Cattle grazing behavior and monitoring techniques and the impact on rangeland resources and conservation

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Literature Review

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Abstract

Knowledge of cattle grazing movement and how to alter and manage grazing behavior is critical to improving rangeland conservation. This review describes how cattle graze and the movement associated with grazing, particularly in the rangelands in the Central Coast region of California. Additionally, the paper addresses the effects of cattle movement on rangeland forages and conservation. Technologies such as accelerometers, unoccupied aerial vehicles (UAV), Global Positioning System (GPS), and Geographic Information System (GIS) are useful tools in monitoring grazing and the associated behavior. The data collected with these tools provide insights to better manage cattle and natural resources. Altering cattle grazing behavior and movement can be accomplished through various methods including, but not limited to the following: placing supplements in strategic locations, changing the season that the land is used, and/or using fencing systems to help manage natural resources. Furthermore, selecting animals that are willing to graze particular areas will also help producers manage grazing more effectively. Additionally, producers implement various techniques to monitor the grazing behavior of their cattle. These methods include visual appraisal, measuring residual dry matter (RDM), and strategically moving supplementation.

Introduction

Fifty-seven million acres of California's total land surface area is comprised of publicly and privately owned rangelands (California Department of Forestry and Fire Protection Fire and Resource Assessment Program, 2018), of which ranchers use roughly 38 million acres to raise cattle from forage (Larson-Praplan, 2014). The Central Coast rangelands of California – including parts of Sonoma, Napa, Marin, Contra Costa, Alameda, Santa Clara, San Mateo, Santa

Cruz, San Benito, Monterey, and San Luis Obispo Counties – are mostly comprised of annual rangelands (FRAP, 2003; CCRC, 2021). The annual rangelands found within the state provide some of the most important range forages and essential forage for more than 67% of livestock using California rangelands, with the Mediterranean climate zone producing roughly 80% of the forage for livestock (FRAP, 2003; Huntsinger and Bartolome, 2014). Central Coast annual rangelands are comprised of annual-dominated non-native grasslands, native-dominated grasslands, oak woodlands, chaparral, and coast scrub (George et al., 2020). Some of the common annual forage types of this area include: *Dactylis glomerata* (dryland orchardgrass), *Phalaris aquatica* (harding grass), and *Trifolium hirtum* (rose clover) (Forero et al., 2020).

Traditionally, rangelands have been monitored by producers through informal estimation of forage quality and quantity, as well as how precipitation affected the vegetation (Woods and Ruyle, 2015). However, new technology and methodologies are always emerging to help beef cattle producers better manage their cattle on rangelands. These technologies and methodologies allow producers to monitor the grazing behavior of cattle which can help them better manage the cattle on rangelands. In turn, producers are thereby better able to manage and conserve the rangelands on which cattle graze. Technology such as accelerometers, Global Positioning System (GPS), and Geographical Information System (GIS) – by monitoring both cattle location and activity levels – can be useful to identify changes in livestock behavior on rangelands over long periods of times (Bailey et al., 2018; Batzia et al., 2005).

Additionally, unoccupied aerial vehicles (UAV), also referred to as drones, can be used to determine grazing patterns, as well as determining pasture depletion (Alvarez-Hess et al., 2021). UAVs can also be used in water stress analysis, yield estimate, biomass estimate, and soil monitoring (del Cerro et al., 2021). GPS can be paired with GIS, along with UAV or other data as available, to determine the spatial parameters of grazing cattle (Putfarken et al., 2008). Through the use of accelerometers, UAV, GPS, and GIS, cattle producers and rangeland managers can more precisely determine rangeland use during a grazing season. By being able to monitor behavior more closely, managers can make more timely decisions, which allows for better animal performance and welfare (Bailey et al., 2019). Additionally, producers can use cattle to manage rangelands by putting cattle in at a specified location, time, intensity, and duration (Burcham, 1961). A better understanding of the effects of cattle movement and grazing patterns on rangelands can enhance rangeland resource monitoring to achieve conservation on California's Central Coast rangelands.

