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Pack Stock Grazing Capacity Calculations for Pilot Management Study of Upper Lyell Canyon, Yosemite National Park

Resources Management and Science

Bell mare in Upper Lyell- South meadow, August 2009

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Abstract

Grazing capacities are an important tool for managing meadows that receive pack stock use. Models to calculate grazing capacity are typically an equation comprised of estimates for grazing area, forage productivity, allowable level of vegetation utilization, and the forage consumption rate of pack stock. By using existing data and information available from literature relevant to grazing capacity models in Sierra Nevada mountain meadows, this report presents conservative estimated grazing capacities for the pack stock meadows in Upper Lyell Canyon, erring on the side of resource protection to preserve meadow ecosystem function.

Total estimated capacity for both meadows (Upper Lyell- South and Upper Lyell- North) ranged from 167 to 249 stock nights, depending on meadow condition. An average of these two values (208 stock nights) is suggested as a capacity estimate for years where productivity is likely to be average, such as years with average snowpack. Many uncertainties in the capacity model are discussed, particularly with regard to chosen productivity values. Means for improving capacity models are also discussed, including the need for follow-up monitoring to further inform pack stock management and refine capacity estimates.

Introduction

Recreational pack stock use is common on federal lands, and pack stock are typically released to graze from stock camps when forage-rich areas such as meadows are nearby. Studies have demonstrated that overgrazing can lower vegetation productivity or growth form (Miller and Donart 1981, Stohlgren et al. 1989, Fahnestock and Detling 2000), alter plant community composition (Olson-Rutz et al. 1996), increase bare ground (Cole et al. 2004), alter chemical composition of soils or nutrient cycling (Lindsay 1979, Blank et al. 2006), and may lead to incised or widened meadow stream channels and altered meadow hydrology (Knapp and Matthews 1996). In Yosemite National Park, studies investigating pack stock effects and conditions in subalpine meadows used by pack stock are ongoing (Fischer and Elliot 2007, Ballenger et al. 2010, Ballenger et al. 2011, Kuhn et al 2013, in review). The ultimate goal of these studies is to provide managers with information they need to develop management strategies that allow for wilderness stock use without compromising the integrity of the resources they manage. One important step in this process is to estimate grazing capacity, or the level of vegetation consumption that can be sustained without undesirable effects on meadow function. This definition of grazing capacity emphasizes a more protective approach, in contrast to commercial livestock grazing that typically emphasizes animal production. As a result, the capacity model presented here reserves a large portion of meadow vegetation for natural ecosystem function and the native herbivores sustained by meadow plants.

The purpose of this report is to articulate a method for calculating initial grazing capacities for pack stock use management in Yosemite National Park and apply this method to one of the park's busiest pack stock sites. The grazing capacity model presented here is based on adaptations from models developed in the Sierra Nevada outside Yosemite, and includes only inputs that can be accessed from literature or existing park data. A discussion of the model's accuracy, including potential modifications and refinements, follows. It should be emphasized that this is a first look at applying a

grazing capacity model at Yosemite, and that the many factors influencing inputs to this model result in capacities that are far from precise. Rather, grazing capacities are meant as an informed starting point for site-specific pack stock management. Subsequent monitoring of grazing use indicators and meadow condition is essential, to ensure that meadows do not receive unacceptable impacts and to adjust capacities in either direction, depending on monitoring data.

Pilot study site: Upper Lyell Canyon

Upper Lyell Canyon is located in the Lyell Fork of the Tuolumne River, Yosemite National Park at 2,730 m (9,000 ft.) elevation. It is a popular area for overnight camping among commercial stock groups in Yosemite National Park, with approximately ¼ of the park's commercial stock use occurring here (Yosemite National Park, Wilderness Management Branch, Commercial Use Authorization database, accessed November 9, 2010, Table 1). Pack stock are typically turned out for grazing from the campsites that are located adjacent to approximately 20 total hectares of two subalpine meadows associated with this site. Grazing capacities are typically calculated for meadow areas, since grazing generally occurs in meadows where the grasses and sedges consumed by stock are abundant. Therefore, these methods are particularly suitable for Upper Lyell Canyon, since pack stock graze the two large meadows (separated by approximately 100m of forested area) at the southern end of this canyon.

