows. High use meadows had widely varying amounts of 2008 pack stock use prior to the survey, but even those meadows having no documented 2008 use (Castle Camp, Cold Canyon, Hook Lake, Miller Lake and Upper Kerrick) had 19-34% of plots with pack stock evidence persistent from previous years. This demonstrates that the physical evidence of use (mainly hoofpunching and manure) can last beyond one season. Because of the myriad of known negative effects of trampling on meadows (such as soil compaction, erosion, decrease in vegetation, increase in bare ground, shifts in plant communities), there is cause for concern that trampling will degrade ecosystem function in these meadows. Trampled areas (hoofpunches less than ½ meter apart) were mapped in most of the high use meadows, and hoofpunches were found in greater than 30% of gridpoint plots in most high use meadows. This suggests that most of the high use meadows had at least one third of their area with soil moisture high enough to be susceptible to hoofpunching at the time when stock first entered the meadow. Monitoring wet areas in meadows and determining the rates that different meadows dry out early in the season would contribute valuable information for determining when stock use can occur without unacceptable levels of hoofpunching.

Streambank surveys

Meadow ecosystems are severely affected when associated stream channels are degraded (Odion *et al.* 1988). Headcut formation, channel incision and streambank erosion have the ability to compromise healthy hydrologic function when such processes are exacerbated. This can cause the lowering of water tables in meadows to the detriment of meadow plant communities (Odion *et al.* 1988). In the meadows surveyed in 2008, the proportion of erosion features along stream survey reaches varied greatly among meadows, although the three streams with the greatest proportion of erosion features were in high use meadows (Upper Lyell, Lower-Upper Lyell, and Castle Camp). These three streams also had 20-30% of erosion features with stock evidence within 2m of the stream. On average, high use meadows had 5% more erosion features compared to low-no use meadows, particularly fracturing and blocking. However, further analyses would be needed to detect any statistical significance in this difference. There is evidence in the literature that streambank shearing and increased erosion occur in grazed areas (Kauffman and Krueger 1984), so the effect that pack stock may have on stream banks in Yosemite is of concern.

It is difficult to compare surveys from different streams because of confounding factors such as differing streamflow rates, gradients, bank substrate composition, stream channel composition, and historic use patterns, among others. However, the finding that survey reaches in Upper Lyell and Lower-Upper Lyell (high use meadows) had nearly four times the proportion of erosion features of Lower Lyell (a low use meadow) warrants further investigation. Future studies that pair survey reaches in grazed meadows with reaches along the same stream in ungrazed meadows could be used to better develop a correlation between pack stock use and streambank erosion.

Stream banks armored with vegetation, large rocks, and woody debris are less subject to erosion than those composed mainly of bare soil. Vegetation contributes greatly to bank stability, with wet meadow vegetation decreasing the erodibility of stream banks ten times more than dry meadow vegetation (Micheli and Kirchner 2002). In addition, shrubs (mainly willows) are thought to provide much greater streambank stabilization than herbaceous vegetation (Cooper *et al.* 2006).All stream banks in this study were well-armored with vegetation, though the composition of life forms varied greatly among meadows. On average, high use and low-no use meadows had similar proportions of shrubs, herbaceous vegetation, rock, etc. lining stream banks. However, low-no use meadows did have a lower proportion of bare stream banks, no sections of streambank with only bare soil or gravel, and fewer sections of low-moderate herbaceous cover. The proportion of "bare" stream banks in high use meadows was still low, however (less than 7%), so risk of erosion due to lack of vegetation on the banks appears to be low. This does not diminish the potential for erosion from pack stock use due to the factors mentioned above, such as bank shearing and trampled banks.

Mapping and quantification of pack stock use

Not surprisingly, the highest amounts of pack stock evidence mapped per unit area occurred in meadows with the highest 2008 pre-survey pack stock use per unit area (Upper Lyell and Benson Lake). However, all high use meadows but one (Upper Kerrick, which has seen very little use in recent years) had areas of hoofpunching dense enough to be mapped as trampled. This suggests that these meadows have some areas of wet soils when pack stock enter these meadows at the start of the season. Trampling has been shown to increase bare ground, lower vegetation cover, increase soil compaction and erosion, and potentially drive community shifts away from a healthy dominance of mat-forming grasses and sedges (Cole 1987, McClaran and Cole 1993, Cooper *et al.* 2006). Therefore, investigation of the extent of wet areas in these meadows early in the season and the rate at which they dry out during the season would contribute important information as to when (and to what extent) these meadows are most susceptible to trampling impacts.

Grazed areas were mapped in all meadows that had pre-survey 2008 pack stock nights except Matterhorn Canyon. Grazed areas were defined in this study as areas at least 20 square meters that had the appearance of continuous (not patchy) clipped vegetation. Other studies have shown detrimental effects to meadows when percent utilization of vegetation reaches certain thresholds (Stohlgren *et al.* 1989, Cole *et al.* 2004), indicating that impacts from grazing could be realized at sites receiving high levels of use. Our study did not measure percent utilization of vegetation, but meadows with extensive grazed polygons mapped (or projected, based on the use data) should be monitored in the future. Meadows that receive consistently high use every year (such as Benson Lake, Castle Camp, Matterhorn Canyon, Upper Lyell sites) could be monitored for percent utilization of preferred forage species, particularly during high stock use years.

Field staff mapped concentrations of manure in every high use meadow surveyed except for Castle Camp. (In the case of Castle Camp, completely inundated site conditions of this meadow observed in the early season most likely caused disintegration of manure to the point that it is not visible.) Manure was generally most concentrated around pack stock camp holding areas, although medium to high-density manure points were found throughout all meadows that received 2008 stock use prior to the survey. Recent attention has been given to the possibility that fecal coliform, *Giardia*, or other pathogens could be transported to water sources through pack stock manure (Derlet and Carlson 2006). Manure on trails or in meadows can be swept into watercourses by runoff from snowmelt or storm events, so this concern is not unwarranted. However, in a recent study of pack stock kept at Tuolumne Meadows in Yosemite, less than 0.5% of stock shed detectable oocysts of *Cryptosporidium* (Atwill 2008), lessening concerns about contamination of water sources with that parasite from this herd. Monitoring water downstream from high use meadows for

contamination with pathogens and parasites, particularly during spring runoff or storm events, would be useful to help determine the risks to water quality from pack stock manure.

Other findings

The summary findings from the high use meadows in this study identify three key factors in assessing stock use in relation to meadow integrity: effects from levels of stock use, effects from timing of stock use, and effects of stock on resources of special concern. Determining a threshold at which stock use levels have undesirable effects can be problematic, particularly due to the variation between meadows, and differences in the resistance or resilience of each meadow to effects from pack stock use (Cole 1995). Ratliff *et al.* (1987) recommends methods for determining appropriate levels of pack stock use based on estimates of forage production in meadows. Others recommend thresholds for utilization of forage without deleterious effects on certain measures of meadow health (Cole *et al.* 2004). Land managers in Yosemite National Park are beginning to test utilization thresholds to develop estimates for appropriate total pack stock nights per year at each meadow in order to avoid reaching thresholds where unacceptable impacts occur. In the near future, pilot studies will test and monitor initial prescribed stock use levels. Careful monitoring of site conditions using the baseline information in this study and integration of factors such as snowpack and weather patterns would provide feedback to adjust pack stock numbers.

Regardless of use level, meadow health and function may be compromised if pack stock enter a meadow too early in the season, before soils have dried sufficiently or plants are sufficiently mature. All but one of the high use meadows in this study had trampled areas, indicating that when stock first entered, soils were wet in at least part of each meadow. Grazing too early in the season, before plants are mature enough to support herbivory, can compromise health of vegetation and alter communities by changing competitive dynamics (Briske 1991). Site visits to meadows early in the season would contribute valuable information toward determining when soils are dry enough and plants are mature (i.e. “range ready”) for pack stock use. Some meadow areas may remain wet throughout the year, never reaching “range readiness.” Condition assessments from this study can help prioritize wet meadow areas for further study.

Regardless of timing or level of use, the presence of pack stock could have a negative effect on sensitive resources of concern. In 2008, land managers took action and closed Upper Kerrick Meadows to pack stock use after field staff documented breeding populations of Yosemite toads and mountain yellow-legged frogs in the meadow. At present, the effects of pack stock on other breeding amphibian populations in Yosemite are largely unknown, and pack stock could have an impact on additional sensitive resources such as archeological sites or rare/threatened plant populations at certain sites. More information on how pack stock may affect various resources of concern is needed to inform effective strategies for balancing pack stock use and resource protection.

Healthy, functioning meadows in the Tuolumne watershed serve as biological filters that improve downstream water quality. This study documents conditions in a select group of meadows in Yosemite receiving pack stock use and forms a baseline for monitoring meadow conditions. A follow-up study is underway to collect site-specific data on the status and trend of meadow vegetation and substrate, analyze streambank data to relate on-the-ground conditions to water quality, and conduct monthly water quality testing. In the future, determining target conditions for meadows and appropriate levels and timing of pack stock use for each meadow will be important steps in managing meadow resources.

While this is the first time that a quantitative conditions assessment of the condition of meadows with high levels of pack stock use versus meadows with low to no use has been conducted in Yosemite, many questions remain unanswered. For instance, what thresholds of different types of pack stock disturbance

lead to undesirable effects on a meadow? How might the relationship between use and effects vary for different meadow types? Once thresholds are better known, are there "early warning" indicators that a site may be close to its disturbance threshold? How much of a site needs to be "range ready" in order to avoid undesirable impacts? How long do the visible impacts of stock use (such as trampling) last, and how long do the ecological impacts (such as increased bare ground or decreased meadow productivity) last? How might impacts from historic use affect the susceptibility of meadows to impacts from current use? Furthermore, how might large-scale processes (i.e., climate change) interact with pack stock impacts or recovery from past use? Research in all of these areas would be valuable in guiding effective monitoring and management of meadows used by pack stock.

Literature Cited

Atwill, E.R. 2008. *Hetch Hetchy watershed pack stock and microbial water quality study*, University of California, Davis, CA. Report prepared for Yosemite National Park.

Briske, D. D. 1991. Developmental morphology and physiology of grasses. In: *Grazing Management: an Ecological Perspective*. R. Heitschmidt and J.W. Stuh, eds. Portland, OR. pp 85-108.

Cole, D.N. 1987. Effects of three seasons of experimental trampling on five montane forest communities and a grassland in western Montana, USA. *Biological Conservation* 40: 219-244.

Cole, D.N. 1995. Experimental trampling of vegetation II. Predictors of resistance and resilience. *Journal of Applied Ecology* 32: 203-214.

Cole, D.N., J.W. van Wagtendonk, M.P. McClaran, P.E. Moore, and N.K. McDougald. 2004. Response of mountain meadows to grazing by recreational pack stock. *Journal of Range Management* 57: 153-160.

Cooper, D. J., J. D. Lundquist, J. King, A. Flint, L. Flint, E. Wolf, F. C. Lott and J. Roche. 2006. *Effects of the Tioga Road on hydrologic processes and lodgepole pine invasion into Tuolumne Meadows, Yosemite National Park.* Report prepared for Yosemite National Park.

Derlet, M.D. and J.D. Carlson. 2006. Coliform bacteria in Sierra Nevada wilderness Lakes and Streams: What is the impact of backpackers, pack animals, and cattle? *Wilderness and Environmental Medicine* 17: 15-20.

Fischer, J, and C. Elliot. 2007. *Pack stock use assessment in mountain meadows: Interim status report.* USDI National Park Service. Yosemite National Park, CA

Frazier J.W., K.B. Roby, J.A. Boberg, K. Kenfield, J.B. Reiner, D.L. Azuma, J.L. Furnish, B.P. Staab, S.L. Grant 2005. *Stream Condition Inventory Technical Guide.* USDA Forest Service, Pacific Southwest Region - Ecosystem Conservation Staff. Vallejo, CA. 111 pp.

Jamarillo, V.J. and J.K. Detling. 1992. Small-scale heterogeneity in a semi-arid North American Grassland. II. Cattle grazing of simulated urine patches. *Journal of Applied Ecology* 29: 9-13.

Kauffman , J.B. and W.C. Krueger 1984. Livestock impacts on riparian ecosystems and streamside management implications- a review. *Journal of Range Management* 37: 430-437.

Manly, B. 2007. *Randomization, Bootstrap. and Monte Carlo Methods in Biology,* Third Edition. Chapman and Hall, New York.

McClaran, M.P and D.N. Cole. 1993. *Pack stock in wilderness: Use, Impacts, Monitoring and Management*. USDA, General Technical Report INT-301.

Micheli, E.R. and J.W. Kirchner 2002. Effects of wet meadow riparian vegetation on streambank erosion I. Remote sensing measurements of streambank migration and eroibility. *Earth Surface Processes and Landforms* 27: 627-639.

NatureServe. 2007. *Classification of the Vegetation of Yosemite National Park and Surrounding Environs in Tuolumne, Mariposa, Madera, and Mono Counties, California*. USDI National Park Service. Yosemite National Park, CA

Odion, D.C., T.L. Dudley and C.M. D'Antonio. 1988. Cattle grazing in southeastern Sierran meadows: Ecosystem change and prospects for recovery. *Plant biology of eastern California,* Mary DeDecker Symposium.

Olson-Rutz, K.M., C.B. Marlow, K. Hansen, L.C. Gagnon, and R.. J. Rossi. 1996. Pack stock grazing behavior and immediate impact on a timberline meadow. *Journal of Range Management* 49: 546-550.

Ratliff, R.D., M.R. George, and N.K. McDougald. 1987. *Managing livestock grazing on meadows of California's Sierra Nevada*. University of California Cooperative Extension Leaflet 21421, Davis, CA.

Ring, C.B., Nicholson, R.A., and J.L. Launchbaugh. 1985. Vegetational traits of patch-grazed rangeland in west-central Kansas. *Journal of Range Management* 38: 51-55.

Starcevich, Leigh Ann. 2009. *Stock Use Data Study Analysis*. Report prepared for Yosemite National Park.

Stohlgren , T.J., S.H. DeBenedetti, and D.J. Parsons. 1989. Effects of herbage removal on productivity of selected high-Sierra meadow community types. *Environmental Management* 13: 485-491.

Trimble, S.W. and A.C. Mendel. 1995. The Cow as a Geomorphic Agent- A Critical Review. *Geomorphology* 13: 233-253.

Vallentine, J.F. 1990. *Grazing management*. Academic Press, San Diego, CA.

Wells, F.H. and W.K. Lauenroth. 2007. The potential for horses to disperse alien plants along recreational trails. *Society for Range Management* 60: 574-577.

Winward A.H. 2000. *Monitoring the vegetation resources in riparian areas* General Technical Report RMRS-GTR-47. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Yosemite National Park. 2007. *Field Monitoring Guide: Visitor Experience and Resource Protection Program*. USDI National Park Service. Yosemite National Park, CA

Appendices

Appendix A. Crosswalk for Six-Letter Plant Association Codes

6-letter code	Scientific name	Common name
ASTALP	*Aster alpigenus*	Alpine aster
CALBRE	*Calamagrostis breweri*	Brewer's reed grass
CALBRE- ASTALP	*Calamagrostis breweri – Aster alpigenus*	Brewer's reed grass – Alpine aster
CALBRE/ VACCAE	*Calamagrostis breweri – Vaccinium caespitosum*	Brewer's reed grass – Dwarf bilberry
CARFIL	*Carex filifolia*	Shorthair sedge
CARSCO	*Carex scopulorum*	Rocky Mountain sedge
CARVES-CARUTR	*Carex vesicaria – Carex utriculata*	Inflated sedge – Bladder sedge
DANINT	*Danthonia intermedia*	Timber oatgrass
DESCES	*Deschampsia cespitosa*	Tufted hairgrass
DESCES – POLBIS	*Deschampsia cespitosa / Polygonum bistortoides*	Tufted hairgrass / Western bistort
PINCON – VACCAE	*Pinus contorta / Vaccinium caespitosum*	Lodgepole pine / Dwarf bilberry
PTIKIN	*Ptilagrostis kingii*	Mountain ricegrass

Appendix B. Gridpoint Data Analysis Summary Tables

Note: Differences significant at p<0.05 level are highlighted in bold type.

Table B-1: Means and test results comparing percentage bare ground for high-use and low/no-use meadows (all plots).

Species	Mean Bare ground (high-use)	SE	Mean Bare ground (low/no-use)	SE	Bootstrap test statistic (one-sided p-value)
Carex filifolia	**37.52**	**4.46**	**22.34**	**3.01**	**1.9649 (0.0353)**
Not *Carex filifolia*	**10.23**	**0.52**	**7.13**	**0.62**	**2.6934 (0.0177)**
A. alpigenus	11.14	1.98	10.66	3.54	0.0870 (0.4843)
C. breweri	11.01	1.26	7.62	1.15	1.4067 (0.1130)
C. scopulorum	**19.00**	**3.28**	**5.26**	**1.53**	**2.7368 (0.0061)**
C. utriculata-vesicaria	**13.69**	**2.76**	**7.53**	**1.80**	**1.3531 (0.0880)**
D. intermedia	4.58	0.45	5.58	1.97	-0.3275 (0.6416)
D. cespitosa	**9.57**	**0.94**	**6.12**	**0.54**	**2.3243 (0.0104)**
P. kingii	8.46	0.86	9.32	1.86	-0.3018 (0.6415)
V. caespitosum	**8.68**	**1.36**	**3.86**	**0.72**	**2.2510 (0.0259)**

Table B-2: Means and test results comparing percentage bare ground for high-use and low/no-use meadows (for meadows with at least 5 plots dominated by the species of interest).

Species	Mean Bare ground (high-use)	SE	Mean Bare ground (low/no-use)	SE	Bootstrap test statistic (one-sided p-value)
Carex filifolia	33.34	4.69	19.81	2.88	1.6538 (0.0645)
Not *Carex filifolia*	**10.23**	**0.52**	**7.13**	**0.62**	**2.6934 (0.0155)**
A. alpigenus	**11.15**	**0.92**	**4.05**	**1.19**	**3.3326 (0.0548)**
C. breweri	12.10	1.13	7.91	1.25	1.7627 (0.0716)
C. scopulorum	9.99	1.30	11.00	NA	NA*
C. utriculata-vesicaria	**14.25**	**2.24**	**4.31**	**0.82**	**3.2101 (0.0062)**
D. intermedia	5.10	0.33	11.23	NA	NA*
D. cespitosa	**9.61**	**1.12**	**6.43**	**0.49**	**1.9758 (0.0317)**
P. kingii	**8.51**	**1.01**	**5.22**	**0.62**	**1.9863 (0.0179)**
V. caespitosum	**11.61**	**1.18**	**3.98**	**0.89**	**3.6032 (0.0156)**

* Only one low/no-use meadow

Table B-3: Means and test results comparing percentage vegetative cover for high-use and low/no-use meadows (all plots).

Species	Mean Vegetative Cover (high-use)	SE	Mean Vegetative Cover (low/no-use)	SE	Bootstrap test statistic (one-sided p-value)
Carex filifolia	50.83	3.34	59.48	3.12	-1.3330 (0.9091)
Not *Carex filifolia*	73.38	0.95	71.92	1.11	0.7026 (0.2535)
A. alpigenus	73.17	2.39	71.34	2.77	0.3536 (0.3644)
C. breweri	71.23	1.07	68.87	2.03	0.7369 (0.2185)
C. scopulorum	66.86	3.03	66.71	3.15	0.0236 (0.4899)
C. utriculata-vesicaria	66.90	3.68	64.66	3.88	0.2904 (0.3759)
D. intermedia	76.89	2.38	82.00	3.72	-0.7859 (0.7189)
D. cespitosa	**76.01**	**1.04**	**68.70**	**2.39**	**1.8222 (0.0372)**
P. kingii	77.56	1.41	77.11	1.58	0.1499 (0.4453)
V. caespitosum	70.70	1.68	73.98	1.37	-1.0705 (0.8379)

Table B-4: Means and test results comparing percentage vegetative cover for high-use and low/no-use meadows (for meadows with at least 5 plots dominated by the species of interest).

Species	Mean Vegetative Cover (high-use)	SE	Mean Vegetative Cover (low/no-use)	SE	Bootstrap test statistic (one-sided p-value)
Carex filifolia	55.03	2.59	62.26	2.85	-1.3200 (0.8862)
Not *Carex filifolia*	73.38	0.95	71.92	1.11	0.7026 (0.2440)
A. alpigenus	66.34	2.78	74.36	3.56	-1.2555 (0.8486)
C. breweri	71.29	1.19	68.09	2.16	0.9273 (0.1794)
C. scopulorum	73.67	3.68	72.30	NA	NA*
C. utriculata-vesicaria	69.79	3.98	76.20	1.45	-1.1685 (0.8662)
D. intermedia	79.19	2.63	71.00	NA	NA*
D. cespitosa	75.20	0.99	70.80	2.07	1.1590 (0.1656)
P. kingii	76.74	1.52	77.28	1.61	-0.1736 (0.5726)
V. caespitosum	67.16	0.99	73.12	1.53	-2.3368 (0.9886)

* Only one low/no-use meadow

Appendix C – Site-specific Findings for High Use Meadows

BENSON LAKE SURVEY AREA

	
Drier area of Benson meadows, with trampled roll pit in foreground	Pond in wet meadow near Benson Lake, with grazed *Carex vesicaria-utriculata* vegetation

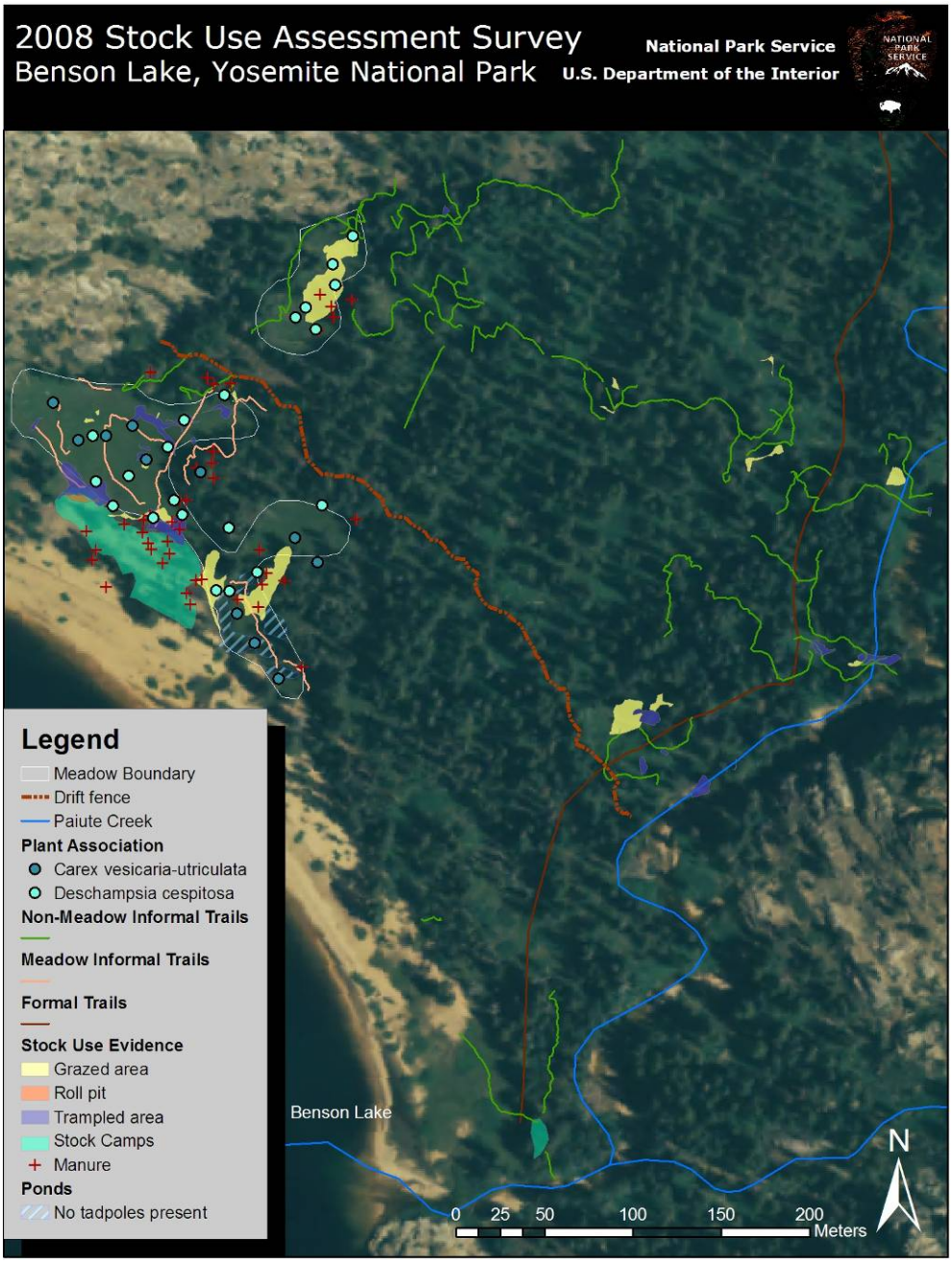
Photo C-1. Benson Lake meadows.

