Multiple-Paddock Grazing Distributes Utilization Across Heterogeneous Mountain Landscapes

A case study of strategic grazing management

By Matt Barnes and Jim Howell

On the Ground

- Grazing capacity increased substantially and rangeland vegetation measurements improved after the Howell Ranch applied strategically planned and managed grazing. Increased capacity was realized from more spatially uniform grazing distribution and harvest efficiency rather than improving conditions over time.
- Dividing a ranch into paddocks and grazing them sequentially, especially at high stocking density, can even out distribution of grazing and thus increase grazing capacity.
- More even utilization across more, smaller paddocks contributes to explaining and resolving the apparent discrepancy between successful ranch-scale applications of multiple-paddock grazing and small-scale studies that found no benefit to rotational grazing.

Keywords: complex systems, planned grazing, strategic grazing management, adaptive management, grazing distribution, grazing capacity.

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We use strategically planned and managed grazing to distribute utilization across broad, complex, and diverse landscapes. Grazing lands are complex creative systems that emerge from ever-changing relationships between organisms and their environment, where many processes, including grazing and recovery and their distribution in space and time, affect the emerging system (*see Provenza et al., this issue*). Planned or strategic grazing can be a creative systems approach to adaptive management. In Holistic Management, planned grazing is a "plan-monitor-control-replan" approach.[1] Planned grazing is a context-specific strategy to achieve a goal, not a grazing "system" in the sense of rigid schedules such as deferred rotation or rest rotation grazing.

On the Howell Ranch, in the mountains of southwestern Colorado, we use planned grazing with a combination of shorter grazing periods, higher stocking density, and more, smaller pastures than the extensive management practiced previously on the ranch. We adopted planned grazing to improve the spatial distribution of grazing such that cattle use nearly all of the area available without overusing preferred areas. Having multiple paddocks gives us more options and more flexibility: each paddock is an opportunity to adapt or create. Here we present a case study of the ranch as managed by Howell since 1997 and by Barnes from 2010 to 2012. Howell describes the ranch, and the first decade of his management of it, in his book *For the Love of Land*.[2]

The Howell Ranch

The Howell Ranch is on the north side of the San Juan Mountains in Gunnison and Montrose Counties, Colorado, in the Southern Rocky Mountains Major Land Resource Area (MLRA 48A). The climate is cold and semiarid; most of the ranch is under snow in winter through midspring. At the nearby weather station in Cimarron, annual average low temperature is 23.3°F (–4.8°C) and annual average high temperature is 59.8°F (15.4°C). Average annual precipitation is about 13.3 inches (33.8 cm), with the peak in August-September as thunderstorms and the low in June.[3] The ranch is comprised of three geographically distinct management units, two owned by the Howell family and one leased.

The lower management unit, Cerro (Fig. 1), is 1,220 acres (490 ha) of montane and steep rangeland, at an elevation of 7,400 to 8,400 feet (2,250 to 2,560 m), near Cimarron. The vegetation is patches of Gambel oak (*Quercus gambelii*) and

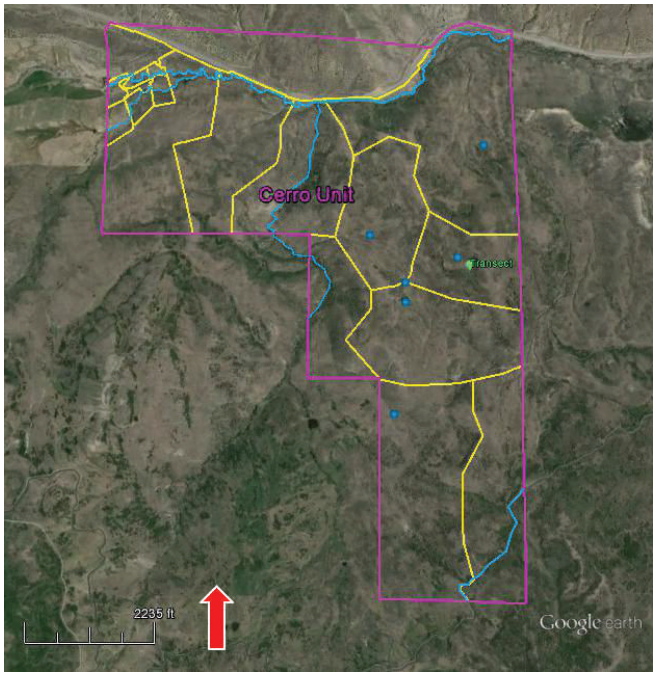

Figure 1. Cerro grazing management unit (magenta line) of the Howell Ranch in the San Juan Mountains of Colorado. The boundary and highway fences are permanent barbed wire. Paddocks are divided by permanent high-tensile electric fence (yellow lines) and are often further subdivided with temporary electric fence.