Table 1. Annual reported stock use from 2004 – 2011 at Upper Lyell Canyon provided in stock nights, where one stock night represents one night of grazing per horse or mule. Note: Use is reported as combined for both meadows.

Year	Annual Use (stock nights)	% of Total Use Parkwide
2004	440	20%
2005	219	15%
2006	487	29%
2007	569	28%
2008	326	13%
2009	294	17%
2010	265	20%
2011	91	6%
Mean	**371**	**22%**

Methods and Rationale

Capacity model

An approach used by others (discussed in Ratliff 1985, Ratliff et al. 1987, Neuman 1994, and Abbott et al. 2003) for estimating forage production in Sierra Nevada mountain meadows was used as the main component of grazing capacity calculations in Upper Lyell Canyon. Capacity calculations involve estimating the size of the grazing area, the amount of forage produced by this area, and the allowable use level (utilization) of this forage. The resulting estimate of forage available for grazing

can then be divided by an estimate for the amount that one pack or saddle animal consumes during a night of grazing to produce an estimate of the capacity (in stock nights[1]) for a given area (Figure 1).

Grazing Area (ha) X **Forage production** (kg/ha) X **Allowable utilization** (%) ÷ **Consumption rate** (kg/ night) = **Capacity** (stock nights)

Figure 1. Equation for grazing capacity model.

Grazing Area

Meadow areas were delineated in ArcMap 9.3.2 using a GIS shapefile of the Yosemite National Park vegetation map overlaid on 2005 NAIP (National Agricultural Imagery Program) imagery. Area occupied by large stream channels (e.g., the Lyell Fork of the Tuolumne River,) was subtracted from the delineated grazing areas to give a more accurate estimate of usable area.

Pack stock do not graze uniformly in meadows however, and are known to prefer certain plant species for grazing, particularly grasses and sedges (Mayer and Duncan 1986, Ratliff 1985, Olson-Rutz et al. 1996, Cole et al. 2004). Therefore, effective management will consider what is known about localized grazing patterns when developing strategies to mitigate grazing impacts. Neuman (1994) and Abbott et al. (2003) recommend that only the area of meadow occupied by preferred forage species, rather than the entire meadow acreage, be used for estimating forage production. Using entire meadow acreage could lead to overestimation of capacity because communities of preferred forage species would be overgrazed.

Data collected in the two pack stock meadows of Upper Lyell in 2007-2009 (Ballenger et al. 2010) provided information to improve estimation of the area most frequently grazed by pack stock. During September of each year, intensively grazed areas[2] were mapped as polygons with GPS units. In 2009, the species of grazed plants were also recorded. This effort revealed two important pieces of information. First, the vast majority of grazing activity occurs in the southern meadow in Upper Lyell Canyon (Figure 2). In 2008, 95% of intensively grazed areas were mapped in Upper Lyell-South, and in 2009, 91% of grazed areas were mapped there. (In 2007, Upper Lyell-North was not surveyed.)

[1] One stock night equals one night of grazing per horse or mule. For example, a stock party with 4 mules and a horse, camping at a meadow for two nights, would equal 10 stock nights.

[2] Intensively grazed areas are at least $5m^2$ in size, with vegetation continuously grazed to less than half its normal height.

