JOURNAL OF RANGE MANAGEMENT

THE TRAIL BOSS

PUBLICATION OF THE
SOCIETY FOR RANGE MANAGEMENT

VOL. 31, NO. 1
JANUARY 1978

First International Rangeland Congress
Denver, Colorado, U.S.A.
August 14–18, 1978

Plans are complete for this first formal conference of individuals and organizations dedicated to wise use of the rangeland resources worldwide. Wide interest already expressed in the First International Rangeland Congress assures attendance and participation by representatives from many countries having broad geographic coverage of the world — the panel of speakers alone represents 34 different countries, and over 40 percent of the papers are from outside the United States.

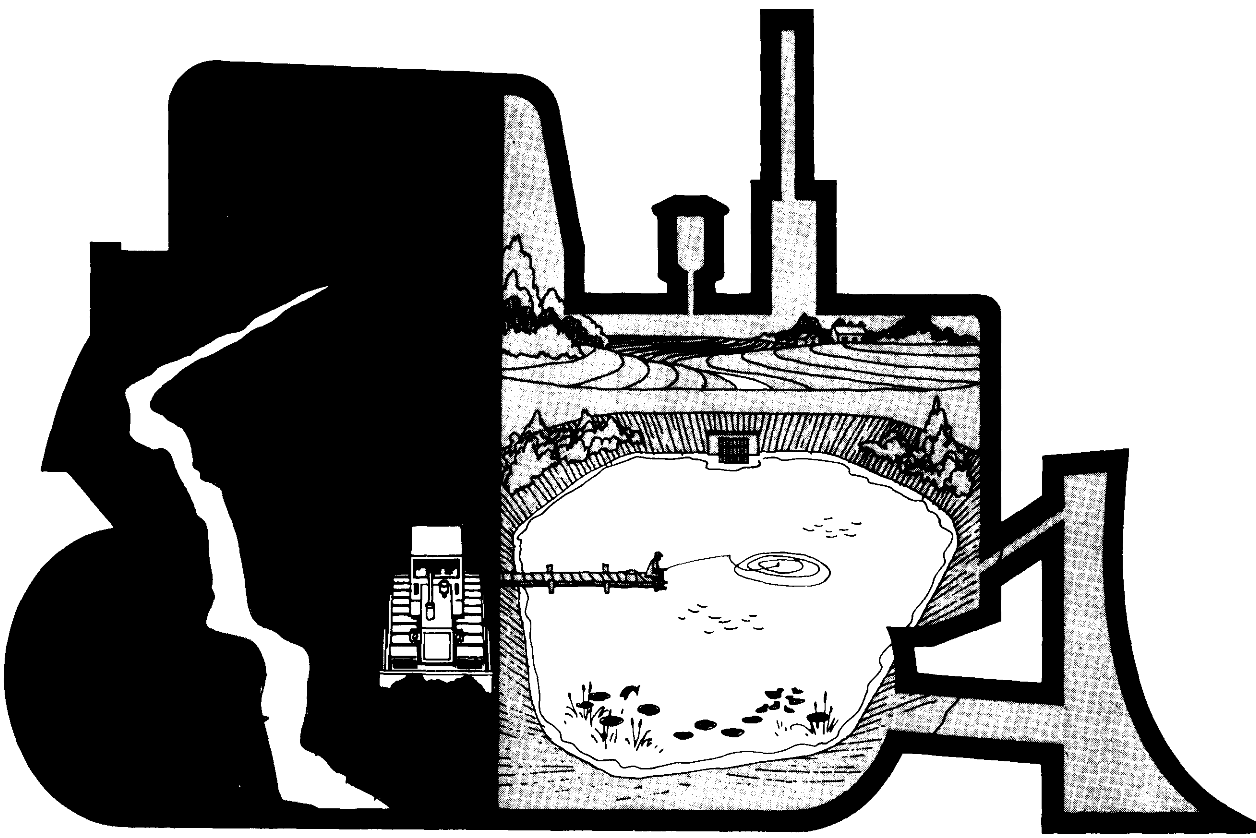
The Convention Center at Denver will provide a comfortable meeting place for exchange of technical and cultural information. The social activities and local tours offer great opportunity for personal exchange. Congress attendees who join one of the Pre-Congress Tours can learn more about the people, the scenery, and the land management problems of North America.

For information and registration forms for the Congress, hotel, and tours, write:

First International Rangeland Congress
2760 West Fifth Avenue
Denver, Colorado 80204

telephone: (303) 571-0174

How to deal with gullies and gullywashers...



and boost your profits!

Dam the gullies or replace them with farm ponds or grass waterways. A properly constructed grass waterway can carry a fast flowing gullywasher as well as a gully. But with no soil erosion. And because you can cross it with your machinery, no more time wasted circling around a gully to get to crop rows on the other side.

Damming a big gully and building a farm pond is an erosion control measure that pays off in other ways, too. As water for irrigation or stock. As hedge against drought. For fire protection. And, of course, as a spot for family fun on a hot summer's day.

Call your Caterpillar-equipped land improvement contractor. Invite him out to check your drainage situation. He can give you an expert's recommendation about the right course of action. He'll know how to properly design and build a grass waterway or farm pond. And, because of the dependable, low-operating-cost efficiency of his Cat-built equipment, he'll be able to quote you a reasonable price.

Your land improvement contractor can help you keep your topsoil and fertilizer from washing away. Give him a call.

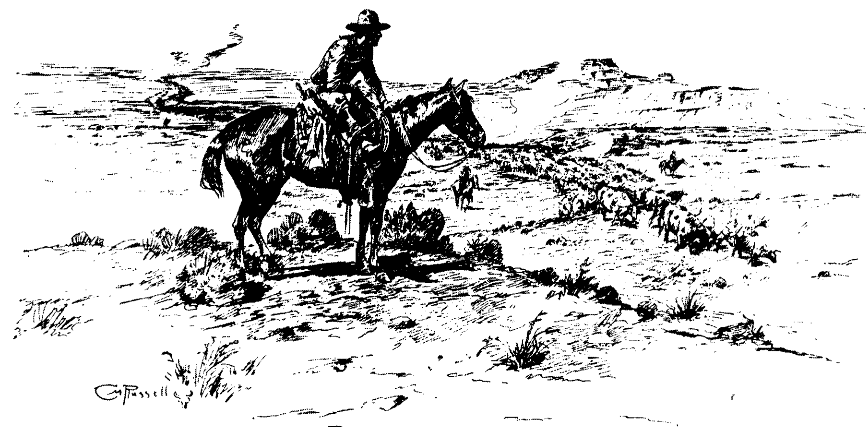
Land investment today builds tomorrow's profits. CATERPILLAR

SOCIETY FOR RANGE MANAGEMENT

Contribution Policy

The Society for Range Management may accept donations of real and/or personal property, subject to limitations imposed by State and Federal Law. All donations shall be subject to control by the Board of Directors and their discretion in utilization and application of said donations. However, consideration may be given to the donor's wishes concerning which particular fund account and/or accounts the contribution would be applied.

We recommend that donor consult Tax Advisors in regard to any tax consideration that may result from any donation. Donations may be made by bequests, legacies, devises or transfers from private individuals, partnerships, corporations, foundations, sections, organizations, estates and trusts, or a memorial fund established as an expression of remembrance to members of real and/or personal property. Donations can be sent to the Society for Range Management, Executive Secretary, 2760 West Fifth Avenue, Denver, Colorado 80204.



THE TRAIL BOSS

The **Society for Range Management**, founded in 1948 as the *American Society of Range Management*, is a nonprofit association incorporated under the laws of the State of Wyoming. It is recognized exempt from Federal income tax, as a scientific and educational organization, under the provisions of Section 501(c)(3) of the Internal Revenue Code, and also is classed as a public foundation as described in Section 509(a)(2) of the Code. The name of the Society was changed in 1971 by amendment of the Articles of Incorporation.

The objectives for which the corporation is established are:

—to develop an understanding of range ecosystems and of the principles applicable to the management of range resources;

—to assist all who work with range resources to keep abreast of new findings and techniques in the science and art of range management;

—to improve the effectiveness of range management to obtain from range resources the products and values necessary for man's welfare;

—to create a public appreciation of the economic and social benefits to be obtained from the range environment; and

—to promote professional development of its members.

Membership in the Society for Range Management is open to anyone engaged in or interested in any aspect of the study, management, or use of rangelands. Please contact the Executive Secretary for details.

The **Journal of Range Management** serves as a forum for the presentation and discussion of facts, ideas, and philosophies pertaining to the study, management, and use of rangelands and their several resources. Accordingly, all material published herein is signed and reflects the individual views of the authors and is not necessarily an official position of the Society. Manuscripts from any source—nonmembers as well as members—are welcome and will be given every consideration by the editors. Submissions need not be of a technical nature, but should be germane to the broad field of range management. Editorial comment by an individual is also welcome and, subject to acceptance by the editor, will be published as a "Viewpoint."

JOURNAL OF RANGE MANAGEMENT

Published bimonthly—January, March, May, July, September, November—by the
Society for Range Management
2760 West Fifth Avenue
Denver, Colorado 80204

INDIVIDUAL SUBSCRIPTION is by membership in the Society for Range Management.

LIBRARY or other INSTITUTIONAL SUBSCRIPTIONS, on a calendar year basis, are $22.00 postpaid to all countries. Payment from outside the United States should be remitted in US dollars by international money order or draft on a New York bank.

CHANGE OF ADDRESS notices should be sent to the Managing Editor, 2760 West Fifth Ave., Denver, CO 80204, no later than the first day of the month of issue. Copies lost due to a change of address cannot be replaced unless adequate notice is given. To assure uninterrupted service, provide your local postmaster with a *Change of Address Order* (POD Form 3575), indicating thereon to guarantee forwarding postage for second class mail.

BUSINESS CORRESPONDENCE, concerning subscriptions, advertising, reprints, back issues, and related matters, should be addressed to the Managing Editor, 2760 West Fifth Ave., Denver, CO 80204.

EDITORIAL CORRESPONDENCE, concerning manuscripts or other editorial matters, should be addressed to the Editor, Dep. Animal and Range Sciences, New Mexico State Univ., Las Cruces 88003.

INSTRUCTIONS FOR AUTHORS appear each year in the March issue; copies of these instructions are available from the editor.

SECOND CLASS POSTAGE paid at Denver, Colorado.

TABLE OF CONTENTS: VOL. 31, No. 1, January 1978

ARTICLES

TECHNICAL NOTES

BOOK REVIEWS

THESES

COVER: This new cover design is being used on a trial basis. The editor would appreciate your comments on it.

Research Needs on Western Rangelands

J. O. KLEMMEDSON, REX D. PIEPER, DON D. DWYER, WALTER F. MUEGGLER, AND M. J. TRLICA

Highlight: A brief history of rangelands leading to the current status of range research in the western United States is reviewed. Five categories of new or unresolved problems needing research are identified. Ranked by priority, the five are: (1) dynamics of individual plants and plant communities; (2) identification, classification, and inventory of range ecosystems; (3) improvement of rangelands for increased productivity and stability; (4) short- and long-term grazing impacts; and (5) influence of economic, social, and political constraints on management of range resources. Recommendations are made for some redirection of current research and for organizing, administering, and coordinating research activities.

About 70% of the western states consists of rangeland, where climate, soils, physiography, or economics restricts development for intensive agriculture. The characteristic vegetation is herbaceous or shrubby, often with a tree overstory. In the more moist portions of this region, rangeland overlaps with forest on 50 to 75 million acres, the exact acreage depending on criteria used to define *forest*. Here, competition for the various uses becomes intense and the value of forage for livestock is often secondary to other uses. Competing demands for land are fewer in more arid, nonforested portions of the region where weather is more variable, primary productivity lower and more erratic, and negative impacts from inappropriate land use more apparent. Since settlement by European man, nonforested rangelands have been valued most for livestock grazing—perhaps their highest economic use. Historically, improper grazing practices have caused public controversy on both forested and nonforested rangeland; and because of overgrazing, often combined with periods of drought, much deterioration of rangeland resources has resulted.

Significant improvement in range condition has been achieved since passage of the Taylor Grazing Act in 1934. Better range management, based on findings of range research and recognition of how multiple resources can be used more compatibly, has brought this about. The more moist, forested ranges have improved the most, but improvement on most rangelands has not achieved the expected stability and full productivity. The current rate of range improvement and the present status of range management do not reflect our current state of knowledge. Economic, social, and political constraints are often a deterrent to full application of what is presently known.

There are compelling reasons to use and care for western rangelands in a manner that insures their highest contribution to the public good. During the early 1960's, when increasing emphasis was placed on feedlot production of cattle and sheep, the contribution of the western range to livestock production diminished in importance in the eyes of agricultural policymakers. As a result, federal appropriations for the traditional areas in management and research on ranges have declined steadily over the past decade and a half. But the relative importance of range and pasture forages in livestock production increased sharply in 1972–1974 with worldwide food shortages and high prices of grain. This trend can be expected to continue; it would not be prudent to view the abundance of grain we have experienced in 1977 as more than a temporary pause in the continuing worldwide food crisis. Thus, the demand for U.S. grain in the international market and the importance of grain as foreign exchange to balance payments for needed imports of oil and other scarce items will grow. As a result, the price of grain will increase to levels where it is less feasible economically to finish livestock on high grain rations to the extent practiced in the past. It is now becoming more economical to substitute roughages for feed grains. Additionally, the present grading system of meat does not encourage feeding cattle to a high finish.

Rangelands always have been important for breeding herds that produce feeder lambs and calves for fattening and finishing on high grain rations. But with a higher cost of grain and the willingness of consumers to purchase meat with less finish in favor of lower prices, the demand for pasture and range forage will increase. In turn, this trend should enhance the value of western rangeland for the production of red meat. However, funding for traditional areas of management and research on rangeland has not caught up with the increasing demands for range resources.

