or (2) The land manager decides to switch to a more effective (if more expensive) treatment.

What the above scenario suggests, however, is that a very cheap, but high risk treatment can be used initially, while treating the leftover spots with a more expensive and lower risk treatment.

Realizing that re-treatments can come from either Variable or Fixed Costs, the re-treatment costs in the last example would be as follows when extra fertilizer (with an estimated probability of failure of .4) is put on the 1 foot topsoiling treatment instead of adding more soil:

Re-treatment Costs per Acre

Fertilizing $845

Expected Re-treatment Costs per Acre

$845 × .4 = $338

Expected Final Cost per Acre

$338 + $15,540 = $15,878

Whether adding fertilizer is an adequate substitute for additional soil is a question which must be resolved through professional judgment and reflected in the probability of failure; according to the Expected Final Cost calculations of this example, quite a bit of fertilizer can be added before the cost approaches the cost of adding more soil.

Assuming that the fertilizer is deemed an appropriate re-treatment of the failed areas, fertilizing the entire area as an initial treatment then re-treating failed areas with the 1 foot of soil treatment is now less expensive than either of the other two proposed treatments. It is cheaper to treat with fertilizer and re-treat some areas with topsoil than to treat it once only with the more expensive topsoiling approach.

Conclusions

Range improvements can be evaluated on the basis of Expected Benefits, Total Costs, and Risks. Varied treatments can be used at different times in the treatment process to achieve various goals, such as to get a minimum response followed by spot treatments to correct problem locations.

The technique of combining Risk and Cost for the Expected Final Cost of a treatment can be applied to any quantifiable benefit curve. This technique, as with all tools, must be used with discretion, and should be subject to the judgment of experienced managers.

Management of Cattle Distribution

Derek W. Bailey and Larry R. Rittenhouse

What does the range manager mean when he says his goal is "good cattle distribution"? Is his goal uniformity of utilization? Is his goal to prevent over-utilization of some areas while enhancing utilization in others? Is his goal to leave a uniform residual standing crop? Is his goal to optimize ingestion rate?

Rangelands present a management challenge to livestock operators, whose raw materials are the nutrients found in forage. Those nutrients are not uniformly distributed in time or space. The challenge of the manager is to harvest those nutrients in the most cost-effective manner possible, while doing it in such a way as to insure the sustainability and productivity of the resource.

For many years, water and salt have been used to manipulate livestock distribution into under-utilized areas of a pasture (Cook 1967). Managers have recognized that other factors may limit livestock movement: cattle avoid steep slopes (Cook 1966), yearling cattle can travel farther than cows with young calves (Arnold and Dudzinski 1978), and impenetrable brush, cliffs, and ravines, may limit animal movement (Senft et al. 1987). Fertilization and burning can be used to "draw" animals into an area (Hooper et al. 1969, Samuel et al. 1980). Herding (drifting) can be a profitable method for improving the utilization of forage on steep slopes (Workman and Hooper 1968).

Experience has taught us a great deal about how water, salt, and topography affect utilization, but our ability to predict distribution of animals is limited. The objectives of this paper are: (1) to explore what is commonly meant by the word distribution, and (2) to examine mechanisms of distribution that might provide clues to management.

Conceptual Models of Cattle Distribution

One hypothesis is that animals simply move along a grazing pathway in some random manner. This grazing pathway may be constrained by physical phenomena, such as steep slopes, dense brush, or other barriers. The pathway ends when the animal stops grazing to meet its requirement for water, salt, or comfort.

An alternative hypothesis is that the distribution is based on a multi-level response by the animal to its environment. The animal's grazing pathway is constrained by non-interactive factors, such as mobility, barriers, and topography, but the decision of where to graze is based

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on perception, knowledge, and memory of potential choices. Bailey (1988) has found that cattle have the ability to remember where they have foraged for periods up to 8 hours. Cattle also appear to be able to associate food availabilities with their locations (Bailey et al. 1988). They have the ability to track changes in the level of resources and adjust their behavior accordingly. These abilities have been demonstrated in other species such as rodents and pigeons (Olton 1977, Roberts and Velduizen 1985) and appear to be a general phenomenon.

Decisions of where to forage are separated from dietary decisions by the frequency of choices (Senft et al. 1987). A large herbivore makes many more choices among plants than among patches (assemblages of vegetation) or plant communities. Because the animal makes thousands of choices among plants each day, it makes sense that they use simple rules to make diet choices. These rules are probably based on forage quality, forage quantity, and concentration of secondary compounds in the forage. Some rules that the animal might use are: choose the tallest plants, choose plants with the highest concentration of nutrients, and avoid plants that have high concentrations of secondary compounds (tannins, phenols, alkaloids, etc.). Cattle don't have the capacity to maintain huge data banks of information on each plant and evaluate the information prior to each bite. Choices are limited to the patch or plant community they occupy at that point in time.

In our conceptual model of the grazing process, cattle quickly explore a new pasture and develop a map-like presentation of the spatial relationships among patches. This is stored in long-term or reference memory and is often termed a cognitive map. Animals use short-term or working memory to remember which patch or patches have been recently visited. Working memory can be used to selectively avoid a recently visited patch or return on a following grazing bout.

Forage quality and quantity in patches will change over time. However, the animal's expectations of the area, stored in long-term memory, will change at a slower rate. Therefore animals may return to areas that have been previously grazed.

We do not know the persistence of working or reference memory under natural conditions. However, it does appear to provide a promising model for studying and describing grazing behavior and animal distribution. Another void in our information is the effect of social interactions in regard to spatial choices. Since most large herbivores are gregarious, we must know if spatial decisions are made collectively or if only one or more animals make the decisions and the others follow.