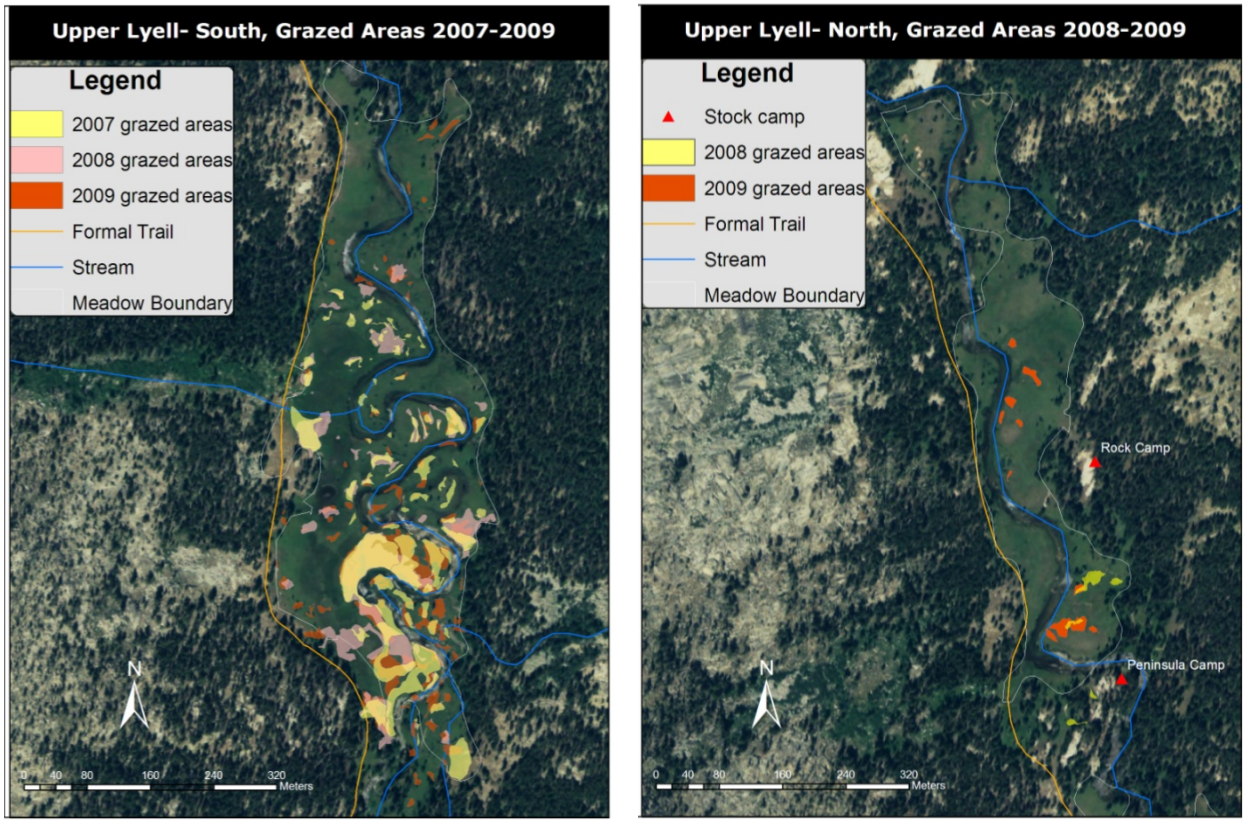

Figure 2. Aerial photo maps of Upper Lyell Canyon meadows, showing areas intensively grazed by pack stock.

The second piece of information revealed by Lyell Canyon data was pack stock grazing preference. Vegetation plot data, collected in 5x5m "gridpoint" plots spaced on a 30m grid across both meadows, produced an assessment of dominant vegetation composition for each meadow and the species grazed (Ballenger et al. 2010, see Appendix A for data collection methods). Analysis of these data and the mapped polygons of grazed vegetation from 2009[3] revealed that grazing was most concentrated in *Carex subnigricans* (nearlyblack sedge) and *Deschampsia cespitosa* (tufted hairgrass) plant associations. Plots with the most intensive grazing (greater than 90% cover of grazed vegetation[4]) were all dominated by either *C. subnigricans* or *D.cespitosa*, indicating strong preference for these two species. *Carex subfusca* (brown sedge) was also commonly grazed, with many plots of this community having greater than 60% cover of grazed vegetation. Some grazing also occurred in *Carex vesicaria-utriculata*[5] (inflated sedge) communities; one third of *C. vesicaria-utriculata* plots had more than 20% cover of grazed vegetation. Basing grazing capacity on the area of meadow occupied by these four preferred plant associations would help ensure that these plant communities would not be overgrazed.

[3] Prior to 2009, vegetation species were not recorded when mapping intensively grazed areas.

[4] It is important to note that the relationship between percent cover of grazed vegetation and percent utilization of vegetation biomass was not determined by the 2008 study.