Simultaneously, pressure by nonconsumptive users and formerly nontraditional users of forests and rangelands have been

---

This paper has been adapted from a report of a Western Regional Task Force, RP 2.06, titled, "Range, Wildlife Habitat and Fisheries: Research Needs and Priorities." It is a contribution of the Regional and National Agricultural Research Planning System. Although organized under the Forest Resource Research Program Group, the Task Force feels its recommendations are broad and apply to all western rangelands.

The authors are the Task Force Chairman and members of the range sub-task force. They are professor, School of Renewable Natural Resources, University of Arizona, Tucson 85721; professor, Department of Animal and Range Sciences, New Mexico State University, Las Cruces 88003; professor and head, Department of Range Science, Utah State University, Logan 84322; principal range ecologist, Intermountain Forest and Range Experiment Station, Logan, Utah 84321; and associate professor, Department of Range Science, Colorado State University, Fort Collins 80521.

The authors gratefully acknowledge the assistance of many colleagues who contributed with their ideas in discussions with the authors prior to convening the Task Force. Although this body of personal knowledge and current CRIS reports were important information sources to the range sub-task force, this paper represents the combined thinking of the authors and they accept full responsibility for its conclusions.

Manuscript received August 8, 1977.

increasing. Environmentalists and various recreationist groups are showing more concern for rangelands and are demanding better management and a voice in the decision-making process governing land use. The strength of these groups is manifested by the impact of recent court decisions favoring the plaintiffs. Examples are lawsuits of the Natural Resources Defense Council vs BLM contesting management of grazing lands and the Isaac Walton League vs Butz over timber harvesting practices on the National Forest System.

The situation is clear. Research and management of western rangelands have been inadequate and lacking in balance for too long; moreover, many resource values have been neglected in past research efforts. Thus, we find ourselves doing too much piecemeal management or management for one or a few traditional uses and essentially no management for other range resources. We also lack adequate data to deal with the current issue of the impact of range use on environmental values. There is a clear mandate for immediate solutions to these long-standing problems. But the proper solutions will come only with concerted and aggressive action by professionals trained in the sciences of natural resource management backed by vigorous and progressive research programs. Otherwise, the range will be managed by default and as dictated by emotion, politics, and irrelevant issues.

Criteria for Identifying Research Needs and Priorities

The primary mission for this sub-task force was to identify new and unresolved problems of rangelands. We comment only briefly on active research programs. Failure to enforce the strong aspects of current range research should not be interpreted as criticism of current research direction.

Our selection of range problems currently in need of research and the priorities of allocating research resources to the solution of these problems was based on the following criteria. Each criterion was given approximately equal weight in assignment of priorities.

1. Social Demands and Political Constraints

Much has happened in the past two decades, both nationally and internationally, to alter the needs and demands of society for the resources of western rangelands. The world demand for food and a diminishing amount of cropland in the United States have caused an increase in the importance of rangelands for production of red meat. The priority of land uses is changing. Citizen groups are vigorously expressing their concerns over land management and are now an important force in the decision-making process. New political constraints in response to changes in land-use and environmental concerns now make it necessary to evaluate the impact of management decisions on a variety of on- and off-site resources.

2. Present State of Knowledge

In this evaluation we have stressed research needs not adequately covered by existing research programs. If information needed for solution of a problem is already available, or is currently being sought by a substantial research effort, that problem was deleted or given low priority for initiation of new research. Task Force members feel many management problems remain unsolved for which there exists the basic knowledge necessary for solutions.

3. Probability of Success

Despite the substantial benefits that might result from solution of a particular resource problem, achievement of these benefits is unlikely if the probability for solution of the problem is poor. Research on some complex problems is not feasible because of obvious constraints on funding, scientific talent, or lack of suitable technology and methodology.

4. Likelihood of Extensive and Immediate Use of Results

Sufficient funds are never available to work on all problems needing research. Therefore, it is important to focus attention on research essential for the solution of major problems. But it is even more important that unresolvable constraints do not prevent application and extensive use of the new research findings once they are available.

5. Logical Sequence of Scientific Inquiry

The solution to many research problems logically will be found by a sequential pattern of research. In the selection of problems needing research, it is important to consider the orderly acquisition of information.

Research Needs

In our evaluation of new research needs on western rangelands, we have delineated five broad problem categories. We consider these the most pressing current problem areas. Each major problem is briefly described, the general research objectives related to the problem outlined, and approaches to problem solutions suggested.

Problem Category I: *Identification, Classification, and Inventory Range Ecosystems*

No system of range identification and classification is currently applicable and consistent over broad areas of the range region. Systems currently in use vary among geographic regions and agencies responsible for the lands. Some systems are based on an identification of both site potential and range condition, while others neglect an evaluation of site potential altogether. The resulting array of systems seriously restricts the usefulness and application of knowledge acquired through research and experience. Land managers need information on range condition in relation to capability of sites to produce forage and sustain various uses. An identification and classification system with regional or national acceptance and application is urgently needed. This would provide a common base upon which to inventory range sites, to evaluate range condition, to accumulate and build management experience, to assess environmental impacts, to extrapolate research results, and to plan management and improvements.

A uniform system for identification and classification of rangeland would provide a framework for all future research and management; it would be useful to land-use planners, managers, and researchers. The system should provide improved information for better allocation of resources among various users.

Objectives:

(1) Develop a uniform regional or national system for evaluating and classifying site potential, condition, and trend of range sites.

(2) Determine capabilities of classification units to support alternative land uses.

(3) Use output of (1) and (2) to allocate and integrate resource use and values for social needs.

(4) Determine the functional relationship between site potential and environmental factors.

Any applicable research approach should be pursued, including those successfully used in development of habitat-type classifications, the system for identification and classification of soils in the United States, and the soil-vegetation survey of California. Identification and classification of site potential presumably should be based on an integration of data for vegetation, soil, climate, geology, landform, topography, and other resources combined to yield a distinctive unit for each range site.

Problem Category II: ***Dynamics of Individual Plants and Plant Communities***

Rangeland ecosystems are extremely complex, exist over a broad range of environments, and are usually characterized by severe stresses. Physical stresses such as extremes of temperature, precipitation, soil moisture and nutrients, and biological stresses such as competition, disease, and herbivory all limit productivity. Moreover, ecosystems become vulnerable during periods of stress. Deterioration often ensues if stress conditions are not alleviated or allowed for through adjustments in management. Relatively little is known about ecosystem response to stress conditions and the mechanisms that produce ecosystem change. We often do not know how individual species respond to various stresses, especially grazing; hence, we are unable to explain community dynamics related to stress. Knowledge of basic physiologic and morphologic mechanisms of species causing changes in ecosystems is usually lacking. Managers need this knowledge to predict changes in plant communities and to devise prescriptions geared to specific stress conditions.

Objectives:

(1) Describe and explain mechanisms of interactions among plants, animals, soils, climate, and other environmental factors which lead to ecosystem changes.

(2) Determine requirements for key plant species and evaluate responses of individual plant species and communities to physical and biological factors contributing to stress.

Studies should be undertaken under both natural and controlled conditions; and they should be directed toward analysis of interactions affecting changes in plant species and communities. Answers to questions regarding basic mechanisms of ecosystem productivity and stability should be sought. Researchers should not overlook opportunities to adapt techniques and methodologies of other disciplies.

Problem Category III: ***Improvement of Rangelands for Increased Productivity and Stability***

Rangeland improvement practices developed in the past have emphasized response in forage production. Virtually no attention has been given to the effect of range improvements on resources other than forage. Little is known about the long-term effects of range manipulations on water quality, wildlife, and fish habitat, soil stability, and other resource values. By concentrating on short-term objectives in the past, we often achieved only temporary gains in forage production. There are few examples of long-term monitoring of plant community responses to specific vegetation manipulation practices. Failure to achieve and maintain stability in vegetation and soils following improvements has resulted from lack of understanding of ecosystem processes. We are unable to prescribe integrated management systems to fit conditions of the post-improvement system. Many examples of range improvement can be characterized as "piece-meal" efforts; they usually lack the necessary adjustment in grazing management practices to provide for maintenance of the altered ecosystems. The results have often been temporary gains with slow reversion to the pre-improvement condition.

This research is important for many reasons. Many western ranges are producing far below their inherent capability and are not contributing to their potential for satisfying human needs. We need to restore rangelands to resemble more nearly their potential ecological condition and thus achieve greater stability of all range resources. Restored ecological productivity will enhance most resource values, regardless of kind, and contribute greatly to red meat production with a low expenditure of fossil fuels.

Objectives:

(1) Evaluate impacts of range manipulation practices on major ecosystem components (i.e., producers, consumers, and decomposers and the abiotic environment).

(2) Develop integrated systems of management designed to maintain productivity and stability following manipulation.

(3) Improve plant materials for various resource needs.

(4) Develop improved methods for on-site water management.

(5) Develop potential sources of biological N-fixation and develop management techniques to utilize them.

We believe emphasis should be placed on using present knowledge of range improvement methods to develop integrated systems of range improvement. This should include the design of management prescriptions tailored to ecosystems improved by various manipulation practices. Consideration should be given to all ecosystem components (not just the forage resource) and the changes in components caused by manipulation. Ideally, in the development of integrated systems of improvement and management, consideration would be given to all applicable means of accommodating animal reductions caused by the nonuse or restricted use that may be required on the improved areas. This would provide incentive for improvement. In this regard, new research into development of supplements and nontraditional sources of livestock feeds (such as waste products for use in combination with range forage) is encouraged. Presumably, the team approach could be effectively used to solve these research problems.

Problem Category IV: ***Short- and Long-Term Grazing Impacts***

Grazing studies of the past have been stereotyped, largely oriented to single goals, and were evaluated primarily in terms of vegetational and livestock responses. The effects of grazing treatments on soil factors also have been measured to a limited extent. The scope of future grazing studies should be expanded to include impacts on other rangeland resources including wildlife. The Natural Resources Defense Council vs BLM law suit focused attention on grazing impacts on federal lands and serves to illustrate the paucity of data concerning the influence of grazing on resources other than vegetation and livestock.

Land managers must be in a position to predict the impact of grazing management decision on all components of forest and range ecosystems. We also must be able to differentiate among grazing stress and other physical and biological stresses in terms of their effects and interactions. In the past, it has been too easy to blame livestock grazing for range damage that in fact may have been caused partly or entirely by other stresses.

Objectives:

(1) Determine impacts of grazing management systems on recreation, wildlife, fisheries, nonpoint source pollution, and other watershed values as well as on livestock, individual plants, and plant communities.

Grazing studies usually require a great investment of facilities, personnel, and time, yet rather limited and unsatisfactory results often have been obtained in the past. Therefore, new grazing studies should be started only with considerable caution, firm commitments for long-term funding, and after very intensive planning. Grazing studies already underway should be examined for opportunities to include the objective delineated above. The studies should be based on growth requirements of key plants and include adequate replication. Researchers should seek imaginative and innovative alternatives to the traditional approach to grazing studies. One possible approach would be to combine grazing studies and demonstration projects which involve whole systems of management rather than the traditional single-goal grazing studies. Federal grazing allotments might be managed to collect data for this specific research objective and under an incentive system to achieve cooperation from permittees. Other approaches involving private livestock operators should be explored.

Problem Category V: *Influences of Economic, Social, and Political Constraints on Management of Range Resources*

The history of the American range, particularly those portions now administered by the federal government, discloses a sequence of events under which condition and stability of ranges have changed dramatically over time. Most of these lands have suffered from misuses. Although they have recovered to some extent, in most cases, they are still less productive and less stable than they once were. Land managers tend to point to so-called "overgrazing," often coupled with other physical and biological stresses, as the direct cause of destructive change. However, misuse or poor management can often be attributed indirectly to economic, social, and political pressures. The pressures which prevailed during the period of deterioration are in many instances still a factor in slow rates of range recover; they only differ in kind and magnitude. Restrictive and perhaps out-of-date policies seriously hamper our ability to put into practice range management knowledge already available. Laws and policies governing tenure status of grazing permits, grazing fee schedules and distribution of receipts from grazing on federal land, predator management, and many others seemingly have great influence on the incentive to invest on a short- or long-term basis in range management. The mood of federal agencies, the Administration, and Congress regarding the low priority of range resources for appropriations has seriously impaired improvement over the past 25 years, but especially in the last decade. Now, new forces, especially environmentalist groups and the courts, are influencing decisions regarding resource management. Researchers should examine the influence that these various forces have on range management both in the private and public sectors, and determine what changes should be made. Policymakers need to understand better the impact of their decisions which influence the rangeland user, consumer, and society at large.

Objectives:

(1) Determine the influence of government policies and legal, social, and economic constraints on the current and future status of range resources.

This research will involve unique combinations of talent. We visualize that individuals with backgrounds in range science, economics, political science, sociology, and law will need to collaborate in team efforts. The research may involve the analysis of data collected from case studies, development of models, and testing of alternative solutions.

Research Priorities

We partitioned problems identified above by two measures of priority: (1) a percentage priority, which suggests the relative distribution of research resources to the various problems, and (2) a ranking, which portrays the relative importance of each problem for research.

		Percent Priority	*Rank*
I.	Identification, Classification, and Inventory of Range Ecosystems	23	2
II.	Dynamics of Individual Plants and Plant Communities	27	1
III.	Improvement of Rangelands for Increased Productivity	22	3
IV.	Short- and Long-Term Grazing Impacts	16	4
V.	Influence of Economic, Social, and Political Constraints on Management of Range Resources	12	3

We believe the research problems ranked 1 and 2 above need immediate attention.