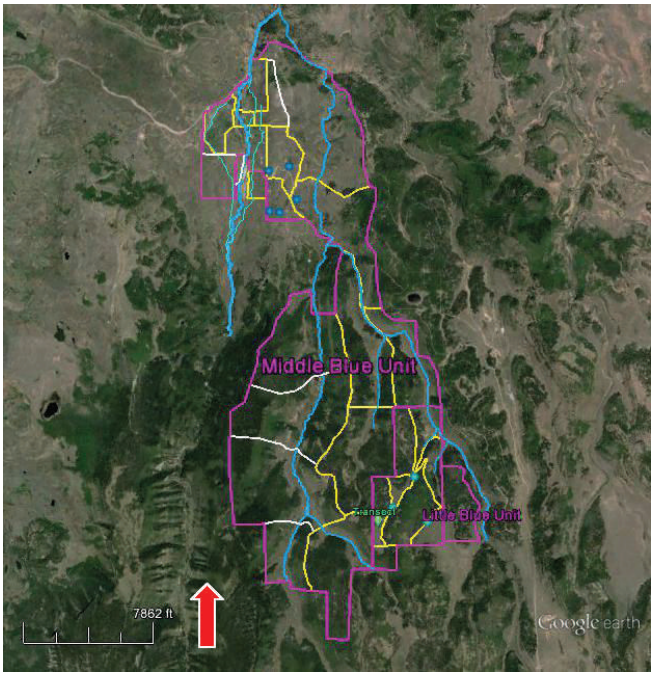

Figure 2. Middle Blue and Little Blue grazing management units of the Howell Ranch in the San Juan Mountains of Colorado. The boundary fences are mostly permanent barbed wire. Paddocks are divided by permanent barbed or electric fence (yellow lines), or temporary electric fence (white lines), and are often further subdivided with additional temporary electric fence. The irrigated meadow is in the northwest of the Middle Blue unit, between the irrigation ditches (thin cyan lines).

mountain big sagebrush (*Artemisia tridentata vaseyana*), with an understory of mostly native cool-season bunchgrasses, primarily wheatgrasses (*Pascopyrum* and *Elymus* spp.) and needlegrasses (*Achnatherum* spp.), as well as the non-native, rhizomatous Kentucky bluegrass (*Poa pratensis*).

The Blue, which is the Middle Blue and Little Blue management units collectively (Fig. 2), is about 10 miles (16 km) east of, and somewhat higher, cooler, and wetter than Cimarron. It is subalpine country that includes canyons of the Little, Middle, and Big Blue Creeks. The vegetation includes Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and quaking aspen (*Populus tremuloides*) forests, as well as open hillsides and parks of mostly silver sagebrush (*Artemisia cana*) with an understory dominated by Thurber fescue (*Festuca thurberi*) and Kentucky bluegrass. On the Middle Blue, the lower elevations have mountain big sagebrush and Gambel oak, and the lowest area is an irrigated meadow.

The Middle Blue (the leased unit) is about 7,000 acres (2,800 ha), at 8,300 to 9,676 feet (2,530 to 2,950 m), and now makes up most of the total acres of the ranch. Most of the unit is steep slopes, up to 50%, with the typical slope being about 20%. These slopes are dominated by the tall, unpalatable bunchgrass Thurber fescue. The Little Blue is 850 acres (including adjacent leased parcels) at 9,020 to 9,660 feet (2,750 to 2,945 m), the highest elevation on the ranch.

Wildlife is found throughout the ranch. Native grazing animals include Rocky Mountain elk, which are resident on the Blue and present on Cerro during fall, winter, and spring, and mule deer, which are resident ranch-wide from spring through fall.

Previous Grazing Management

The traditional management in many of these higher subalpine parks, including the Howell Ranch, is sheep grazing. Relatively large bands of sheep are herded through, using a park of several hundred acres (such as might be in one of our paddocks) for about a week or less during a four-month summer grazing season. When the ranch became cattle country in the mid-20th century, the owners did not continue herding, and they did not replace that herding with cross-fencing.

Prior to Howell taking over the management of Cerro and the Little Blue in 1997, and leasing the Middle Blue in 2004–2005, the lessees stocked the units season-long, resulting in uneven grazing across ecological sites and elevation gradients, especially on Cerro. On Cerro and the Little Blue, the previous lessee had stocked season-long, at about 5.6 AUD/acre, a stocking rate that resulted in heavy use on the lower and flatter sites at Cerro, and the relatively flat parks on the Little Blue.

On the Middle Blue, the lessee typically stocked the irrigated meadow at about 25 AUD/acre, for about 2.5 months,

and used the rangeland for the remainder of the season. The stocking rate on the Middle Blue rangeland is unknown (perhaps moderate to conservative, as the demand was less than half of the total forage supply). The overall conservative stocking rate was essentially irrelevant because the de facto stocking rate was heavy along the riparian areas and very low on most of the uplands.

Under season-long grazing, the lower and flatter areas degraded. On Cerro they became dominated by mountain big sagebrush and, in the most heavily used area, rabbitbrush (*Chrysothamnus viscidiflorus*). The subalpine parks on the Little Blue degraded from Thurber fescue to silver sagebrush dominance. Over the years, Howell observed degradation of the riparian areas, including loss of willows (*Salix* spp.) and stream bank erosion, while the ungrazed bunchgrasses on the steeper slopes remained unpalatable.