Benson Lake is located in the middle of a popular 47-mile backcountry loop trip originating from Twin Lakes on the east side of the Sierra, and is a heavily visited site by backpackers and pack stock groups. Concentrated pack stock use occurs on the northwest side of the lake near the beach. Heavy pack stock use occurs in the forested areas (with many small meadow-like openings) as well as in the two small well-defined meadows closer to the lake (Map C-1). There are several stock camps located at the east end of the beach, with the largest at the officially designated stock camp at the northwest corner of the beach. A fence is present to keep pack stock off the beach and out of the camping areas, but plentiful evidence of pack stock use is present on both sides of this fence. The grazed and trampled areas on the beach side (west) of the fence, as well as the widely-scattered manure there indicate that some stock had been turned out to use the area west of the fence. The entire survey area (including forest) was 195,572 square meters (48.3 acres), and area of the two meadows was 12,342 square meters total (3 acres).

Gridpoint plot data were collected only in the two small meadows, but both the forested area and meadows were surveyed for pack stock use evidence. Field staff did not perform a stream bank survey, as there was no stream channel in the two meadows. Four or five shallow ponds were mapped in the survey area (Photo C-1), but tadpoles were not observed (possibly due to the mid-August survey date). First recorded stock use for 2008 was on 7/30/08.

Vegetation/ Gridpoint plots

Deschampsia cespitosa was the most dominant plant community at Benson Lake, with 19 of the 29 gridpoint plots falling in this vegetation type. *Carex vesicaria- utriculata* made up the rest of the gridpoint plots, indicating that this is a very wet (hydric) meadow. The meadows at Benson Lake were among the wettest surveyed for this project, with all but seven gridpoint plots having at least one obligate wetland species listed as a dominant. Plant communities mapped during the 2007 survey included a small patch of *Salix lutea* in the northeast meadow, with the rest of the documented meadow vegetation being either *Deschampsia cespitosa* or *Carex vesicaria-utriculata*.



Map C-1. Aerial photo map showing Benson Lake gridpoint plots (plant communities), pack stock use evidence and ponds

Stock use evidence

Seventy stock use nights occurred at Benson Lake before the survey, with another 103 occurring post-survey. Therefore, the total 2008 stock use evidence was likely much higher than the data reported. Benson Lake had the highest amounts of evidence observed per unit area (Figure C-1), with approximately 1,200 square meters of trampled area and 2,128 square meters of grazed area. Trampling occurred mainly in *Deschampsia cespitosa* communities, and heavily grazed areas were found in both *Deschampsia* and *Carex vesicaria-utriculata* communities. Forty-five manure points were mapped, evenly distributed between categories of low, medium, and high density. Informal trails crisscrossed the larger meadow and forested areas, with several stream crossings and trampled areas at Paiute Creek where stock would obtain water.

Because pack stock should not be grazing on the south side of the fence, more concentrated use occurs in the smaller meadow on the north side of the fence. Most of the smaller north meadow showed signs of intensive grazing, and many manure piles were observed.

Benson Lake had the highest percentage of gridpoint plots with stock evidence (97%) and also the highest percentage of plots with greater than 10% cover of pack stock use evidence (86%). The most common pack stock use evidence found in plots was grazed vegetation; all but one of the plots had some grazing present. More than half the plots at Benson had 40-95% cover of grazed vegetation, with *Deshcampsia cespitosa* highly grazed (nearly all *Deshcampsia* plots were 50-99% grazed vegetation cover). Hoofpunching was the second most common pack stock evidence found in plots, with 72% of the Benson Lake plots having some hoopfpunching present (up to 10% cover in many plots), indicating wet soils were widespread in the meadow when stock first entered this year. Manure was also very common in plots (59% of plots).

Other findings

Meadows at Benson Lake may be very susceptible to impacts from pack stock use (especially trampling) because of their small size and hydric nature. The high levels of hoofpunching in the meadows (hoofpunching found in 72% of plots) suggests that soils had not dried out over a large area of the meadow when stock use began this season.The high levels of pack stock evidence found at Benson Lake (compared to other sites) were likely still lower than what would have been found after the full season of use, since more than half of the pack stock nights for 2008 occurred post-survey. For instance more than half the plots had 40-95% cover of grazed vegetation at the time of the survey, but. the percent cover of grazed vegetation would likely be much higher by the season's end. Other studies have found that utilization levels of 25-45% in common Sierra subalpine meadow communities cause significant decreases in meadow productivity, increases in bare ground and community shifts (Ratliff *et al*. 1987, Cole *et al*. 2004). While our study did not measure utilization directly, the high percent cover of grazed vegetation found by this study warrants more detailed future monitoring of vegetation utilization to ensure these thresholds are not being reached. This survey was performed too late in the season to observe Yosemite toad tadpoles, but the shallow ponds in the survey area could provide habitat. Amphibian surveys and toad habitat assessments of the area are necessary to evaluate the resources of these ponds.

CASTLE CAMP

Trampled area with bare ground

Trampled wet areas at Castle Camp.

Photo C-2. Castle Camp meadow

Castle Camp is a popular camping area for pack stock trips accessing Virginia Canyon from Virginia Lakes Resort on the east side of the Sierra, requiring only a nine to ten mile ride to reach the site. The meadow is small (29,022 square meters or 7.1 acres) and receives consistently high pack stock use in recent years (average of 270 pack stock nights for the past five years). This meadow was surveyed early in the season (7/10/08), just hours before 2008 pack stock use began, so only residual evidence from previous use was mapped, and inferences could not be made from evidence of this year's use. The site is made up of a wet meadow bisected by Return Creek and a small, dry meadow (dominated by *Carex filifolia)* on a gravelly rise just south of the main meadow (Map C-2). The large meadow was very wet at the time of survey, with an estimated 25-35% of the meadow covered with shallow standing water and greater than 50% of the meadow with saturated soil. Many shallow ponds were mapped, which may serve as roll pits later in the season as they dry out. Tadpole presence or absence was not noted in these ponds, so status of this meadow for amphibian breeding habitat is unknown from this study. The Castle Camp meadow is bisected by Return Creek, which is approximately 5-8m wide and fast-flowing in the early season. Stock parties must cross the creek to get to the main pack stock camp on the south edge of the meadow, and crossings are present in several places.

Vegetation/ Gridpoint plots

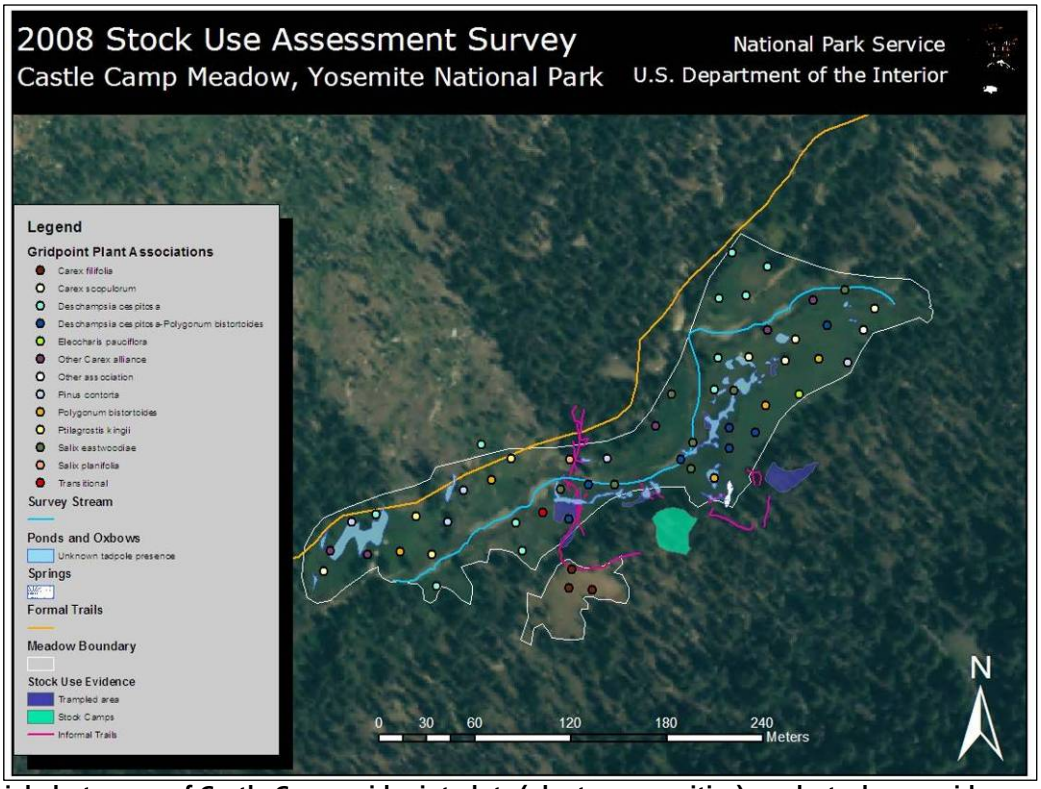
Deschampsia cespitosa (often with a strong presence of *Polygonum bistortoides*) was the most dominant plant community, with nearly half of the gridpoint plots falling in this type. *Salix* sp. and *Carex scopulorum* communities were also common in the meadow, comprising approximately 15% and 10% of the gridpoints, respectively. Obligate wetland and facultative wetland species dominated 73% of the plots, indicating that this is a very wet meadow. There was a striking absence of *Calamagrostis breweri*, *Aster alpigenus*, and *Vaccinium caespitosum* in this meadow, all species that are usually common in subalpine meadows of Yosemite. *Ptilagrostis kingii* was also not common at Castle Camp, with only a few patches present in the northwestern quarter of the survey area. Castle Camp was the only meadow where *Carex illota* was dominant in three plots, another indicator that this is a very wet meadow, and likely a fen. Fens are a type of

meadow, rare in the Sierra Nevada, that slowly sequester large amounts of carbon in the soil through time. They are highly vulnerable to permanent impacts, and the organic soils in fens can take centuries to rebuild.

Stream bank survey

Return Creek is approximately 5-8m wide throughout Castle Camp Meadow, with large cobbles and boulders making up most of the stream channel. The streamflow was high at the time of the survey. The stream banks were armored with a high percentage of willow shrubs, and dense herbaceous vegetation covered most of the remaining stream bank (Figure C-2).

The percentage of stream surveyed with erosional features (40%) was the second-highest of any stream in the survey (Upper Lyell had 44%). Thirty-five erosional features were mapped along the survey reach, and 10 of these had pack stock use evidence (manure or hoofprints//hoofpunches) within 2m of the feature. Most of the erosional features were stream bank blocks that had sloughed off into the channel, with fractured (but attached) sections of stream bank also common. Five headcuts were mapped along the stream, with some stream access points so rutted that they are becoming headcuts (Photo C-2).



Map C-2. Aerial photo map of Castle Camp gridpoint plots (plant communities), pack stock use evidence and ponds.

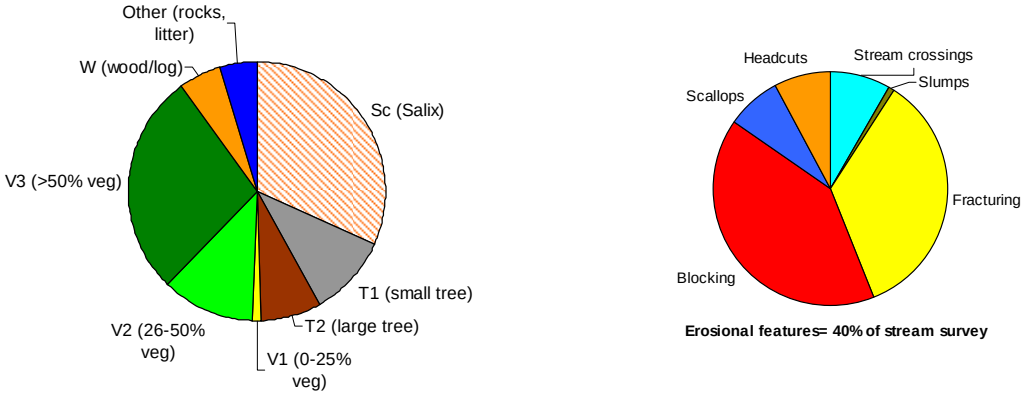
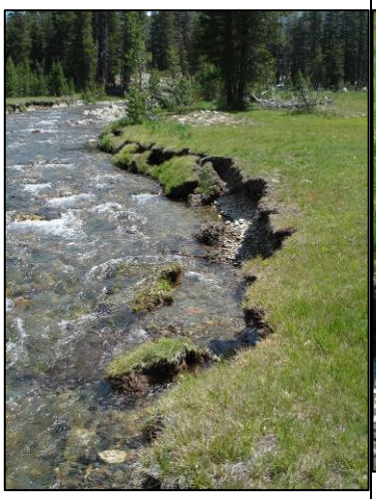


Figure C-2. Stream bank composition (left) and erosional feature composition (right) for survey reach of Return Creek in Castle Camp Meadow. The length of erosional features totaled 40% of the survey reach length.



"Blocking" erosion features

Stream crossing which is becoming a headcut

Trampled banks

Photo C-2a. Stream banks along Return Creek at Castle Camp

Stock use evidence

Pack stock evidence polygons mapped at Castle Camp totaled 1,314 square meters, which comprises 4.5% of the survey area. All evidence documented in the 2008 survey was residual from previous years, since no 2008 pack stock use took place before this year's survey. All polygons mapped in the meadow were trampled areas, and the large pack stock camp just south of the meadow was also mapped. Numerous informal trails were mapped throughout the meadow. No dense manure points (greater than 2 piles in 2m) were found at Castle Camp.

34% of gridpoint plots at Castle Camp had some form of pack stock evidence present, but none of the plots had greater than 10% cover of evidence. Hoofpunching was the most common evidence found in plots (23% of plots), followed by hoofprints (16% of plots) and manure (14%).

Other findings

Castle Camp was the most heavily used pack stock use meadow in 2008 (576 stock nights or approximately 38 stock nights/acre), but all of the use occurred after the 2008 meadow survey. Only 239 stock nights occurred in 2007 (all before the 2007 meadow survey), and field staff conducting the 2007 survey commented on the extensive amount of pack stock evidence after that amount of use (more than 75% of the meadow had been heavily grazed, numerous roll pits, trampled areas, and dense manure). As stock use numbers in 2008 were more than twice that of 2007, one may assume that the levels of stock evidence would be much higher. However, this inference is confounded by the fact that stock typically graze in the understory of wooded areas surrounding this site when forage in the meadow is depleted (Mark Fincher, personal communication).

Castle Camp is a very wet, relatively small meadow, which likely makes it vulnerable to hoofpunching impacts. The first pack stock use of 2008 occurred the night that the survey was conducted. The meadow was saturated at this time, and field staff also noted that the phenology of grasses and sedges was in an immature reproductive state. Monitoring hoofpunching and vegetation would be useful at this site to ensure that undesireable impacts to meadow resources do not occur.

Deschampsia cespitosa dominates the vegetation at Castle Camp. Cole *et al.* (2004) determined in a study at Yosemite that utilization of 25% of the biomass for this species would cause 20-25% declines in productivity. Because of the high number of stock nights in recent years at Castle Camp, concern over grazing levels is not unwarranted. ,. However, since our study did not measure percent utilization, further monitoring is necessary to make determinations about actual amounts of vegetation biomass removed in grazing.

Data on tadpole presence were not collected at Castle Camp, but it is possible that the numerous shallow ponds at Castle Camp provide good amphibian breeding habitat. Future studies are needed determine the status of amphibian populations at Castle Camp, and if found, how they may be affected by pack stock use in the meadow.

COLD CANYON (SMOKY JACK MEADOW)

Overview of Cold Canyon meadow, looking south.

Closeup of wet *Deschampsia cespitosa* community near stock camp

Photo C-3. Cold Canyon meadow

Cold Canyon (commonly known as Smoky Jack Meadow) is a large meadow (158,474 square meters or 39.2 acres) that has had relatively low pack stock use (average of 31 stock nights for the past 5 years or 0.79 stock nights/acre). Pack stock groups likely access the site on the way to or from Tuolumne Meadows, with approximately 9 miles of riding each way. This meadow was surveyed early in the season (7/15/08), before any 2008 pack stock use occurred, but some residual evidence from previous use was found. First date of recorded stock use for 2008 was 7/27/08 slightly less than 2 weeks after this survey was conducted.

Cold Canyon meadow is a mosaic of dry areas (gravelly on meadow edges and mounds throughout meadow) and low-lying wet areas. Approximately 10-15% of the meadow was estimated to be very saturated at the time of survey (notably soft, spongy, and wet when walked upon), mostly in the northwest part of the meadow. Conifer encroachment was common (particularly on the east and southwest sides of the meadow), with an estimated 25% of the meadow having lodgepole pine seedlings or saplings present. Numerous ponds were mapped at Cold Canyon, mainly in the south end of the meadow and along the stream in the north end of the meadow (Map C-3). Fifty-two ponds were mapped in the meadow, but only six of these (all in the north half of the meadow) had tadpoles (species not determined) present. Tadpoles were also found throughout the main stream and backwaters of the main stream bisecting the meadow, wherever the water was slow-flowing.

One stock camp was found just outside the northwest edge of the meadow, and most of the pack stock evidence mapped was located near this camp and in the northwest part of the meadow. No pack stock use evidence was found on the east side of the creek, and it is possible that horses may not use the east side of the meadow, since crossing the channel (which is generally deep and has overhanging banks) would be difficult. Stream crossing may be possible for horses at the north end of the meadow, where the creek is shallower and rockier.

Vegetation/ Gridpoint plots

Due to time constraints and the large size of this meadow, field staff gathered full plot data at approximately half the gridpoints (every other gridpoint in the meadow), and collected plant association information at the remaining gridpoints. Cold Canyon meadow vegetation is largely *Calamagrostis breweri* / *Vaccinium caespitosum*, with more than half the gridpoint plots falling in this type. *Ptilagrostis kingii* (29% of plots) and *Danthonia intermedia* (10% of plots) were dominant in patches throughout the meadow. Dry gravelly bands on meadow edges (mainly on the east side of the meadow) are *Carex filifolia*-dominated (10% of plots). Wetter areas were mainly *Deschampsia cespitosa* (24% of plots), although the wettest areas were *Carex scopulorum* and *Carex vesicaria-utriculata* (5% and 4% of plots, respectively).