Evaluation of Current Research

We believe some lines of current research require redirection. For example, research on mechanical and herbicidal control of noxious plants has produced some effective methods, but new knowledge is still needed. Thus, some of this research should be continued to assure that methodology keeps pace with technology. However, unless additional funds can be obtained, we feel a large portion of noxious plant control research should be reoriented into learning how present methods of control can be utilized more effectively and integrated into systems of range improvement for specific problems. We favor expanding research on biological control of noxious plants. We also believe that research on plant control by use of fire should be continued.

Research on dates and rates of fertilizer application and on large empirical grazing system and grazing intensity studies should be greatly reduced or restructured; present knowledge in this area exceeds current application. Research on remote sensing of rangelands should be examined critically for usefulness of results obtained to date and those expected in the future. We also recommend abandonment of modelling research for academic purposes *per se*; goal-oriented modelling research has been productive and should be continued.

Recommendations for Organizing, Administering, and Coordinating Research Activities

Solutions to research problems are coming too slowly and are not meeting the need of resource managers. The difficulty, in part, lies in poor information transfer, failures in research planning and administration, and funding which is inadequate to cope with research needs. The downward trend over the past 10 years in funding for research and management of rangelands reflects the failure of government policymakers to recognize and understand the importance of rangelands. They fail to grasp the significance of the current and potential role of rangelands in red meat production, and that the western range is a region rich in many other resource values that must be maintained in the national interest. Western rangelands that have not regained an acceptable state of condition since earlier periods of misuse are susceptible to erosion and flooding. The damages incurred on-site, to adjacent dependent communities, and to downstream areas including municipalities are insidious and costly, but frequently overlooked. In the absence of adequate research and proper management, these damages will mount and resource values will decline. Policymakers need to recognize these social costs of failing to manage rangelands properly, and that these alone are justifiable reasons for maintaining a strong research and management program for western rangelands.

Even in the absence of new funds for research, some progress can be achieved by better utilization of current funds. In this regard, stringent peer review procedures must be employed when assessing research projects for initiation or continuation. Objectives for some currently funded projects appear too broad; they should be sufficiently narrow to reasonably assure accomplishment within the stated duration of the project. However, shortsighted emphasis on objectives that are too narrow often leads to disorderly and fragmented research efforts. This is particularly detrimental to the comprehensive approach often required for ecosystem research involving multiple and interdependent resource values. In such cases, specific short-term objectives must be logically structured into long-term projects which may be required for problem solution.

Long-term projects should not be discouraged; the nature of some problems makes them mandatory. Rather, they should be funded on a short-term basis (maximum of 5 years) but with provision for continuation if adequate progress is demonstrated. Unproductive projects should be promptly abandoned and funds reallocated. Rapid shifts in priorities for research from year to year to fit what is currently in vogue in terms of granting agencies rather than addressing the real research needs are upsetting to productive research efforts and should be discouraged. Flexibility in research programming may be prudent on a small scale to accommodate critical emerging problems. and to help maintain research budgets. However, rapid shifts are wholly unrealistic in terms of satisfying research needs, maintaining continuity in a research program, and solving resource management problems.

Successful planning and coordination of range research requires up-to-date information on research activities nationwide. The Current Research Information System (CRIS) was developed in 1966 to meet this need for agriculture and related sciences. CRIS is apparently not serving as a good clearinghouse for research in range management. We rated CRIS reports as poor in providing information on existing research projects, and the progress of research. Procedures for completing CRIS reports are often out-of-date, research objectives are stated too broadly, and reported progress is too incomplete to be useful.

In planning range research it is imperative that we remain continually aware of the many values inherent in rangelands. Forage is not the only product; rangelands also produce wildlife, water, recreational opportunities, minerals, sources of energy, and often wood fiber. All of these values are becoming increasingly important and more frequently in demand by society. Management aimed at one value will inevitably affect the other values. Research must be directed towards unravelling these interrelations and providing the basis for sound multiple-use management of rangelands.

Election Results

The 1,877 ballots cast in the 1977 election were counted on December 2. Selected by the membership to serve the Society during the next 3 years were:

President Elect .... **Daniel L. Merkel**
Directors .... **Charles M. Jarecki**
William Laycock

The new officers will be installed at the forthcoming Annual Meeting in San Antonio, at which time Bob Williamson, the current president elect, will succeed to the presidency. Daniel Merkel will serve as president in 1979, and the two newly elected directors will serve for the 3-year term 1978–1980.

Retiring next month from the Board of Directors are Past President Bob J. Ragsdale and Directors Lyman G. Linger and E. H. McIlvain. The very significant service rendered to the Society by these men is greatly appreciated.

Daniel Merkel is at present SCS range conservationist at the Rocky Mountain Forest and Range Experiment Station.

Charles Jarecki is a cattle and grain rancher in Polson, Mont., and William Laycock is range scientist with the Agricultural Research Service.

A committee of members of the Colorado Section counted the ballots. Ballots and tally sheets are kept on file in the Society office for 1 year.

Factors Affecting Forage Consumption by Cattle in Arizona Ponderosa Pine Forests

WARREN P. CLARY, PETER F. FFOLLIOTT, AND FREDERIC R. LARSON

Highlight: Forage consumption was significantly correlated with forage production and tree density, but not with steepness of slope, rockiness of soil, or distance from water. This suggests that good range management practices can effectively distribute livestock use.

Management practices designed to increase multiple use values of ponderosa pine forests are being tested in Arizona (Brown et al. 1974). Some of these practices will increase herbage production (Clary 1975), but there is a question as to what extent cattle will consume the additional forage. Factors related to forage consumption need to be identified in evaluating possible impacts of forest overstory manipulations on grazing values.

An earlier study on the Coconino Plateau in north-central Arizona found that distance to water, steepness and length of slope, access routes, forest density, season of use, range condition, floristic composition, and possibly rockiness influenced the manner in which pine-bunchgrass ranges were grazed (Glendening 1944). Slope steepness and distance upslope were important variables on uniform terrains in Montana, but the amount of rockiness was not (Mueggler 1965). In a Utah study, Cook (1966) concluded that although factors such as slope, distance to water below, percent palatable plants, and thickness of brush were correlated with utilization, no single factor could be used as a reliable index for predicting use. Young et al. (1967) found that forest density and understory vegetation influenced the distribution of forage utilization in northeastern Oregon.

This note summarizes the results of a study conducted to define factors related to forage consumption by cattle on the Beaver Creek Watershed in north-central Arizona, and to provide insight as to how timber management practices will likely affect utilization of the range resource.

The Study

The study was conducted on one-half of a summer-use cattle allotment (13,000 acres) on the Beaver Creek Watershed at the edge of the Coconino Plateau, near Flagstaff, Ariz. Yearling cattle grazed the allotment from June 1 to October 15 under a 4-unit rest-rotation system. Under this system, one range unit was rested for the entire grazing season while each of the other units were grazed 1.5 months per season. Range riding several days each week kept the animals well distributed.

Timber on this allotment is primarily ponderosa pine (*Pinus ponderosa*), with some intermingling Gambel oak (*Quercus gambelii*) and alligator juniper (*Juniperus deppeana*). Although the area had not been commercially logged for 15 years, 17% of it had been uniformly thinned 5 years prior to the study.

Principal grasses and grasslike plants include blue grama (*Bouteloua gracilis*), sedges (*Carex* spp.), spike muhly (*Muhlenbergia wrightii*), mutton bluegrass (*Poa fendleriana*), bottlebrush squirreltail (*Sitanion hystrix*), and black dropseed (*Sporobolus interruptus*). Principal forbs and half-shrubs are western ragweed (*Ambrosia psilostachya*), showy aster (*Aster communtatus*), and broom snakeweed (*Gutierrezia sarothrae*). Total herbage production in the year of the study averaged 200 lb/acre.

Elevations range from 6,600 to 7,400 ft. Soils are volcanic with considerable surface rockiness (Williams and Anderson 1967). Annual precipitation averages 20 to 25 inches.

Methods

Fifty-eight clusters of five 9.6-ft^2 plots were distributed on the study area by a stratified random procedure. Production of green forage was determined by weight estimate (Pechanec and Pickford 1937a). A sixth plot at each cluster was estimated, clipped, and oven-dried to provide a conversion factor to oven-dry weight. Utilization was determined by ocular estimates (Pechanec and Pickford 1937b).

Eight independent variables were empirically related to two dependent variables that expressed forage consumption and utilization. The dependent variables were: forage consumed (Y_1), in lb/acre (calculations included grasses, forbs, and half-shrubs); and utilization of perennial grasses (Y_2), in percent by weight. The independent variables were: perennial grass production (X_1); average preference rating of the grasses present on each sample area (X_2) (Clary and Pearson 1969); ponderosa pine density-basal area per acre (X_3); percent forest crown cover estimated from aerial photographs (X_4); percent slope at the sample area (X_5); distance from nearest water along probable travel route (X_6); elevation difference between the sample area and nearest water (X_7); and soil (X_8).

Multiple regression techniques were used in the analysis. Preliminary analysis suggested that forest variables be expressed both linearly and logarithmically.[1]

Authors are supervisory range scientist, Southern Forest Experiment Station, Alexandria, Louisiana; professor, University of Arizona, Tucson; and silviculturist, Rocky Mountain Forest and Range Experiment Station, Flagstaff, Ariz.

Manuscript received January 6, 1977.

[1] Basic data included values of O. Consequently (*1*) was added to all data values to allow logarithmic transformations.

Table 1. Characteristics of the regression variables.

Variables	Unit of measure	Minimum	Mean	Maximum
Dependent:				
Forage consumed	lb/acre	0	62	569
Utilization of perennial grasses	% of weight	0	34	84
Independent:				
Perennial grass production	lb/acre	0	147	675
Average preference rating of grasses at sample area	Numerical rating	16	21	30
Ponderosa pine density	Ft^2 basal area/acre	0	72	166
Forest crown cover	%	10	43	90
Slope at sample area	%	0	10	30
Distance from water	Ft	500	3,820	11,210
Elevation from water	Ft	0	113	432

Table 2. Correlations of selected variables with two expressions of forage use.

Dependent variable	Independent variable	Simple correlation coefficient	Multiple correlation coefficient
Y_1	X_1	+0.82	
	$\log(X_3 + 1)$	−0.78	
	$\log(X_4 + 1)$	−0.63	
	$\log(X_3 + 1), X_3$		0.85
	$\log(X_3 + 1), X_3, X_4$		0.89
	$\log(X_3 + 1), X_1, X_3$		0.89
Y_2	X_1	+0.34	
	X_5	−0.28	
	$\log(X_4 + 1)$	−0.45	

Dependent variables:
Y_1 = forage consumed (lb/acre).
Y_2 = utilization of perennial grasses (% by weight).
Independent variables:
X_1 = perennial grass production (lb/acre).
X_3 = ponderosa pine density (basal area/acre).
X_4 = forest crown cover (%).
X_5 = slope (%).

Results and Conclusions

Forage consumed by livestock averaged 62 lb/acre (Table 1); 97% of the consumption was perennial grasses. Forage consumption increased as grass production increased and forest density decreased. Two variables—perennial grass production and ponderosa pine density (logarithm of basal area)—accounted for 67 and 61%, respectively, of the variation in pounds of forage consumed (Table 2). Two combinations of variables accounted for over 75% of the variation in forage consumed.

Utilization of perennial grasses averaged 34% by weight. Although percent utilization of perennial grass was associated with perennial grass production, forest crown cover (logarithm), and percent slope, correlations were too low to be of practical value. Combining variables did not improve the correlations.

Most topography and distance variables related to forage consumption in other studies were not significant on Beaver Creek. Poss ible reasons were that the topography is more gentle on the Coconino Plateau than on many western mountain areas and that steep canyons were not sampled in this study, so only limited variability was present. Likewise, the amount of rockiness and average forage preference did not vary greatly.

However, Glendening's earlier (1944) study on similar areas of the Coconino Plateau described noticeable effects on grazing use by physical factors such as distance to water and steepness and length of slope. Why did this result not appear in the present study? In Glendening's study, the allotments ranged from 13,000 to 29,000 acres with no cross fences and a much lower density of developed watering places. The average distance to water in the present study was about one-half that found by Glendening. In addition, the allotment evaluated in the present study was cross-fenced into approximately 6,500-acre units and was under a management system which included rest-rotation and regular range riding. Under this management, cattle were well distributed, utilizing the forage resource wherever it occurred.

Variables most highly correlated with amount of forage consumed were those that would be influenced by timber management practices. Conversely, the factors unaffected by forest management practices, such as topography, surface characteristics, and distance to water, had little relation to forage consumption. These results suggest that, with *proper* livestock management, physical features on areas similar to the Beaver Creek Watershed will not severely restrict cattle movement except possibly on extreme slopes. Therefore, these features should not greatly hinder cattle from utilizing additional forage produced following reductions in forest overstory as a result of timber management practices.

Literature Cited

Brown, Harry E., Malchus B. Baker, Jr., James J. Rogers, and others. 1974. Opportunities for increasing water yields and other multile use values on ponderosa pine lands. U.S. Dep. Agr., Forest Serv. Res. Pap. RM-129, Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo. 36 p.

Clary, Warren P. 1975. Range Management and its ecological basis in the ponderosa pine type of Arzona: The status of our knowledge. U.S. Dep. Agr., Forest Serv. Res. Pap. RM-158, Rocky Mountain Forest and Range Exp. Sta. Fort Collins, Colo. 35 p.

Clary, Warren P., and Henry A. Pearson. 1969. Cattle preferences for forage spcies in northern Arizona. J. Range Manage. 22:114-116.

Cook, C. Wayne. 1966. Factors affecting utilization of mountain slopes by cattle. J. Range Manage. 19:200-204.