Strategic Grazing Management

General Grazing Strategy

Since Howell took over management in 1997 on Cerro and the Little Blue, and 2004–2005 on the Middle Blue, the Howell Ranch has used the Holistic Management framework for decision making. He envisioned the ranch's holistic context in terms of quality of life, forms of production, and future resource base, and then evaluated decisions relative to this context.[1] The ranch is managed as a summer custom grazing operation to fit the climate and landscape, and to maximize adaptability. The centerpiece of our grazing management is the Holistic Planned Grazing process,[4] made context-specific with grazing management units divided into multiple paddocks.[2] In our experience, more paddocks provide more opportunities to practice adaptive management. We plan the number of paddocks, and the grazing and recovery within them, to manage distribution in space (*see Norton et al., this issue*) and time, based on plant growth and recovery (*see Steffens et al., this issue*) and across plants. Our planned grazing contains elements of both rotational grazing and rotational rest; a single herd moves through a series of pastures in each management unit. It incorporates rotational rest in that some of the pastures are rested each year. These methods are not applied in the rigid sense of named grazing "systems." We plan the grazing each year, including which paddocks to use and in what order (based on everything we know at the time of planning, including history and ranch needs), with the total number of days in the grazing season divided among the paddocks in proportion to their relative grazing capacities.

Stocking rates are planned to result in moderate grazing intensity, based on recent stocking rates and intensity of use (the result is "fed back into the equation"), but are flexible based on actual conditions, with drought-year reductions in either animal numbers, season length, or both. A benefit of multiple-paddock grazing is that if we find paddocks consistently last more or less days than planned, we know that we are under- or overstocked relatively early in the season and can adapt by changing the season length.

The grazing season approximately corresponds to the growing season, beginning in late May or early June, and usually ending in late September or early October, before rifle hunting season begins. In this environment, without irrigation, plant recovery from grazing requires most if not all of a growing season (as is common for temperate, semiarid rangelands; *see Steffens et al., this issue*), so we rarely stock a rangeland paddock more than once in a season. The irrigated pastures recover from grazing in 40 to 60 days, so we generally stock them twice per season.

The paddock layouts are based on existing fences, topography, and the total forage mass in each paddock. On the Middle Blue, for example, beginning in 2005, Howell fenced across the canyons, splitting each several times, so that each rangeland paddock contained both riparian area and uplands. A single herd is moved such that each paddock is grazed for several days to three weeks at a time. Within a paddock, the cattle graze from creek to ridge, without fencing the riparian areas (Figs. 3 and 4). The riparian areas do appear heavily (>60%) used at the end of a grazing period, but if the grazing period is early enough in the growing season, they will be recovered by the end of the season. We have observed improved overall condition of the riparian areas, including increases in willow cover in many areas, now that they have adequate recovery periods.

Stocking density is not directly planned, but is a function of the overall stocking rate and the number and size of paddocks. It is different in every paddock and every grazing period.

The grazing period is generally over when overall utilization on uplands is moderate, including utilization of the dominant and usually unpalatable bunchgrass Thurber fescue. In some paddocks, almost every bunch has had at least a bite taken out of it. The only common species that is heavily utilized is the very palatable and grazing-tolerant Kentucky bluegrass. Paddocks are not grazed again within the year. On the Blue, which we manage for elk habitat as well as for livestock grazing, most paddocks are grazed every other year, which allows the plants to produce aboveground biomass, which is later knocked down to become litter. At the end of each grazing period, we record the stocking rate for that grazing period and the overall intensity (low, moderate, or high), information that we use to adjust future stocking rates to more closely match the grazing capacity.

There is regrowth in a few weeks, but it is no longer accessible to livestock. Elk do return to graze the regrowth. When a paddock has a relatively early grazing period, the elk seem to use it preferentially later that year. When a paddock is grazed relatively late, the elk seem to use it preferentially the next year.

Tools and Techniques

The primary tool that we use to apply strategic grazing is cross-fencing. Where old barbed wire fences exist, we use them. We also use both "permanent" and temporary elec-

Figure 3. On the Howell Ranch, cattle graze from creek to ridge, without fencing off any riparian areas—but only for short grazing periods.

tric fence. In our country where snowdrifts and elk destroy fences, polywire can be put up and taken down in less time than permanent barbed or high tensile wire fence can be fixed. So "permanent" is a relative term. Once the animals are trained to electric fence, a single strand of polywire is enough of a psychological barrier that most of the cattle will respect it most of the time. If the training is successful, after a few weeks our cattle are more likely to break through a barbed wire fence than an electric one.

We also use occasional strategic supplement placement and herding in the larger pastures. Whenever moving cattle, but especially when herding, we use low-stress livestock handling[5] to the best of our ability.

Management Units and Grazing Methods

The three grazing management units (or cells) are stocked with a total of two or three herds of cow-calf pairs and sometimes yearlings. They all have more paddocks, shorter grazing and longer recovery periods, and higher stocking rates than under previous management (Table 1).

Cerro is split into 10 permanent paddocks, of 75 to 210 acres (30 to 85 ha) each, plus seven very small ones in the 30-acre (12-ha) headquarters area. The grazing plan is based on the larger paddocks, with the smaller ones used as needed at