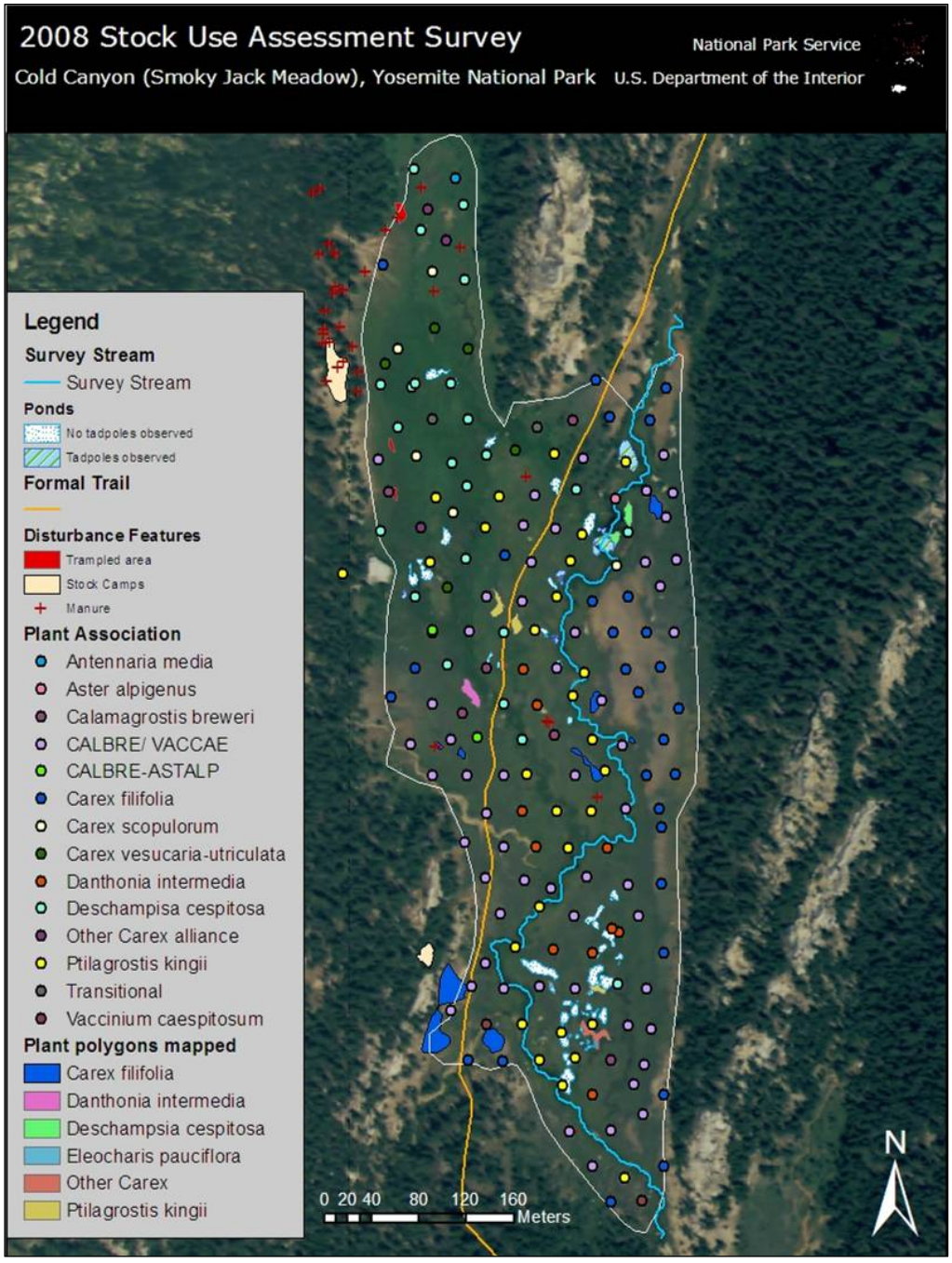
Cold Canyon has more dry area compared to many of the other meadows in this study. Only 6% of the plots were dominated by an obligate wetland species, and 45% of the plots were dominated by facultative wetland (FACW) species. *Vaccinium caespitosum* was one of the most common FACW species at Cold Canyon. Field staff on this project and U.S. Geological Survey ecologist observe that this species is found typically in drier areas of meadows at Yosemite (Peggy Moore, personal communication). Therefore, Cold Canyon is actually drier than the species wetness ratings would suggest. The common dominance of dry meadow species such as *Carex filifolia*, *Ptilagrostis kingii*, and *Danthonia intermedia* also suggest that this meadow is drier overall.

Cold Canyon meadow was unique in a few aspects of its species composition. It had more plots dominated by *Antennaria* sp. (mainly *Antennaria media*) than most of the meadows. Six percent of the plots were *Antennaria* dominated, and 16% of the plots had *Antennaria* as a subdominant species. *Trichophorum clementis*, a special status/rare plant at Yosemite, was a subdominant in 4% of the plots. There was a lack of *Aster alpigenus*, which is a common wet subalpine meadow plant at Yosemite. *Aster alpigenus* was only dominant in one plot at Cold Canyon.

Stream bank survey

The stream running through Cold Canyon is generally narrow and varies in depth, with overhanging banks in most places. It was at low flow at the time of the survey and an anecdotal observation a month later revealed that streamflow continued to drop significantly later into the season. The channel substrate had areas of very silty or sandy soil, and some cobbled areas. Deep pools (more than 4 feet deep) were observed at the time of the survey.

The stream survey reach at Cold Canyon was longer than most of the other meadows, well-armored with willow (*Salix*) and bilberry (*Vaccinium*), with dense graminoids dominating the stream bank in the upper half of the meadow (Figure C-2). In fact, no portion of the stream bank transect had vegetation less than 25% cover. Only 3% of the survey reach had erosional features (18 features mapped), mostly in the central part of the reach. Erosional features consisted mainly of blocks and stream bank fractures, although 4 headcuts were also found. No pack stock use evidence was found within 2m of the erosional features.



Map C-3. Aerial photo map of Cold Canyon (Smoky Jack Meadow) gridpoint plots (plant communities),pack stock use evidence and ponds. Several polygons of plant communities were also mapped.

Stock use evidence

Field staff conducted this survey before 85 stock use nights for 2008 occurred. No use was reported for 2007, and any evidence documented was likely two or more years old, unless undocumented use by private parties had occurred. Usage reported for 2004-2006 was light (22-26 stock nights), so it is not surprising that there was little pack stock evidence visible in the meadow at the time of the 2008 survey.

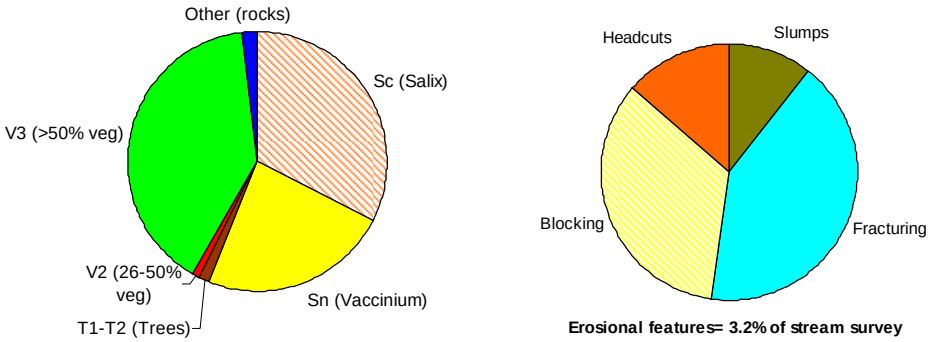


Figure C-2. Stream bank composition (left) and erosional feature composition (right) for survey reach of Cold Canyon Meadow. The length of erosional features totaled 3.2% of the survey reach length.

Stock evidence polygons totaled 1,046 square meters, or 0.7% of the survey area, which was the lowest percent evidence for any meadow except Upper Kerrick. Five small polygons of trampling were mapped for a total of 173 square meters, and one large stock camp just outside the northwest edge of the meadow was mapped. Thirty-three manure points of varying density were mapped, mainly near the stock camp and in the northernmost part of the meadow.

Nineteen percent of gridpoints plots contained pack stock evidence, and no plots had greater than 10% cover of evidence. This is the lowest percentage of plots with evidence for any high use meadow (except for Upper Kerrick, which also had 19% of plots with evidence present). Hoofpunching was the most common evidence found in plots (11% of plots), followed by manure (8% of plots).

Other findings

Cold Canyon is drier than many of the meadows surveyed, and it is very large, so it may be more resistant to pack stock impacts than other meadows. The wettest areas of the meadow are also the most heavily used areas, near the stock camp,however, so trampling or hoofpunching may occur if soils are still wet here. Recent stock use has been light in the meadow, but the 2008 use that took place after the survey was three to four times higher than usage in the past four years. It would be useful to re-survey the meadow after this heavier level of use re-evaluate where use is concentrated and resultant effects on meadow vegetation and soils.

Evidence from this survey indicates that pack stock may utilize only meadow areas on the west side of the creek, which may prevent impacts to the many ponds in the southeast part of the meadow thatamphibians may utilize. Our study, which only observed amphibians anecdotally in the course of the rest of the survey work, found tadpoles (unknown species) in several of these ponds. More detailed amphibian surveys are needed to determine the status of populations and habitat for any species of concern in Cold Canyon. In addition, continuing to monitor stock evidence at this meadow will identify areas of concentrated stock use at this large site, and potential conflicts with resources of concern.\

DOROTHY LAKE

Overview of Dorothy Lake meadow, dry Vaccinium community in foreground and large pond in the background

Dry *Vaccinium caespitosum* / *Juncus* sp. common to dry meadow edges here

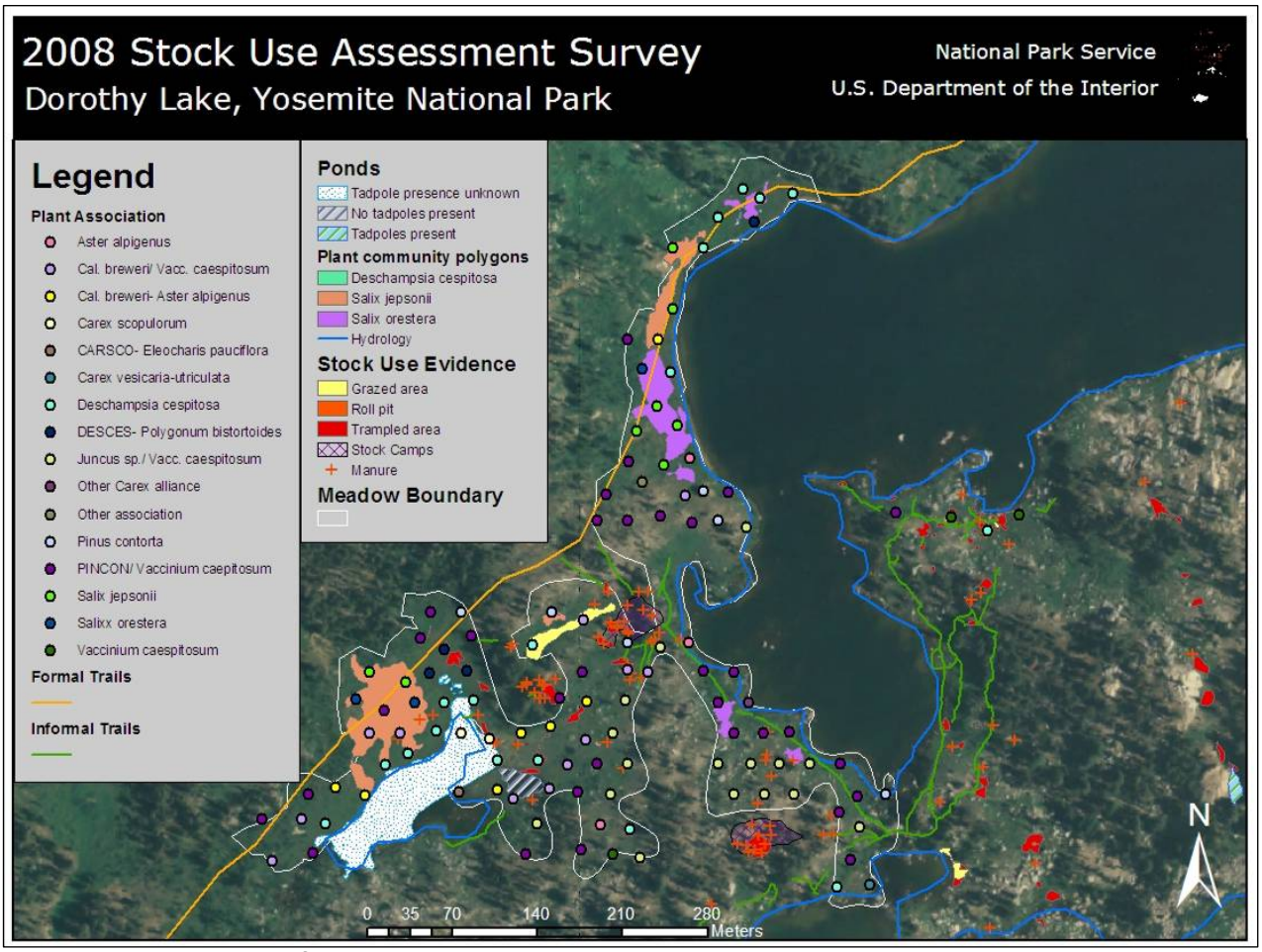
Hoofpunches/prints near the edge of the large pond

Photo C-4. Dorothy Lake meadow

Dorothy Lake, at the northernmost tip of Yosemite National Park, is a popular backpacking and pack trip destination on the Pacific Crest Trail. It is accessed by 16-18 trail miles from Leavitt Meadows or Leavitt Lake near Sonora Pass on Highway 108. The main meadow at Dorothy Lake is on the southwest side of the lake, although pack stock use also occurs in the very small meadow areas on the southeast side of the lake, and the southeast slope above the lake (Map C-5). Originally, the survey area targeted only the large southwest meadow butwhen field staff arrived and observed current stock use occurring only on the southeast side of the lake, they expanded the survey area to include this area. The total meadow area was approximately 79,904 square meters (19.7 acres). None of soils in the meadow were saturated at the time of the survey (8/21/08). There were many rocks and boulders throughout the meadow area, and areas of dry gravelly soil. Conifer encroachment was common; field staff estimated seedling or sapling lodgepole pine present in 50% of the meadow.

The first recorded stock use for 2008 at Dorothy Lake was 8/6/08. A little more than half of the 2008 use occurred before the survey (35 of the 52 stock nights), so some of the evidence produced in 2008 may not be captured by this survey. Two large stock camps are located on the southwest side of the lake. Much of the stock evidence mapped was near these camps or concentrated in the southwest part of the meadow, although field staff found fresh areas of trampling, grazing, and roll pits on the southeast side of the lake where 2008 use was concentrated.

No stream survey was performed, since the stream that feeds and drains Dorothy Lake flows outside the meadow through the rocky, forested area. One large pond and several small ponds were mapped in the southwest part of the main meadow, and a smaller pond was mapped on the southeast hillside above the lake. Some of these ponds had tadpoles present, and three adult Yosemite toads were observed in the main meadow. Numerous tree frogs were observed in the meadow areas near ponds.



Map C-5. Aerial photo map of Dorothy Lake gridpoint plots, pack stock use evidence and ponds.

Vegetation/ Gridpoint plots

The meadow survey area at Dorothy Lake was drier than many other meadows in the study. There was conifer encroachment with dry *Vaccinium caespitosum* communities scattered throughout the meadows (32% of gridpoints), and many dry areas where a mix of *Vaccinium caespitosum* and *Juncus parryi* (or *drummondii*) was dominant in 16% of gridpoints (See Photo C-4). There were also large areas of willow in the north and southwest ends of the survey area (9% of gridpoints). In contrast to the drier communities, *Deschampsia cespitosa* (occasionally with *Polygonum bistortoides* as a subdominant) was very common, particularly near the pond in the southwest meadow (19% of plots). *Calamagrostis breweri/ Vaccinium caespitosum* communities were also fairly common (with 10% of gridpoints falling in this vegetation type).

Obligate wetland species dominated 6% of the gridpoint plots, and facultative wetland (FACW) species dominated 88% of plots. However, *Vaccinium caespitosum* (rated as FACW by the regional classification) occurs in drier areas at Yosemite (Peggy Moore, personal communication), and this species is a very common dominant at Dororthy Lake. Therefore, Dorothy Lake meadow is drier than the high proportion of FACW species would suggest. In addition, the lack of *Carex vesicaria-utriculata* (only one plot was dominated by this species) suggests that there are no areas saturated enough to support this common dominant of wet communities.

Dorothy Lake vegetation was distinctive in the strong presence of *Juncus parryi* (or *drummondii*- identification was uncertain) and willows. Several plots were also dominated by the shrubby lupine *Lupinus*

lepidus var. *lobbii*. *Muhlenbergia filiformis* was dominant in several plots near the large pond. One newly-documented species for Yosemite, *Elatine rubella* was found in ephemerally saturated soils near the pond. Additional rare plant surveys are warranted in this area.

Stock use evidence

Thirty-five of the 52 stock nights for Dorothy Lake in 2008 occurred before the site survey on 8/21/08. Zero stock nights occurred in 2007, and any evidence recorded was either from current year use or before 2007. Seventy polygons of stock use evidence were mapped for a total of 5,935 square meters, or 7.4% of the survey area. All but five of these polygons were trampled areas- very few grazed areas were mapped. Trampling and grazing most commonly occurred in *Deschampsia cespitosa* communities. Hoofpunching was observed in several of the small ponds and deep hoofpunches were found in saturated soils near the ponds. The two large stock camps totaled 2,195 square meters. Manure points of varying densities totaled 83. Manure was concentrated around stock camps where horses are tied and in the southwest part of the meadow, though fresh manure was observed on the southeast side of the lake.

Current year's use appeared to be concentrated on the southeast side of the lake, where one packer was turning out pack stock on the east side of the lake outlet and then blocking off the stream crossing with a rope to contain pack stock on that side of the creek. The hillside above southeast side of the lake was briefly surveyed for pack stock evidence (not surveyed as thoroughly as meadow areas), but many trampled areas were observed. This hillside was fairly steep (up to 20 degrees slope), and some of the loose soil between rocks was churned up and eroding down the hillside.

Fifty-seven percent of Dorothy Lake plots had some pack stock evidence present, and 10% of plots had greater than 10% cover of pack stock evidence. Hoofpunching and hoofprints were the most common evidence found in plots (35% of plots each). Manure was found in 16% of plots, and grazed vegetation was more rare (9% of plots.)

Other findings

The meadow areas around Dorothy Lake are mainly dry, although the presence of hoofpunching in over a third of the plots suggests that wet soils were fairly widespread in the meadow when stock first entered this season. Dorothy Lake is not a small meadow (nearly 20 acres), although the useable areas for pack stock are smaller due to high cover of conifer encroachment and thick willow cover in some areas. Some stock were kept on the southeast side of the lake, further concentrating use, and erosion was observed on the steep hillside above this area where stock scrambled up to forage.

An abundance of tree frogs and three Yosemite toads were recorded during the 2008 survey, all in the southwest part of the meadow where pack stock use has been concentrated in the past. A more thorough survey for amphibians and their habitat would contribute better information as to their status at this site.

HOOK LAKE

Overview of Hook Lake meadow

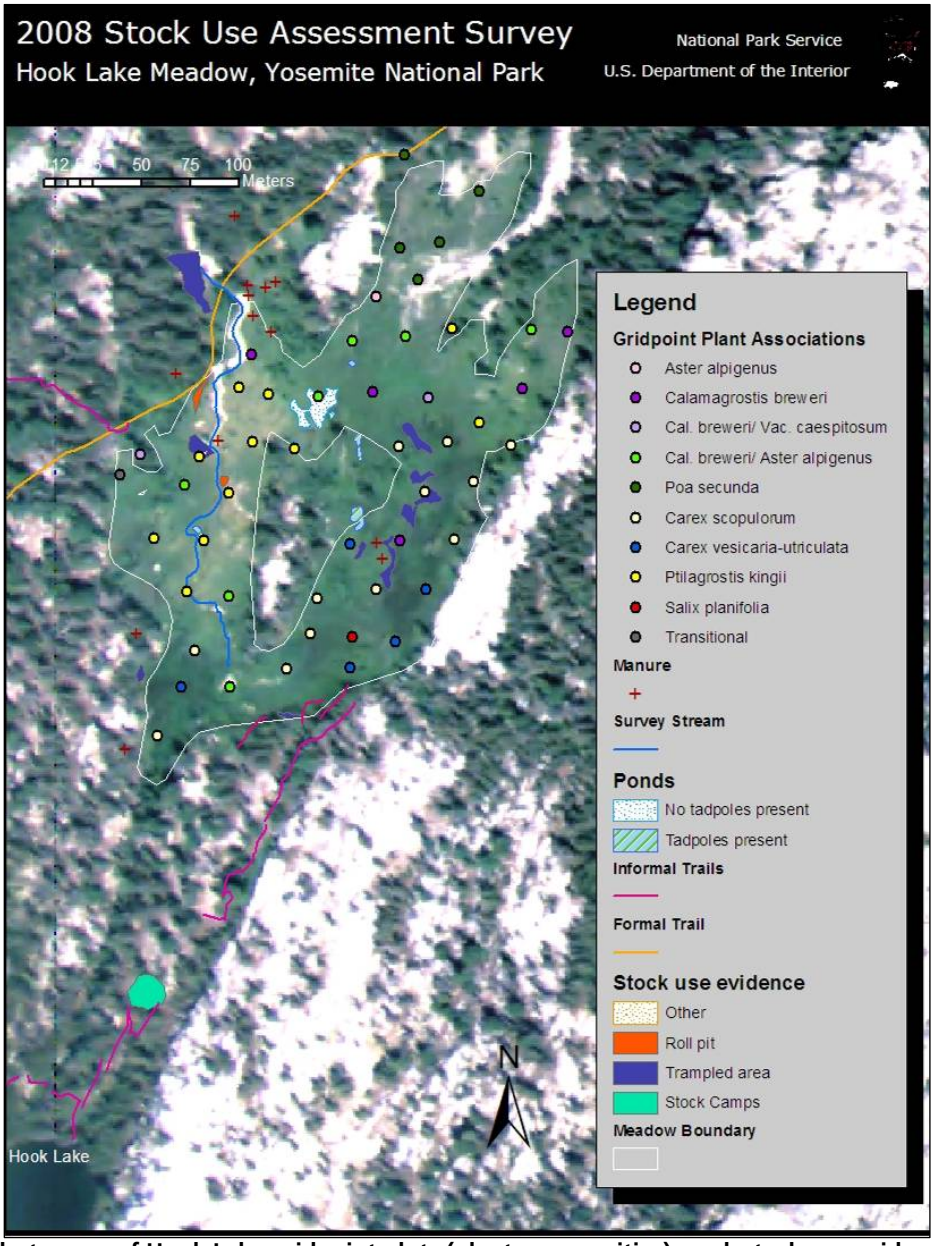
Wet *Carex vesicaria-utriculata* communities that dominate much of the meadow.

Photo C-6. Hook Lake meadow

Hook Lake is located approximately ¾ mile east of Miller Lake along the Pacific Crest Trail, approximately 13 trail miles from Virginia Lakes Resort on the east side of the Sierra. It is not named on topographic maps, nor is it visible from the main trail, so visitation by backpackers is light. Guided pack trips use the area as it is an excellent fishing lake. The main meadow at Hook Lake is located approximately 250m northeast of the lake. There is a very small meadow area on the south end of the lake which was not surveyed due to time constraints, but plant community polygons were mapped there. Hook Lake meadow is a doughnut-shaped meadow surrounding a low granite outcrop (Map 6) and is approximately 33,564 square meters (8.2 acres) in size. The meadow was extremely wet at the time of the survey on 7/13/08, with an estimated 25% of the meadow covered with a shallow sheet flow of water and at least 50% of the meadow having saturated (notably soft, spongy, and wet) soil. Sedges and grasses were beginning to flower at the time of the survey, but no mature fruits were present. There are no stock camps immediately adjacent to the meadow. The closest stock camp is approximately 150m south of the meadow edge, and another stock camp is located near the small meadow area at the south end of the lake. No stock use had occurred in 2008 before the survey date, but stock use began at this site on 8/5/08.

The main channel running into the meadow was on the west side of the "doughnut," and was most discernible where it entered the meadow at the top. The stream turned into a network of shallow channels and sheet flow at its lower end, so the stream survey was only conducted for the upper 250m.

Six ponds were mapped in the meadow, and all but one of them had tadpoles present (species not determined). At least two adult Yosemite toads were observed in the meadow, and a tadpole thought to be yellow-legged frog was sighted in one of the ponds (this was not confirmed by a herpetologist, however). Tree frogs abounded, and two garter snakes and a small swimming mammal (vole?) were also observed.



Map C-6. Aerial photo map of Hook Lake gridpoint plots (plant communities), pack stock use evidence and ponds.