Glendening, George E. 1944. Some factors affecting cattle use of northern Arizona pine-bunchgrass ranges. U.S. Dep. Agr., Forest Serv., Southwest Forest and Range Exp. Sta., Tucson, Ariz., Res. Rep. 6. 9 p.

Mueggler, Walter F. 1965. Cattle distribution on steep slopes. J. Range Manage. 18:255-257.

Pechanec, Joseph F., and G. D. Pickford. 1937a. A weight estimate method for determination of range or pasture production. J. Amer. Soc. Agron. 29:894-904.

Pechanec, Joseph F., and G. D. Pickford. 1937b. A comparison of some methods of determining percentage utilization of range grasses. J. Agr. Res. 54:753-765.

Williams, John A., and Truman C. Anderson, Jr. 1967. Soil survey of Beaver Creek area, Arizona. U.S. Dep. Agr., Forest Serv. and Soil Conserv. Serv., in cooperation with Arizona Agr. Exp. Sta. U.S. G.P.O. 75 p.

Young, J. A., J. A. B. McArthur, and D. W. Hedrick. 1967. Forage utilization in a mixed-coniferous forest of northeastern Oregon. J. Forest 65:391-393.

A Comparison of Esophageal Fistula and Fecal Material to Determine Steer Diets

M. VAVRA, R. W. RICE, AND R. M. HANSEN

Highlight: Cattle diets were determined by esophageal fistula and fecal material collection procedures from yearling cattle grazing shortgrass range in northeastern Colorado. Diets were quantified by microhistological procedures from samples collected in June, July, August, and December of 1969; and June, July, and August of 1970. Total grasses occurred significantly less in esophageal samples, while total forbs were significantly lower in fecal samples. Individual grass species did not appear to follow a set pattern of variation from esophageal to fecal sampling; some were greater in fecal samples while others were greater in fistula samples. Forbs occurred at greater percentages in fistula samples, with the exception of burning bush (*Kochia scoparia*) in 1969. Correlation and regression analysis revealed little relationship in botanical composition determined on fecal and esophageal samples. However, an importance value ranking revealed esophageal and fecal samples were similar when individual species were ranked from the most common to the least common in the diet.

Microhistological examination of fecal material or esophageal fistula extrusa are two common techniques for estimating the botanical composition of the diets of herbivores. Esophageal fistulation has been primarily used with domestic animals (Vavra et al. 1973) while fecal examination has been used with wildlife (Hansen et al. 1975) and where several herbivores graze in common (Hansen et al. 1973). Reviews of each method exist (esophageal fistulation, Van Dyne and Torrell 1964; fecal collection, Ward 1970). The microhistological examination method of Sparks and Malechek (1968) appears to be the most common technique used in recent years and applies to material collected by both procedures. Anthony and Smith (1974) compared dietary residues collected from the rumen and feces and raised several questions about the fecal analysis technique. Higher estimates of evergreen species and lower estimates of some forbs resulted from fecal analysis as compared to rumen analysis. Also, the authors stated that quantification of food items such as flowers, tubers or acorns would not be possible with fecal analysis. Use of the esophageal fistula has been restricted to domestic animals because a tractable animal amenable to frequent handling is essential. Additional problems include: (1) associated surgery, McManus (1961); (2) incomplete collection, Campbell et al. (1968); (3) fistulated animals can only be grazed for short time periods, Van Dyne and Torrell (1964).

This study was conducted to determine if diet determinations differed when esophageal fistula extrusa or fecal material was used as the sampling medium. Additionally, simple correlations and regressions were calculated to determine: (1) the relationship between data collected by esophageal fistula and fecal material and (2) regression equations to be used to adjust fecal data should differences exist.

Materials and Methods

The study was conducted on the Pawnee Site of the U.S. International Biological Program Grassland Biome. This area was located on the Central Plains Experimental Range, approximately 57 km north of Greeley, Colo. The range is administered by the USDA/Agricultural Research Service. A more complete description of the pastures, area and cattle grazing formulae can be found in Vavra et al. (1973).

Samples were collected on heavy, moderate, and light grazing intensities in June, July, and August of 1969; and on heavy and light intensities in December of 1969 and during June, July, and August of 1970. Four animals were used per pasture treatment during both years. Esophageal and fecal samples came from the same animals. Fecal material used was from a 24-hour total collection, which began directly after the esophageal fistula collection. Samples were then paired by animal and by sample day for analysis.

Microhistological examination of material followed the method of Sparks and Malechek (1968). Forty microscope fields were examined at 100× for each sample. Frequency of occurrence was recorded and converted to density; then relative density was calculated as an estimate of percent composition by dry weight.

Statistical analysis followed Steel and Torrie (1960). Selected plant species which made up the major diet constituents (>5% of total diet) and plant groupings of warm-season grasses, cool-season grasses, total grasses, total forbs, and total shrubs were compared between sampling techniques. The least squares analysis of variance was used to determine significant differences due to technique. Main effects (technique, pasture, collection month) and first order interactions were tested. Data were pooled by year for the analysis to remove any variability due to year. Simple correlation and regression analyses were run on data pooled by month, by year, and over the entire study. All references to statistical significance imply differences at the 0.05 level of probability.

Authors are associate professor, Oregon State University, Eastern Oregon Agricultural Research Center, Union 97883; department head, Division of Animal Science, University of Arizona, Tucson 85721; and professor, Department of Range Science, Colorado State University, Fort Collins 80523.

This paper reports on work supported in part by National Science Foundation Grants GB-7824 and GB-41233X to the Grassland Biome, U.S. International Biological Program for "Analysis, Structure, Function and Utilization of Grassland Ecosystems." The study area is administered by the U.S. Dep. Agr., Agricultural Research Service at the Central Plains Experimental Range, Nunn, Colo.

Manuscript received May 3, 1977.

Table 1. Mean percent weight of diet constituents of cattle.

	1969		1970	
	Esoph	Fecal	Esoph	Fecal
Western wheatgrass (*Agropyron smithii*) Agsm	10	9	6	7
Red threeawn (*Aristida longiseta*) Arlo	4[a]	8[b]	6	5
Blue grama (*Bouteloua gracilis*) Bogr	29[a]	41[b]	45[a]	73[b]
Buffalograss (*Buchloe dactyloides*) Buda	4[a]	1[b]	1	< 1
Sun sedge (*Carex heliophila*) Cahe	6	8	12[a]	7[b]
Sand dropseed (*Sporobolus cryptandrus*) Spcr	1[a]	< 1[b]	3	2
Needleandthread (*Stipa comata*) Stco	1	1	8[a]	2[b]
Total warm season grasses	40[a]	49[b]	57[a]	81[b]
Total cool season grasses	16	17	21[a]	14[b]
Total grasses	55[a]	67[b]	74[a]	92[b]
Astragalus sp. Astr	1	< 1	3	1
Spreading wildbuckwheat (*Eriogonum effusum*) Eref	5[a]	11[b]	< 1	< 1
Burning bush (*Kochia scoparia*) Kosc	2[a]	6[b]	2	< 1
Scarlet globemallow (*Sphaeralcea coccinea*) Spco	12	11	6[a]	2[b]
Evening primrose (*Oenothera coronopifolia*) Oeco	3	4	2	2
Spreading fleabane (*Erigeron divergens*) Erdi	0	0	4	< 1
Wavyleaf thistle (*Cirsium undulatum*) Ciun	5	3	1	< 1
Slimflower scrufpea (*Psoralea tenuiflora*) Pste	1	1	4[a]	< 1[b]
Total forbs	37[a]	29[b]	23[a]	7[b]
Fringed sagewort (*Artemisia frigida*) Arfr	6	5	2	< 1
Total shrubs	7	5	1[a]	< 1[b]

[a, b] Means with different superscripts within year and between technique differ significantly at the .05 level.

Additionally, individual species were ranked as to "importance value": sequentially from greatest to least amount in the diet for the two techniques. Importance value was a ranking used to compare the occurrence of plant species in the diet as estimated by each method. "Important" dietary constituents would be those that occurred most often in the diet. Scientific names of all plants mentioned in the text are listed in Table 1.

Results

The percent composition by weight of selected dietary constituents as determined by the two methods is presented in Table 1. Of individual grass species, significant differences due to technique occurred for red threeawn, blue grama, buffalograss, and sand dropseed during 1969 and blue grama, sun sedge, and needleandthread during 1970. Definite trends within species between techniques for the two study years were not evident. More western wheatgrass occurred in esophageal samples than in fecal samples in 1969, while the reverse was true in 1970. More red threeawn and sun sedge occurred in esophageal samples in 1969 but again the reverse was true in 1970. Esophageal samples contained more blue grama and needleandthread during both years. The lack of a definite trend among individual species was responsible for the lack of year to year trend when the grasses were pooled into cool- or warm-season categories. Significantly less total grasses occurred in esophageal samples during both years of the study.

With the exception of burning bush in 1969, greater percentages of individual forb species were present in esophageal than in fecal samples. Differences were significant in 1969 for spreading wildbuckwheat and in 1970 for scarlet globemallow and slimflower scurfpea. Significantly less total forbs occurred in fecal samples during both years. Shrubs (primarily fringed sagewort) made up a small portion of the diets but appeared in greater percentages in esophageal samples.

Generally, correlation and regression coefficients were quite low (rarely exceeding $r = 0.50$) regardless of how the data were pooled. An example of a typical esophageal-fecal relationship is presented in Figure 1.

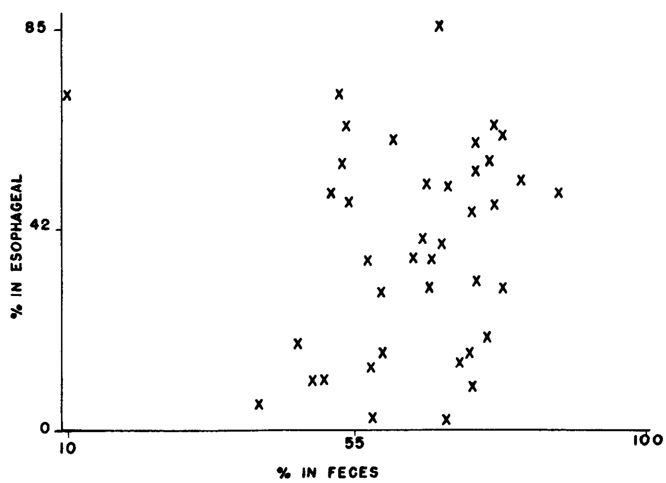


Fig. 1. *The relationship between feces and esophageal fistula extrusa analyses for the determination of percent blue grama in steer diets.*

Individual species were ranked from the most common to the least common in the diet on a percent weight basis (Table 2). In both years four of the top five ranked plants were common to both sampling techniques. The five most common species in the diets made up 64.6% and 75.6% in 1969; and 76.4% and 93.5% of the diets in 1970 for esophageal and fecal sampling, respectively. The average change in rank (ACR) of grasses and forbs between sampling techniques and within a year was calculated by dividing the total number of changes by the total number of species represented. Shrub species were not considered. This calculation should give an indication of the degree of variation of each class of plants in the diets. Grasses had ACR values of 1 and 2 for 1969 and 1970, respectively. Forbs were more variable having ACR values of 2 and 2.5 for the respective sampling years.

Discussion

When one first considers the examination of plant fragments in feces to determine the botanical composition of herbivore

Table 2. Importance ranking of individual plant species occurring in cattle diets as determined by examination of esophageal fistula extrusa and feces.

Rank	1969		1070	
	Esoph	Fecal	Esoph	Fecal
1	Bogr	Bogr	Bogr	Bogr
2	Spco	Spco	Cahe	Agsm
3	Agsm	Agsm	Stco	Cahe
4	Arfr	Arlo	Agsm	Arlo
5	Cahe	Cahe	Spco	Spco
6	Eref	Kosc	Arlo	Spcr
7	Arlo	Arfr	Pste	Stco
8	Ciun	Oeco	Erdi	Oeco
9	Buda	Ciun	Spcr	Astr
10	Oeco	Eref	Astr	Kosc
11	Kosc	Stco	Arfr	Arfr
12	Stco	Buda	Oeco	Pste
13	Pste	Pste	Kosc	Erdi
14	Astr	Astr	Buda	Ciun
15	Spcr	Spcr	Ciun	Eref
16	Erdi	Erdi	Eref	Buda

diets, the obvious shortcoming is the differential digestion of various plant species in the diet. However, data are available in the literature to refute this. Regal (1960) stated that cutinized epidermis passes through the animal's digestive tract undigested. Hanna et al. (1973) reported that the outer portion of the epidermis was more resistant to digestion than other cellular structures because it is cutinized and lignified. Chatterton and Powell (1974) found different rates of digestion of various cellular constituents of orchardgrass (*Dactylis glomerata*); however, the cuticle (cutinized layer over the epidermis) remained intact and was not significantly attacked by microbes.

Wallace and Van Dyne (1970) reviewed lignin digestibility values (lignin is an important constituent of the epidermis that prevents digestion, see above) and found a range of −40 to +64%. Data collected by Wallace and Van Dyne (1970) on lignin digestibility varied from 4% to 46% depending on season of year and plant maturity. The greater the digestibility of lignin the smaller the chance of a discernible epidermal fragment passing through the digestive tract of a ruminant, and the smaller the chance of identification as a diet constituent. Our data indicate that cuticular resistance to digestion is greater in grasses than in forbs because total grasses in esophageal samples were always significantly less than in feces and forbs were significantly higher in esophageal samples than in feces.

Fecal samples in this study were collected for a 24-hour period just after collection of esophageal fistula samples. Diet composition of the fistula sample could not be duplicated in the feces. Fistula samples represent only a portion (1 or 2 hours) of the total grazing period. Actual percentages of plant species in the diet of an animal probably vary with time of day and with exact location of the animal on the pasture (where vegetation exists according to soil type, aspect, etc.).