During the European settlement of California, rangelands were widely used by both colonists and various grazing livestock. As a result, numerous annual plant species, such as *Poa annua* (Annual Bluegrass), *Hordeum leporinum* (Mouse Barley), and *Lolium multiflorum* (Ryegrass), were introduced during this time and became dominant in the Mediterranean climate region, largely converting the composition of the grasslands from native to non-native (Burcham, 1961).

Producers grazing cattle in the Central Coast rangelands, which are comprised of 12 of the 58 counties in California, have found that this ecosystem has a unique combination of climate, plant communities, and animal populations (Figure 1; California Census Office, 2020; CCRC, 2021). The annual grassland that comprises the Central Coast rangeland can be identified as the Coastal Prairie subtype. The Coastal Prairie grassland stretches from just south of the Oregon border along the coast, along the San Francisco Bay, all the way down to Monterey Bay

(Bartolome, 1987). As a result, the rangelands of the Central Coast contain unique ecosystems; thus, management tools need to be adapted to better manage it.

Figure 1. Map of California highlighting the 11 counties that comprise the Central Coast rangelands.

Cattle grazing behavior

By knowing the associated behavioral characteristics that cattle exhibit during grazing events, producers can better manage the rangelands that the cattle are grazing. Ingestive behavior (grazing) in ruminants can be characterized by a long consumption time, which ranges from 4 to 12 hours per day, and then the chewing of cud (Gregorini et al., 2006). Cattle graze during discrete events which vary in frequency and distribution depending on the specific animal and the environment it inhabits (Wallis De Vries and Daleboudt, 1994). Furthermore, cattle can implement foraging strategies that can adapt to the changes that occur to vegetation (Gregorini et al., 2006). This adaptation includes controlling the quantity and quality of their consumption (Gregorini et al., 2006). The physical characteristics of plants and the environmental conditions also add to the grazing behavior of the animal (Wallis De Vries and Daleboudt, 1994). Thus, the foraging strategies implemented by cattle can lead to the balancing of nutrient intake (Krys and Hess, 1993).

One way to influence grazing behavior is through the use and strategic placement of feed supplements. Supplementation is provided when cattle are grazing low-quality forages, which have low nitrogen content (i.e., crude protein) and digestibility (i.e., neutral detergent fiber) (Adams, 1985). In one study, steers grazing Russian wild rye were supplemented with corn, which decreased daily forage intake of the supplemented steers, yet supplementation did not alter the total grazing time of the steers. The three treatment groups each had different grazing patterns, and the distribution of grazing activity through the implementation of a supplementation program affected the overall forage intake through grazing (Adams, 1985). Wyffels et al. (2019) indicated that supplemented cattle that graze dormant rangelands show a repeatable intake behavior. Additionally, higher levels of supplementation in cattle are shown to produce calves with a higher weaning weight while traveling a lesser distance per day when compared with cattle that have a lower level of variation in supplementation. However, these cattle tend to lose more weight when grazing dormant season rangelands due to a reduced amount of nutrients avaible (Wyffels et al., 2019).

Typically, animals that are meeting production goals are retained within the herd in response to better adaptation and/or acclimation to grazing (i.e., learning where forage and water sources are) in their given environment (Mulliniks et al., 2016). Cattle become better acclimated to their environment through physiological and metabolic processes, as well as through learning to more effectively use rangeland resources, such as forages, by adapting to the particular environment in which they graze (Mulliniks et al., 2016). Through their acclimation to the environment, these cattle may meet production goals more efficiently and are retained within the herd when compared with their poorly-acclimated contemporaries (Shahhosseini, 2013; Mulliniks et al., 2016). For example, females that had a high supplement consumption rate (i.e., fast eaters) had more of a ‘go-getter’ type of temperament resulted in better reproductive performance compared to ‘laid-back’ females (Wesley et al., 2012). As a result of better reproductive performance, ‘go-getter’ females were less likely to be culled from the herd (Wesley et al., 2012). Since cattle are gregarious animals, individual cattle will tend to move with the herd, and younger animals in the herd will therefore follow previously acclimated animals during the grazing season (Mulliniks et al., 2016). Animals that have acclimated to the environment thereby pass on knowledge of grazing a particular location and/or environments to the younger grazers in the herd (Mulliniks et al., 2016). Additionally, animals learn what to consume while in utero through exposure to forage flavors in their mothers’ amniotic fluid (Lyons and Machen, 2000). Thus, grazing behavior can also be influenced by the use of animals that have previous grazing experience in that particular location or similar environments.