Vegetation/ Gridpoint plots

Hook Lake meadow is largely dominated by wet sedges, with *Carex scopulorum* communities dominating 25% of the gridpoint plots and *Carex vesicaria-utriculata* dominating 10% of the plots. *Ptilagrostis kingii* dominated the drier west side of the meadow (23% of plots). *Calamagrostis breweri* was common, particularly when co-dominant with *Aster alpigenus* (15% of plots). *Vaccinium caespitosum* was uncommon at Hook Lake, generally only present in patches along the meadow edge.

Hook Lake was one of the wettest meadows surveyed, with 15% of the gridpoint plots dominated by an obligate wetland species. Facultative wetland species dominated 55% of the plots. No *Carex filifolia* communities (indicating dry gravelly areas) were present. The western quarter of the meadow, dominated by *Ptilagrostis kingii*, was the only part of this meadow that appeared to thoroughly dry out during the growing season.

Vegetation at Hook Lake was distinctive in the dominance of wet sedges. This was also one of the only meadows where *Eleocharis pauciflora*, *Ranunculus alismifolius*, and *Poa secunda* were common dominants or subdominants (10-15% of the plots).

Stream bank survey

The stream feeding the upper end of Hook Lake meadow is ephemeral, narrow in most places, and loses its distinct channel in the southern portion of the meadow. The banks of the survey reach were armored with herbaceous vegetation (Figure C-3), although Hook Lake had a greater proportion of moderately-vegetated banks (<50% vegetation cover) than any other site. No portion of the survey reach was armored with shrubs of any type. The lack of shrubs and lower cover of herbaceous vegetation suggests that this stream would be more vulnerable to erosion.

Erosional features were found along 15.5% of the survey reach, which is a fairly high proportion considering the narrow width and slow streamflow observed in the channel. Six erosional features were mapped, evenly split between blocking, fracturing and stream crossings. All but one of these features had either manure or hoofpunching within 2m of the banks.

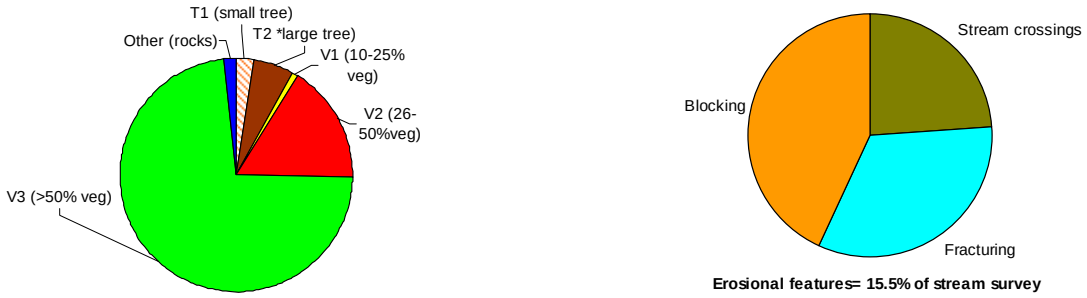


Figure C-3. Stream bank composition (left) and erosional feature composition (right) for survey reach of the stream through Hook Lake Meadow. The length of erosional features totaled 15.5% of the survey reach length.

Stock use evidence

No pack stock use had occurred in 2008 prior to the survey in mid-July, and no use had been reported for any of the four previous years except for 2004, which had 8 stock nights. Therefore, any evidence found during this survey was either more than 3 years old, or resulted from the unreported use of private parties. Despite this, field staff found a relatively high amount of evidence. Stock use evidence polygons totaled 1,682 square meters, or 5% of the survey area. Ten trampled areas and two roll pits were mapped as polygons, with many of the trampled areas in shallow standing water at the time of the survey. Trampling commonly occurred in areas dominated by *Muhlenbergia filiformis* or *Ptilagrostis kingii*. Fourteen manure points were mapped at low-medium density, concentrated mainly at the northwest edge of the meadow. Informal trails were mapped leading from the stock camp into the meadow.

Hook Lake had 23% of gridpoint plots with pack stock evidence present, and no plots with greater than 10% cover of pack stock use evidence. Hoofpunching was the most common form of evidence in plots (17% of plots), and manure was also common (10% of plots).

A return visit was made on 8/08/08 to collect sedges for identification, and extensive new pack stock use evidence was observed anecdotally at that time. One stock party with several horses had camped there on 8/05/08, after the survey was completed. There were new hoofpunches throughout the meadow (which was

still mostly saturated at this time), a new roll pit, and many grazed areas. Stock use for Hook Lake in 2008 totaled 76 stock nights, nearly 10 times the use of any previously reported year, so it is safe to assume that pack stock evidence was much greater by the end of the year than our data show.

Roll pit in dry area of Hook Lake meadow

Yosemite toad at Hook Lake meadow

Photo C-6. Stock evidence and toad sighting at Hook Lake meadow

Other findings

Much of Hook Meadow is composed of hydric plant communities with saturated soils. Vegetation on the drier western side is composed of *Ptilagrostis kingii*, which pack stock do not typically consume. Therefore, grazing is likely concentrated in the more fragile, wet plant communities at this site which would be more susceptible to trampling impacts. Amphibians including Yosemite toads utilize the meadow, and there is a possibility that mountain yellow-legged frogs occur here as well (one unconfirmed tadpole sighting). Despite the fact that no pack stock use was reported for this site since 2004, evidence of stock use was found in the form of trampling, roll pits and manure. This suggests that either undocumented use is taking place, or evidence of use may be visible for at least 3 years at this site. The potential fragility of Hook Lake due to its hydric nature and amphibian populations warrants further detailed investigation and monitoring of pack stock effects at this site.

KERRICK CANYON (UPPER KERRICK MEADOW)

Barren areas common in Upper Kerrick meadow

Mounding found in northwest part of meadow

Photo C-7. Upper Kerrick meadow

Kerrick Canyon is part of the popular Matterhorn Canyon-Smedberg Lake-Benson Lake backcountry loop, and the upper meadow easily accessed by 7.5 miles of trail from Twin Lakes on the east side of the Sierra. Two formal hiking trails converge at the north end of the meadow, and a formal trail runs parallel to the creek, bisecting the meadow from north to south (Map C-6). Upper Kerrick meadow was the largest site surveyed, covering 284,677 square meters (63 acres). The meadow was a mosaic of very wet and very dry areas, with many shallow ponds full of emergent sedges and many dry gravelly areas devoid of vegetation. An area of parallel mounds (one to two feet tall) covered with *Vaccinium cespitosum* and grayish-yellow ground lichens was found in the north part of the meadow (Photo C-7, right). Field staff mapped 58 ponds, nearly all teeming with tadpoles (mostly tree frog) at the time of the survey. At least one adult meadow yellow legged frog was found. Adult Yosemite toads were also present, and hundreds of newly metamorphosed Yosemite toads were found along the pond edges. A wildlife biologist conducted amphibian surveys at the time of our survey, so amphibian populations and habitat were more thoroughly documented than at other sites. Due to concerns over amphibian welfare, park management closed this meadow to pack stock use shortly after the survey, before any 2008 stock use occurred.

Due to the size of the meadow and high number of gridpoints created by the 30m spacing, full plots were collected at approximately 60-80% of the points. At every 4^{th} or 5^{th} gridpoint, only the plant community type was documented.

The headwaters of Rancheria Creek are located just upstream from the survey meadow. A stream survey was conducted through the entire length of Upper Kerrick, starting just southwest of the large stock camp on the north end of the meadow. A second stock camp, not as large or frequently used, was found just outside the southeast tip of the meadow.

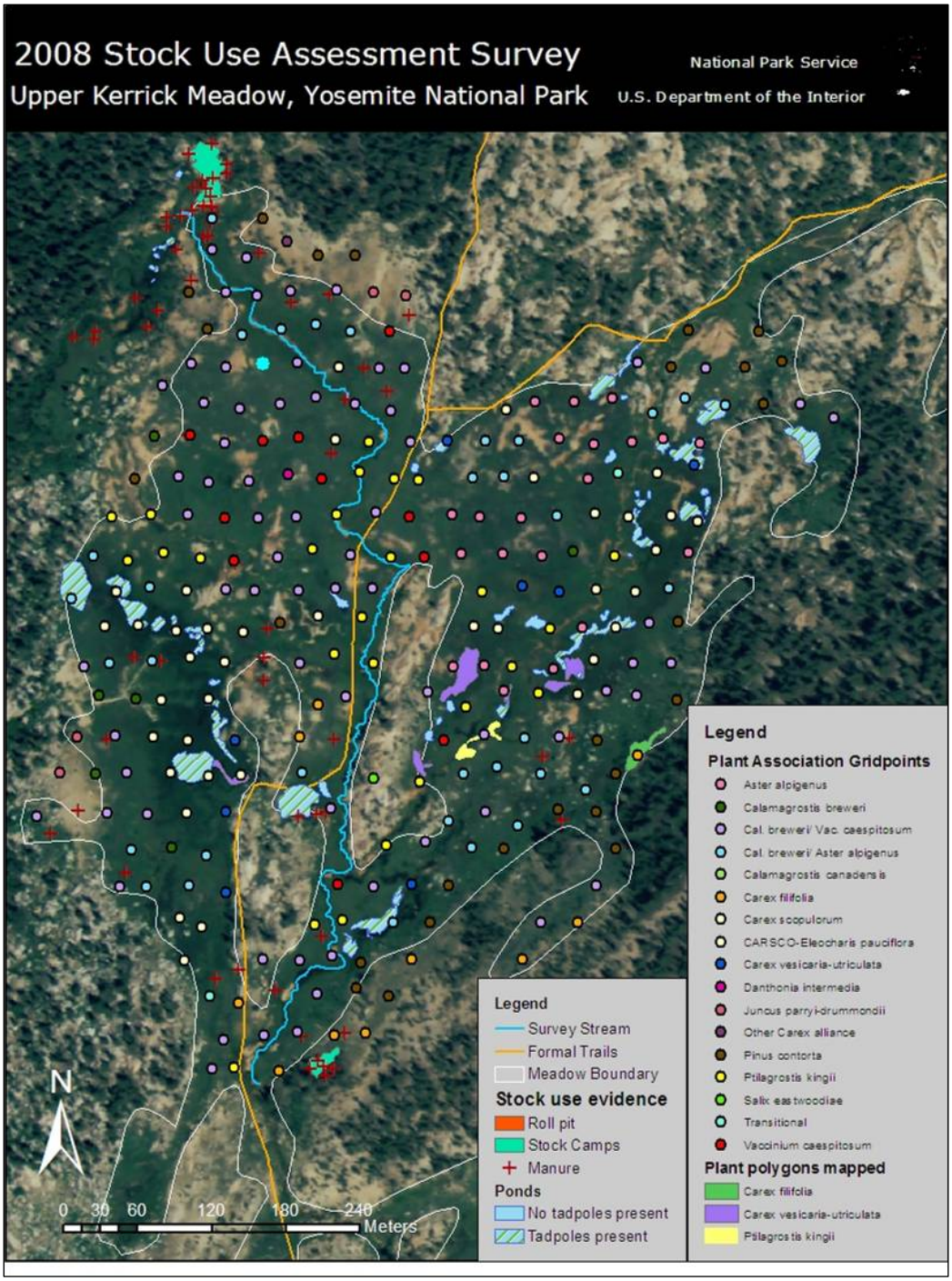
Vegetation/ Gridpoint plots

The two most dominant communities in Upper Kerrick meadow were at opposite ends of the moisture spectrum, with *Calamagrostis breweri* / *Vaccinium caespitosum* (moderately dry) dominating 26% of the gridpoints and *Carex scopulorum* often codominant with *Eleocharis pauciflora* (very wet) dominating 15%

of gridpoints. The next most dominant communities were also opposite in wetness- *Aster alpigenus* (wet) usually codominant with *Calamagrostis breweri* comprised 24% of gridpoints and *Ptilagrostis kingii* (dry) dominated 10% of gridpoints. Dry meadow edges were often conifer-encroached (10% of plots) or dominated by *Vaccinium caespitosum* (4% of plots), *Carex filifolia* (3% of plots), or Juncus *parryi* (2% of plots).

The many wet areas of Upper Kerrick are reflected in plot data - obligate wetland species dominated 22% of the plots. Facultative wetland (FACW) species dominated 63% of the plots, but if *Vaccinium caespitosum* (considered FACW in the national classification but grows in drier areas at Yosemite) is not considered a wetland indicator, then only 36% of the plots are dominated by FACW species.

There was a complete lack of *Deschampsia cespitosa*, a common species in wet areas of Yosemite meadows that are inundated early in the season. Instead, *Carex scopulorum*, *Eleocharis pauciflora* and *Aster alpigenus* dominated these areas. The strong presence of *Eleocharis pauciflora* also made Upper Kerrick vegetation unique from the other meadows surveyed.



Map C-7. Aerial photo map of Upper Kerrick gridpoint plots (plant communities), pack stock use evidence and ponds. Several polygons of plant communities were also mapped.

Stream bank survey

The stream survey reach in Upper Kerrick meadow consisted of a meandering, slow-flowing channel that varied in width and depth, with a mainly gravelly channel substrate that was rocky in a few places. Numerous fish lived in the stream. The banks were well armored with shrubs, with 51% of the transect consisting of willow shrubs and 28% consisting of bilberry (Figure C-4). The remaining transect was mostly thick herbaceous vegetation, or small sections of boulders and bedrock.

Erosional features comprised 6% of the survey length, mostly due to the 9 separate headcut features mapped. Ten small fracturing features and five blocking features were also mapped. No pack stock use evidence was found within 2m of any of these features.

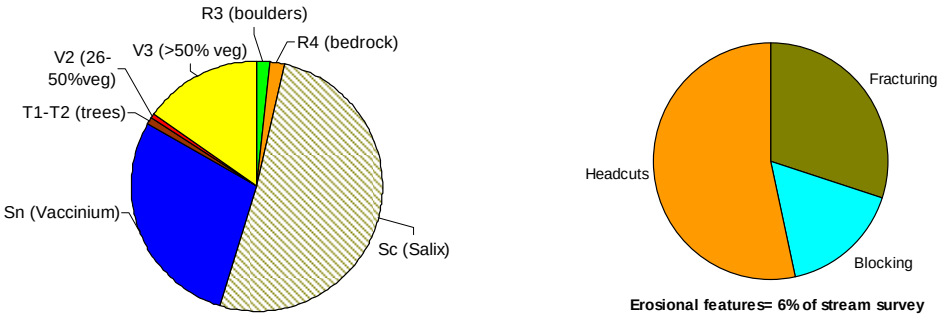


Figure C-4. Stream bank composition (left) and erosional feature composition (right) for survey reach of the stream through Upper Kerrick meadow. The length of erosional features totaled 6% of the survey reach length.

Headcut (between 2 orange flags) extending away from the main channel (running right to left) in Upper Kerrick

Gravelly barren areas typical of meadow edges in Upper Kerrick

Photo C-7a. Upper Kerrick stream survey and meadow

Stock use evidence

No pack stock use occurred in Upper Kerrick Meadow in 2008, due to a closure of the meadow shortly after the survey took place. Usage in 2007 was light (11 stock nights), and 2004-2006 usage ranged from 22-57 stock nights. Therefore, any evidence mapped during the 2008 survey was resulting from previous years' use.

Evidence mapped in Upper Kerrick was the lowest of any of the high use meadows, with the two stock camps and two roll pits totaling 1,168 square meters, or 0.4% of the survey area. No trampled areas were found. There were 64 manure points mapped, mostly low-medium density. These were concentrated near the stock camps on the north and south ends of the meadow, although a few low-density manure points were scattered throughout the meadow.

Upper Kerrick Canyon and Cold Canyon meadows both had the lowest proportion of gridpoints with any pack stock use evidence (19% of points). Manure was the most common evidence found in plots (11% of

plots), although hoofpunching was found in some plots (8% of plots). The concentration of hoofpunches was always too low to consider mapping them as trampling polygons.

Other findings

Field staff observed that Upper Kerrick meadow does not show much evidence from recent pack stock use, yet the vegetation appears somewhat stunted and lower in cover compared to other meadows in the survey. The large gravelly areas devoid of vegetation (Photo C7a) may be cause for concern and warrant further investigation. It is possible that this large meadow received high use during the sheep grazing period of the 1800s and has not recovered from historic impacts, but there are no site-specific records or historic data to support this. Sites still suffering from historic impacts could be more sensitive to pack stock use, but further investigation into the relationship between historic impacts, current use and meadow recovery is needed. The welfare of amphibian populations at Upper Kerrick is also of concern, and this meadow was closed to stock use in 2008 after large breeding populations of Yosemite toad were found there. Information on the effects of pack stock use on these toads is necessary to develop management strategies that will support the health of these populations.

MATTERHORN CANYON

Collapsing stream banks along Matterhorn Creek, with meadow in background.

Roll pit in Matterhorn Canyon meadow

Photo C-8. Matterhorn Canyon meadow

Matterhorn Canyon is frequently visited by backpackers and pack stock groups. It also receives sporadic high pack stock use from National Park Service trail crew camps. Matterhorn meadow is located in the lower part of the canyon approximately five miles south of Burro Pass. The main meadow is a fairly large site (102,283 square meters or 25.3 acres) and it has received high levels of use by pack stock in recent years. However, estimates of stock nights per acre are confounded in that reported use for Matterhorn Canyon also includes the small meadow (4.3 acres) less than ½ mile northeast of the main Matterhorn meadow. The meadow survey was conducted on 8/08/08, after only 72 of the 238 stock nights for 2008 had occurred. Despite this, there was a great deal of pack stock evidence found, mainly in the form of trampled areas which may be partially residual from 2007 stock use (262 stock nights). The first recorded stock use for 2008 in Matterhorn Canyon was on 7/28/08.

Matterhorn Canyon is bisected by a widely meandering shallow creek 8-10m across, fast-flowing, and cobbly, which pack stock must cross to reach one of the stock camps (Map C-8). Three other camps are located just outside the meadow: two large camps on the north side and one small camp on the west side.

There was only one pond in the survey area. It was spring-fed with a deep hole at one end of the pond with water bubbling up from the bottom. The flow from this spring fed a lush community of thigh-high *Carex vesicaria-utriculata*, *Calamagrostis canadensis*, and *Salix eastwoodiae* in the south "arm" of the meadow. There were many low-lying wet depressions (old oxbows and backwaters of the creek) dominated by *Salix eastwoodiae* and *Carex vesicaria-utriculata*). At the time of the survey, 15-20% of the meadow was estimated to have saturated soil.

There were no tadpoles, frogs or toads observed during the meadow survey.

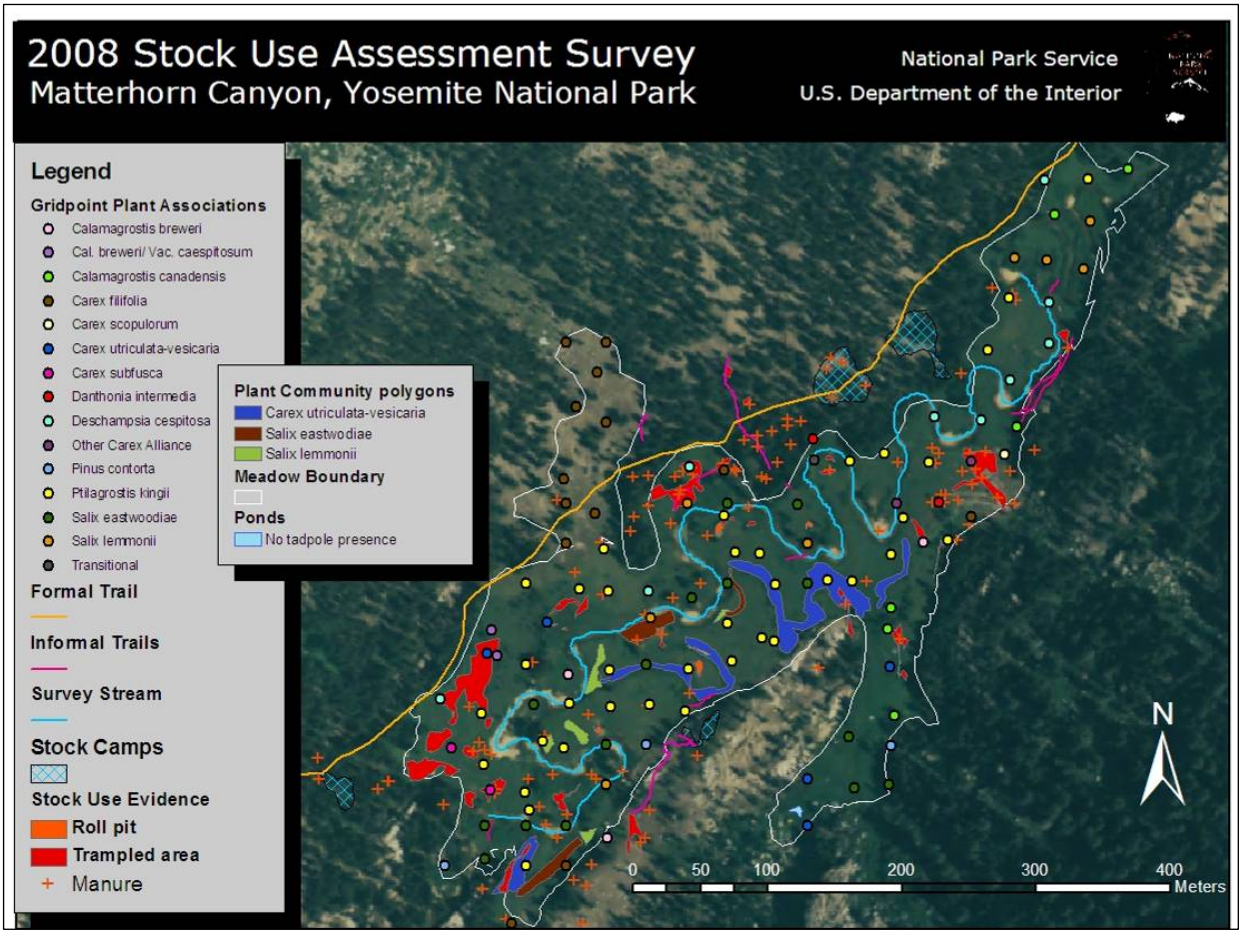
Vegetation/ Gridpoint plots

Matterhorn Canyon meadow is dominated *Ptilagrostis kingii* (34% of gridpoint plots), which occurs throughout the meadow and two species of willow (*Salix lemmonii* and *Salix eastwoodiae*, 21% of gridpoints), which mainly occur along the creek and old oxbows or abandoned channels. *Carex filifolia* is the third most common plant community (12% of gridpoints), but occurs almost exclusively in the dry, gravelly north "arm" of the meadow. *Deschampsia cespitosa* and *Carex vesicaria-utriculata* are the two wet herbaceous communities in the meadow, dominating 8% and 5% of gridpoints, respectively. Thick *Salix*

eastwoodiae mixed with *Carex vesicaria-utriculata*, dominated many of the old oxbows and abandoned stream channels of the creek.