The forbs and shrubs reported by Taylor (1972) to be highly digestible in the study area were the same ones which Dearden (1973) reported to be less discernible to microscope technicians after digestion than before digestion. Cell wall thickness is the characteristic which probably influences the identification of fragments to a greater extent than any other (Dearden et al. 1972). Estimated percentages in diets are interdependent variables and whenever a technician overestimates or underestimates one plant species the percentages of other species in the sample are adjusted upward or downward by an equivalent amount. Although statistical significance can be demonstrated for the various sources of errors in the microscopic technique of Sparks and Malechek (1968) the importance of plants making up the major portion of a mean diet are in the same general order (Dearden et al. 1975).

If the esophageal fistula method is considered the standard as it often has been (Laycock et al. 1972), then it should be used where resources warrant. However, fecal analysis can be used where the degree of accuracy needed is less, where rare or endangered animal species are studied, where unmanageable animals are studied, or where several herbivores occupy the same range. Actual percentages of a species in the diet are probably less important than the relative value (importance value) of that species. An importance value ranking should identify the most important diet constituents and therefore fulfill the need of most diet investigations.

Literature Cited

Anthony, R. G., and N. S. Smith. 1974. Comparison of rumen and fecal analysis to describe deer diets. J. Wildl. Manage. 38:535-540.

Campbell, C. M., K. S. Eng, Jr., A. B. Nelson, and L. S. Pope. 1968. Use of esophageal fistula in diet sampling with beef cattle. J. Anim. Sci. 27: 231-233.

Chatterton, N. J., and J. B. Powell. 1974. Stomatal guard cell integrity and resistance to rumen fluid digestion. Agron. J. 66:812-814.

Dearden, B. L. 1973. Analysis of the discernibility of plant species during digestion. PhD Thesis. Colorado State Univ., Fort Collins. 93 p.

Dearden, B. L., R. M. Hansen, and R. E. Pegau. 1972. Plant fragment discernibility in caribou rumens. Proc. 1st Int. Reindeer and Caribou Symp. Biol. Pap. Univ. Alaska Spec. Rep. No. 1:257-277.

Dearden, B. L., R. E. Pegau, and R. M. Hansen. 1975. Precision of microhistological estimates of ruminant food habits. J. Wildl. Manage. 39:402-407.

Hanna, W. W., W. G. Monson, and G. W. Burton. 1973. Histological examination of fresh forage leaves after in vitro digestion. Crop. Sci. 13:98.

Hansen, R. M., and B. L. Dearden. 1975. Winter foods of mule deer in Piceance Basin. J. Range Manage. 28:298-300.

Hansen, R. M., D. G. Peden, and R. W. Rice. 1973. Discerned fragments in feces indicates diet overlap. J. Range Manage. 26:103.

Laycock, W. A., H. Buchanan, and W. C. Krueger. 1972. Three methods for determining diet, utilization and trampling damage on sheep ranges. J. Range Manage. 25:352-356.

McManus, W. R. 1961. Properties of roughage feedstuffs collected from esophageal fistulas. Aust. J. Exp. Agr. and Anim. Husb. 1:159.

Regal, V. 1960. The evaluation of the quality of pasture grasses by the microscopic method. Proc. VIII Int. Grass. Cong. Paper 4B/2. 3 p.

Sparks, D. R., and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscopic technique. J. Range Manage. 21:264.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481 p.

Taylor, J. T. 1972. Nutritive value of Colorado range plants. PhD Thesis. Colorado State Univ., Fort Collins. 105 p.

Van Dyne, B. M., and D. T. Torell. 1964. Development and use of the esophageal fistula: A review. J. Range Manage. 17:7.

Vavra, M., R. W. Rice, and R. E. Bement. 1973. Chemical composition of the diet, intake and gain of yearling cattle on different grazing intensities. J. Anim. Sci. 36:411-414.

Wallace, J. D., and G. M. Van Dyne. 1970. Precision of indirect methods for estimating digestibility of forage consumed by grazing cattle. J. Range Manage. 23:424.

Ward, A. 1970. Stomach content and fecal analysis: methods of forage identification. Range and Wildl. Habitat Evaluation. 146 p.

Intensive-Early Stocking and Season-Long Stocking of Kansas Flint Hills Range

ED F. SMITH AND CLENTON E. OWENSBY

Highlight: Native Flint Hills bluestem range was stocked at twice the normal rate, 1.7 acres per steer. Daily steer gain and gain per acre were greater for IES. Late summer gain by steers on SLS was less than the gain during early summer on either treatment. For the complete trial, steers under SLS gained more per head, 210 lb compared with 141 lb, due to the 154-day grazing period compared with 75 for IES. Although more grass had been removed by mid summer with IES, by the end of the summer grass yield was higher on IES than on the pasture stocked only half as heavily but full season. Percent big bluestem increased under IES and decreased with SLS. Percent Kentucky bluegrass decreased under IES and increased with SLS, but that may have resulted from more complete burning under IES.

Steer gains during the latter half of the growing season on Kansas Flint Hills range are barely one-half those of the first half of the season (Anderson et al. 1970), because forage quality declines with grass maturation and translocation of nutrients to reserve pools. Reduced intake due to high temperatures may also contribute to slower gains during late summer (Dwyer 1961). Stocking rate effects also become manifest during late summer. Launchbaugh (1957) indicated steer gains were comparable with light, moderate, and heavy use during the early season, but decreased in late summer as stocking rate increased. Apparently, selectivity of animals for forage quality does not become critical until late in the growing season when nutritive value is low, which suggests an increase in forage-use-efficiency by intensive grazing in the early growing season when nutritive value is highest. The advantage would give increased gains per acre without sacrificing gain per animal.

Klipple (1964) tested early-season intensive grazing, late-season intensive grazing, and season-long grazing with steers in eastern Colorado. Monthly cattle gains during the early growing season on pastures stocked season-long were the same as on early-intensive-use pastures; yearly gain/acre on the early-intensive-use pastures was higher than on season-long stocked pastures. Late-season-intensive-use produced less gain per head than season-long or early-intensive-use. Forage production was lower on early- and late-season intensive use pastures than on pastures used all season.

We studied the effects of intensive-early stocking (IES) and season-long stocking (SLS) on steer gain, herbage production, botanical census, and grazing distribution.

Materials and Methods

The study area was two 60-acre pastures in the Flint Hills region of the True Prairie, 5 miles northwest of Manhattan, Kans. Vegetation was primarily warm-season perennial grasses; big bluestem (*Andropogon gerardi* Vitman) and little bluestem (*A. scoparius* Michx.) were the major dominants. Indiangrass [*Sorghastrum nutans* (L.) Nash] and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] were secondary. Kentucky bluegrass (*Poa pratensis* L.) was sparsely present. Numerous forbs, woody plants, and other grasses constituted the remainder. Range sites were described by Anderson and Fly (1955). The pastures were burned during late April each year.

Cattle

Each year on May 2 from 1972 through 1975, the pastures were stocked with either Angus, Hereford, or Angus × Hereford cross yearling steers averaging 451 lb and approximately 14 months old. Steers were identified and individually weighed the first day of each month and July 15. Weights for 1973 are missing. From the afternoon of the day before being weighed, they were confined in pens without feed or water. One pasture allowed 1.7 acres per steer from May 2 to July 15 (75 days). Steers on the other pasture were allowed 3.4 acres per steer from May 2 to October 3 (154 days).

Herbage Production

Herbage remaining after grazing was estimated by clipping ten 1/100,000th-acre plots in loamy upland, breaks, and clay upland range sites July 16, 1972–74. At the end of the growing season herbage was clipped from 10 caged and 10 uncaged areas in the same range sites. The cage was moved each year. Herbage was separated into grasses and forb-brush components and dried to moisture-free. During 1975, method of yield estimation was changed and those data are not presented.

Botanical Census

Plant census was from modified step-point samples (Owensby 1973). Within each pasture 1,500 points were read along a predetermined grid. Each set of 1,500 points was partitioned randomly into three subsets for statistical analysis. Basal cover and botanical composition estimates were determined in June from 1971 to 1975. The 1971 plant census data were used as a base, and analysis of variance was calculated on the change in basal cover and botanical composition.

Authors are research animal scientist, Department of Animal Science and Industry; and research range scientist, Department of Agronomy, Kansas State Universty, Manhattan 66506.

The report is Contribution No. 522-T, Department of Animal Science and Industry and Cont. No. 1614-T, Department of Agronomy, KAES, Kansas State University, Manhattan.

Table 1. **Perennial grass yields (lb dry matter/acre) at growing season's end by year and range site from caged areas on season-long and intensive-early stocked pastures.**

	Years			Range sites		
Grazing system	1972	1973	1974	Loamy upland	Breaks	Clay upland
Season-long	2146[1]	2538	2248	2422[1]	2192	2268
Intensive-early	2278	2493	2729	2863	2435	2202

[1] LSD.05 = 282.

Grazing Distribution Surveys

Grazing use was estimated on July 16 and in late November to determine grazing distribution by the Deming method (Deming 1939). Grazing use was estimated ocularly along a line grid throughout each pasture and rated on a scale of 1 to 5 (1 = light use, 5 = heavy use).

Statistical Analyses

Analyses of variance were calculated using subsamples as an estimate of error variance, since the experiment was not replicated. Though not considered strictly statistically valid, the analyses aid in interpretation.

Results and Discussion

Herbage Production

Perennial Grass Component

Perennial grass yield from grazed areas July 16 was greater ($P<.05$) on the SLS pasture (1,301 lb dry matter/acre) than on the IES pasture (872 lb dry matter/acre). The lesser perennial grass amount remaining on the IES pasture at mid-season reflected the higher stocking rate. Although the stocking rate on the IES pasture was two times that of the SLS pasture, perennial grass yields on the IES pasture were 67% of the perennial grass yields on the SLS pasture. Since twice as much grazing use was expected, there appeared to be added growth early in the season on the IES pasture compared with the SLS.

At growing season's end, the perennial grass component after grazing was greater ($P<.05$) on the IES pasture than on the SLS one (1,610 to 1,334 lb dry matter/acre). The rest from July 15 to October 3 gave plants time to produce enough photosynthetic tissue to restore vigor on the IES pasture.

Perennial grass yields for SLS and IES pastures from areas caged to prevent livestock grazing were similar for the first 2 years, but the third year the IES pasture produced more grass than the SLS pasture (Table 1). The higher perennial grass production came from loamy upland and breaks range sites. Greater productivity on the pasture may have been due to an increased vigor of the dominant grasses from late-season rest from grazing.

Forb-brush Component

At mid-season, forb-brush amounts were greater from grazed areas on the SLS pasture than from the IES pasture, except in 1974, when the IES pasture yielded more forbs and brush (Table 2). Forb-brush yields were greater on clay upland and break sites than on loamy upland site. Apparently, IES resulted in greater use of that yield component in 1972 and 1973.

Table 2. **Forb-brush amounts remaining (lb dry matter/acre) on July 16 by year and range site from grazed areas under season-long and intensive-early stocking.**

	Year				
Grazing system	1972	1973	1974	Range site	Amounts remaining
Season-long	220[1]	472	236	Loamy upland	176[1]
Intensive-early	123	167	336	Breaks	293
				Clay upland	307

[1] LSD.05 = 83.
[2] LSD.05 115.

Forb-brush amounts on grazed areas by growing season's end were greater for the SLS pasture than for the IES pasture in 1972, but did not differ in 1973 and 1974 (Table 3). On caged areas, forb-brush amounts were higher in 1972 and 1973 at growing season's end from SLS than for the IES pasture, but yields did not differ in 1974.

Table 3. **Forb-brush amounts (lb dry matter/acre) remaining on grazed and caged areas following the growing season on season-long and intensive-early stocked pastures (avg. of all range sites).**

	Grazed			Caged		
Grazing system	1972	1973	1974	1972	1973	1974
Season-long	306[1]	293	280	431[2]	569	414
Intensive-early	136	269	371	212	319	524

[1] LSD.10 = 135.
[2] LSD.05 = 217.

Plant Census

Botanical composition and basal cover between 1971 and 1975 were used to detect change of some important components of the Flint Hills plant communities under season-long and intensive-early stocking. Harmful or beneficial effects of the two grazing systems are evaluated by the magnitude of the change.

Basal Cover

Big bluestem was the only major dominant which changed its basal cover differentially with respect to stocking system, increasing more under IES than SLS on all range sites (Table 4).

Table 4. **Basal cover (%) of big bluestem and perennial forbs under season-long and intensive-early stocking (avg. of three range sites).**

	Grazing system	
	Season-long	Intensive-early
Big bluestem		
1971	1.10	1.31
1975	1.66	2.71
Change	+0.56	+1.40
LSD.05 = 0.62[1]		
Perennial forbs		
1971	0.21	0.23
1975	0.89	0.50
Change	+0.68	+0.27
LSD.05 = 0.27[1]		

[1] Least significant differences ($P<.05$) refer only to change in basal cover.

Kentucky bluegrass basal cover increased more from 1971 to 1975 on loamy upland and clay upland range sites under SLS than IES (Table 5). Since regrowth following livestock removal on the IES pasture provides a continuous fuel source, burning was more complete on the IES pasture than the SLS one and resulted in a greater mortality of Kentucky bluegrass on the IES pasture. Grass-like plants, largely cool-season species, behaved similarly to Kentucky bluegrass, increasing in basal cover under SLS and remaining essentially stable under IES (Table 5). Perennial forb basal cover increased under both IES and SLS, but the increase was greater under SLS on all range sites (Table 4). Apparently, increased forb grazing early in the growing season or the more complete burn with IES than with SLS resulted in the differential response.

Table 5. Basal cover (%) of Kentucky bluegrass and grass-like plants in pastures under season-long and intensive-early stocking on indicated range sites.