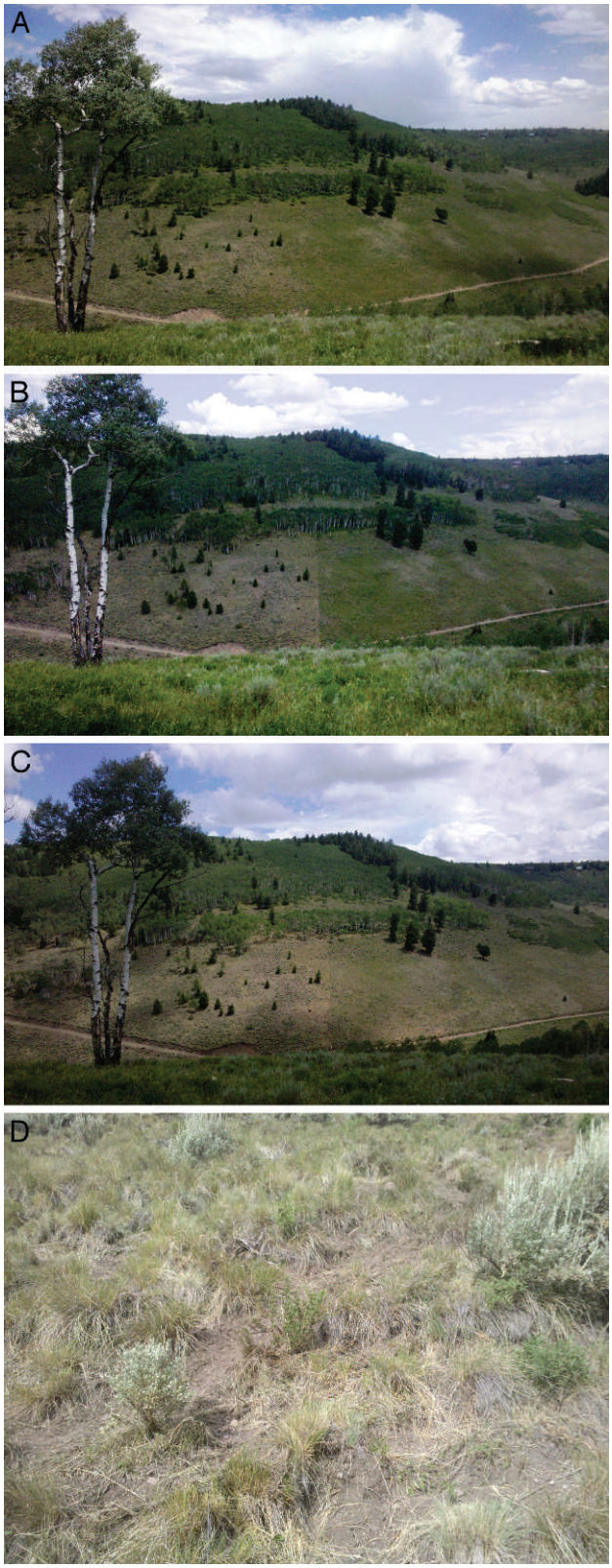

Figure 4. Grazing use at a fence line between two sequentially grazed paddocks on a steep (43%) slope: (**A**) before either of them was grazed, (**B**) after the first paddock (left) was grazed, and (**C**) after both paddocks were grazed. **D**, Overall use was moderate, including use of the dominant and usually unpalatable bunchgrass Thurber fescue.

Table 1. Grazing management parameters on the Howell Ranch, under previous extensive management and current strategic management, averaged across years. Under previous management, distribution was most uneven on the Middle Blue rangeland and on Cerro; currently distribution is even in all paddocks (by ocular assessment). Current data are based on permanent paddocks; in practice these are often subdivided into temporary paddocks. Thus these paddock numbers, recovery time, and stocking density are minima; size and grazing period are maxima

Land type, ranch unit	Average across years and paddocks*												
	Permanent paddocks		Paddocks used/year		Paddock size		Grazing period		Grazing-season recovery time	Stocking rate		Stocking density	
	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Current	Previous	Current†	Previous	Current
	(count)				(acres)		(days)		(days)	(AUD/acre)		(AU/acre)	
Deeded rangeland										5.6	8.8		
Cerro	1	10	1	9.7	1200	119	120	12	108	5.6	10.8	0.05	0.9
Little Blue	1	9	1	6.5	670	74	120	17	103	5.6	5.7	0.05	0.5
Middle Blue lease‡													
Rangeland	1	13	1	7.2	4465	357	45	9	230	4.4§	10.7	0.03	1.3
Irrigated pasture	4	5	4	5††	112	89	75	6	45	25.3	45.0	1.3	3.8

* Current years: deeded rangeland, 1997–2011; leased rangeland, 2005–2011; leased pasture, 2004–2011. Previous years are immediately prior and had different operators. 2012 data excluded due to exceptional drought.

† Current stocking rates are adjusted based on grazing intensity in each grazing period (if use was light or heavy), to reflect grazing capacity for moderate utilization.

‡ The Middle Blue rangeland and pasture are currently one grazing management unit (i.e., one herd uses all paddocks).

§ Previous-year data for the Middle Blue are estimates. The actual stocking rate is unknown. This baseline stocking rate is from National Agricultural Statistics Service data for southwest Colorado.

†† There are usually two grazing cycles per year on the five irrigated paddocks, i.e., 10 grazing periods.

the beginning or end of the season, or for horses. We often plan to rest one of the paddocks each year, often the one that was used last in the previous year. With a single herd of 70 to 90 AU of cow-calf pairs for a four-month grazing season, we have grazing periods of six to 22 days (median 14 days). In 2012 we split most of those 10 larger paddocks in half yet again, so we had 20 grazing periods with a median length of seven days.

We generally stock the Middle Blue with a single herd of about 300 cow-calf pairs plus bulls for about four months, with grazing beginning and ending on the irrigated meadow (late May or early June to late June, and late August to late September), and on the mountain rangeland in between (late June to late August).