Matterhorn Canyon had 12% of plots dominated by obligate wetland species and 23% of plots dominated by facultative wetland species. Although the meadow has a moderate proportion of obligate wetland species dominance (compared to all meadows surveyed), the proportion of facultative wetland species is very low, so the total proportion of wetland indicator species (35%) is lower than all other meadows except Lower-upper Lyell and Lower Lyell.

Some distinctive features in the species composition of Matterhorn Canyon meadow include the strong presence of *Antennaria media* (dominant or subdominant in 19% of plots). *Antennaria* had only patchy dominance, however, since these plots were always part of larger *Ptilagrostis kingii*, *Deschampsia cespitosa* or *Salix* sp. communities. Matterhorn Canyon also had more gridpoints in *Calamagrostis canadensis* communities than any other meadow (6% of plots). *Aster alpigenus* and *Vaccinium caespitosum* were uncommon at Matterhorn Canyon, with only one plot dominated by each species. Matterhorn was the only meadow where *Veratrum californicum* or *Elymus trachycaulus* was dominant (1 plot each). *Carex subfusca* and *Mimulus primuloides* were dominant in patches in Matterhorn meadow (8% and 3% of plots, respectively), and these species were not common in any of the other meadows surveyed.



Map C-8. Aerial photo map of Matterhorn Canyon gridpoint plots (plant communities), pack stock use evidence and one pond.

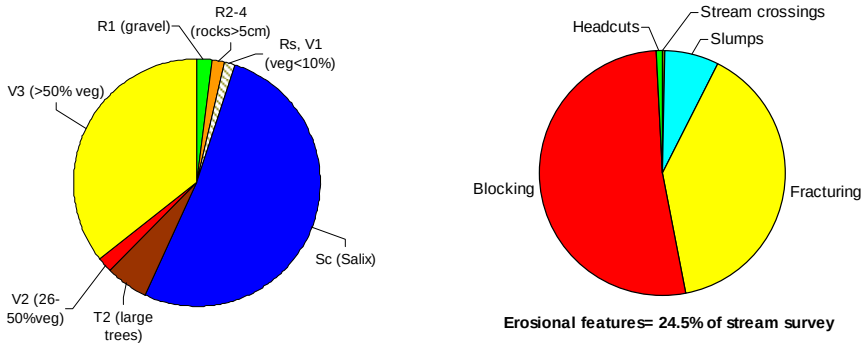


Figure C-5. Stream bank composition (left) and erosional feature composition (right) for survey reach of the stream through Matterhorn Canyon meadow. The length of erosional features totaled 24.5% of the survey reach length.

Stream bank survey

The stream bank at Matterhorn meadow was well-armored by patches of the tall willow *Salix lemmonii* and short willow *Salix eastwoodiae*. Matterhorn had the highest proportion of stream bank with willows (52%) of any meadow, but had no non-clonal shrubs lining the banks (Figure C-5). Most of the remaining bank was armored with dense herbaceous vegetation, although there was a higher proportion of stream bank that was unarmored compared to any of the other meadows surveyed. About 3% of the Matterhorn stream bank was composed of gravel, bare soil, or less than 10% cover of herbaceous vegetation.

Matterhorn's survey reach had one of the highest proportions of erosional features of any meadow, (exceeded only by Upper Lyell, Castle Camp, Lower-upper Lyell, and Dog Lake East). The stream bank had 24.5% erosional features, composed mainly of blocking and fracturing (Figure 15). Eighty-three erosional features were mapped. Two small headcuts and two stream crossings were found. Thirty-six percent of the erosional features had pack stock evidence within 2m of the bank (mostly a social trail with hoofprints present). Other features were within 2m of scattered hoofprints, hoofpunches or manure piles.

Stock use evidence

Approximately one third of the 2008 stock nights occurred before the survey was conducted on 8/08/08, so it is likely that total pack stock evidence mapped would have been much higher if the survey had been conducted at the end of the 2008 season. Despite this, pack stock evidence polygons mapped totaled 7,261 square meters, or 7.1% of the total meadow area. Some evidence mapped may have been residual evidence from the high use of 2007 (262 stock nights). Thirty-two trampling polygons were mapped for a total of 3,952 square meters, the stock camps accounted for 3,141 square meters, and 6 roll pits accounted for the remaining area of pack stock evidence. Trampled areas occurred in a variety of wet plant communities, including *Carex scopulorum*, *Carex vesicaria-utriculata*, *Deschampsia cespitosa*, *Salix lemmonii*, and plots dominated by *Mimulus primuloides* or *Elymus trachycaulus*. Grazing was most obvious in *Deschampsia cespitosa* and *Carex vesicaria-utriculata* communities.

Informal trails were mapped near the stock camps and along the stream in the east end of the meadow, but there were many short social trails (along stream banks, often "bottlenecking" through the willows) which escaped mapping because they were shorter than the minimum mapping unit of 25 feet. 113 manure piles were mapped, mostly low-medium in density, although high density areas were mapped near the stock camps on the north end of the meadow and in a trampled area on the east end of the meadow.

Matterhorn meadow had a high proportion of plots with stock evidence present (85% of plots), and 18% of plots had greater than 10% cover of evidence. Grazing was the most common form of evidence (60% of plots), although most of the plots had less than 10% cover of grazed vegetation at the time of the survey. Hoofprints and manure were also common (50% of plots each) and hoofpunching was found in 44% of the plots.

Other findings

Use levels in Matterhorn increased greatly in 2007 and 2008 (2-6 times the use of 2002-2005), so concern for how this higher use level may be impacting the meadow is not unwarranted. The south end of the main meadow appeared particularly sensitive to physical impacts, where field staff found the majority of deep trampling. Although Matterhorn is a relatively large meadow, the high cover of willow communities reduces the useable pack stock area. This appears to concentrate use in the herbaceous communities and cause more trampling in the wetter vegetation, which is unavoidable by pack stock as they look for desirable forage. Grazed vegetation was the most common pack stock evidence found in this survey (60% of plots had some amount of grazed vegetation), and while cover of grazed vegetation was low in these plots at the time of the survey, more than twice as much use occurred after the survey, so grazed vegetation was likely much higher by the end of the season. Monitoring the utilization of desirable forage species such as *Deschampsia cespitosa*is needed at this site to determine if utilization thresholds found by others to cause significant decreases in meadow productivity(Cole *et al*. 2004) are being exceeded at this site.

The first date pack stock used this meadow in 2008 was 7/28, andfield staff anecdotally observed that 15-20% of the meadow was saturated at the time of the 8/08/08 survey. Many areas of trampling were mapped, and hoofpunching was found scattered in plots over nearly half of the meadow. Observing range readiness indicators such as soil moisture and vegetation phenology would beuseful for determining when the meadow has dried enough that unacceptable levels of hoofpunching would not occur.

Although no amphibians were seen at the time of the survey, Matterhorn was one of the lower elevation meadows surveyed (8,460 feet in elevation) and by the second week of August, amphibian breeding would likely have finished. Therefore, future amphibian surveys of this area earlier in the season would be useful to determine which species may utilize the meadow.

MILLER LAKE

North meadow at Miller Lake

South meadow at Miller Lake (right) showing ponds and saturated areas common in this meadow

Photo C-9. Miller Lake meadows

Miller Lake is a popular destination for backpackers, located along the Pacific Crest Trail approximately 15 miles hike in from either Tuolumne Meadows or Virginia Lakes Resort on the east side of the Sierra. The site contains two similar-sized meadows on opposite sides of the lake connected by approximately 250m of informal trail on the west side of the lake (Map C-9). The meadows are fairly small, with a total area of 74,065 square meters (18.3 acres) between the two meadows. The Pacific Crest Trail runs along the north end of the north meadow. The main stock camp is located on the southwest side of the lake and all pack stock evidence observed was in the south meadow. A smaller stock camp is located on a knoll above the southwest lake shore, southeast of the inlet creek. Stock could move between the north and south meadows using the informal trail, unless some temporary barricades are set up. Miller Lake has had low pack stock use in recent years (0, 0, and 11 stock nights each year from 2005-2008), although usage in 2004 was 123 stock nights. No pack stock use occurred in 2008 before the survey on 7/12/08, so any evidence observed was likely from previous years. The first recorded stock date for 2008 at Miller Lake was 8/3/08.

Narrow, meandering stream channels run through both meadows, with the north meadow channel having several forks. The north meadow had one pond along the stream channel, with no tadpoles present. The south meadow had numerous shallow ponds; 15 ponds were mapped, and 9 of these contained tadpoles. The south meadow was much wetter than the north, with an estimated 10% of the meadow (not including ponds) saturated at the time of the survey. Decomposed granite was common on the meadow edges, and *Carex filifolia* and *Vaccinium caespitosum* dominated these areas.

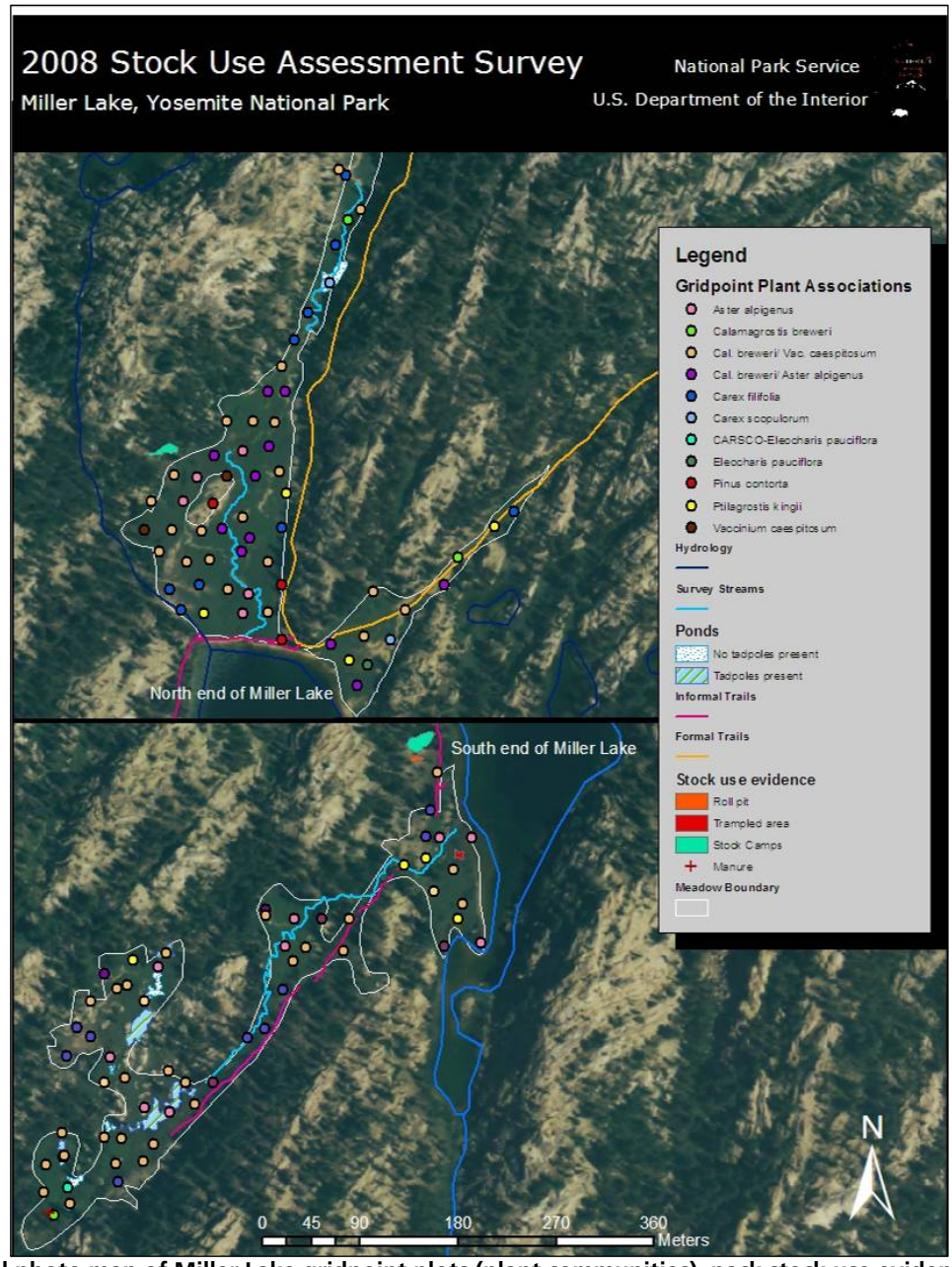
Vegetation/ Gridpoint plots

Calamagrostis breweri / *Vaccinium caespitosum* communities were overwhelmingly dominant in both meadows at Miller Lake, with 40% of gridpoints falling into this type. *Carex filifolia* was also common on the gravelly edges of both meadows, comprising 19% of the gridpoints. *Aster alpigenus* (17% of plots) and *Calamagrostis breweri – Aster alpigenus* (14% of plots) was also very common, with more *Calamagrostis* found in the north meadow.

Obligate wetland species dominated 30% of the plots at Miller Lake, suggesting that these are very wet meadows. Facultative wetland (FACW) species dominated 58% of the plots, but the common dominance of

Vaccinium caespitosum at Miller Lake is driving that percentage up. If *Vaccinium caespitosum* (considered FACW in the regional classification but grows in drier areas at Yosemite) is not considered a wetland indicator, then only 20% of the plots are dominated by FACW species.

One striking aspect of the vegetation communities at Miller Lake is the complete absence of *Deschampsia caespitosa*, which commonly grows in wet areas of meadows. Instead, *Aster alpigenus* is one of the most common dominants in these areas. Another observation is the common dominance of *Eleocharis pauciflora* at Miller Lake; it was dominant or subdominant in 8% of the plots.



Map C-9. Aerial photo map of Miller Lake gridpoint plots (plant communities), pack stock use evidence and ponds. The map has been split to show the north and south meadows on the same map.

Stream bank survey

The two streams bisecting the meadows at Miller Lake were meandering and narrow (approximately 1m wide), with overhanging banks, sandy/gravelly channel substrate, and low streamflows at the time of the survey. The north meadow stream was very shallow and hard to distinguish in places, and this stream was surveyed in the sections where an obvious channel was visible (Map C-9).

Figure C-6 depicts the data from both streams combined. The banks were armored by patches of bilberry shrubs and thick herbaceous vegetation (40% of each type). Low willow shrubs armored approximately 8% of the banks. There were more trees and bilberry lining the banks of the south meadow stream, whereas the north meadow stream had a higher proportion of dense herbaceous vegetation.

Erosional features comprised 5.8% of the stream survey length, but this is because a one large headcut along the northeast edge of the lake was included in the survey (Photo C-9). Six erosional features were mapped along the two streams, with one headcut and one fracturing feature in the south meadow and two blocking and two headcut features in the north meadow. Manure was found within 2m of two of these features.

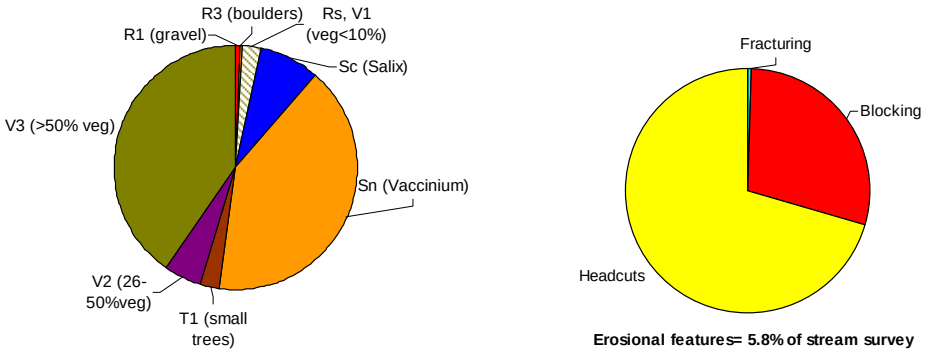


Figure C-6. Stream bank composition (left) and erosional feature composition (right) for survey reaches of two streams in Miller Lake meadows. The length of erosional features totaled 5.8% of the survey reach length, and included the length of a headcut separate from the stream that feeds directly into north Miller Lake.

North end of stream survey at Miller Lake

Large headcut on northeast end of Miller Lake

Photo C-9a. Stream survey illustrations for Miller Lake.

Stock use evidence

Miller Lake had the second lowest level of pack stock use evidence mapped at any high use meadow, with evidence polygons totaling 679 square meters or 0.9% of the total meadow area. (Cold Canyon was the lowest, with 0.7%). However, no 2008 use had occurred when the survey took place, and use from 2005-2007 was extremely light (0, 0, and 11 stock nights). Three small polygons of trampling near the lake and one roll pit near the stock camp were mapped. One point of medium density manure piles was mapped at the southwest end of the south meadow.

Miller Lake had 27% of plots with pack stock use evidence present, and no plots with greater than 10% cover of evidence. The most common evidence was old manure piles, which were found at 19% of the gridpoints plots. Hoofpunching or hoofprints were less common, found at 6% of the plots.

Other findings

The south meadow at Miller Lake, with its many shallow ponds, amphibian breeding habitat (tadpoles were found in most ponds), wetter soils, and small size could be very susceptible to negative impacts from high amounts of pack stock use and use early in the year before soils have dried out. The north meadow is much drier, has only one pond (no tadpoles observed) and so may be more resistant to impacts from pack stock use. More detailed amphibian surveys are needed to determine the species, population sizes and habitat quality of these meadows, as well as further information on how pack stock use affects amphibians. Monitoring wet areas in the south meadow during the early season would be useful to help determine when soils here become less susceptible to hoofpunching.

SMEDBERG LAKE

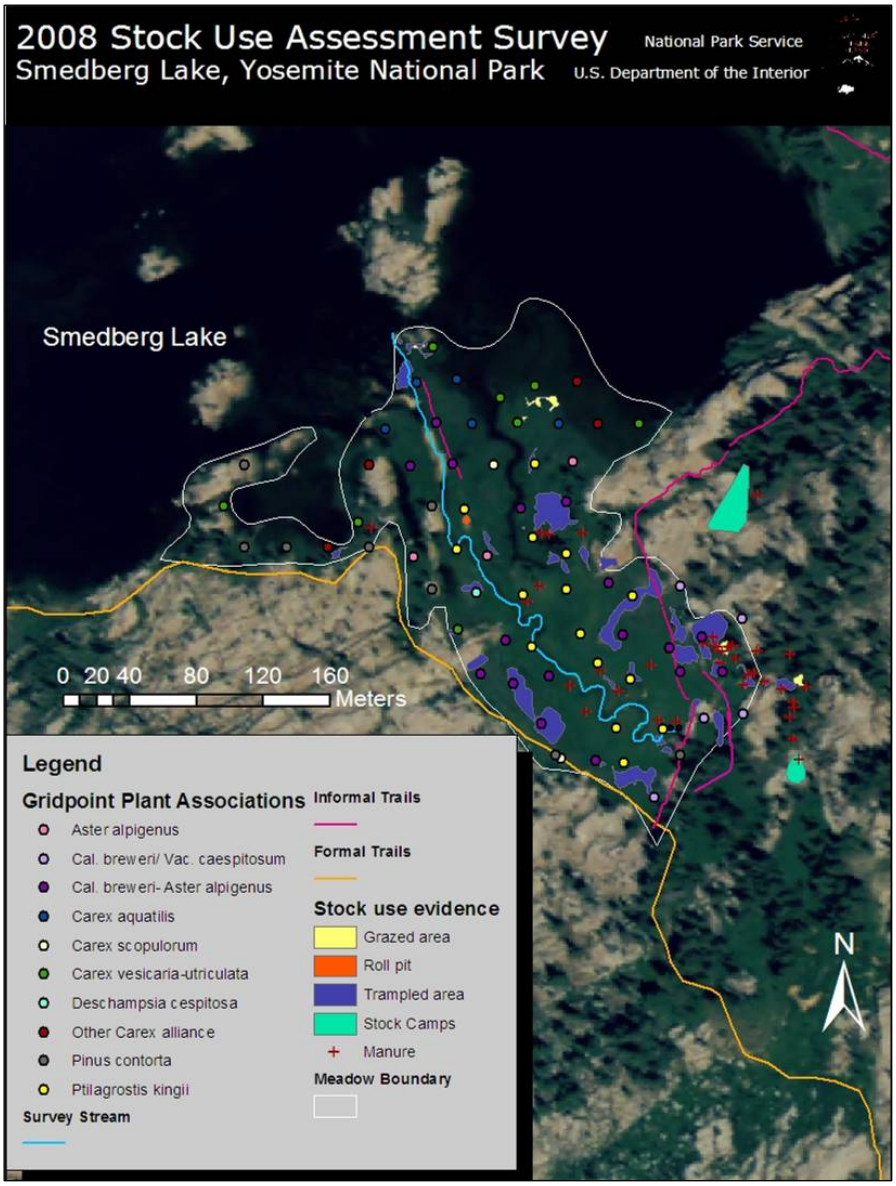
Overview of Smedberg Lake Meadow

Hoofpunches/prints in stream channel at Smedberg Lake

Photo C-10. Smedberg Lake Meadow

Smedberg Lake is frequently visited by backpackers and pack stock groups, as it is located in the middle of a popular 47-mile backcountry loop trip originating from Twin Lakes on the east side of the Sierra. It also receives sporadic high administrative stock use from trail crews. The meadow, located on the south side of Smedberg Lake, was one of the smaller meadows surveyed this year (46,272 square meters or 11.4 acres). A 20-30m wide, meandering stream bisects the meadow (Map C-10). The meadow was estimated to be 15% saturated area at the time of the survey on 8/10/08, mainly due to the wide, highly-saturated lake inlet dominated by wet sedges. Most of the rest of the meadow was dry. There was little to no conifer encroachment in this meadow, although some of the gridpoint plots on the west side were in the trees on rocky outcrops. No ponds were mapped, but at least two adult Yosemite toads were observed in the meadow and many tree frogs were observed along the stream margin. Belding's ground squirrels were also observed in the meadow.

Field staff documented two stock camps, one of which is an administrative site, which was in use by Yosemite National Park trail crew (with administrative stock) at the time of the survey. Forty of the 90 stock nights for 2008 had already occurred at the time of this survey, and fresh pack stock evidence was observed throughout the meadow. This meadow received 52 stock nights of use in 2007, nearly no use in 2005-2006, and 68 stock nights in 2004. The reported first stock use date for Smedberg Lake in 2008 was 8/4/08.



Map C-11. Aerial photo map of Smedberg Lake gridpoint plots (plant communities) and pack stock use evidence.