Grazing system	Range site		
	Loamy upland	Breaks	Clay upland
Kentucky bluegrass			
Season-long			
1971	0.18	0.12	0.37
1975	1.01	0.17	1.10
Change	+0.83	+0.05	+1.47
Intensive-early			
1971	0.60	0.20	0.76
1975	0.86	0.14	0.64
Change	+0.26	−0.06	−0.12
$LSD_{.05}$ = 0.49[1]			
Grass-like plants			
Season-long			
1971	0.21	0.29	0.14
1975	0.93	0.55	0.41
Change	+0.72	+0.26	+0.27
Intensive-early			
1971	0.32	0.27	0.16
1975	0.35	0.16	0.43
Change	+0.03	−0.11	+0.27
$LSD_{.05}$ = 0.36[1]			

[1] Least significant difference ($P<.05$) refer only to change in basal cover.

Overall, IES was more beneficial to the plant community than was SLS, favoring big bluestem and deterring undesirable components such as Kentucky bluegrass, grass-like plants, and perennial forbs.

Percent Composition.

Big bluestem % composition increased under IES over the 4-year period and decreased under SLS (Table 6). The only other major dominant to change in % composition differentially with respect to grazing system was little bluestem, which decreased more under SLS than under IES.

On breaks range sites, sideoats grama % composition increased more under IES than under SLS (Table 7). That was likely due to the increased grazing pressure on breaks sites with IES compared to SLS. Kentucky bluegrass % composition increased on loamy upland and clay upland range sites in the SLS pasture and decreased on the IES (Table 7). Again the more complete burn on the IES pasture probably accounted for the differential response. The breaks range site was lightly grazed under SLS and burned completely, accounting for similar trends in % composition under both systems. Grass-like plants responded similarly to Kentucky bluegrass in % composition changes (Table 7).

Table 6. Composition (% total basal cover) of big and little bluestem under season-long and intensive-early stocking (avg. of three range sites).

	Grazing system	
	Season-long	Intensive-early
Big bluestem		
1971	28.9	26.0
1975	21.7	30.8
Change	−7.6	+4.8
$LSD_{.05}$ 3.8[1]		
Little bluestem		
1971	15.5	11.9
1975	11.0	10.8
Change	−4.5	−1.1
$LSD_{.05}$ = 2.7[1]		

[1] Least significant differences ($P<.05$) refer only to change in percent composition.

Table 7. Composition (% total basal cover) of indicated species under season-long and intensive-early stocking for indicated range sites.

Grazing system	Range site		
	Loamy upland	Breaks	Clay upland
Sideoats grama			
Season-long			
1971	8.0	10.0	7.3
1975	7.1	12.9	11.2
Change	−0.9	+2.9	+3.9
Intensive-early			
1971	3.7	8.6	9.0
1975	6.4	16.7	11.6
Change	+2.7	+8.1	+2.6
$LSD_{.05}$ = 4.0[1]			
Kentucky bluegrass			
Season-long			
1971	4.5	2.8	13.1
1975	12.5	2.0	25.9
Change	+8.0	−0.8	+12.8
Intensive-early			
1971	16.1	3.6	14.3
1975	10.6	1.7	5.7
Change	−5.5	−1.9	−8.6
$LSD_{.05}$ = 3.3[1]			
Grass-like plants			
Season-long			
1971	5.3	6.4	5.2
1975	11.4	6.7	4.1
Change	+6.1	+0.3	−1.1
Intensive-early			
1971	8.7	4.9	3.0
1975	4.5	2.0	4.2
Change	−4.2	−2.9	+1.2
$LSD_{.05}$ = 3.4[1]			
Perennial forbs			
Season-long			
1971	4.1	5.1	8.5
1975	13.3	9.4	11.4
Change	+9.2	+4.3	+2.9
Intensive-early			
1971	6.9	3.9	4.3
1975	5.8	5.7	5.0
Change	−1.1	+1.8	+0.7
$LSD_{.05}$ 5.4[1]			

[1] Least significant differences ($P<.05$) refer only to change in percent composition.

During the 4-year period SLS resulted in an increase in perennial forb % composition, while under IES perennial forb % composition remained relatively stable.

IES favored maintenance of a desirable plant community, but SLS resulted in a slow deterioration of % composition of the desirable species and an increase in undesirable components.

Grazing Distribution

IES resulted in more uniform grazing of all range sites than SLS did. Grazing distribution patterns were essentially the same throughout the 4 years.

By mid-July all areas of the IES pasture had received at least moderate use, with approximately 10% of the total area used moderately heavy. Moderately heavy use was concentrated on an upland ridge along the east side of the unit (Fig. 1A). Two small areas, one near water and another near salt, also had received moderately heavy use. Grazing distribution over all range sites was uniform.

In mid-July approximately 60% of the total area of the SLS pasture had received moderately light use, 35% moderate use, and 5% moderately heavy use (Fig. 1B). Uneven grazing distribution was associated with range sites. Break areas and outfacing slopes away from water were grazed least. Similar range site distribution on the IES pasture did not result in uneven grazing.

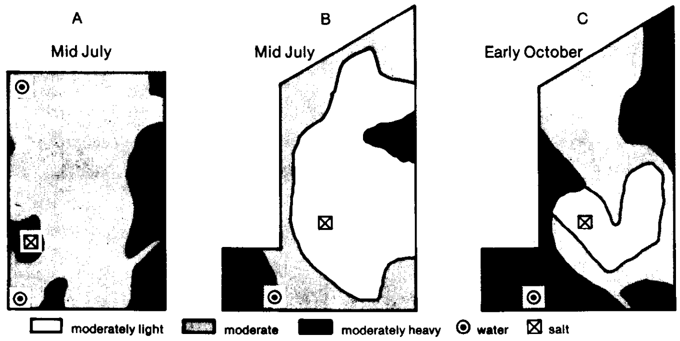


Fig. 1. *Grazing patterns of pastures studied: (A) in mid-July, pasture stocked intensive-early; (B) mid-July, pasture stocked season-long; (C) early (October, pasture stocked season-long.*

In early October after cattle removal from the SLS, grazing was moderately heavy over 40% of the pasture, moderate 40%; and moderately light 20% (Fig. 1C). Again, range site distribution appeared to be the primary determinant for grazing intensity. Usually breaks range sites received moderately light grazing, while level loamy upland and clay upland sites were moderately to moderately heavily grazed.

Cattle Gain

From May 2 to July 15, the daily gain of steers under IES was similar to those under SLS in 1972 and 1974 and greater in 1975; the 3-year average was greater under IES (Table 8). The IES system used grass when its nutritive value was highest. Gain per acre was more under IES. Under SLS, daily gain declined as the season progressed and was lower from July 15 to October 3 than for the earlier period. The 154 days of SLS produced 210 lb gain per steer compared with 141 lb for 75 days under IES.

Conclusions

1. Intensive early stocking (2X) from May 1 to July 15 maintained perennial grass herbage production comparable to that of season-long stocking.

2. Grazing distribution was more uniform under IES than under SLS.

3. Desirable warm-season perennial grasses were favored more by IES than by SLS.

4. Kentucky bluegrass and perennial forbs were favored more by SLS than by IES.

Table 8. Steer gains on intensive-early stocked and season-long stocked pastures.

	Intensive-early stocked	Season-long stocked		
	May 2-July 15 75 days	May 2- July 15 75 days	July 15- Oct. 3 79 days	May 2- Oct. 3 154 days
No. of steers, all years	104	52	52	52
Acres per steer	1.7	3.4	3.4	3.4
Gain per steer (lb)				
1972	132	122	66	188
1974	159	153	109	262
1975	131	117	64	181
Avg.	141	131	79	210
Daily gain per steer (lb)				
1972	1.78[a1]	1.65[a]	0.84[b]	1.22[c]
1974	2.09[a]	2.01[a]	1.36[b]	1.68[c]
1975	1.77[a]	1.58[b]	0.83[c]	1.18[d]
Avg.	1.88[a]	1.75[b]	1.00[c]	1.36[d]
Gain per acre (lb)				
1972	78	36	19	55
1974	96	45	32	77
1975	77	34	19	53
Avg.	83	39	23	62

[1] Values in same row with different letters differ significantly ($P<.05$).

5. Daily gain and gain per acre by steers were increased by IES compared to SLS.

6. Gain per steer was lower with IES than SLS because of the shorter grazing season, 75 days for IES compared with 154 days for SLS.

Literature Cited

Anderson, Kling L., and C. L. Fly. 1955. Vegetation-soil relationships in Flint Hills bluestem pastures. J. Range Manage. 8:161-169.

Anderson, K. L., E. F. Smith, and C. E. Owensby. 1970. Burning bluestem range. J. Range Manage. 23:81-92.

Deming, M. H. 1939. A field method for judging range utilization. U.S. Dep. Interior, Grazing Div. 13 p.

Dwyer, Don D. 1961. Activities and grazing preferences of cows with calves in northern Osage County, Oklahoma. Oklahoma Agr. Exp. Sta. Bull. B-588. 61 p.

Klipple, G. E. 1964. Early- and late-season grazing versus season-long grazing of shortgrass vegetation on the central Great Plains. U.S. Dep. Agr., Forest Serv. Rocky Mountain Forest and Range Exp. Sta. Res. Pap. RM-11.

Launchbaugh, J. L. 1957. The effect of stocking rate on cattle gains and on native shortgrass vegetation in west-central Kansas. Fort Hays Branch, Kansas Agr. Exp. Sta. Bull. 394. 29 p.

Owensby, Clenton E. 1973. Modified step-point system for botanical composition and basal cover estimates. J. Range Manage. 26:302-303.

Nutritional Characteristics of Blue Grama Herbage under the Influence of Added Water and Nitrogen

U. G. BOKHARI

Highlight: The effects of water and nitrogen treatments on nutritional characteristics of blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.] herbage were studied at a native shortgrass prairie site in northeastern Colorado. Results indicated greater total nonstructural carbohydrates (TNC) (g m^{-2}), protein (g m^{-2}), gross energy (GE) (kcal m^{-2}), and total carbon (g m^{-2}) in herbage from the water and water + nitrogen treatments than from the untreated control or nitrogen treatments. On the other hand, there were greater concentrations (% dry weight) of TNC and nitrogen in the nitrogen treatment than in the other three treatments. The greater yield of TNC, protein, and GE in the water and water + nitrogen treatments was mainly a result of greater aboveground-live biomass production than in the control or nitrogen treatments. TNC/N and C/N ratios of herbage from these treatments were calculated and are discussed in light of their importance in nutrition of grass forage for livestock production.

Production in the shortgrass prairie ecosystem in North America is usually limited by water and nutrient availability. Addition of water and nutrients (mainly nitrogen) has increased production of range grasses several-fold (Lauenroth and Sims 1973; Klages and Ryerson 1965; Wight and Black 1972). The effect of water stress and other environmental factors on carbohydrate reserves and regrowth potentials has been discussed in a number of reviews (May 1960; Jameson 1963; Cook 1966; White 1973). Carbohydrate contents of herbage undergo diurnal and seasonal changes due to changes in their environment, such as temperature, water potential of soil and leaves, and nutrient status of soil (McIlroy 1967; Waite and Boyd 1953; Green and Beard 1969; Holt and Hilst 1969; Dina and Klikoff 1973).

The effect of nitrogen fertilization on forage quality of range grasses depends upon the species, rate of application, time of application, and other environmental conditions. Kelsey et al. (1973) and Pettit and Fagan (1974b) reported that nitrogen fertilization increased crude protein concentration of blue grama and other grass species. Heavy application of nitrogen decreased carbohydrate contents of several grasses (Waite 1958; Adegbola and McKell 1966). Several investigators have reported that irrigation and fertilization decrease carbohydrate reserves in perennial plants (Pettit and Fagan 1974a; Brown and Blaser 1965; Nowakowski 1962).

Total nonstructural carbohydrates (TNC) are important sources of available energy which affect the quality of forage and its digestibility (Cooper 1973; Wilson and Ford 1973; Noble and Lowe 1974). The ratio of available energy-to-protein in pasture has been found to have a great effect on growth and performance of animals (Reid and Jung 1973).

This study was conducted to investigate the relationship between TNC and protein contents of blue grama plants at various phenological stages under the influence of additional increments of water and nitrogen.

Methods and Materials

The study site is situated about 40 km northeast of Fort Collins at 40°49′ N latitude, 104°46′ W longitude and at an elevation of 1,650 m (4,500 ft). Mean annual precipitation is 311 mm, with a range of 110 to 580 mm recorded over the past 31 years at the Central Plains Experimental Range. Approximately 70% of the mean annual precipitation occurs during the April to September growing season. Mean monthly temperature ranges from below 0°C in December and January to 22°C in July. Mean open pan evaporation was 1,230 mm, with a high of about 1,350 mm in 1974. Principal perennial species are blue grama (*Bouteloua gracilis*), fringed sagewort (*Artemisia frigida*), plains pricklypear (*Opuntia polyacantha*), needleleaf sedge (*Carex eleocharis*), and scarlet globemallow (*Sphaeralcea coccinea*).

Four treatments each of two replications on a 1-ha plot included control (no additional water or nitrogen), water, nitrogen, and water + nitrogen treatments. The nitrogen treatment was initiated in the spring of 1970 by applying 150 kg N/ha as ammonium nitrate to maintain a difference of at least 50 kg/ha of mineral nitrogen (NH_4 + NO_3) between the nitrogen and control treatments. The water treatment was initiated in 1971 by applying water by means of a sprinkler system to maintain matric potential between 0 and −0.8 bars at a depth of approximately 10 cm in the water and water + nitrogen treatments. The water + nitrogen treatment received additional amounts of nitrogen in the spring of 1972, 1973, and 1974 at the rate of 150, 100, and 100 kg/ha of equivalent nitrogen, respectively. An additional 100 kg/ha of nitrogen was also applied to the nitrogen treatment in 1973 and 1974.