The Middle Blue is primarily rangeland, fenced into 13 permanent or semipermanent paddocks (11 that are currently available for grazing), some of which are further split with temporary fence, so the actual number of paddocks varies between years. Of the semipermanent paddocks, we use about half each year, so that there is plenty available for elk in the fall, and so that there will be some old material in a paddock to be trampled in the next grazing period. Those paddocks are 50 to 700 acres, each grazed for two to 27 days, with the 27 being only in the largest paddock, and the median between 6 and 10 days (depending on the actual number of paddocks used in the grazing season).

The irrigated meadow is about 447 acres (as fenced, including dryland corners), fenced into five permanent pastures of 25 to 130 acres. Given the length of the season and using each of these paddocks twice, grazing periods are one to 15 days with a median of six days. In practice we subdivide many of these with temporary electric fence, and most of the grazing periods are shorter.

The Little Blue, just above the Middle Blue, has been stocked in a variety of ways in recent years. When managed as a separate grazing management unit, it is usually stocked with 40 to 60 AU, mostly yearlings. Because it is much smaller and not as steep, we do not need as many paddocks. It is fenced into only nine paddocks (including two adjacent leased parcels), of which we often only use six or seven in a season. With a four-month season, this means grazing periods of 5 to 21 days, and a median of about 13 days. We also stock this unit less heavily than the others to promote elk use in the fall.

Adapting to Drought

In 2012 we knew we were going into a drought, and so we adapted by combining the Little Blue into the Middle Blue as a single grazing management unit, and reducing numbers to 56% of the "normal" Middle Blue herd. We only used three of the nine Little Blue paddocks, for three to six days each, and rested the remaining six. The combined Blue grazing management unit in 2012 involved moving a single herd through 28 grazing periods, from the irrigated meadow up to the mountain rangeland and back down to the irrigated meadow, over a season of just under four months, for an average of about four days per pasture. In retrospect it was a good plan, as 2012 turned out to be an exceptional drought year. (These data are excluded from the averages in Table 1 as not representative of current management.)

Rangeland Monitoring

To assess how strategic grazing was affecting the land, Howell started monitoring transects in representative paddocks on the Little Blue in 1997 and Cerro in 2001. On both transects, at 100 points, we recorded the cover class, distance to the nearest perennial plant, and the life form of that plant. The original sampling method, used on the Little Blue, was for the person to randomly throw a dart over his shoulder 100 times while walking a predetermined pattern within a permanently marked rectangle.[6] We kept that sampling method on the original transect on the Blue, but on Cerro, a more recently established transect, we use a line-point transect with a point every two feet. Howell has been the observer on both transects in all years.

Overall, we documented a shift from bare ground and litter to live basal plant cover, as well as increasing life-form diversity (Fig. 5). The improvement was substantial on the subalpine site (Little Blue), but we documented only slight improvement on the montane site (Cerro). The difference between sites may be real, or an artifact of the first measurement on Cerro not reflecting baseline conditions. This transect was not established until 2001, when the drought began, and four years after the transect on the Little Blue was established. On the Little Blue, most of the change had already happened by 2001, so it is possible that similar change occurred on Cerro between 1997 and 2001, and we just never captured it. Nevertheless, Cerro is a drier site and has had higher stocking rates. Also on Cerro, almost every pasture has been grazed every year, so the average recovery period is about one year, as opposed to one to two years in that paddock on the Little Blue.

On the Little Blue, in a relatively level park (a shallow subalpine loam site), we saw a clear decrease in bare ground and increase in live plant basal cover. Similarly, the average distance to the nearest perennial plant decreased markedly on the Little Blue over 14 years.

The life-form composition is changing, with grass remaining dominant (by cover) but forbs increasing. Overall plant cover is increasing; the columns (Fig. 5C) show relative proportions. The life forms are becoming more evenly represented, thus suggesting increasing diversity, primarily due to forbs. In this case, on the Little Blue, these are mostly palatable forbs, especially aspen pea (*Lathyrus laetivirens*), which have visibly become more abundant. Despite this improvement and increasing cover, changing the grazing management has not been enough to return this subalpine park from brush to bunchgrass dominance. In a nearby park crossed by a boundary fence, across the fence from the ranch, an area still grazed periodically by sheep and not cattle is still