[5] Because *Carex utriculata* and *Carex vesicaria* are difficult to distinguish in the field but are functionally the same (i.e., grow in temporarily inundated areas), no distinction between them was made during data collection.

Using vegetation composition data from the gridpoint plots (Ballenger et al. 2010), we calculated the proportion of plots dominated by the preferred forage species *Carex subnigricans*, *Deschampsia cespitosa*, *Carex subfusca* and *Carex vesicaria-utriculata.* Multiplying this proportion by meadow area resulted in an estimate of the area of preferred forage for pack stock in the Upper Lyell meadows (Table 2).

Table 2. Estimated area of preferred forage species for Upper Lyell Canyon meadows. Note: "Meadow area" reflects area after subtraction of river channel area.

	Upper Lyell- North					**Upper Lyell-South**				
Forage community	**# plots**	**Total plots**	**Prop. plots**	**Meadow area (ha)**	**Forage area (ha)**	**# plots**	**Total plots**	**Prop. plots**	**Meadow area (ha)**	**Forage area (ha)**
Carex subfusca	1	116	.01	7.3	**0.06**	2	136	0.01	12.2	**0.18**
Carex subnigricans	1		.01		**0.06**	11		0.08		**0.99**
C. utriculata-vesicaria	3		.03		**0.19**	20		0.15		**1.80**
Deschampsia cespitosa	24		.21		**1.51**	32		0.24		**2.88**
TOTAL AREA Preferred Forage:					**1.83**	**TOTAL AREA Preferred Forage:**				**5.84**

Forage production

Major factors known to influence productivity in meadows are vegetation composition, elevation, and meadow (or "range") condition (Ratliff 1985). Other factors such as soil texture/level of compaction from previous/historic activities, plant vigor, rooting depths, microhabitat swales and hydrologic condition also influence productivity (Aimee Smith and Dave Weixelman, personal communications), but there is a lack of information on how to quantitatively factor these into productivity estimates. However, information on how to factor vegetation, elevation, and range condition into estimates of productivity for Sierra Nevada meadows is available (Crane 1950, Ratliff 1985, Ratliff et al. 1987, Weixelman and Zamudio 2001, Abbott et al. 2003), so those factors were applied to productivity calculations in Upper Lyell Canyon.

Ratliff et al. (1987) illustrate how productivity decreases with increasing elevation for Sierra meadows, giving examples from various studies. Meadow productivity also decreases with decreasing meadow condition (Ratliff 1985). Ratliff (1985) gives production estimates for a limited number of plant communities, but these are not adjusted for elevation or meadow condition. Ratliff et al. (1987; tables 3-5) does estimate production for different elevations and range types, but the plant communities are classified broadly as "wet", "moist", or "dry," and production estimates for specific community types are not given. To maximize the number of factors included in productivity estimates, we used estimates from Abbott et al. (2003) Appendices 6.1-6.2. These authors refine the estimates of Ratliff et al. (1987) by providing tables of production estimates for meadows of different moisture types and different range conditions at 100-foot increments in

elevation. To classify the moisture types for the four preferred forage communities in Upper Lyell meadows, we crosswalked plant associations to their species-specific wetland indicator rating (US Army Corps of Engineers 1996) and assigned a moisture category based on that rating (Table 3).

Table 3. Moisture rating and productivity values for preferred forage communities in Upper Lyell Canyon meadows. Productivity values are listed by meadow condition class for 9,000ft elevation (from Abbott et al. 2003).

Forage community	Wetland indicator rating	Moisture type	Productivity (kg/ha)			
			Excellent	Good	Fair	Poor
Carex subfusca	FAC-	moist	3084	2018	1346	785
Carex subnigricans	FAC-	moist	3084	2018	1346	785
Carex utriculata-vesicaria	OBL	wet	2579	1626	1121	617
Deschampsia cespitosa	FACW	moist	3084	2018	1346	785