Samples for biomass estimation and chemical analyses were taken by clipping at least six quadrats (0.50 m^2) in each replicate of each treatment on six sampling dates.

Samples were dried at 60°C to a constant weight and weighed, and an aliquot from each sample was taken for chemical analyses. Total nonstructural carbohydrates (TNC) were extracted and determined according to the procedure of Smith (1969). Total nitrogen was determined by the microKjeldahl method. Gross energy (GE) was

The author is senior plant physiologist, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins 80523.

This paper reports on work supported in part by National Science Foundation Grants GB-7824, GB-13096, GB-31862X, GB-31862X2, GB-41233X, DEB73-02027 A03, and DEB73-02027 A04 to the Grassland Biome, U.S. International Biological Program, for "Analysis of Structure, Function, and Utilization of Grassland Ecosystems." This study was conducted at the native shortgrass prairie site, the field research facility of the Natural Resource Ecology Laboratory, Colorado State University, located on the USDA, Agricultural Research Service, Central Plains Experimental Range in northeastern Colorado.

Manuscript received April 5, 1977.

determined by the adiabatic bomb calorimetry method (Phillipson 1964). Total carbon was determined volumetrically by combusting an aliquot of the dried sample in a leco induction furnace. Total TNC (g m^{-2}) and total N (g m^{-2}) values were calculated by multiplying the concentration (per gram dry weight basis) of the above constituents at different sampling dates with the respective aboveground live biomass of blue grama on those dates from the four treatments. Gross energy (GE) values were calculated by multiplying the 1970–1972 average content of GE (kcal g^{-2} dry weight) of aboveground live herbage with the biomass of blue grama during the 1973 and 1974 growing season. Data were analyzed statistically using a model of repeated analysis of variance, testing for treatment differences while repeating each determination across a replicate of each treatment.

Results and Discussion

Data presented here in the form of tables and figures are mostly from the 1973 growing season because the data from the 1974 growing season are not complete and include only three sampling dates. Only salient features of the 1974 data will be presented and discussed at appropriate places.

Total Nonstructural Carbohydrates (TNC g m^{-2})

During 1973 the maximum TNC in herbage of blue grama was found in the water + nitrogen treatment (30.5 g m^{-2}), followed by the water treatment (9.9 g m^{-2}) and the nitrogen (5.2 g m^{-2}) and control treatments (2.9 g m^{-2}) (Fig. 1).

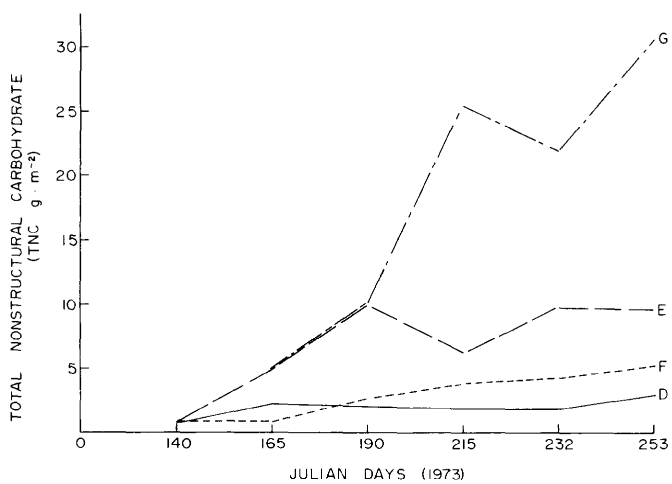


Fig. 1. *Total nonstructural carbohydrates (TNC, g m^{-2}) in the aboveground live compartment of the control (D), water (E), nitrogen (F), and water + nitrogen (G) treatments during the 1973 growing season.*

The TNC contents of herbage in all the treatments exhibited two peaks during the 1973 growing season except for the nitrogen treatment, which peaked at the end of the growing season. One of the two peaks in the three treatments occurred during the middle of the growing season, but not at the same time and the second at the end of the growing season. Mean annual TNC (g m^{-2}) content in herbage from the control, water, nitrogen and water + nitrogen treatments were 1.92, 6.86, 2.97, and 18.64 g m^{-2}, respectively.

During the 1974 growing season the maximum amounts of TNC in the herbage were from the water + nitrogen treatment (12.66 g m^{-2}). There was no significant difference between the peak TNC content of the control, water, and nitrogen treatments (about 3.00 g m^{-2}) in each case). The three dates in the 1974 growing season are at a comparable time of sampling with the 1973 growing season, and the data up to that point in time during both years does not reveal any significant year-to-year variation in the TNC content of the four treatments.

The greater amounts of TNC (g m^{-2}) in the herbage of the water and water + nitrogen treatments were mainly due to greater biomass production in the two treatments and not necessarily due to greater TNC concentrations (percent dry weight). For example, mean annual aboveground live biomass of water and water + nitrogen treatments during 1973 were 91.5 and 230.8 g m^{-2}, respectively, as compared to 21.1 g m^{-2} from the control and 33.4 g m^{-2} from the nitrogen treatments. Aboveground peak standing live biomass was 150.0 g m^{-2} from the water and 348.9 g m^{-2} from the water + ntrogen treatments. On the other hand, the TNC concentrations of herbage from the water and water + nitrogen treatments were slightly lower (7.3% and 7.8%, respectively) than the control (9.5%) and nitrogen (8.5%) treatments. The decrease in TNC concentrations of these treatments was due to its rapid utilization by the vigorous growth that results from the addition of water + nitrogen, which confirms early findings of Waite (1958) and Nowakowski (1962). Additional supply of nitrogen in the presence of adequate water increased biomass of blue grama more than that of water alone (Lauenroth and Sims 1973). This increase in aboveground live biomass places extra demands on photosynthates to support the growth and maintenance of these structures. Consequently, there is faster turnover of TNC pool in the shoots of these two treatments and also a greater dilution of TNC due to build up of more fibrous components in the shoots at maturity. For the utilization of additional amounts of nitrogen in the case of the water + nitrogen treatment there are additional demands on the carbohydrates to provide additional carbon skeleton for the incorporation of nitrogen into amino acids and proteins.

Comparing the peak TNC yield (g m^{-2}) of the four treatments, the herbage from the water + nitrogen treatment had 900%, 200%, and 400% greater TNC than that of the control, water, and nitrogen treatments, respectively. The increase in TNC of the nitrogen treatment over that of the control treatment was about 80%. The water treatment recorded an 89% increase in TNC over that of the nitrogen treatment. Repeated measures of analysis of variance indicated no significant difference between the TNC at different sampling dates (Tukey's Q = 10.07) except for the water + nitrogen treatment. There were significant dates × treatment interactions ($P < 0.001$), mainly due to the water + nitrogen treatment following the second sampling date. Addition of water alone had no significant effect on TNC content (Tukey's Q = 13.36); however, water in conjunction with nitrogen significantly increased TNC content during the middle and final vegetative growth period.

Gross Energy Content (kcal m^{-2})

The GE content of blue grama herbage from the four treatments is given in Figure 2. During the 1973 growing season the maximum GE in the herbage was in the water + nitrogen treatment (1,296 kcal m^{-2}). The maximum GE content from the control treatment was 110 kcal m^{-2}, and it was 636 kcal m^{-2} from the water and 192 kcal m^{-2} from the nitrogen treatments.

The mean annual GE content of herbage from the control, water, nitrogen, and water + nitrogen treatments was 62.4, 342.4, 194.6, and 863.7 kcal m^{-2}, respectively. During the 1974 growing season, the maximum GE content in the herbage from the water + nitrogen treatment was at the middle of the growing season (788 kcal m^{-2}). During the same period, the control, water, and nitrogen treatments recorded maximum values of 114, 144, and 146 kcal m^{-2}, respectively. The average

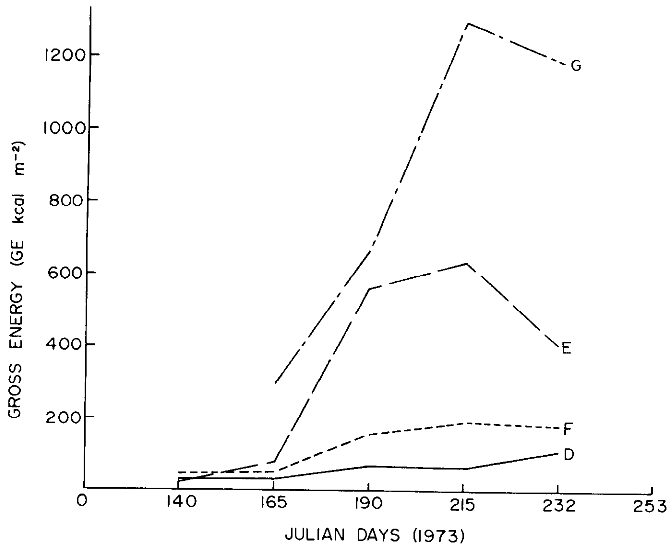


Fig. 2. *Gross energy (GE, kcal m^{-2}) in the aboveground live compartment of the control (D), water (E), nitrogen (F), and water + nitrogen (G) treatments during the 1973 growing season.*

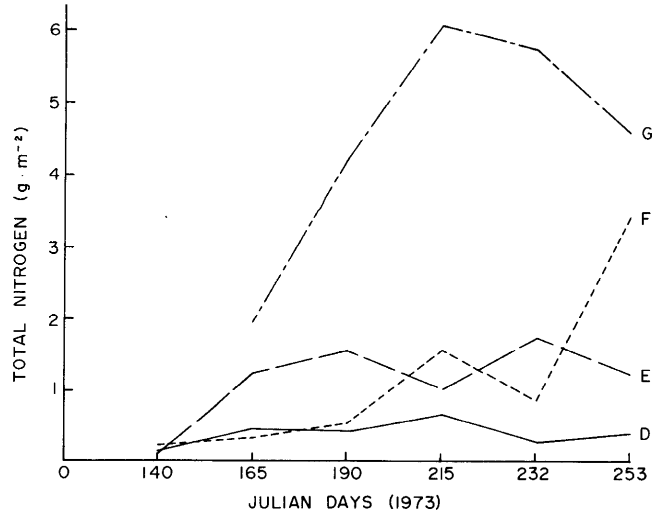


Fig. 3. *Total nitrogen (g m^{-2}) in the aboveground live compartment of the control (D), water (E), nitrogen (F), and water + nitrogen (G) treatments during the 1973 growing season.*

annual GE content from the control, water, nitrogen, and water + nitrogen treatments was 4.11, 4.15, 4.12, and 4.21 kcal/g dry wt, respectively.

The greater amounts of GE in the water (194.6 kcal m^{-2}) and water + nitrogen (863.7 kcal m^{-2}) treatments than that of the control (62.4 kcal m^{-2}) or nitrogen (194.6 kcal m^{-2}) treatments are due to greater amounts of aboveground live biomass, and not due to greater GE concentrations (kcal g dry wt^{-1}). GE is composed of two components, the nonlabile energy (structural components), which is not available for redistribution once it is fixed, and the labile energy (nonstructural carbohydrates), which is available for distribution between all the plant parts. Of the two components of GE the nonlabile energy is the predominant form. Both nonlabile and labile energy content (kcal m^{-2}) of blue grama shoots from the water and water + nitrogen treatments are higher than the control or the nitrogen treatments. Similar results were reported earlier by Bokhari et al. (1974) when blue grama plants were grown in environment controlled growth chambers under identical treatment conditions as described for this study. The magnitude of GE of the shoots from the growth chamber experiment was, of course, different than that of the field experiments.

Total Nitrogen Content (g m^{-2})

The total nitrogen content of blue grama herbage during the 1973 growing season varied from a maximum of 6.0 g m^{-2} in water + nitrogen treatment to a maximum of 0.67 g m^{-2} in the control, 1.74 g m^{-2} in the water, and 3.41 g m^{-2} in the nitrogen treatments (Fig. 3). The control, water, and nitrogen treatments exhibited two peaks while the water + nitrogen treatment showed one peak during the 1973 growing season. The mean annual total nitrogen content in herbage of the control, water, nitrogen, and water + nitrogen treatments was 0.40, 1.15, 1.16, and 4.11 g m^{-2}, respectively.

The amounts of total nitrogen in the biomass of the nitrogen treatment indicated greater content than that of the control and water treatments mainly because of greater concentration of nitrogen (percent dry weight). For example, the maximum concentration of nitrogen in herbage of the control treatment during the 1973 growing season was 2.50%, and it was 2.00% in the water treatment, 3.20% in the nitrogen treatment, and 2.64% in the water + nitrogen treatment. Mean annual concentration of nitrogen in herbage of the control, water, nitrogen, and water + nitrogen treatments was 1.97, 1.41, 2.19, and 2.15%, respectively.

During the 1974 growing season, the maximum total nitrogen content (g m^{-2}) from the control, water, nitrogen, and water + nitrogen treatments was 0.55, 0.85, 1.12, and 3.07 g m^{-2}, respectively. Nitrogen concentration varied from a minimum of 1.67% to a maximum of 2.31% in the control, from 1.20% to 1.60% in the water, from 2.34% to 3.00% in the nitrogen, and from 1.14% to 3.10% in the water + nitrogen treatments. During 1974 maximum nitrogen concentration in herbage was identical with the water + nitrogen and nitrogen treatments. Repeated statistical comparisons by analysis of variance indicated significant dates × treatment interactions ($P < 0.001$), which is attributable mainly to the water + nitrogen treatment. There were no significant differences in terms of nitrogen content (g m^{-2}) of herbage at different sampling dates (Tukey's $Q = 1.66$) from the control, water, and nitrogen treatments. Water + nitrogen significantly (Tukey's $Q = 2.20$) increased nitrogen content.