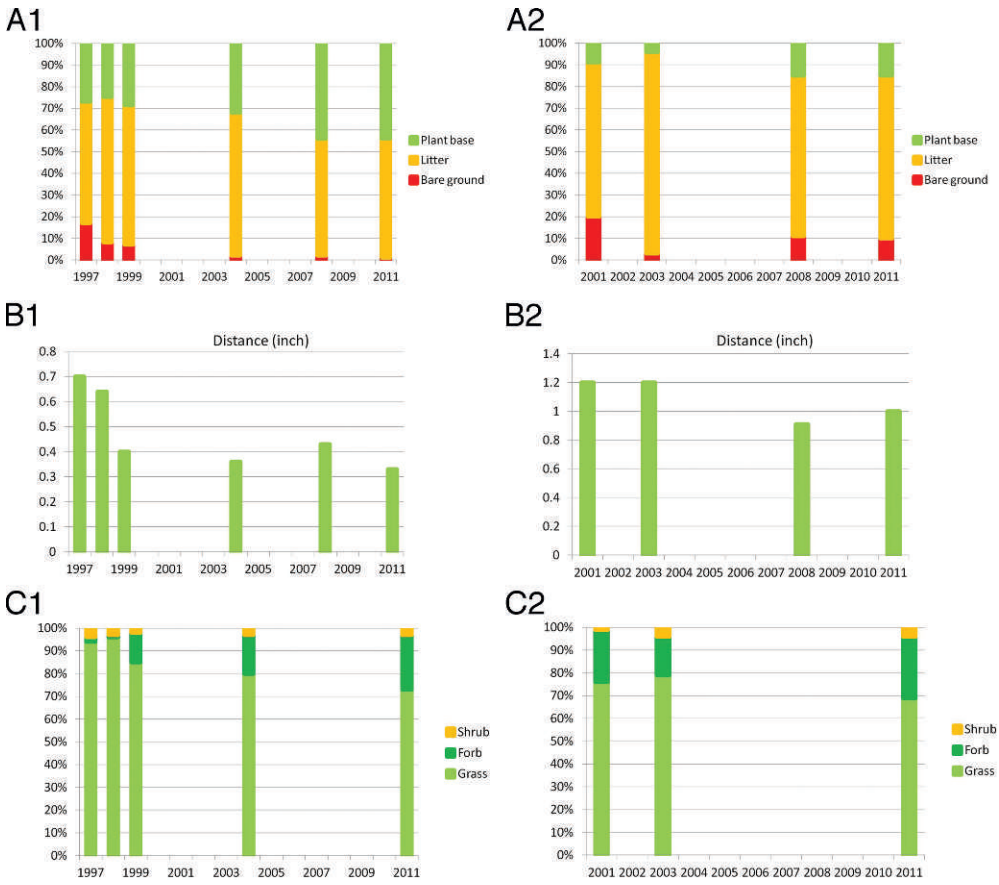

Figure 5. Monitoring data show improving conditions under strategic grazing management. **Column 1**, subalpine site (Little Blue); **Column 2**, montane site (Cerro). **A**, Cover class; **B**, distance to nearest perennial plant; **C**, life-form composition by cover.

bunchgrass-dominated with visibly less sagebrush and forbs (and less diversity).

These desirable changes (increasing plant and litter cover, tighter plant spacing, and more even representation of plant life forms) represent an improvement in the rangeland overall. This improvement happened with stocking rates higher than the previous, visibly unsustainable stocking rate, and about four times the stocking rates on adjacent public land grazing permits. Much of this happened during drought.

Increasing Grazing Capacity

To assess the effectiveness of our management in terms of livestock production, we measure grazing capacities and stocking rates at the scale of AUD/acre rather than acres/AUM. This is partly because our grazing periods are measured in days, and to reflect the finer scale at which the grazing process actually occurs.

The variable of interest is the grazing capacity, i.e., the amount of forage that could be harvested with moderate utilization, given the supply and the grazing management methods—the potential stocking rate rather than the actual stocking rate. We used actual stocking rates to estimate grazing capacity, which is reasonable because the herd is usually moved out of each paddock when use is moderate across the paddock. However, there is some noise due to not grazing the same acres every year, and to some variation in grazing intensity among paddocks and years. To make our stocking rate data better reflect the actual grazing capacity, we adjusted our numbers with an arbitrary scale based on intensity of grazing at the end of each grazing period. If intensity in a paddock was heavy, we multiplied the actual AUD/acre by 0.8, and if it was light, by 1.2; and if it was in between ("moderate-plus" or "moderate-minus"), by 0.9 or 1.1. We adjusted values in 60% of grazing periods, generally decreasing over the years, with an average adjustment factor of about 1.09 (i.e., average relative use of moderate-minus). The numbers presented here represent an adjusted ideal grazing capacity projected from actual use.

On the deeded land (Cerro and the Little Blue), the baseline data were prior to 1997 when the previous lessee had run about 5.6 AUD/acre season-long, which was clearly not sustainable. We do not have actual baseline data for the Middle Blue rangeland, so we used USDA National Agricultural Statistics Service (NASS) data for private-land grazing leases in southwest Colorado.[7] This is a lower baseline than for the deeded rangeland, and in Howell's experience the previous

stocking rates were lower on the Middle Blue. We do know that the irrigated meadow was stocked at about 25 AUD/acre, for about 75 days.

The ranch showed substantial increases in grazing capacity relative to the previous management (Table 1). Averaged over the years since the ranch began strategic planned grazing, this was a 1.6-fold increase on the deeded land—which had previously been heavily stocked. The Middle Blue rangeland had not been as heavily stocked to begin with because those steep hillsides were not being used, so strategic grazing resulted in an even larger improvement in grazing capacity: an estimated 2.4-fold increase. Had we used the same baseline as for the deeded rangeland, this would still be a 1.9-fold increase. Generally, the relative increases in grazing capacity on the rangeland units reflect the severity of distribution problems under previous grazing management. We were also able to increase capacity on the irrigated meadow 1.8-fold, though that is probably partly due to better irrigation water management.

The increase in grazing capacity relative to 1996, which represents the previous management and serves as our baseline, happened immediately when Howell started planned grazing in 1997 and installed higher stocking rates (Fig. 6). In the first three years, the ranch was probably overstocked, but since then the capacity has been more or less around 150% of the pre-1997 rate. This strongly suggests that the increased capacity was due less to improving conditions over time than to more efficient harvest of existing forage—i.e., that grazing capacity is a result of our grazing management methods, not just of forage mass. Current stocking rates would not be sustained under season-long grazing.