Assessing current meadow condition for Upper Lyell meadows was the next step needed for choosing an appropriate productivity value for the grazing capacity model. Condition class rankings of "excellent", "good", "fair", and "poor" have been consistently used in rating condition of grazed meadows (Crane 1950, Ratliff 1985, Ratliff et al. 1987, Neuman 1994, Abbott et al. 2003). These ratings involve several factors, but typically include determining the proportion of current vegetation that had reached its potential, or "climax" community (Dyksterhuis 1949). However, new range classification guidelines have been developed by the U.S. Forest Service (Weixelman and Zamudio 2001) which take into account vegetation composition and soil conditions (rooting depth and percent bare ground) and assign an ecological status of "high", "moderate" and "low" to meadow condition. Meadow species are classified by seral status and then the relative proportion of early to late seral species is determined for each meadow. This proportion is then crosswalked a rating that informs ecological status for the meadow (Figure 3).

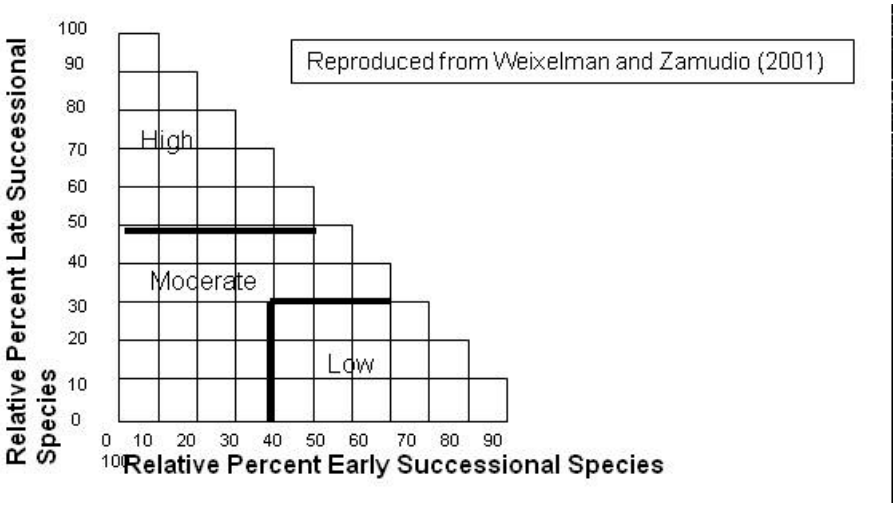

Figure 3. Scorecard to rate ecological status. High= high ecological status; Moderate= moderate ecological status; Low= low ecological status. The horizontal axis represents the relative percent frequency of early successional plant species in a meadow; the vertical axis represents the relative percent frequency of late successional species. Data were collected in 10x10cm plots (Weixelman and Zamudio 2001).

Plant species data from the 5x5m plots collected in Upper Lyell meadows (Ballenger et al. 2010) informed an assessment of meadow condition at these sites. Each plot had up to three dominant species recorded (see Appendix A for methods), and these were crosswalked to seral ratings of "early," "late," or "mid" (US Forest Service 2009, R5 plant list). The relative frequency of occurrence for species in each seral stage was then calculated (Table 4), and this was crosswalked to a condition rating from Figure 3 (above). In order to use productivity values from Abbott et al (2003), the three condition ratings from Figure 2 were crosswalked to the four range condition classes in the following way:

- Excellent= the upper half of "High" from Figure 2 (i.e., above 75% late seral species)
- Good=the lower half of "High" from Figure 2 (i.e., 50-75% late seral species)
- Fair= "Moderate" from Figure 2
- Poor= "Low" from Figure 2

Based this crosswalk, both meadows in Upper Lyell would rate in "Good" condition. However, the proportion of late seral species is within 5% of "Moderate" from Figure 2, and uncertainty generated by the number of assumptions required to crosswalk Upper Lyell data with meadow condition ratings recommends a conservative approach. Therefore, capacity calculations presented here include productivity values from "Fair" condition, as well as "Good" condition, to represent the uncertainty of these values.

Table 4. Relative frequency of seral stage categories for species recorded at gridpoint plots. N= number of occurrences across all plots (of a total 116 plots in Upper Lyell-North and 134 plots in Upper Lyell-South). "Unknown" represents either plants that were unable to be identified, or plants for which a seral stage rating was not available.