Grazing monitoring techniques

Accelerometers

Accelerometers are also useful in detecting various animal behaviors, such as lying period and frequency, grazing activity, and the health status of individual animals, such as an animal lying laterality for extend periods of time (Rodriguez-Baena et al., 2020). Research using accelerometers has also been able to validate the position in which a cow's head is in and distinguish between grazing and non-grazing behaviors (Nielsen, 2013). For example, to quantify head down behavior, as seen in grazing, an accelerometer was placed around the neck, and a 10-second mean value of the X-axis from the accelerometer was the best fit to determine this behavior (González et al., 2015).

Collar accelerometers, such as MooMonitor+ (Dairymaster, Tralee, Ireland), have been found to be able to detect grazing in commercial applications, and have proven to be accurate, long-lasting devices that help producers better manage their grazing cattle while reducing production costs (Werner et al., 2019). Ear tag accelerometers have also been found to be precise and accurate in detecting grazing behavior. For example, Pereira et al. (2020) found that the accelerometer ear tag, Smartbow (Smartbow GmbH, Weibern, Austria) algorithm had a 90% precision, 92% recall, and 91% accuracy when detecting grazing behavior at pasture when compared to the visual observation data.

Unoccupied aerial vehicles (UAV)

Unoccupied aerial vehicles are another way to monitor grazing behavior and intensity in livestock (Sun et al., 2020, Alvarez-Hess et al., 2021). For example, Sun et al. (2020) monitored a yak herd for 5-6 days per month for 4 months. The UAV took photographs of the yak herd at the height of 70-100 m, which allowed for the producer to view an aerial photograph of roughly 3 hectares. Through the photographs, the producer monitored herd size, distribution, and geographic location of the herd and/or individuals.

Producers are also able to measure the total biomass of the pasture using UAV-borne sensor systems (Alvarez-Hess et al., 2021). By monitoring the movement and distribution of a group of livestock, producers are then able to determine where vegetation depletion is occurring; thus, allowing for better utilization and maintenance of resources (Alvarez-Hess et al., 2021). In a study conducted by Michez et al. (2019), sward height and spectral information collected from UAVs was used to observe top canopy and subcanopy parameters to reflect the grazing activity within grasslands consisting of *Lolium perenne* (ryegrass) and *Trifolium repens* (clover). It was also found that the best model for indicating grazing activity of the swards was a combination of UAV sward height information and UAV vegetation indices. However, using UAV sensor systems to detect pasture use can encounter a few challenges, such as the need for more UAV measurements, when the location is actively and intensively being grazed (Alvarez-Hess et al., 2021).

Global Positioning System (GPS) & Geographic Information System (GIS)

In the 1990s, GPS tracking emerged and allowed researchers to more accurately monitor livestock grazing patterns. Through the use of GPS, data could be collected over a span of weeks or even months, which helped to corroborate the effectiveness of techniques that were used to improve grazing distribution (Bailey et al., 2018). By using GPS technology on livestock, livestock producers and rangeland managers can enhance their decision making on how to improve the distribution of the livestock on rangeland (George et al., 2007). Without the use of

GPS, producers would have to collect data for behavioral characteristics via direct visual observations. González et al. (2015) used visual observations and random sampling of grazing, with each record including date, time, and what behavior the animal was presenting at the time of observation to test the accuracy of the GPS. In their experiment, distance traveled was the fastest during traveling behavior, moderate while the animal was foraging and other active behaviors, and slowest during rumination and rest periods ($P < 0.05$).

GPS collars that collect near-continuous data at a high frequency, such as 10 and 4 Hz, are able to capture, fine-scale differences in behaviors in a cost-effective way compared to visual observations (Figure 2; González et al., 2015; Putfarken et al., 2008). By using GPS technology in cattle management systems, researchers have been able to help improve herds by improving the overall use of various rangelands areas, such as those far from water or in higher elevations (Bailey et al., 2018).