At the same time, the cattle inventory in Gunnison County overall has decreased substantially, based on NASS data.[8] These data are for 1 January of each year and so likely better reflect the previous summer's stocking rates than the nominal year's summer stocking rates; thus to relate this data to the Howell Ranch data we assigned the NASS data to the previous nominal year (the line in Fig. 6). The NASS data is missing from 1987 to 2000, so we interpolated a linear trend between 1986 and 2001 (dashed line) and used the interpolated value for 1996 as the baseline for the sake of comparison with the Howell Ranch data. Much of that decrease in cattle inventory is likely due to the long-term drought that began in about 2000. The Howell Ranch experienced the same drought, but appears to have been less affected by it. In 2002, at the time the driest year in memory if not recorded history, the Howell Ranch stocking rate decreased in similar proportion to Gunnison County. But the Howell Ranch bounced back the next year, while the county average recovered only partially and more slowly. So, between strategic grazing management and the inherent flexibility of stocking rates in a custom grazing operation, the Howell Ranch seems to be more resilient.

Of course, in the drought of 2012, which was even drier than 2002, we had decreased grazing capacity and thus stocking rate. During that year we had forage until within a week of the usual end of the season, largely because we destocked early, while some herds on the western slope were coming off of their summer range as soon as a month or two early.

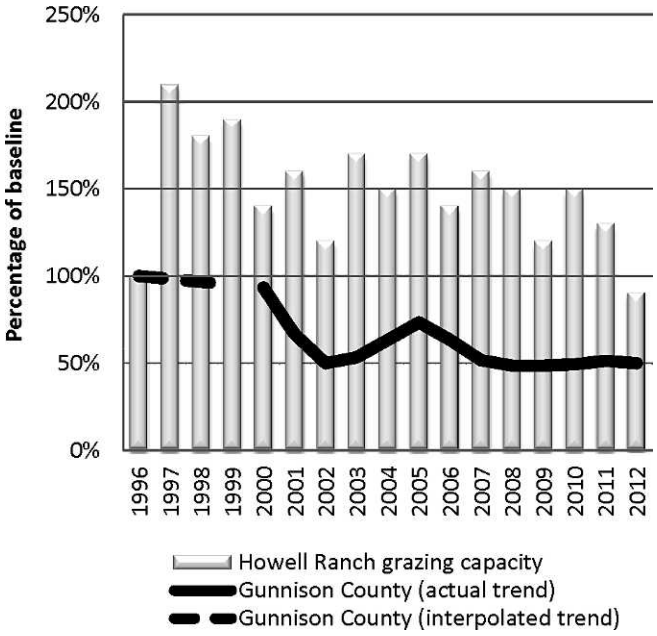

Figure 6. Grazing capacity on the Cerro and Little Blue units of the Howell Ranch (bars), as projected from stocking rates under season-long grazing (1996), and strategic multiple-paddock grazing (1997–2012); and trend of cattle numbers in Gunnison County, Colorado (line; data from USDA National Agricultural Statistics Service).

Management Implications

The Howell Ranch is a unique expression of management based on ecological processes in a specific context, but underlying processes are not unique (*see Provenza et al., this issue*). The numbers and sizes of paddocks, lengths of season, grazing and recovery periods, and stocking rates are context-specific; no other ranch will be the same, but other ranches in mountainous topography and cool climates, dominated by cool-season grasses, may have similar results from similar management. This case study suggests some principles that may be widely applicable.

Under extensive grazing management, real-world ranches, more so than research stations, almost always have overgrazed areas and areas that are underutilized or not grazed at all. The heavily grazed areas in reality have a higher stocking rate than intended for the pasture or ranch, and these tend to be centers of degradation[9] (e.g., the riparian areas and level subalpine parks in this case study). The Howell Ranch shows, on a commercial scale, that well-planned and adaptively managed multiple-paddock grazing can improve the distribution of livestock grazing across a large, diverse landscape and across plant species, and that this can result in increasing grazing capacity while improving rangeland health (*see Norton et al., this issue*). The increase in grazing

capacity documented here is primarily due to the change in distribution and use of plants not previously contributing to forage consumption, as described by Norton et al. (*this issue*). This example supports arguments that grazing capacity is a function of grazing management methods as well as forage mass, because the methods affect the proportion of forage actually available to livestock. This case study also corroborates recent research showing more even spatial distribution of grazing in multiple-paddock grazing management;[10] the benefits of multiple-paddock planned grazing may have been lost in grazing studies where paddock size and diversity were minimized.[11,12] More even grazing pressure across the landscape, especially at broad scales, explains much of the apparent discrepancy between past studies and successful applications of well-planned multiple-paddock grazing[9,13] (*see Norton et al., this issue*).

Smaller paddocks promote more even use whether they are in research trials or on a ranch that is subdividing paddocks for rotational grazing.[10] In our experience, increased stocking density appears to amplify this effect at the ranch scale, though not necessarily at small scales, e.g., many grazing studies.[9] Also our experience on many ranches has often been more net benefit from combining existing herds and using existing fences than from building new fences. On ranches, including this case study, increased stocking density is usually a result of dividing paddocks and rotating the herd through them; as such stocking density is confounded with paddock number and size. A valuable contribution of future research would be to separate the effects of stocking density per se from those of paddock number and size, at a realistic spatial scale.