Vegetation/ Gridpoint plots

Calamagrostis breweri- Aster alpigenus dominated 25% of the gridpoint plots throughout Smedberg Lake meadow. *Ptilagrostis kingii* was common in the central section of meadow, with 19% of gridpoints falling into this type. The hydric sedge communities of *Carex vesicaria–utriculata* and *Carex aquatilis* dominated 19% of gridpoint plots, located at the north end of the meadow at the mucky lake inlet.

The proportion of plots at Smedberg Lake dominated by obligate wetland species (56%) was the highest of any high use meadow. Facultative wetland species dominated 24% of plots. The high proportion of obligate wetland species at Smedberg suggests that soils would be saturated or even inundated early in the season, and may be wet for much of the growing season.

Noteworthy features of the vegetation communities at Smedberg Lake included the dominance in 7% of the plots by *Carex aquatilis*. This sedge was only found to be dominant at one other meadow (Matthes Lake). *Carex athrostachya* was subdominant in one of the plots at Smedberg Lake, and this species was not

documented in any plots at the other meadows. *Muhlenbergia filiformis* was dominant at one of the plots in Smedberg meadow, which was also an unusual dominant in the meadows surved. *Deschampsia cespitosa* was uncommon at Smedberg (dominant at only one gridpoint), and with seasonally saturated areas dominated by *Aster alpigenus* instead.

Stream bank survey

The stream survey reach at Smedberg Lake was short (420m), up to 2m deep at the upper end but shallow (30-50cm deep) at the lower end near the lake. This stream was very wide- up to 30m across in many places. It was not flowing at the time of the survey, but pools were observed throughout the channel and fish were present in approximately half of these pools. The stream banks were well-armored with thick herbaceous vegetation (50% of transect, Figure C-7). Willow (35% of transect) and bilberry shrubs (8% of transect) comprised most of the remaining transect.

Erosional features were found along 8.3% of the survey length, with eight of the 10 features mapped being fractured sections of stream bank. Two headcuts on the west side of the stream were also mapped. Hoofpunching was found within 2m of one of the headcuts.

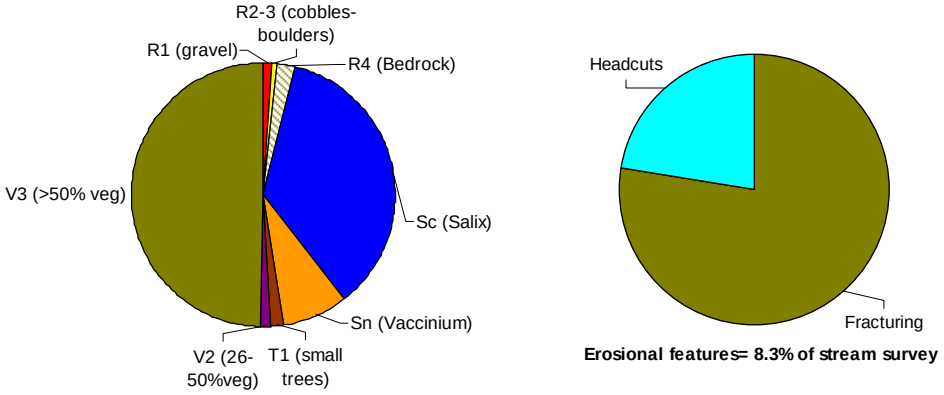


Figure C-7. Stream bank composition (left) and erosional feature composition (right) for survey reach of stream through Smedberg Lake meadow. The length of erosional features totaled 8.3% of the survey reach length.

Stock use evidence

Forty of the 90 stock use nights for 2008 occurred prior to the survey on 8/10/08, so the data reported may account for less than half of the pack stock evidence for 2008. Smedberg Lake had 52 days of pack stock use in 2007, and very light use in 2005-6 (0-11 stock nights), so some residual evidence from 2007 may be included in this survey.

Thirty-nine polygons with evidence of stock use, and two stock camps were mapped at Smedberg Lake, for a total area of 3904 square meters or 8.4% of the meadow. All but six of these polygons were trampled areas; one roll pit and five grazed areas were mapped. The majority of trampling occurred in saturated *Aster alpigenus* communities, although some *Ptilagrostis kingii* communities had trampling as well. Grazing occurred mainly in the wet sedge communities at the edge of the lake, where hoofpunching (not dense enough to be mapped as trampling) was also observed.

Smedberg Lake had a very high proportion of plots with pack stock use evidence present (94%), and 16% of plots had greater than 10% cover of evidence. Hoofpunching was the most common form of evidence (50% of plots), followed by hoofprints (43%). Manure was present in 32% of the plots, and 26% of the

plots had grazing evidence. Half of the sedge plots (*Carex aquatilis* and *Carex vesicaria-utriculata*) had 15-30% cover of grazed vegetation at the time of the survey, and nearly all of the Aster alpigenus-dominated plots had hoofpunches (with one plot having 20% cover of hoofpunches).

Other findings

Because it is a relatively small and wet meadow, Smedberg Lake meadow may be more susceptible to negative impacts from pack stock use if use becomes too high or occurs before the meadow dries out. The amount of hoofpunching at this site, the presence of hoofpunches in 50% of plots), and hoofpunching found even in drier *Ptilagrostis kingii* communities suggests that soils were still quite wet when stock entered the meadow this year. Observing range readiness indicators such as soil moisture and vegetation phenology would beuseful for determining when the meadow has dried enough that unacceptable levels of hoofpunching would not occurLess than half the stock use nights for 2008 occurred before the survey, yet 26% of plots contained grazing evidence (with 15-30% cover of grazed vegetation in sedge communities). It seems logical that grazed vegetation , particularly in targeted forage species was likely much higher by the end of the season. Monitoring vegetation utilization during high use years would be useful to determine if thresholds of vegetation utilization recommended by others to avoid decreases in meadow productivity and other negative effects (Cole *et al.* 2004, Ratliff *et a*l. 1987) are exceeded.

Numerous tree frogs and several Yosemite toads were observed anecdotally at Smedberg Lake during the course of other survey activities. More thorough amphibian surveys are needed to determine the status of populations and amphibian habitat at this site. n. In addition, futher information on the effects of pack stock use in meadows on amphibian populations is needed so that management strategy can best balance pack stock use and amphibian population health.

TILDEN LAKE SITES

The two sites at Tilden Lake occur at opposite ends of the nearly two mile-long lake. "Tilden South" refers to the three small meadows bordering the lake at its south end, and "Tilden North" refers to the two long meadows at the north end of the lake. Packers do not differentiate between Tilden North and Tilden South when reporting their use, so it is impossible to know with certainty how use is allocated between the two sites. Riding or leading pack stock up to the north end of Tilden Lake is not allowed because there is no formal trail (although there is disagreement over this point because some older USGS maps show a trail). However, stock turned out to graze at Tilden South may wander up to Tilden North, and stock evidence was common at Tilden North in this survey. Therefore, in any calculations for pack stock use among the two meadows, use numbers were divided equally among Tilden North and Tilden South, even though more use probably occurs at the south site (Mark Fincher, personal communication).

TILDEN LAKE SOUTH

Southwest meadow at Tilden South.

Areas of bare soil and trampling at Tilden south (southwest meadow)

Photo C-10. Tilden Lake meadows

Tilden South meadows are made up of three small meadows at the south end of Tilden Lake (Map C-12). These meadows are separated from the Tilden North site by approximately 2 ¼ km informal trail that runs along the west side of the lake. The meadows border lake, with two of them having a long, narrow shape that hugs the shoreline. The narrow meadow on the southeast side of the lake has one stock camp and a formal trail (the hiking trail to Macomb Ridge) running through it. Other stock camps (4) are located just outside the northwest meadow, but stock probably move freely between the larger northwest meadow and the small, narrow southwest meadow, as there is only 200m of informal trail separating them. There is a small rock wall with removable branches (to form a gate) that keeps stock from travelling north of the northwest meadow along the trail on the lakeshore. Alternatively, packers may turn out their stock on the north side of this gate, sending them up to the Tilden North site for grazing.

All reported pack stock use (21 nights) at Tilden Lake for 2008 occurred before the survey on 8/24/08, and there was no reported use for 2007, so pack stock evidence documented at Tilden South most likely from 2008 use. The calculation of stock nights per acre is confounded by private stock use at Tilden, which is not tracked by the stock use database at Yosemite (Mark Fincher, personal communication). Usage in 2004-

2006 was much higher, with 163, 128, and 75 stock nights reported for all of Tilden Lake during these years. The first reported stock use date for 2008 was 8/18/08.

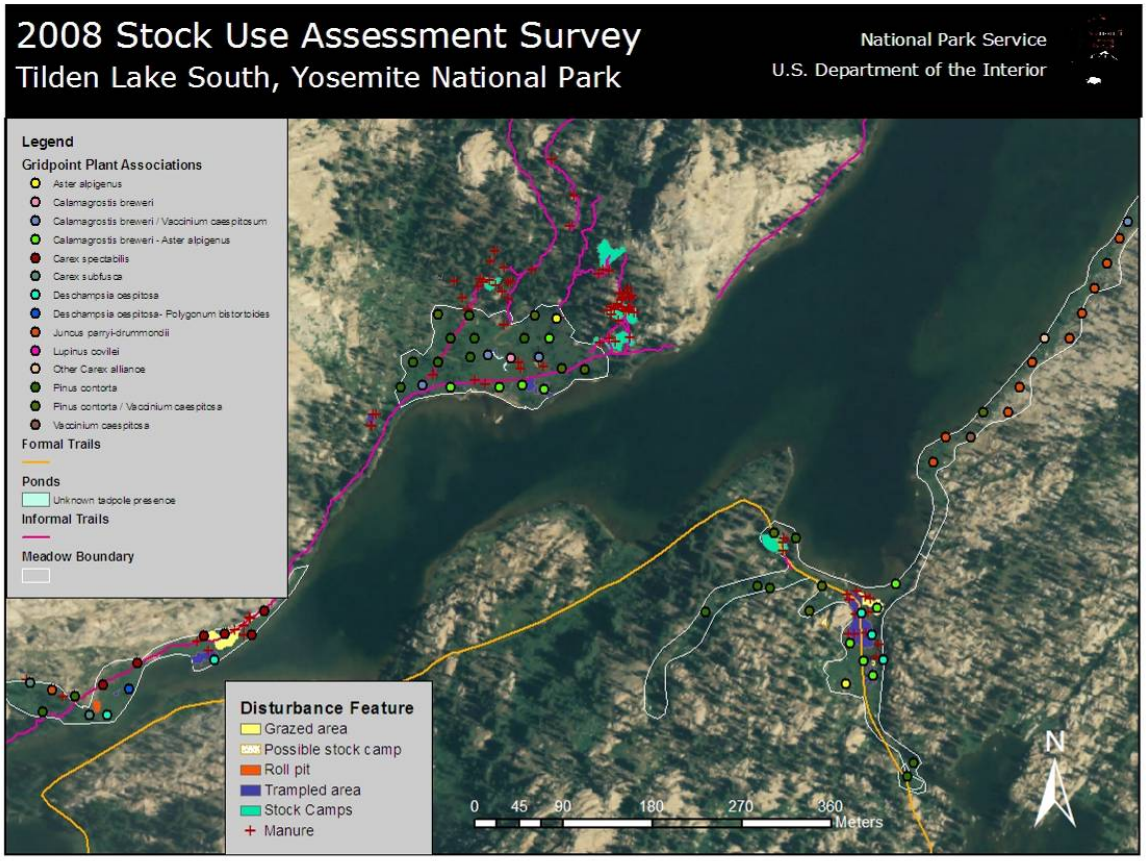
No part of these meadows was saturated at the time of the survey. Two small ponds were mapped in the northwest meadow but due to the lateness of the survey date in the season, tadpole presence was not noted. A small stream (approximately 100m long) bisected the northwest meadow, draining into the lake. This stream was very short and narrow, so was not included in the stream survey data.

Vegetation/ Gridpoint plots

Full plot data were not collected at many of the gridpoints, since much of the area described as meadow on the Yosemite vegetation map turned out to be lodgepole pine, rocky outcrops and/or decomposed gravel often dominated by *Juncus parryi* (or *drummondii*, identification uncertain). Of the 69 original gridpoints, only 26 full plots were collected. *Calamagrostis breweri* / *Aster alpigenus* was the dominant community (30% of plots), followed by *Deschampsia cespitosa* (sometimes with *Polygonum bistortoides* as subdominant, 21% of plots). *Carex spectabilis* dominated 18% of plots, while *Carex subfusca* dominated 6% of plots.

Obligate wetland species (*Aster alpigenus*) dominated 19% of the plots at Tilden South. Facultative wetland species (mainly *Calamagrostis breweri* and *Carex spectabilis*) dominated 69% of the plots. The total percent of plots dominated by either facultative or obligate wetland species was one of the highest of the high use meadows, exceeded only by Benson Lake and Dorothy Lake.

The vegetation at Tilden South was unique in several ways. The southwest part of the survey area was dominated largely by *Carex spectabilis*, and the only other sites that had this species as a dominant were in Lyell Canyon. *Carex subfusca* (also found as an occasional dominant in Lyell Canyon) was a common dominant at South Tilden. *Veratrum californicum* and *Lupinus covillei* were subdominant in two of the plots at Tilden South, and these were only occasionally present as a subdominant in the meadows of this study (Hook Lake, Matthes Lake, Matterhorn Canyon, Long Meadow, and Upper Lyell). There was a striking absence of *Ptilagrostis kingii*, a plant common to most subalpine meadows. *Trichophorum clementis*, considered a rare plant at Yosemite, was dominant in one of the plots at Tilden South.



Map C-12. Aerial photo map of Tilden South gridpoint plots (plant communities), pack stock use evidence and ponds.

Stock use evidence

All 2008 pack stock use occurred prior to the 2008 survey, so this survey should have captured all evidence created by current year's use. Use in 2008 was light compared to 2004-2006 (2007 had no documented use). There were 21 stock nights reported for all of Tilden Lake (north and south). In 2004-2006 the numbers were 163, 128, and 75 stock nights.

Stock evidence polygons mapped totaled 4,288 square meters (1.3 acres), or 11.4% of the survey area. Nineteen trampling polygons were mapped, for approximately 1,740 square meters. Grazed areas accounted for 986 square meters, and one large roll pit was mapped in the southwest meadow. The southwest meadow appeared particularly susceptible to physical impacts from pack stock use, possibly due to the loose, sandy soils there. Large bare areas and areas of trampling were common in the southwest meadow (Photo C-10).

Trampling and grazing commonly occurred in *Calamagrostis breweri – Aster alpigenus* and *Deschampsia* communities, with extensive grazing noted in *Carex spectabilis* communities. Ninety-three manure points were mapped, with 22 high density points (greater than 5 piles in 2m) mapped around the large stock camp in the northwest meadow and throughout the southeast meadow. Llama manure was mapped in the southeast meadow. This manure may be very high in nitrogen, as the surrounding vegetation was very yellow and burned in appearance.

Tilden South had a high proportion of plots (92%) with pack stock evidence present, and 28% of plots had greater than 10% cover of evidence. Hoofprints were the most common form of evidence in plots (73% of plots), followed by grazed vegetation, which was present in 58% of plots. 12% of plots were more than 70% grazed with *Carex spectabilis* and *Calamagrostis breweri* as the preferred forage species. Manure was present in 42% of plots, and hoofpunching in 38% of plots.

Other findings

Twenty-one stock nights were reported for Tilden lake in 2008, and if these are split evenly between the north and south sites, then Tilden South received no more than 11 stock nights of use. This would be considered light use, except for the small size of the meadows available here. It appears that pack stock target *Carex spectabilis* for grazing in the southwest meadow, churning up the sandy soil in the process. Monitoring to determine the percent vegetation utilized for these preferred forage communities would be useful to ensure that thresholds of vegetation utilization recommended by others is not exceeded (Cole *et al*. 2004, Ratliff *et al*.1987).

Obligate or facultative wetland species dominate 88% of the plots at Tilden South, suggesting that this site could be have wet soils that are susceptible to hoofpunching early in the season. Hoofpunching was found in 38% of gridpoint plots, and 19 small polygons of trampling were mapped. This suggests that monitoring the extent of wet soil early in the season would be helpful in determing the point when soils have dried enough so that unacceptable levels of hoofpunching will not occur.

TILDEN NORTH

Lower meadow at Tilden North

Extensive hoofpunching in one of the shallow ponds at Tilden North

Photo C-11. Tilden North meadow.

Tilden North consists of two long meadows, bisected by a stream that drains into the north end of Tilden Lake (Map C-13). A narrow informal trail, hard to discern in many places, connects the lower and upper meadows through the forest on the west side of the stream. The total area of both meadows is 87,005 square meters, or 21.5 acres. There was no pack stock use evidence in the upper meadow, but the lower meadow had many manure piles, trampling, and grazed areas. One stock camp was located just outside the west edge of the lower meadow. The informal trail visible through most of the upper meadow continues up the drainage, providing hikers easy access to Mary Lake.

Because use numbers reported by commercial packers do not differentiate between Tilden North and Tilden South sites, it is impossible to know how use is allocated between the two areas. Riding or leading stock up to the north end of Tilden Lake is technically illegal because the trail along the west side of the lake is not a formal trail. However, fresh pack stock evidence was found in the lower meadow on the north end of the lake, so stock are obviously using this meadow, possibly travelling the approximately 1.5 mile long informal trail when they are turned loose to graze. In any calculations for pack stock use among the two meadows, use numbers were divided equally among Tilden North and Tilden South, even though more use probably occurs at the south sites (Mark Fincher, personal communication).

All reported pack stock use (21 nights) at Tilden Lake for 2008 occurred before the survey on 8/24/08, with first reported stock use occurring on 8/18/08. There was no reported use for 2007, so pack stock evidence documented at Tilden South most likely from 2008 use. Usage in 2004-2006 was much higher, with 163, 128, and 75 stock nights reported for all of Tilden Lake during these years.

Ten percent of the meadow was estimated to be saturated at the time of the survey on 8/24/08. Nine ponds were mapped at Tilden North, and there was one large pond at the south end of the lower meadow that was not mapped. This pond, as well as 6 of the other ponds, were dry at the time of the survey. Of the three remaining ponds with water, three had tadpoles present. Adult tree frogs were found in the north meadow. A portion of stream in the lower meadow had shallow backwater areas that were dry at the time of the

survey. Stream surveys were performed in both the upper and lower meadow, but the 100m rocky, forested stretch of stream between the two meadows was excluded.

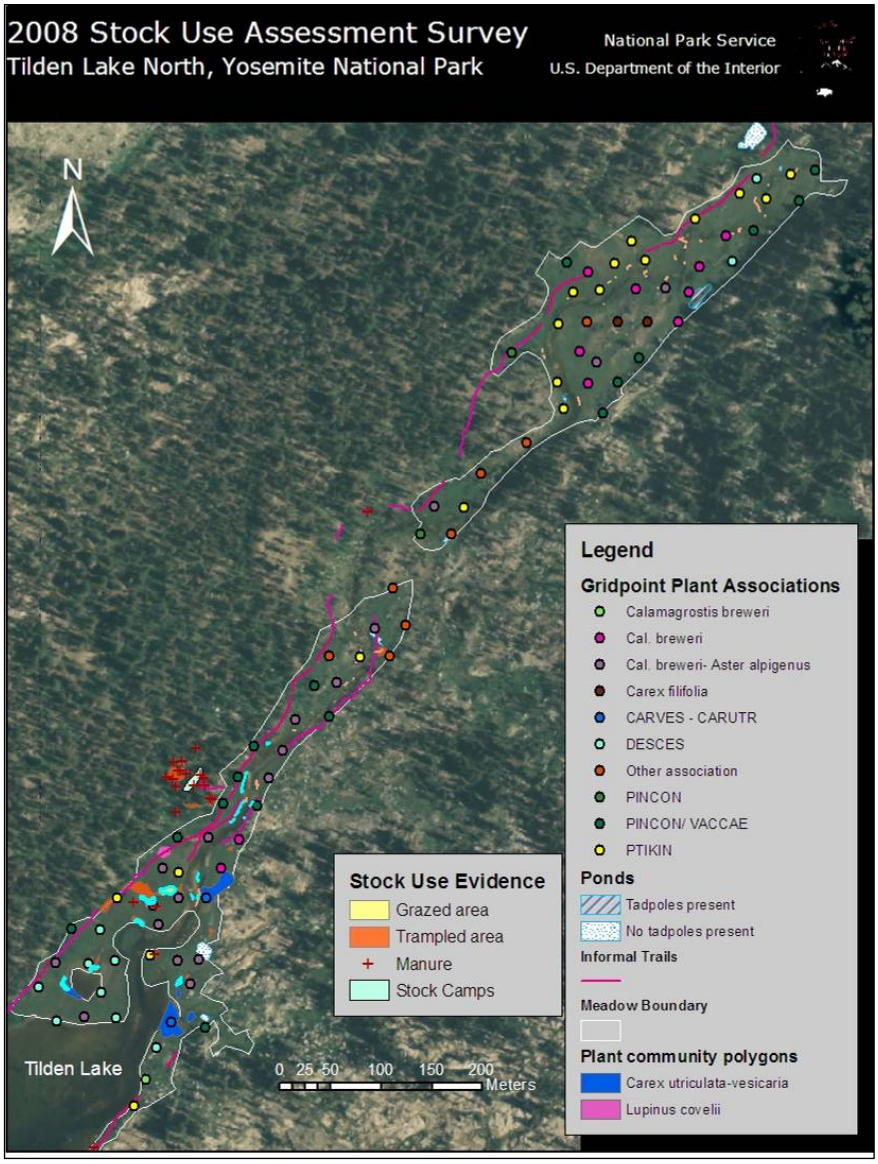
Conifer encroachment was common on the meadow margins, with 25-30% of the meadow estimated to have encroachment. Of the 90 original gridpoints, 17 were rejected on the basis of too much conifer cover. Seven plots were rejected because they were in rocky areas dominated by *Juncus parryi* (or *drummondii*, identification uncertain).

Vegetation/ Gridpoint plots

Calamagrostis breweri- Aster alpigenus and *Ptilagrostis kingii* communities dominated Tilden North, with 30% of plots falling into each of these types. *Deschampsia cespitsosa* was also common (18% of plots), as well as *Calamagrostis breweri* / *Vaccinium caespitosum* (15% of plots). Carex vesicaria- utriculata was common in the lower meadow, emerging from many of the shallow ponds there, but this species was not found in the upper meadow.

Tilden North had the lowest percentage of plots (4%) dominated by obligate wetland species of all high use meadows except for Lower-Upper Lyell. However, 61% of the plots at Tilden North were dominated by facultative wetland species (mainly *Calamagrostis breweri* and *Deschampsia cespitosa*). Only three of the high use meadows (Lower-upper Lyell, Matterhorn Canyon, and Cold Canyon) and three low use meadows had lower proportions of plots dominated by obligate or facultative wetland species. Therefore, Tilden North is in the drier end of the spectrum among the meadows in this study.