	Upper Lyell- North		Upper Lyell- South	
Seral rating	**N**	**%frequency**	**N**	**%frequency**
Early	49	22.9%	44	18.8%
Late	115	53.7%	128	54.7%
Mid	45	21.0%	51	21.8%
Unknown	5	2.3%	11	4.7%

Utilization and consumption

A decision must be made as to the amount of forage allowable for utilization, accounting for sufficient residual biomass for plants to maintain their fitness and for organic matter to accumulate in soils for proper meadow function. Ratliff (1985) recommended that vegetation utilization not exceed 35% of annual production in order to maintain meadow productivity. However, in a study at Yosemite, Cole et al. (2004) found that if utilization exceeded 25% for some common meadow communities (*Deschampsia cespitosa* and *Calamagrostis breweri*), meadow productivity dropped at least 10% and bare ground increased. Ratliff et al. (1987) proposed that allowable utilization should be related to meadow condition, so that managers would allow less grazing on meadows in lower condition to provide for meadow recovery. This idea was adopted in developing preliminary

capacity estimates at Sequoia and Kings Canyon National Parks, by adding a 10% "cushion of residual biomass over and above those suggested by the model to allow for more natural rates of accumulation of thatch and organic matter in meadow soils" (Neuman 1994, pp 37-38). Thus, meadows ranging in condition and moisture regime at SEKI had estimated utilization thresholds of 15-35%. For Upper Lyell Canyon, a conservative utilization value of 25% was used in capacity calculations, based on recommendations by Cole et al. (2004) and informed by meadow condition.

The widely-accepted utilization rate by pack stock of 14.8 kg (32.5 lbs) per animal per night (Ratliff et al. 1987) was used in pack stock capacity calculations for Upper Lyell Canyon. This is adapted from equivalents of "animal use nights" (Society for Range Management 1998) and is defined as the vegetation biomass that one horse or mule consumes per night of grazing.

Results

Based on inputs from the grazing capacity model, estimated capacity for Upper Lyell- South meadow ranges from 126-188 stock nights, depending on meadow condition. Upper Lyell- North capacity is 41-61 stock nights, for a combined total of 167-249 stock nights for both meadows (Table 5). Uncertainty in assigning meadow condition suggests an average capacity between "good" and "fair" meadow ratings, or 208 stock nights, could be used as a first approximation for pack stock capacity at the site.

Table 5. Inputs for grazing capacity model and calculated grazing capacities for Upper Lyell Canyon meadows. "Prod." = productivity of that meadow type.

	Forage communities	Area (ha)	Prod. (kg/ha), "Good" condition	Prod. (kg/ha), "Fair" condition	Utilization rate	Consump. rate (kg/night)	Stock nights, "Good"	Stock Nights, "Fair"
Upper Lyell- North	*Carex subfusca*	0.063	2018	1336	0.25	14.8	2.1	1.4
	Carex subnigricans	0.063	2018	1336			2.1	1.4
	Carex utriculata-vesicaria	0.189	1626	1121			5.2	3.6
	Deschampsia cespitosa	1.510	2018	1336			51.6	34.4
						TOTALS:	**61**	**41**
Upper Lyell- South	*Carex subfusca*	0.179	2018	1336	0.25	14.8	6.1	4.1
	Carex subnigricans	0.987	2018	1336			33.8	22.5
	Carex utriculata-vesicaria	1.794	1626	1121			49.5	34.2
	Deschampsia cespitosa	2.871	2018	1336			98.4	65.6
						TOTALS:	**188**	**126**
				TOTALS, both meadows			**249**	**167**
				Mean (both meadows):			**208**	

Discussion

One component of successful management of grazed meadows is determining how much use is appropriate for each area so that undesirable resource impacts are avoided. This involves developing grazing capacities as a starting point for regulating use and as part of a larger management framework informed by resource monitoring and meadow-specific considerations (such as presence of archeological sites, species of special concern, potential for use-type conflicts) that vary by site. The grazing capacity model presented here is based on the best available information in the literature and data from Upper Lyell Canyon. However, there is potential to refine the model, and this capacity estimate should be viewed as preliminary. As such, monitoring to assess the ecological condition of meadows is an imperative follow-up to prevent undesirable effects from grazing. Frequent monitoring of field conditions is the best way to determine if too much use is occurring, or if more use may be allowed. It is important to include similar ungrazed areas in monitoring (i.e, reference areas), so that environmental effects such as snowpack, drought, and seasonal temperature variation are not mistaken for effects from grazing. Development of methods to monitor meadow conditions for grazing at Yosemite is underway, so that managers will have timely feedback with data to adapt their strategies in effectively balancing resource protection with pack stock use.