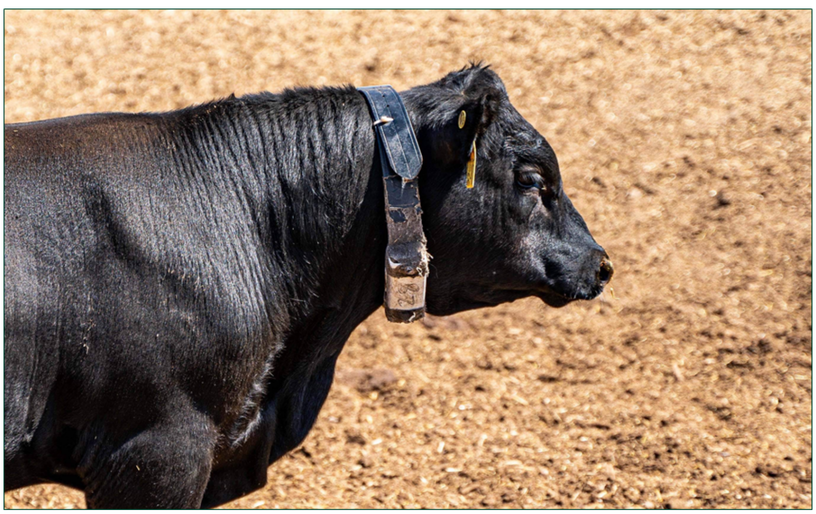

Figure 2. GPS collar unit placed around the neck of a bull (Z. McFarlane, personal communication, January 21, 2021).

Data that is collected using GPS and/or UAVs can then be organized and visualized in GIS. Lie et al. (2020) developed a GIS platform that allows users to make a prediction of the spatial feeding behavior of the herd based upon previous movements of individuals within that same area. Additionally, GIS can also be useful in determining the percentage of vegetation within a given area, which can help producers to better manage cattle in rangeland environments (Cingolani et al., 2008).

Cattle producers have a variety of GIS programs available, such as ArcGIS (ESRI, Redlands, CA) and MapInfo (Precisely, Burlington, MA), which allow for the visualization of GPS and UAV data. However, these programs can be costly and require training for the producer. Google Earth (Google, Mountain View, CA) is another option for producers to use that can be easier to use, yet only allows certain brands of GPS devices to directly import into the program (Google Earth Outreach, 2021). Other GPS devices may need to first export their data to computer files, which can then be imported into Google Earth.

Grazing methodologies used to conserve Central Coast rangelands

Conservation grazing uses livestock, in some instances using a reduced stocking rate, to reduce dead organic material, while managing non-native species to improve rangeland conditions (Oles et al., 2017; San Lucia Conservancy, 2022). Targeted grazing is another way to conserve Central Coast rangelands, particularly for reducing the encroachment of invasive species and creating fire breaks (Bailey et al., 2019). Targeted grazing is achieved by implementing a particular livestock species, such as cattle, during a particular season, length of time, and a certain density to achieve particular goals relating to vegetation (Launchbaugh and Walker, 2006). By using a higher density of grazing animals in targeted grazing on an area that has an abundance of invasive species, while paying attention to the season and duration of the grazing, the plant species composition may change (Launchbaugh and Walker, 2006, Bailey et al., 2019). A singular targeted grazing plan is not applicable to every invasive species; thus, a new targeted grazing plan needs to be formulated to cater to the specific invasive species that is being managed (Launchbaugh and Walker, 2006). For example, Davey et al. (2015) studied the impact of targeted cattle grazing on an invasive annual grass species, medusahead (Taeniatherum [formerly *Elymus] caput-medusae* [L.] Nevski) in annual grasslands and blue oak (*Quercus douglasii* Hook. & Arn.) woodland communities. They found that moderately stocked rotational grazing plans reduced medusahead cover by nearly 50% in a three-year timespan. Targeted grazing, by reducing vegetation biomass and thereby potential flame length and rate of spread, can also help create fire breaks (Diamond et al., 2009). Through the implementation of targeted grazing, producers can actively manage the selective grazing behavior of cattle while on rangelands (Bailey and Brown, 2011).