Tilden North had vegetation typical of most of the subalpine meadows in the study, with only a few notable differences detected in the survey data. There was a higher proportion of plots dominated by *Solidago multiradiata* (4% dominant, 11% subdominant) or *Senecio scorzonella* (11% dominant) compared to other meadows in the study. Two species of lupine, *Lupinus covillei* and *Lupinus lepidus* var. *lobbii*, were also common in plots, with 5% of plots having *Lupinus covillei* as a subdominant and 2% of plots having *Lupinus lepidus* var. *lobbii* as a subdominant.



Map C-13.Aerial photo map of Tilden North gridpoint plots (plant communities), pack stock use evidence and ponds.

Stream bank survey

The stream channel at Tilden North bisected the survey area and was at low flow at the time of the survey (only a few inches deep in many places). The channel was approximately 3-5m wide, with a cobbly substrate comprising the bed material. The upper meadow stream banks appeared very stable, with thick herbaceous vegetation and some willow armorment. Data from the upper and lower meadow stream reaches were combined in Figure C-8 below.

The stream banks were mainly armored with dense vegetation (44% of survey reach) and bilberry shrubs (32% of survey reach). Thick willows stabilized 11% of the total survey reach, but all willows were in the upper meadow. The banks at Tilden North (particularly the lower meadow) were rockier than any other stream surveyed in this study, with 8% of the banks stabilized by rocks greater than 10cm in diameter.

Erosional features were found along 13.7% of the survey reach, and were fairly evenly distributed between the upper and lower meadows. 52 erosional features were mapped, with the majority of these being fractured sections of stream bank. Blocking was also common (11 features mapped), and three headcuts were mapped. Hoofprints/punches were found within 2m of one of the erosional features in the lower meadow, and the informal trail was within 2m of 15 of the features.

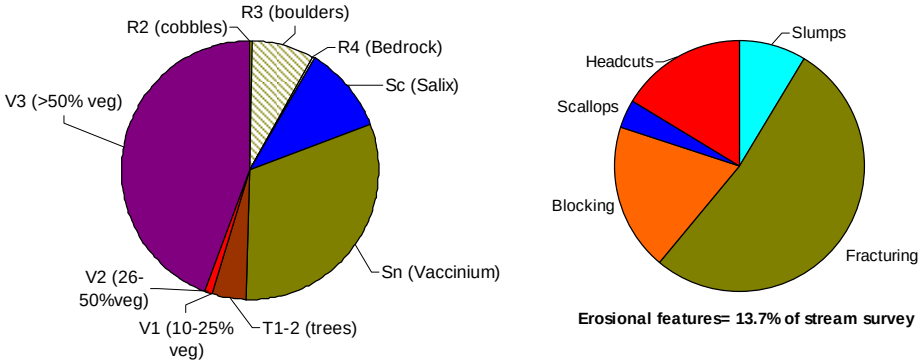


Figure C-8. Stream bank composition (left) and erosional feature composition (right) for survey reach of stream through the north meadows at Tilden Lake. The length of erosional features totaled 13.7% of the survey reach length.

Stream in upper meadow of Tilden North

Headcut along survey reach in lower meadow at Tilden North

Photo C-13. Stream survey illustrations for Tilden North

Stock use evidence

All 2008 pack stock use occurred prior to the 2008 survey, so our survey should have captured all evidence created by current year's use. Stock use in 2008 was light compared to 2004-2006 (2007 had no documented use). There were 21 stock nights reported for all of Tilden Lake (north and south). In 2004-2006 the numbers were 163, 128, and 75 stock nights.

At Tilden North, only the lower meadow had pack stock use evidence. Polygons of evidence mapped totaled 1330m^2, or 2.1% of the survey area. Trampling was the most common evidence mapped, with 17 polygons comprising an area of 1170m^2. Trampled areas in pond bottoms were not mapped, though numerous hoofpunches were found in many of the shallow ponds which had no water at the time of the survey (See Photo C-13). Trampling most commonly occurred in *Calamagrostis breweri – Aster alpigenus*

communities. Six grazing polygons were mapped, all in *Carex vesicaria-utriculata* communities along pond edges and the lakeshore.

Forty-four percent of gridpoint plots had some pack stock evidence present, and 4% had more than 10% cover of evidence. Hoofpunching was the most common form of evidence (35% of plots), followed by hoofprints (30% of plots). Grazed vegetation was found in 21% of plots, though no plot had greater than 10% cover of grazed vegetation. Manure was found in 12% of plots.

Other findings

Twenty-one stock nights occurred at Tilden lake in 2008, and if these are split evenly between the north and south sites, then Tilden North received no more than 11 stock nights of use. This is considered light use, but hoofpunching and trampling may result if use occurs before soils have dried out sufficiently. According to reported use, stock did not enter the meadow until 8/18/08, but despite this late entry data, 35% of plots had hoofpunches. Many ephemeral ponds are present in the lower meadow and extensive hoofpunching was seen in the drying mud of theseponds. This study did not observe any amphibians on site, but more thorough amphibian surveys could be used to determine which species utilize the meadow and ephemeral ponds for breeding.

Upper Lyell Canyon Meadows

The two sites in upper Lyell Canyon are large meadows connected by an informal social trail through the forest that is approximately 200m long. In this report, "Upper Lyell" refers to the uppermost meadow in the canyon (farthest south), and "Lower-Upper Lyell" refers to the next meadow to the north. The Lyell Fork of the Tuolumne River bisects both meadows. Stock could easily move between the two sites in a single night, although observations of pack stock behavior and stock use evidence suggest that the majority of use occurs in the uppermost meadow (Upper Lyell). Packers do not differentiate between the two sites when reporting their use, so it is impossible to know with certainty how pack stock use numbers should be allocated between the two sites. Therefore, in any calculations for pack stock use among the two meadows, use numbers were divided equally among Upper Lyell and Lower-Upper Lyell, even though more use probably occurs at Upper Lyell.

Lyell Canyon sees consistently high pack stock use, with the second-highest calculated average for stock nights/acre (Castle Camp is highest). Stock nights ranged from 219-564 for the years 2004-2007, and all of Lyell Canyon's 326 stock nights for 2008 occurred before the meadow survey on 9/11/2008. Therefore, all pack stock evidence created at these sites in 2008 should be captured by this survey. The first reported use night for Lyell Canyon was 7/23/08.

Lower-Upper Lyell Meadow

Stock crossing the Lyell Fork at Lower-Upper Lyell

Lower-Upper Lyell meadow with informal trail

Photo C-14. Lower-Upper Lyell Canyon meadow

Lower-Upper Lyell, though smaller than Upper Lyell, is a large meadow encompassing 81280m^2 (20.1 acres). The meadow was estimated to have 5% or less area of saturated soils at the time of the survey (9/10/08), mainly in shallow depressions filled with wet sedges. One small pond was mapped at the southeast corner of the meadow, and the observer did not note whether or not tadpoles were present. Conifers encroachment was estimated to cover 10% of the meadow, mainly along meadow edges.

Stock parties cross the Lyell Fork at the south end of the meadow in order to access campsites on the other side. One camp is located south of the meadow (Map C-14). Another is located just outside the north end of the meadow. The most popular camp is just outside the meadow to the east, behind a large slickrock

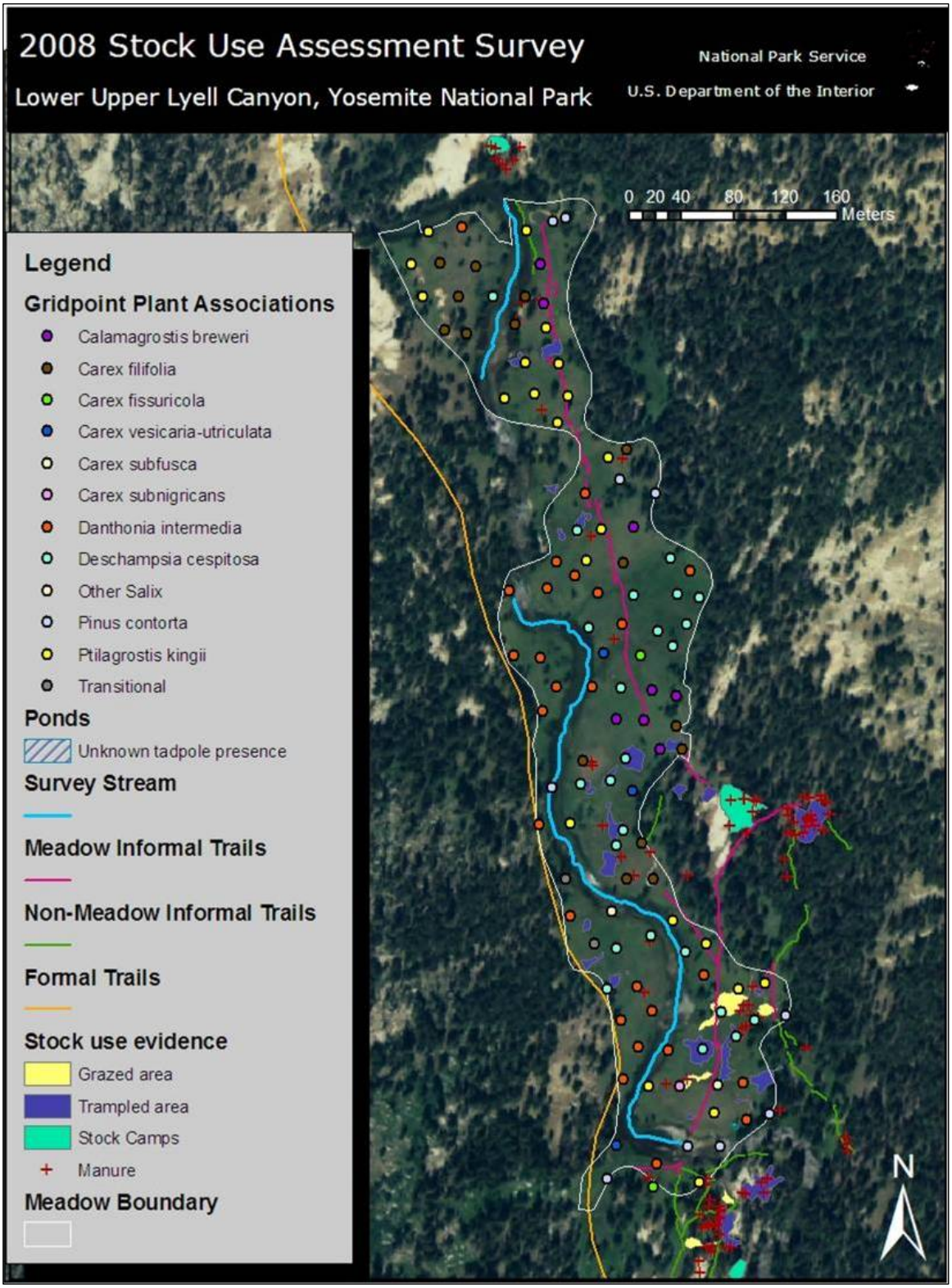
outcrop. A well-worn informal trail bisects the meadow from north to south, connecting the campsites to the main stream crossing. A network of informal trails connects the south end of the meadow to Upper Lyell meadow.

Vegetation/ Gridpoint plots

Dry communities of *Danthonia intermedia* and *Ptilagrostis kingii* (25% and 22% of plots, respectively) dominate Lower-Upper Lyell. Moist communities of *Deschampsia cespitosa* (23% of plots) are also common. *Carex filifolia* (14% of plots) is common in the north end of the meadow and along the eastern edge.

The vegetation found in plots at Lower-Upper Lyell suggests that this meadow is the driest of any of the high-use meadows. Three percent of plots are dominated by obligate wetland species, and only 24% of plots are dominated by facultative wetland species. The combined proportion of plots dominated by wetland indicators (27%) is the lowest of any of the high use meadows.

Certain aspects of the species composition in communities of Lower-Upper Lyell were distinctive. *Aster alpigenus* was strikingly absent from the vegetation (only present as a subdominant in one plot). Lower-Upper Lyell was the only meadow in this study with *Achnatherum occidentale* dominant in any plots (dominant in 2% of plots and subdominant in 4% of plots). It was also the only meadow where *Artemisia tridentata* shrubs dominated any plots (1% of plots). (Lower Lyell had *Artemisia* as subdominant in several plots). *Antennaria* sp. (phenology was too advanced to determine species) was dominant in 7% of plots at Lower-Upper Lyell and subdominant in 9%. Three sedge species uncommon to meadows in this study were relatively common in Lower-Upper Lyell, with *Carex fissuricola*, *Carex subfusca*, and *Carex subnigricans* dominant or subdominant in 11%, 3%, and 4% of plots, respectively.



Map C-14. Aerial photo map of Lower-Upper Lyell gridpoint plots (plant communities), pack stock use evidence and ponds.

Stream bank survey

Stream banks in Lower-Upper Lyell were armored mainly with thick herbaceous vegetation (64% of survey length), although willows armored 22% of the banks (Figure C-9). Lodgepole pine (mainly large trees) were found along 8% of the banks. Erosional features were found along 40.5% of the survey length, mainly because of the high number (and length) of headcuts. Both Lower-Upper and Upper Lyell meadows had more headcutting than any other meadow. Of the 78 erosional features mapped along the Lyell fork through Lower-Upper Lyell, 18 were headcuts. Fracturing and blocking were nearly equal (22-25 features mapped). Two stream crossings were mapped at the south end of the meadow. Stock use evidence was found within 2m of 19% of the erosional features, in the form of scattered hoofpunches/hoofprints or a social trail with hoofprints present.

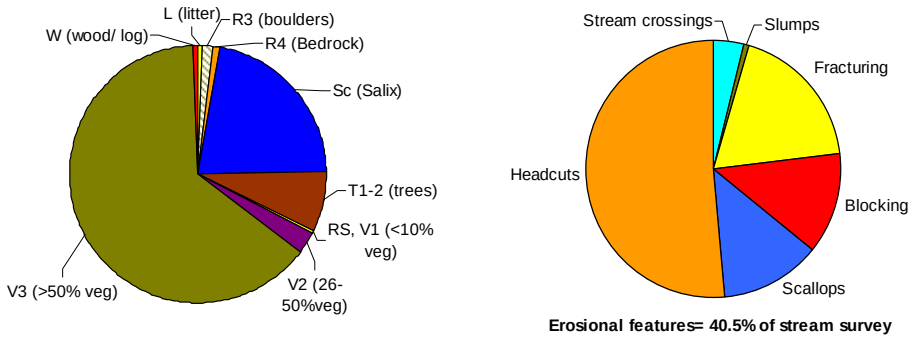


Figure C-9. Stream bank composition (left) and erosional feature composition (right) for survey reach of the Lyell Fork in Lower-Upper Lyell Canyon. The length of erosional features totaled 40.5% of the survey reach length.

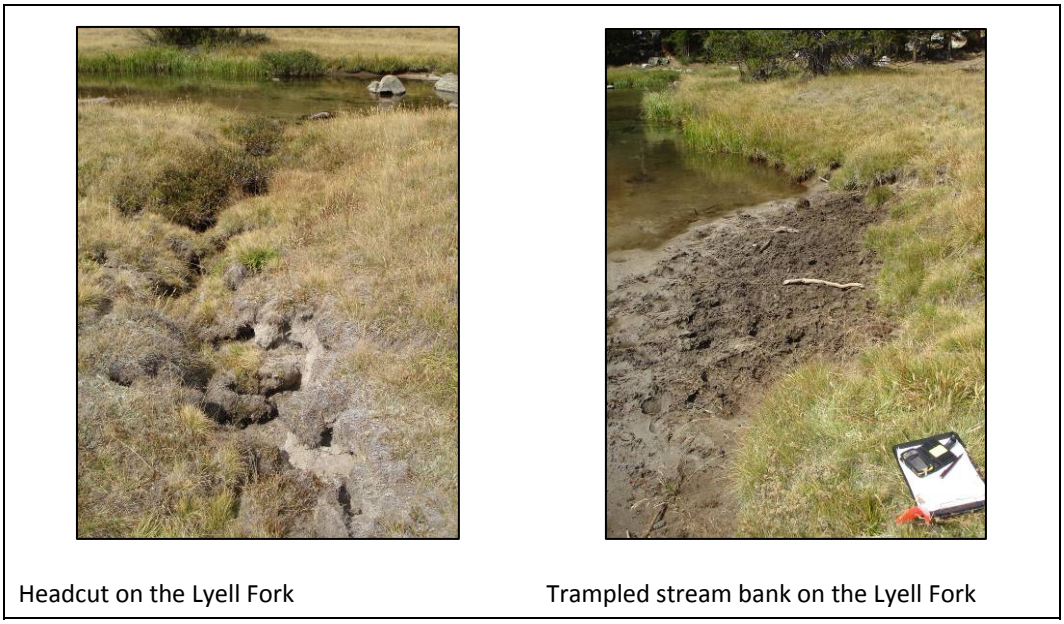


Photo C-15. Stream survey illustrations of the Lyell Fork at Lower-Upper Lyell

Stock use evidence

Nearly all pack stock evidence at Lower-Upper Lyell was found on the east side of the Lyell Fork, and mainly in the south end of the meadow. The total area of evidence polygons mapped was 6296m^2, or 7.7% of the survey area. Trampled areas were by far the most common type of evidence mapped (30 of the 35

polygons mapped), and occurred mainly in *Deschampsia cespitosa* communities. Five polygons of grazing were mapped, also in *Deschampsia*. One hundred three manure points were mapped, and nearly half of these were high density (greater than 5 piles per 2m). Nearly all the manure points were concentrated near the stock camp areas and in the southernmost part of the meadow.

Stock evidence occurred in 61% of plots at Lower-Upper Lyell, with 12% of plots having greater than 10% cover of evidence. Hoofpunching was the most common evidence found (33% of plots), followed by manure (26% of plots) and hoofprints (23% of plots). Grazed vegetation was found in 22% of plots, though only 5% of plots had greater than 10% cover of grazed vegetation.

Other findings

Hoofpunching is most often found in wet vegetation communities, since it occurs easily in saturated soils. Despite the dryness of Lower-Upper Lyell meadow vegetation, one-third of plots still contained hoofpunching. This suggests that soils may still be wet when horses first enter the meadow for the season. The first pack stock date for Upper Lyell was 7/23/08, which was the earliest for any of the high use meadows except for Castle Camp. Monitoring range readiness conditions for soil moisture and plant phenology would contribute information needed to determine appropriate timing for stock use at this site.

The Lyell Fork running through Lower-Upper Lyell also bisects two other meadows in this study- Upper Lyell (a high use meadow) and Lower Lyell (a low-no use meadow). The survey reaches in Lower-Upper Lyell and Upper Lyell (high use meadows) had nearly four times the proportion of erosional features of the survey reach in Lower Lyell (low-no use meadow). This comparison may be questionable since the survey reach of Lower Lyell was considerably shorter than the other two reaches (987m compared to 1420m and 3310m), is five miles downstream, may be different soil types, and also has had a different history of use. However, one current difference between Lower Lyell and the other two sites is the absence of overnight pack stock use. This study found that 17-19% of erosional features on the Lyell Fork in high use meadows had stock evidence within 2m of the bankful line(frequently social trails with hoofprints or hoofpunching), so concern about damage to stream banks from stock use is not unwarranted. The magnitude of difference in erosional features that occur along the Lyell Fork in high use vs. low-no use meadows suggests that further investigation in this area would be worthwhile.

The level of stock use in Lyell Canyon is consistently higher than use at any site in this study (excepting Castle Camp). This makes it a primary candidate for careful monitoring for indicators for meadow health. In particular, the southeast portion of Lower-Upper Lyell appears to have more concentrated use, based on physical evidence created by pack stock. Targeted monitoring of areas preferred by stock may allow change to be detected in a higher-impacted area of meadow before the entire meadow is affected.

UPPER LYELL CANYON

Upper Lyell meadow with Lyell Fork in the foreground

Ephemeral pond with hoofpunches at Upper Lyell

Photo C-16. Upper Lyell meadow

This meadow was one of the largest high-use meadows in the study, encompassing an area of 14,651 square meters (36.3 acres). Upper Lyell also consistently receives some of the highest pack stock use levels at Yosemite each year, which were calculated to be a five-year average of 7.2 stock nights per acre. This calculation assumes that use is spread equally over Upper Lyell and Lower-Upper Lyell, but observation of pack stock behavior and pack stock use evidence found suggests use is concentrated in Upper Lyell, and actual stock nights per acre are likely much higher in Upper Lyell than what was calculated.

There are three main stock camps at Upper Lyell. The largest and most popular of these is at the southernmost edge of the meadow and requires stock parties to cross the Lyell Fork at that end of the meadow. The other two camps are on the western edge of the meadow and are seldom used by stock (Map C-15).

None of the meadow was estimated to be saturated at the time of the survey on 9/11/08, except for a few saturated areas near stream crossings and drying ephemeral ponds. However, a training trip was conducted on 7/3/08 and 15% of the meadow was estimated to be saturated at that time, with all of the ponds and low-lying areas fully inundated. The first pack stock use of Upper Lyell occurred on 7/23/08, so it is likely that many of these areas were still saturated at that time.

The stream survey was conducted during the 7/3/08 training trip, so any pack stock evidence reported as part of the stream survey was from previous years' use. Stock evidence mapping and gridpoint plot collection was conducted during the 9/11/08 survey, which was after all 2008 pack stock use was complete.

Fifteen shallow ponds were mapped during the 9/11/08 survey, and approximately half of these were dry at that time. It is possible that these ponds may have housed tadpoles earlier in the year, but no amphibians were observed during the course of this survey. Shallow backwaters of the Lyell Fork, dominated by wet sedges, were anecdotally noted but not mapped.