The difference in monitoring results between the site grazed every year and the site grazed every other year may suggest a benefit of longer recovery periods, especially on relatively dry sites. Nongrazing periods inadequate for plant recovery are probably a primary reason why some operations and grazing studies have not seen the full benefit of multiple-paddock grazing[10,13] (*see also Steffens et al., this issue*). Inadequate recovery also reduces the effect of multiple-paddock grazing on distribution of utilization within a paddock, because previously grazed plants are likely to be regrazed, magnifying the pattern begun in previous grazing periods. Reading between the lines of many grazing studies, many of them may also have had inadequate recovery between grazing periods—which from the plant point of view may be worse than frequency of use under a continuous grazing situation. The improvement in distribution possible with well-planned grazing on a full-scale ranch was probably achieved to some degree in all small-scale pastures regardless of their management[9] (*see Norton et al., this issue*). This may explain why so many studies found no difference between continuous and rotational grazing[11,12] given the scale of their studies.

Grazing distribution can be managed in other ways besides rotation through fenced paddocks, through manipulating animal behavior,[14,15] especially herding and supplement placement,[5,16] or through fire.[17] Herding, if it involves bunching livestock and moving the herd to new areas while preventing animals from returning to previously grazed areas, can be considered a form of planned, strategic, or even rotational grazing without cross-fences. Electric fence, especially temporary electric, is cheaper, faster, more wildlife-friendly, and infinitely more flexible than barbed or woven wire. We generally recommend enough fencing (usually electric, often temporary) to eliminate repeat grazing of preferred plants, and then to augment that fencing with other tools such as herding and strategic supplement placement to further improve distribution.

Regardless of the specific methods of implementation, strategic grazing management that relieves excess pressure on preferred areas and plants by providing adequate recovery time during the growing season (*see Steffens et al., this issue*) and spreads utilization across the landscape, shifting use to previously under- or unused areas (*see Norton et al., this issue*) and plants (*see Peterson et al., this issue*), will allow for improved rangelands while increasing grazing capacity.

References

1. Savory, A., with J. Butterfield. 1999. Holistic management: a new framework for decision making. Washington, DC, USA: Island Press. xviii+616 p.
2. Howell, J. 2008. For the love of land: global case studies of grazing in nature's image. Charleston, SC, USA: BookSurge Publishing. xxvii+470 p.
3. Western Regional Climate Center. Cimarron, Colorado (051609): period of record monthy climate summary. Available at: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?cocima. Accessed 16 July 2013.
4. Butterfield, J., S. Bingham, and A. Savory. 2006. Holistic management handbook: healthy land, healthy profits. Washington, DC, USA: Island Press. xxi+248 p.
5. Cote, S. 2004. Stockmanship: a powerful tool for grazing lands management. Arco, ID, USA: USDA Natural Resources Conservation Service. 150 p.
6. Anonymous. 1999. Early warning biological monitoring—rangelands and grasslands. Albuquerque, NM, USA: Allan Savory Center for Holistic Management. 29 p.
7. USDA National Agricultural Statistics Service. 2007. 2007 private non-irrigated grazing lease survey, Colorado. 4 p. Available at: http://www.nass.usda.gov/Statistics_by_State/Colorado/Publications/Special_Interest_Reports/graze07.pdf. Accessed 16 July 2013.
8. USDA National Agricultural Statistics Service. Data available at: http://quickstats.nass.usda.gov/results/6DF98AA5-6F81-32E2-BAB4-3C657EA364FC. Accessed 16 July 2013.
9. Norton, B. E. 1989. The application of grazing management to increase sustainable livestock production. *Animal Production in Australia* 22:15–26.
10. Barnes, M. K., B. E. Norton, M. Maeno, and J. C. Malechek. 2008. Paddock size and stocking density affect spatial heterogeneity of grazing. *Rangeland Ecology & Management* 61:380–388.

11. Briske, D., J. Derner, J. Brown, S. Fuhlendorf, R. Teague, B. Gillen, A. Ash, K. Havstad, and W. Willms. 2008. Benefits of rotational grazing on rangelands: an evaluation of the experimental evidence. *Rangeland Ecology and Management* 61:3–17.
12. Briske, D. D., J. D. Derner, D. G. Milchunas, and K. W. Tate. 2011. An evidence-based assessment of prescribed grazing practices. *In:* D. D. Briske [ed.]. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps. Washington, DC, USA: USDA Natural Resources Conservation Service. p. 21–74.
13. Teague, R., F. Provenza, U. Kreuter, T. Steffens, and M. Barnes. 2013. Multi-paddock grazing on rangelands: why the perceptual dichotomy between research results and rancher experience? *Journal of Environmental Management* 128:699–717.
14. Provenza, F. D. 2003. Foraging behavior: managing to survive in a world of change. Logan, UT, USA: Utah Agricultural Experiment Station. 63 p.
15. Launchbaugh, K. L., and L. D. Howery. 2005. Understanding landscape use patterns of livestock as a consequence of foraging behavior. *Rangeland Ecology & Management* 58:99–108.
16. Bailey, D. W., H. C. VanWagoner, R. Weinmeister, and D. Jensen. 2008. Evaluation of low-stress herding and supplement placement for managing cattle grazing in riparian and upland areas. *Rangeland Ecology & Management* 61:26–37.
17. Fuhlendorf, S. D., W. C. Harrell, D. M. Engle, R. G. Hamilton, C. A. Davis, and D. M. Leslie, Jr. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. *Ecological Applications* 16:1706–1716.

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