Grazing management, such as targeted grazing, can be achieved through various methods such as different types of electric fences and moving protein supplementation (Morgan, 2016, Campbell et al., 2016, Stephenson et al., 2017). Virtual fencing collars or temporary electric fences on grasslands can help to restore biodiversity and associated ecosystem services while also allowing the cattle to achieve production goals (Campbell et al., 2018; Morgan, 2016). The virtual fencing collars provide both auditory and electrical stimuli cues to encourage the animals to return back to the inclusion zone and to where the herd is located at (Campbell et al., 2018).

Virtual fencing has been found to be effective at keeping cattle out of areas that producers do not want them in, even when there was a feed attractant in that area, and they have been found to not negatively impact the individual animal (Ranches et al., 2021).

Another method to influence cattle distribution is through the use of low-moisture block (LMB) protein supplements, which can change the distribution of cattle within a rangeland environment. For example, Stephenson et al. (2017) found that when cattle consumed greater (i.e., the recommended) amount of supplements, they remained closer to the LMB for longer periods of time (8.8 ± 0.9 hr/d versus 1.3 ± 0.3 hr/d) (Stephenson et al., 2017). An increase in the producer profits, due to targeted, more uniform grazing, can lead to improved conservation of not only the pasture and landscape, but to the entire grazed rangeland (Huntsinger and Bartolome, 2014).

Central Coast beef producer's current grazing monitoring techniques

In the late spring of 2021, a grazing management and cattle marketing survey was emailed to over 400 San Luis Obispo Cattlemen's Association and Central Coast Rangeland Coalition members through Qualtrics (Qualtrics International Inc., Provo, UT, USA). A total of 35 questions were asked, and follow-up interviews were conducted with willing participants. These follow-up interviews, over Zoom or phone calls, asked an additional 7 follow-up questions related to grazing management and marketing techniques. In total, there were 51 responses to the initial survey and 10 interviews were conducted. Participant responses to the survey indicated that the main ways that individuals monitored the grazing of their animals was through visual appraisal, measuring residual dry matter (RDM), and by moving supplementation, such as protein tubs, to different areas during the grazing period in that pasture to promote grazing closer to that area (J. Lewis, person communication, June 24, 2021).

Sixty-one percent of respondents monitored grazing through visual appraisal. This allowed them to also monitor plant recovery while checking their cattle. Additionally, some producers implemented photographic technology and sampling alongside their visual appraisals. By taking photos at various pasture locations and during different times during the grazing period on that pasture, they were able to keep photographic records from year to year and visually compare the pasture over time. Respondents also indicated they visually monitored the cattle herd to make grazing management decisions. Data included overall herd health, body condition scores (BCS), and conception rates (J. Lewis, person communication, June 24, 2021).

During the 10 interviews, participants further echoed their use of visual appraisal in their grazing management. However, participants seemed to be unsure of the value of the techniques they implemented in their grazing management practices. Participants also commented that they were interested in implementing more technology-based grazing management techniques (J. Lewis, personal communication, June 24, 2021).

Conclusion

Through the long history of cattle grazing in California, cattle producers have learned to better manage their cattle, and have sought new and effective ways to manage and conserve the rangeland on which cattle graze. One way to better understand and manage how cattle use the rangeland is through better knowledge of the details of cattle grazing behavior. Cattle have adapted foraging strategies in response to the animal's overall environment, as well as in response to how forage changes during the grazing season. Monitoring this grazing behavior can be achieved using various reliable technologies such as accelerometers, UAV, GPS, and GIS. Upon identification of the grazing behavior in response to the environment, producers can better manage cattle on rangelands by implementing various forms and goals of grazing management, such as targeted grazing, to conserve their rangelands. Presently, based on a survey, producers utilizing the Central Coast rangelands mainly use visual appraisals of the pasture to make grazing management decisions, and were unsure of the value of the grazing management techniques that they implement. However, producers seemed open to implementing more technology in their management of grazing. Overall, grazing cattle or other livestock species on rangelands is a multifaceted undertaking, but when done correctly, can help producers achieve production goals while also improving other rangeland resources.

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