The grazing capacity model presented here greatly simplifies the variables that drive the capacity equation, and changing any of the inputs would obviously result in different estimated capacities. For instance, forage consumption rate is assumed constant, when in reality there may be wide variation among animals, or even among the same animals at different times. Also, these capacities do not account for variable productivity due to interannual variation in snowpack, precipitation, or temperature. Vegetation biomass can vary widely between years, based on climatic factors such as the previous year's precipitation (Walker et al. 1994). A period of drought would lower vegetation productivity, such that forage utilization might exceed chosen thresholds as stock use approaches capacity. Monitoring forage utilization during the season of use (such as methods described in Coullodon (1999)) would be important in informing management to adjust capacity in these cases, to avoid exceeding utilization thresholds. Likewise, utilization could be monitored during productive (wet) years, to potentially allow more stock use than the estimated capacity. In addition, the utilization threshold chosen for this model (25%) could be modified for future capacity calculations, depending on resource conditions and management priorities.

Grazing efficiency, a variable often applied when calculating stocking rates for livestock systems, would produce much lower capacity estimates if applied to the model for Lyell Canyon. Grazing efficiency, expressed as a percent, is calculated by dividing forage consumed by the total available standing crop (Vallentine 2001). This concept reflects the idea that some vegetation will be lost from non-consumptive causes, such as trampling or fouling with manure, and that utilization may not be uniform across the landscape. On annual rangelands, grazing efficiency is estimated at 50% for flat areas and as low as 10% for steep slopes (Becchetti et al. 2011). Therefore, including a grazing efficiency variable in the model for Lyell Canyon would effectively reduce the capacity

estimates by 50%. There are several reasons why a grazing efficiency variable for capacity estimates may not be applicable for pack stock capacities in the Sierra Nevada. Pack stock grazing at Yosemite differs in many ways from the livestock systems that apply grazing efficiency principles, perhaps most notably in the lower density of animals and sporadic nature of grazing episodes. The lower animal density and shorter duration of use by pack stock at Yosemite would result in less trampling and manure, compared with livestock production settings. Furthermore, our calculations with a utilization rate of 25% and an estimate for grazing area based only on area occupied by preferred forage species (rather than total meadow area) provides an added protection against excessive vegetation damage. With these conservative calculations, grazing efficiency may be less relevant. However, we may further consider grazing efficiency in pack stock capacities as feedback from utilization monitoring and studies on pack stock behavior become available.

While based on the best information available, adapting condition ratings from Wiexelman and Zamudio (2001) to the Lyell Canyon data increased uncertainty in our assignment of meadow condition rating. This issue mainly stemmed from differences in data collection methods. Weixelman and Zamudio (2001) assessed all species present in 10x10cm plots whereas Ballenger et al. (2010) assessed only dominant species present in 5x5m plots, so the frequency of rarer species was overlooked in Upper Lyell Canyon. Ballenger et al. (2010) also collected plots across the entire meadow area, whereas Weixelman and Zamudio (2001) assessed a small portion of meadow. In light of uncertainties created by inherent differences in these datasets, it seemed prudent to err on the side of conservative estimates for meadow condition in calculating capacities. This justified the inclusion of productivity values for “fair” condition meadows, as well as the “good” condition values suggested in this analysis of Lyell Canyon data.

An alternative approach for estimating productivity is to collect meadow vegetation clippings (biomass) to directly measure forage production at each site. This may yield more accurate results, but would be more labor-intensive and could be infeasible for remote backcountry meadows. Nonetheless, a study measuring productivity in Yosemite meadows would be necessary to check our assumptions of productivity for the model presented here (i.e., those taken from Abbott et al. 2003). Good agreement between the two values would validate further application of Abbott et al. (2003), to calculate grazing capacity for other meadows.