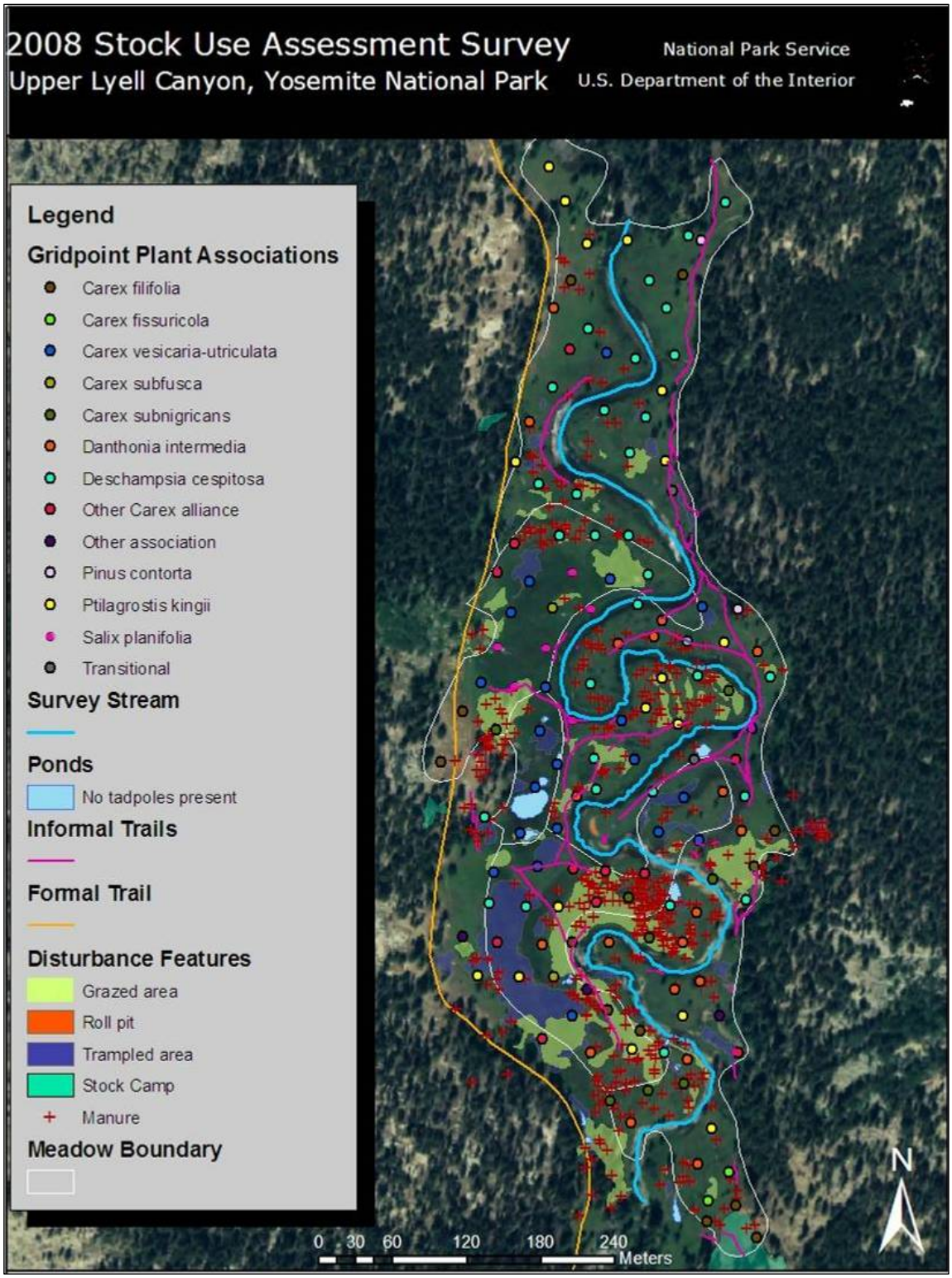
Vegetation/ Gridpoint plots

Deschampsia cespitosa was the most common vegetation community encountered in Upper Lyell, dominating 24% of the gridpoint plots. Wet communities of *Carex vesicaria-utriculata* were the next most

common type, dominating 15.3% of the plots. Drier communities of *Ptilagrostis kingii* comprised 12% of the plots, and 7% of the plots were in areas dominated by *Carex subspicata*. Unknown sedge species dominated 8% of the plots, due to grazed vegetation and lack of floral parts.

Obligate wetland species dominated 16% of the plots in Upper Lyell, and facultative wetland species dominated 23% of plots. Therefore, the total proportion of plots dominated by wetland indicators (39%) is lower than most of the high use meadows surveyed. *Carex vesicaria-utriculata* indicates areas that remain wet far into the season, however, and the 15% of this type of vegetation at Upper Lyell suggests that the meadow has many saturated areas.

One distinctive feature of the vegetation communities in Upper Lyell is the complete absence of dominance of *Aster alpigenus*, *Calamagrostis breweri*, or *Vaccinium caespitosum* in all the plots collected. It is possible that they were present in plots, but in such low density that they would not be recorded even as a subdominant. These are very common species in most subalpine meadows, and it was surprising they were not detected in the Upper Lyell plot data. Several other species were dominant in plots at Upper Lyell but uncommon in many of the other meadows surveyed. *Antennaria* sp. (phenology too far advanced to identify to species) was a dominant in 9% of the plots, and was only dominant in two other meadows (Matterhorn and Cold Canyon). *Carex subnigricans* dominated 9% of the plots in Upper Lyell, and was only found as a dominant in two other plots (one at Elizabeth Lake and one at Mathes Lake). *Carex subfusca* was dominant in several plots in Upper Lyell, and was only dominant in two plots in two other meadows (Tilden South and Matterhorn). *Carex capitata* and *Carex canescens* ssp. *canescens*, both special-status sedges in Yosemite, have been documented at this site, but they were not captured by our study plot data.



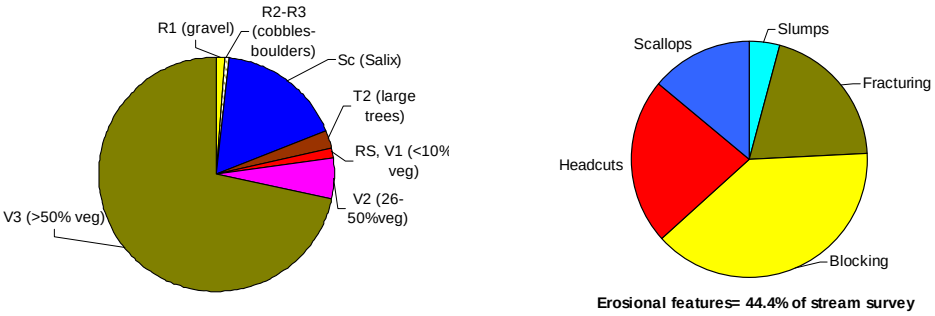
Map C-15. Aerial photo map of Upper Lyell gridpoint plots (plant communities), pack stock use evidence and ponds.

Stream bank survey

The vast majority of stream bank along the Lyell Fork in Upper Lyell was armored with thick herbaceous vegetation (72% of survey length, Figure C-10). Willows comprised 17% of the survey length. Six percent of the survey reach had vegetation below 50% cover, and 2% of the survey reach had vegetation below 10% cover.

The stream survey reach in Upper Lyell had the highest proportion of erosional features (44%) of any stream surveyed in this study, partially due to 21 headcuts mapped along the survey length. 129 erosional features were mapped in total, with blocking more common than any other feature. As mentioned above, the stream survey was performed in early July, before any pack stock evidence from 2008 use was created. Despite this, 15% of the erosional features had manure within 2m, and 17% of the erosional features were within 2m of an informal trail (with hoofprints noted on some portions of the trail).

Figure C-10. Stream bank composition (left) and erosional feature composition (right) for the survey reach of the Lyell Fork in Upper Lyell Canyon. The length of erosional features totaled 44.4% of the survey reach length.



	
Deep headcut and collapsed bank on the Lyell Fork in Upper Lyell meadow	Blocking features typical of the survey reach in Upper Lyell

Photo C-17. Stream survey illustrations in Upper Lyell.

Stock use evidence

All of the 2008 pack stock nights occurred before the pack stock evidence was mapped during the 2008 survey, so all evidence of 2008 use should be captured in our data.

Upper Lyell had the highest proportion of pack stock evidence mapped per unit survey area, with 23% of total meadow area mapped with evidence. In total, 97 polygons of evidence were mapped. Grazed areas were the most common evidence (42 polygons for 12% of the survey area), closely followed by trampling (47 polygons for 8% of the survey area). Both grazing and trampling were common in many communities, including *Carex vesicaria-utriculata*, *Deschampsia cespitosa*, *Carex subspicata*, and even dry communities of *Carex filifolia* and *Ptilagrostis kingii*. Five roll pits in the south end of the meadow were also mapped. Manure was abundant in Upper Lyell, with 478 points of manure concentration mapped. This is more than 4 times the number of manure points mapped at any other site. One-half of these points were low density (2 piles per 2m), ¼ were medium density (3-4 piles per 2m), and ¼ were high density (5 or more piles per 2m). Unlike other meadows, most high density manure points were found in the main meadow of Upper Lyell and not just near stock camps. Manure concentrations were highest in the south half of the meadow, however.

A very high proportion of plots had pack stock evidence present (96%), and 55% of plots had greater than 10% cover of evidence. The only other meadow with higher proportions of evidence is Benson Lake, which was a much smaller site. Manure and grazed vegetation were the most common forms of evidence found in plots (72% of plots for both), followed by hoofpunching (55% of plots) and hoofprints (49% of plots.) High cover of grazed vegetation was detected in plots, with 40% of plots having more than 20% of vegetation grazed, and 15% of plots having more than 50% of vegetation grazed.

Other findings

The same implications for Lower-Upper Lyell apply to Upper Lyell meadow, with added emphasis onemphasis added by the fact that the quantity of physical pack stock evidence seen in Upper Lyell is higher than any other meadow in this survey. The high concentrations of manure (more than five piles per 2m) found away from stock camps and meadow edges suggests that very high levels of use are occurring in many areas of the meadow. The fact that in such a large meadow, 96% of plots contain pack stock evidence and more than half the plots have greater than 10% cover of evidence confirms high levels of use. A high cover of grazing was detected in plots and the 12% of the survey area was mapped as intensively grazed vegetation (with grazing concentrated on palatable sedges, *Calamagrostis* and *Deschampsia* communities). Although this study did not quantify vegetation utilization directly, our evidence strongly suggests utilization monitoring is needed at this site to determine whether or not maximum levels of utilization recommended by others (Ratliff *et al.* 1987, Cole *et al.* 2004) is being exceeded at this level of use. Hoofpunching was found in 55% of plots, suggesting that the much of the meadow was still wet when the first pack stock use of 2008 occurred.

The presence of amphibians or suitable amphibian breeding habitat at Upper Lyell is unknown from this study, since the survey was conducted late in the season. However, the presence of numerous ephemeral ponds and backwaters of the Lyell fork in Upper Lyell warrants surveys for amphibian presence.

Appendix D. Summary of Individual Meadow Findings from the 2008 Stock Use Study

[Note: 6-Letter codes are used to abbreviate plant names. Appendix A contains a crosswalk to full names.]

Vegetation	Streambanks	Stock evidence	Other findings
Benson Lake			
Two small meadows with vegetation indicative of hydric conditions (DESCES & CARVES-UTR). Drift fence is intended to keep stock out of meadow closer to lakeshore. Stock also graze herbaceous understory of surrounding forest.	N/A- no stream channel in meadows	Contains highest percent of stock evidence per unit area among all meadows surveyed, even though most stock use for 2008 occurred after our survey. Grazed vegetation was the most common stock evidence. Scattered hoofpunching was nearly as common as grazing. Stock evidence is present on both sides of drift fence, almost equally.	Stock evidence found on both sides of drift fence, so stock were likely turned out on both sides of fence this year. Amounts of grazing and hoofpunching warrant further investigation into levels and timing of use. No amphibians found, but shallow ponds are present. Survey may have been too late to see tadpoles.
Castle Camp			
Vegetation indicative hydric conditions DESCES, CARSCO, and areas of Salix). Stock also graze in herbaceous understory of surrounding forest.	About 40% of the streambank transect had erosion features. This is the second-highest percent of erosion among meadows studied. Two sites in Lyell Canyon had higher percent erosion. Five headcuts were present. Streambanks armored with low willows and herbaceous vegetation.	Not much stock evidence present, - survey performed before 2008 use occurred. Many residual hoofpunches and hoofprints were noted, however. Stock must cross river to reach camp, and stream crossing is extremely rutted and widening.	Stock use was very high in 2008, but our survey was conducted before stock use occurred in 2008. Meadow was very wet and vegetation was immature just before stock entered this year, so monitoring hoofpunches and vegetation could be important. High use numbers also warrant further investigation into percent vegetation utilization of vegetation. Amphibians not noted here, but habitat appears present and more rigorous surveys would be useful to determine status of population and habitat.
Cold Canyon			
Overall, vegetation indicative of moist meadow, (CALBRE/ VACCAE) with many dry gravelly areas. of CARFIL (also dry areas of PTIKIN and DANINT) . Wettest area in northwest part of meadow near stock camp (DESCES, CARSCO and CARVES-UTR)	Lowest percent erosion of any high-use meadow (3%). Four headcuts present. Streambanks armored with mostly herbaceous veg, willow and dwarf bilberry.	Very little stock use evidence found, since survey took place before 2008 stock use, and no stock use reported for 2007. A few small areas of trampling mapped. Some residual manure found, especially near stock camp. No stock evidence found on east side of creek.	Stock use was light. Wettest areas of meadow are closest to stock camp. Stock may only be using west side of meadow. Continuing to monitor and map stock evidence will answer this, and identify areas of concentrated use where future monitoring could be targeted. Many ponds are present-more detailed amphibian surveys would be useful to assess population and habitat status.

Dorothy Lake			
Vegetation indicative of fairly dry meadow, with VACCAE and JUNPAR, but also some wet areas of DESCES and Salix shrubs. Many areas with conifer encroachment. Some thick continuous areas of willow.	N/A (no stream channel in meadow)	Survey occurred mid-season so not all stock evidence captured, and there was no recorded use in 2007. Still, fairly extensive trampling and hoofpunching were found, especially near pond and lake edges. Intensively grazed areas also common.	Area useable by stock is definitely smaller than '97 vegmap suggests, due to high conifer encroachment and areas of willow. Some stock are being confined to small area on southeast side of lake, leading to concentrated impacts there and on hillside above. Three Yosemite toads found in SW meadow where stock use usually occurs, warranting more detailed amphibian studies.
Hook Lake			
Vegetation indicative of extremely wet meadows. (CARSCO and CARVES-UTR) Large area of dry PTIKIN on west side.	16% of stream had erosional features, which seemed high considering narrow width of channel and slow flow observed in it (even though it was early season) Banks nearly all herbaceous vegetation, but this site had greatest areas of lower vegetation cover on banks (not as well-armored)	No reported use on this site since 2004, and survey occurred before any 2008 use. Despite this, ten trampled areas and two roll pits were mapped, and some areas of manure. Was there undocumented use, or has visible evidence of use persisted more than 3 years?	Meadow has large areas of hydric soils, and Yosemite toads were found. Because dry area of meadow is unpalatable vegetation, stock concentrate grazing in wet areas. Potential fragility of this meadow and amphibian population warrants more intensive study at this site.
Kerrick (Upper) Canyon			
Huge meadow, with a mix of large hydric areas (CARSCO and CARVES-UTR) and extreme dry areas, often with large bare patches. Not many moist areas in between. Numerous ASTALP.wet areas as well.	Erosional features were 6% of survey length. Nine headcuts mapped. Banks had >50% of length armored in willows, 28% bilberry. Most shrub-covered banks of any site (mix of willows and bilberry).	No stock use in 2008 (meadow closed due to presence of toads) and use in last five years had been light. Stock evidence mapped was lowest of any site, no trampled areas. A few scattered hoofpunches, some residual manure, and two roll pits.	In spite of light use in recent years, vegetation appears more stunted and more bare ground than at other sites. Perhaps impacts from historic use still affecting site, but this is just speculation. Toad populations are of concern – meadow closed to stock use in 2008 (and remains closed) but more information on stock-toad interactions is needed.
Matterhorn Canyon			
Vegetation indicative of overall moist conditions, with some dry areas (PTIKIN and gravelly areas of CARFIL) and some wetter (Salix and CARVES-UTR areas in abandoned oxbows, as well as wet areas of DESCES).	25% erosional features. Two headcuts. Site had greatest armorment of willows (51%, with many tall *Salix lemmonnii*) but also greatest percent unarmored banks (3%)	One-third of 2008 use occurred before survey, but lots of stock evidence found (maybe residual, due to high 2007 use)- 32 trampled areas, six roll pits, and high levels of manure. Grazed vegetation was very common- 60% of plots had some grazing evidence. Stock must cross creek to reach one of the camps, leading to some bank impacts.	The many trampled areas found indicate a need for more information on range readiness indicators. Extent of grazed vegetation found after only 1/3 of 2008 use occurred suggests that utilization monitoring could be important when seasonal use is anticipated to be high. No amphibians were found, but survey was probably too late to detect them if present.

Miller Lake			
Vegetation indicative of overall moist conditions, though south meadow is relatively wet, and north meadow drier. CALBRE/ VACCAE is dominant type, with ASTALP in wet areas and CARFIL in dry areas	6% erosional features, but this number may be high because one headcut was particularly long. Three headcuts. Banks armored with bilberry (mainly) and thick herbaceous vegetation	No 2008 use before survey, and previous four years had light use, so very little stock evidence was found. Evidence consisted of three small trampled areas, residual manure, and few scattered hoofpunches.	South meadow is particularly wet, had numerous tadpoles (unsure what species) so may be more sensitive to stock impacts. Early season monitoring is suggested to determine range readiness. (Side note: 2009 survey found numerous Yosemite toad tadpoles)
Smedberg Lake			
Highest proportion of obligate wetland species for any meadow. CALBRE-ASTALP dominates much of the meadow and large areas of CARVES-UTR (and CARAQU) along shallow lake margin. Some drier areas of PTIKIN in center of meadow.	8% erosional features. Two headcuts. Herbaceous vegetation armored most of the streambank, though 35% of transect had low willows.	Less than half of the 90 stock nights for 2008 occurred before survey, and use was moderate (50) in 2007 and very low in 2005-2006. High levels of trampling evidence (33 polygons), and wet sedges along lake margin were heavily grazed. ASTALP communities appeared most susceptible to hoofpunching in the meadow.	Site was likely very wet when stock entered this year, as indicated by extent and severity of hoofpunching and trampling. Investigation of range readiness is warranted. Vegetation utilization (grazing) monitoring is also warranted during high use years, since % cover of grazed vegetation in certain communities was high after less than half of stock nights for 2008 had occurred. Several Yosemite toads found- more detailed amphibian surveys, and studies on effects of packstock on amphibian populations are suggested.
Tilden- north			
2 long narrow meadows. Vegetation indicative of overall moist conditions (CALBRE-ASTALP, PTIKIN, DESCES and CALBRE/ VACCAE.) Shallow ponds with CARVES-UTR common in lower meadow but no wet sedges in upper meadow. Lowest % of obligate wetland species of any meadow except Lower-Upper Lyell.	Erosional features covered 14% of transect. Three headcuts. Banks armored with dense herbaceous (44% of transect) and bilberry shrubs (32%) Willows armored 11% of transect, in upper meadow only.	2008 survey captured all (reported) stock use- 21 nights. No use in 2007, but use in 2004-2006 was heavy (75-263 nights). Use is reported for all of Tilden, but probably more use occurs at Tiden-south. Only lower meadow had stock evidence- 17 small trampled areas, 6 areas of grazed vegetation, and manure.	First 2008 stock entry into the meadow was late according to reported use (8/18/08), but hoofpunching was still found in 35% of plots. Amphibians were not noted, but many ephemeral ponds were observed, with extensive hoofpunching in the drying mud. Amphibian surveys earlier in the season would be useful to determine if any species utilize the site.
Tilden- south			
Moist to wet- CALBRE/ASTALP and *C. spectabilis*, *C. subfusca*. Site made up of 3 small meadows that border the lake at south end. Site is unique in dominance *C. spectabili*s in one of the small meadows. *Lupinus covelli* also common.	n/a, no stream present in meadows.	2008 survey captured all (reported) stock use- 21 nights. No use in 2007, but use in 2004-2006 was heavy (75-263 nights). Use is reported for all of Tilden, but more use likely occurs at Tiden-south. Trampling common, esp. in sandy soils of southwest meadow. 19 trampled areas mapped. Also extensive grazing on *C. spectabilis*, and high levels of manure.	Amount of trampling/ hoofpunching suggests further study of range readiness indicators. Preferential grazing on sedges suggests that percent utilization monitoring could help determine level of biomass removal. No amphibians found.

Uppermost Lyell			
Moist to wet in some areas (DESCES and CARVES-UTR), drier in others (PTIKIN, DANINT). *Carex subspicata* and *C. subnigricans* also common.	Highest % erosional features of any site (44%). 21 headcuts. Herbaceous vegetation armored 72% of transect length. Willows=17%. 8% of transect had sparse vegetation cover Lower Lyell (low-no use meadow) had almost 4x less erosional features than the 2 stream reaches of Upper Lyell Canyon- suggests further investigation	All 2008 use (326 stock nights) occurred before survey. Use stats are for both Upper and Lower-Upper Lyell together, but anecdotal observations suggest that majority of use occurs in Upper Lyell. Had highest stock evidence of any site (per acre), with 96% of plots having some form of visible evidence. Many areas of grazing and trampling mapped (>40 each). 5 roll pits, and high levels of manure.	Consistently high use levels every year at Lyell stock sites makes it a prime candidate for monitoring. These meadows are large, so it may make sense to target monitoring in "hotspots" where high levels of impacts are found. No amphibianss found at either site, but many ephemeral (and some permanent) ponds and backwaters of the Lyell appear to have potential habitat- further survey work needed.
Lower-Upper Lyell			
Driest of the high-use meadows- only 3% obligate wetland species. DANINT and PTIKIN communities dominate. Some wetter areas of DESCES present.	High level of erosional features (41%) relative to other sites surveyed. 8 headcuts. Both high use meadows in Lyell had more headcutting than any other sites. 64% of banks armored with herbaceous vegetation. 22%= willows. Lower Lyell (no use meadow) had almost 4x less erosional features than the 2 stream reaches of Upper Lyell Canyon- deserves more investigation.	All 2008 use (326 stock nights) occurred before survey. Use stats are for both Upper and Lower-Upper Lyell together, but anecdotal observations suggest that majority of use occurs in Upper Lyell. Less stock evidence here than upper meadow, but still extensive (30 trampled areas mapped, high levels of manure especially near camps), hoofpunches found in 1/3 of plots. Well established social trail runs through meadow from north to south. Stock must cross river to reach two of the camps.	Despite relative dryness of this site, hoofpunching is still found across 1/3 of plots, suggesting further investigation of range readiness indicators. Consistently high use levels every year at Lyell stock sites makes it a prime candidate for monitoring. These meadows are large, so it may make sense to target monitoring in "hotspots" where most evidence of stock is found.

Appendix E. Photo Illustrations of Low-no Use Meadows

Dog Lake meadow

Dog Lake East meadow

E of Gaylor Pit

E of Mahan meadow

E Sunrise Lake meadow

Echo Lake meadow

Elizabeth Lake Meadow

Long Meadow

Lower Lyell meadow

Matthes Lake meadow

Snow Flat meadow

W of Tilden meadow

Acronyms

FAC – Facultative wetland species (equally occurs in wetlands and non-wetlands)

FACU – Facultative upland species (usually occurs in non-wetlands)

FACW – Facultative wetland species (occurs in wetlands greater than 67% of time)

GIS – Geographic information system

GPS – Global positioning system

OBL – Obligate wetland species (occurs in wetlands greater than 99% of the time)

UPL – Obligate upland species (almost never occurs in wetlands)