What then is the effect of different densities of animals? On a time-constant basis, the impact of different densities of animals can be quite dramatic. Standing crop will be reduced much more rapidly in a paddock with high animal density than in a similar-sized paddock at a lower animal density. However, there is little evidence that animal density influences grazing behavior. There is no evidence that the relative consumption rate among patches or plant species in a pasture changes as a result of changes in animal density. What does seem to be obvious is that the rate of total forage consumption is proportional to changes in animal density. Therefore, observed changes in grazing pattern probably result from an increased rate of forage removal.

High rates of forage consumption resulting from high animal densities may confuse animals. They might search out areas that previously had an abundance of preferred forage but were currently depleted. As mentioned earlier, expectations of food availability (long-term memory) of cattle change slowly. Under high densities, the consumption rate may greatly exceed the animal's ability to update its information bank, expecially on very large areas. This could lead to a more random distribution pattern. Search time should increase, ingestion rate should decrease, and overall harvest efficiency should decline.

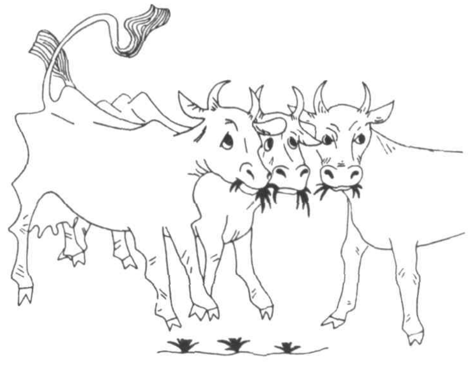
Management of Distribution Based on Animal Behavior

Limitation of Choices

Few would argue that limiting the choices to free-grazing animals has an impact on pasture use. Placement of fences in relation to topography can make dramatic differences in the way animals distribute themselves. For example, cattle will utilize forage on very steep slopes if no other choices are available. Place the fence some distance from the toe of the slope and virtually no use will occur on the slope until animals are near starvation. A similar situation exists when a riparian area is bounded by steep slopes on each side. But, provide access to the slope at some lesser incline and use will increase. Addition or removal of physical barriers are powerful tools to change choices and improve distribution.

Changing the Variation of Choice Alternatives

When a large pasture is subdivided into smaller units, the number of alternative patches and the distribution of patches are altered. If fences are located in such a way that patches in a paddock are similar, a different apparent distribution of animals will occur than if patches are dissimilar. The greater the variation among patches the more likely animals will concentrate on some patches and avoid others. Concentration of grazing may result in overutilization of preferred plant species and a subsequent loss of plant vigor and competitive ability. If the alternatives are similar, animals will tend to use the patches more evenly. The more homogeneous a paddock is, the less likely animals will concentrate in certain areas.



The reasoning behind this hypothesis follows. Large herbivores tend to match their consumption rate to the level of preferred forage resources available (Senft et al. 1987). This relationship appears to be more closely tied to the nutrients in the forage than actual biomass (Senft et al. 1985). Therefore, areas with high-quality forage receive a disproportionately high rate of biomass removal. Subsequent forage growth is high quality. This can lead to a spiralling effect of animals spending more and more time grazing certain areas of the pasture. A similar type of behavior could lead to "patch grazing" observed by Ruyle et al. (1988). They reported that cattle maintained small areas (patches) of heavily grazed Lehmann lovegrass

The idea of manipulating cattle distribution in a systematic manner based on animal memory of locations and diet selection rules has not been exploited. If an area is burned or fertilized, animals may consider it so much better than other areas that they would be willing to travel up steep slopes or long distances from water in order to graze it. But, animals may not change patterns of use in the areas they pass through to reach the burned or fertilized areas. Changing the similarity among patches will probably not overcome the effects of water, salt, steep slopes, comfort, or physical-barrier limits. Integration of these techniques with the proven techniques of water and trail development and salt placement may improve cattle distribution.

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A Post-Chernobyl Grazing Economy—North Wales in the Second Year and Beyond

Sian Mooney and William A. Kerr

Editor's Note: Readers may wish to refer to the article "Nuclear Accidents and Rangelands: The Effect of Chernobyl on the Grazing Economy of North Wales," by William A. Kerr and Sian Mooney *Rangelands* 10(1):6-9, 1988. We all need to be aware of the potential effects of nuclear contamination. There is much to be learned from these two articles.

As the grass flushed in 1987, signaling the commencement of a new grazing cycle, areas of North Wales in the United Kingdom began their second year of coping with radioactive material received in the wake of the Chernobyl accident. Government policy progressed from crisis management to a state of ongoing disaster administration. The short-term disruptions to farmers' grass management systems have largely been eliminated. Serious questions now arise regarding the long-term policies required to deal with contaminated areas. This is particularly important given that preliminary data suggest the level of radioactivity may not be declining as fast as originally projected.

In the summer and fall that followed the disaster at Chernobyl in April 1986, sales and movement of ewes and lambs were banned affecting a total of 2.5 million sheep of 5,000 operations. Later, in areas where radiation levels persisted, these activities were undertaken within a set of stringent regulations which were bureaucratic, time-consuming, and poorly designed to facilitate good management of the grazing resource. As a result, some overgrazing occurred and was particularly evident on geographically discontinuous farms.

In its attempts to deal with the crisis, the government was initially hampered by two problems. First, there were no data available concerning the effects of radiation on

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Author's Note: This *note* is an update of a report on the effect of Chernobyl radiation on North Wales, United Kingdom, published in *Rangelands*, Vol. 10, No. 1, 1988.