Despite uncertainties in the model, the grazing capacities presented here provide a good starting point for managing use in Upper Lyell Canyon. The range in estimated capacity provides potential flexibility in management application. For example, within-season monitoring of resource condition could be triggered when use nears the “Fair” capacity estimate (167 stock nights), whereby decision on further current-year use could depend on conditions. In a particularly productive year (for instance, above-average snow pack), the “Good” capacity estimate (249 stock nights) may be more appropriate. For simplicity, the range of capacities could be averaged to result in a single number (208 stock nights) to use as a threshold for years with average snowpack. It should be noted that all these capacity estimates are lower than the average use from 2004 – 2011 (371 stock nights).

If the park implements a grazing capacity limit, the site should ideally be monitored for meadow condition, vegetation utilization and actual stock nights to better understand the relationship between actual utilization rates and stock nights, and between meadow condition and use. With this understanding, we could effectively identify whether adjustments to the capacity are needed. In large meadows such as these, having information on where use tends to concentrate (as in Fig. 2) helps identify areas for targeted monitoring. Measuring actual vegetation utilization of key species in these areas (with methods such as those in Coullodon (1999)) will help connect the dots between use levels (i.e., number of stock nights) and grazing utilization. Effective correlation between use level and utilization is essential for validating and/or refining grazing capacity models.

In conclusion, a grazing capacity model is presented here that may be applied to Yosemite's meadows to generate site-specific preliminary estimates for grazing capacity. However, there is potential to refine any of the model variables—forage production, grazing area, and meadow condition—as well as opportunity to examine management decisions on allowable utilization levels. Therefore, the capacity estimates presented here should be viewed as a first approximation, to be updated with further feedback from monitoring and management.

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Appendix A. Methods for Gridpoint Plot Data Collection

Excerpt from Ballenger *et al*. (2010)

Boundaries for each meadow survey area were defined with GIS by using meadow polygons from the 1997 Yosemite vegetation map. Using ArcMap 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 in most meadows. Each pre-determined plot location was visited using Trimble Juno ST GPS units and all data were recorded in the unit's data dictionary. At each point, a temporary 5x5m square plot was set up and cover class data were collected to assess vegetation cover of dominant species, substrate characteristics, and pack stock use evidence. Small mammal burrow holes and burrow exudium within the plot boundaries were quantified, and litter depth and vegetation canopy height were measured. All data were collected from July 8 – October 1, 2008.

Cover class data were collected using the following breaks:

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, the field crew was carefully trained in cover estimations and calibrated at the start of each work week and/or meadow. In addition, the same crew members collected data throughout the summer, to minimize effects from observer bias.

The following data were collected at each 5x5m plot:

- Total vegetation cover: Bird's eye view of all vascular vegetation cover in the plot (could not exceed 100%, does not account for layered vegetation).
- Dominant species cover: The species with the highest percent cover was listed as Dominant Species 1 and its cover was estimated. Two other dominant species (and their cover) were recorded if they had at least half the relative cover of the most dominant species. These less dominant species are termed "subdominant."

- 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 1997). 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: 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).
- Litter cover: Litter was defined as plant material that was dead before this 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: Cover of water (regardless of depth) at the time of plot collection.
- Burrow cover: Any burrow holes and exudium (often obvious in the form of cylindrical dirt piles) were included in this estimate.
- # Burrow holes: Any small mammal burrow entrances (recent or old), were counted in the plot.
- Manure cover: Any horse manure (fresh or old) present in the plot
- Hoofpunch cover: Any distinguishable hoof marks >2cm deep. Hoofpunches break through the root mat in vegetated areas.
- Hoofprint cover: Any distinguishable hoof prints <2cm deep that do not break through the root mat.
- Grazed vegetation cover: Any 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. This 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 a plot needed to be rejected for any reason (described below), that information was recorded here.

Cover was estimated for vegetation that was alive during this growing season, and since data were collected through the end of the growing season, cover for vegetation that was shriveled and dried was visualized in its fully alive condition.