In the control and nitrogen treatments there seems to be a buildup of nitrogen in the shoots (probably as nitrate, as postulated by Sullivan, 1962) due to lack of capability of the shoots (photosynthates) to provide sufficient carbon skeleton for the incorporation of additional nitrogen. On the average there are greater protein concentrations in the shoots of the nitrogen treatment (15%) than those of the water (9%) or water + nitrogen (13%) treatments. Uresk and Sims (1975) reported an average of 10% crude protein in live blue grama herbage from different grazing treatments during 1970 with a minimum of 7.8% at maturity and a maximum of 18% during early vegetative growth.

Total Carbon Content (g m^{-2})

The total carbon content of blue grama herbage from the four treatments during the 1973 growing season is given in Figure 4. The water treatment produced greater content of carbon in herbage than control or nitrogen treatments. The mean annual content of total carbon in herbage of the control, water,

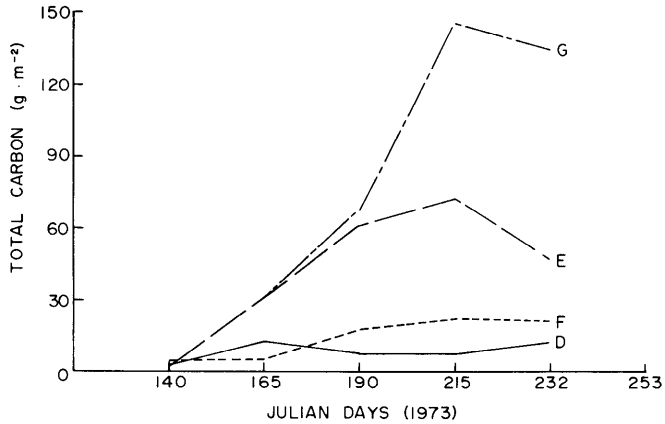


Fig. 4. *Total carbon (g m^{-2}) in the aboveground live compartment of the control (D), water (E), nitrogen (F), and water + nitrogen (G) treatments during the 1973 growing season.*

nitrogen, and water + nitrogen treatments was 8.6, 42.6, 14.0, and 44.2 g m^{-2}, respectively.

During the 1974 growing season, the maximum content of carbon in herbage of plants growing in control, water, nitrogen, and water + nitrogen plots was 12.66 g m^{-2}, 15.61 g m^{-2}, 14.78 g m^{-2}, and 80.03 g m^{-2}, respectively, up to the middle of the growing season.

There were no significant differences in carbon concentration (percent dry weight) of herbage among the four treatments (averaging 41% to 45%) at any given time during the growing season. The carbon concentration in herbage of plants growing in all treatments increased as the plants approached maturity. On the average, the 38% carbon in the herbage at the beginning of the growing season increased to 48% by the end of the growing season.

C/N Ratio

The C/N ratio in herbage of all four treatments fluctuated throughout the growing season (Table 1). Maximum C/N ratio in blue grama herbage during the 1973 growing season was from the water treatment (69.9) and minimum from the nitrogen treatment (6.0). The seasonal average C/N ratio in herbage of plants growing in the control, water, nitrogen, and water + nirogen plots was 18.2, 38.2, 17.2, and 21.1, respectively. During the 1974 growing season, the maximum C/N ratio in herbage was found during the middle of the growing season.

The control treatment, which represents the normal conditions of the native shortgrass prairie site with a lower C/N ratio than the water and water + nitrogen treatment, indicates that there is proportionately greater accumulation of carbon-containing substances in the water and water + nitrogen treatments than in the control treatment. The lowest C/N ratio in the nitrogen treatment (17.2) indicates comparatively greater content of nitrogenous compounds, which again may be due to the presence of nonproteinaceous substances as well as nitrogen in the form of nitrate.

Table 1. Carbon and nitrogen ratios (C/N) in aboveground live herbage of blue grama during the 1973 and 1974 growing seasons.

Year	Sampling dates (Julian days)	Treatments			
		Control	Water	Nitrogen	Water + nitrogen
1973	138–140	19.0	19.0	19.0	—
	159–166	13.2	25.1	15.4	15.8
	179–191	18.0	39.2	32.0	16.0
	207–235	11.0	69.9	13.8	23.8
	235–253	29.8	38.1	6.0	29.1
	Average	18.2	38.2	17.2	21.1
1974	144–151	17.3	25.1	13.8	13.0
	163–168	24.1	28.8	13.1	16.4
	203–206	23.1	31.7	14.4	26.0
	Average	21.5	28.5	13.7	18.4

TNC/N Ratio

The proportion of total available carbohydrate and total nitrogen content (TNC/N) is considered a reliable index of quality and potential utilization of herbage by livestock (Reid and Jung 1973). The TNC/N ratio in all treatments during 1973 increased toward the end of the growing season, except for the nitrogen treatment, which began to decline at this time (Table 2). The maximum TNC/N ratio recorded was about 7.0 in the herbage of the control and water treatments. Average TNC/N ratios during the 1973 growing season were 5.0 from the control, 6.0 from the water, 3.3 from the nitrogen, and 3.8 from the water + nitrogen treatments. Average TNC/N ratios up to the middle of the 1974 growing season were 6.2, 5.4, 3.8, and 3.4 from the control, water, nitrogen, and water + nitrogen treatments, respectively (Table 2).

Table 2. Total nonstructural carbohydrates (TNC) and total N ratios (TNC/N) in aboveground live herbage of blue grama during the 1973 and 1974 growing seasons.

Year	Sampling dates (Julian days)	Treatments			
		Control	Water	Nitrogen	Water + nitrogen
1973	138–140	4.4	7.0	3.7	—
	159–166	4.7	4.0	2.5	2.5
	179–191	4.7	6.3	4.8	2.4
	207–215	2.7	6.0	2.4	4.1
	229–235	6.1	5.5	4.8	3.8
	235–253	7.1	7.7	1.5	6.6
	Average	5.0	6.0	3.3	3.8
1974	144–151	6.1	5.0	5.3	3.0
	163–168	6.5	6.1	2.7	3.2
	203–206	6.2	5.2	3.4	4.1
	Average	6.2	5.4	3.8	3.4

TNC is a source of readily available energy which, according to Cooper (1973), enhances rumen microbial activity and forage utilization and also aids in utilization of protein and nonprotein nitrogen (Macrae et al. 1972; Noller and Rhykerd 1973). Rumen microorganisms require a source of readily available energy for conversion of nonprotein nitrogen to microbial protein (Nowakowski 1962). Low available energy-to-protein ratios have been associated with poor feeding quality of silage, depressed growth and performance of animals on pasture, and a higher susceptibility to metabolic disease (Butler and Jones 1972; Reid and Jung 1973).

Crude Protein (N × 6.25 g m^{-2})

Herbage from the water + nitrogen treatment had a higher content of crude protein throughout the 1973 growing season than did that from the other three treatments (Fig. 5). Maximum amounts of crude protein in the herbage were from the water + nitrogen treatment (37.93 g m^{-2}).

Compared to the other three treatments, the control treatment had the lowest amounts of crude protein throughout the growing season with a maximum amount of 4.18 g m^{-2} during the middle of the growing season and a minimum amount of 1.03 g m^{-2} at the beginning of the growing season. During the 1974 growing season, the maximum content of protein was in the herbage

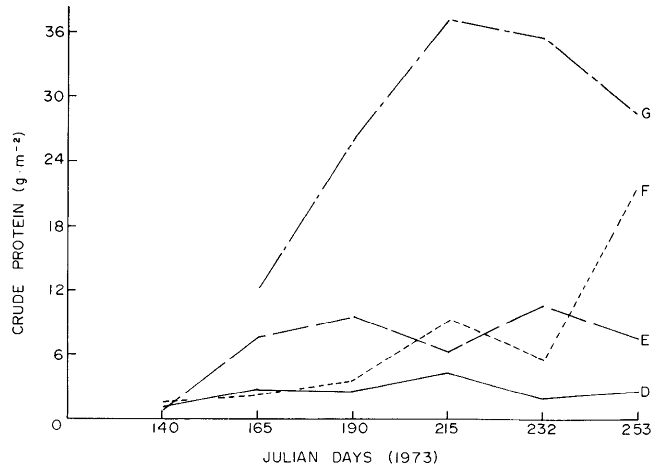


Fig. 5. *Total crude protein (N × 6.25 g m^{-2}) in the aboveground live compartment in the control (D), water (E), nitrogen (F), and water + nitrogen (G) treatments during the 1973 growing season.*

from the water + nitrogen treatment (19.22 g m^{-2}) and minimum from the control treatment. Up to the middle of the 1974 growing season, average protein contents in the control, water, nitrogen, and water + nitrogen treatments were 2.77, 3.85, 5.47, and 14.70 g m^{-2}, respectively, during the 1973 growing season.

Mean annual protein content (g m^{-2}) was greater in the herbage from the water + nitrogen treatment (28.2 g m^{-2}) than in that from the water or nitrogen (7.2 g m^{-2}), or the control (2.5 g m^{-2}) treatments. The greater concentration of protein (% dry weight) was found in the nitrogen treatment, which may not really represent protein nitrogen but most probably nonprotein or nitrate nitrogen. Usually the Kjeldahl procedure used for the determination of total nitrogen does not include nitrate unless a modified procedure is used. However, in most studies crude protein content of fertilized range grasses increased independently of yield (Rogler and Lorenz, 1957; Mason and Miltimore, 1964). Protein contents of blue grama herbage were higher during the middle of the growing season (June and July) in all treatments except the nitrogen treatment, which indicates the appropriate time of its nutritive values for livestock. Rodgers and Box (1967) reported similar trends in protein contents of several grasses including blue grama.

From a nutritional point of view these results indicate that nitrogen fertilization alone may reduce production and forage quality due to reduction in carbohydrate contents. Other quality factors such as increase in protein concentration may compensate for carbohydrate and yield losses. Irrigation alone or in combination with fertilization increases forage production and protein yield but may reduce forage quality due to low protein concentrations. Changes in the yield of protein may compensate for low protein concentration in otherwise highly productive range grasses.

Literature Cited

Adegbola, A. A., and C. M. McKell. 1966. Regrowth potential of coastal Bermudagrass as related to previous nitrogen fertilization. Agron. J. 58: 145-146.

Bokhari, U. B., M. I. Dyer, and J. S. Singh. 1974. Labile and nonlabile energy in blue grama (*Bouteloua gracilis*) as influenced by temperature, water stress, and fertilizer treatments. Can. J. Bot. 52:2289-2298.

Brown, R. H., and R. E. Blaser. 1965. Relationships between reserve carbohydrate accumulation and growth rate in orchardgrass and tall fescue. Crop Sci. 5:577-582.

Butler, G. W., and D. I. H. Jones. 1973. Mineral biochemistry of herbage. p. 146-150. *In:* G. W. Butler and R. W. Bailey (Eds.) Chemistry and Biochemistry of Herbage. Vol. 2. Academic Press, New York, N.Y.

Cook, C. W. 1966. Carbohydrate reserves in plants. Utah Res. Ser. 31, Logan, Utah. 47 p.

Cooper, J. P. 1973. Genetic variation in herbage constituents. p. 379-417. *In:* G. W. Butler and R. W. Bailey (Eds.) Chemistry and Biochemistry of Herbage. Vol. 2. Academic Press, New York, N.Y.

Dina, S. J., and L. G. Klikoff. 1973. Effect of plant moisture stress on carbohydrate and nitrogen content of big sagebrush. J. Range Manage. 26: 207-209.

Green, D. G., and J. B. Beard. 1969. Seasonal relationship between nitrogen nutrition and soluble carbohydrates in the leaves of *Agrostis palustris* Huds. and *Poa pratensis* L. Agron. J. 61:107-111.

Holt, D. A., and A. R. Hilst. 1969. Daily variation in carbohydrate content of selected forage crops. Agron. J. 61:239-242.

Jameson, D. A. 1963. Responses of individual plants to harvesting. Bot. Rev. 29:532-594.

Kelsey, R. J., A. B. Nelson, G. S. Smith, and R. D. Pieper. 1973. Nutritive value of hay from nitrogen-fertilized blue grama rangeland. J. Range Manage. 26:292-294.

Klages, M. G., and D. F. Ryerson. 1965. Effects of nitrogen and irrigation on yield and botanical composition of western Montana range. Agron. J. 57:78-81.

Lauenroth, W. K., and P. L. Sims. 1973. Effects of water and nitrogen stresses on a shortgrass prairie ecosystem. US/IBP Grassland Biome Tech. Rep. No. 232. Colorado State Univ., Fort Collins. 117 p.

Macrae, J. C., M. J. Ulyatt, P. D. Pearce, and J. Handtlass. 1972. Quantitative intestinal digestion of nitrogen in sheep given formaldehyde treated and untreated cosim supplements. Brit. J. Nutr. 27:39-50.

Mason, J. L., and J. E. Miltimore. 1964. Effects of nitrogen content of beardless wheatgrass on yield response to nitrogen fertilization. J. Range Manage. 17:145-147.

May, L. H. 1960. The utilization of carbohydrate reserves in pasture plants after defoliation. Herb. Abstr. 30:239-245.

McIlroy, R. J. 1967. Carbohydrates of grassland herbage. Herb. Abstr. 37:79-87.

Noble, A., and K. F. Lowe. 1974. Alcohol-soluble carbohydrates in various tropical and temperate pasture species. Trop. Grassl. 8:179-187.

Noller, C. H., and C. L. Rhykerd. 1973. Relationship of nitrogen fertilization and chemical composition of forage to animal health and performance. p. 363-394. *In:* D. A. Mays (Ed.) Forage Utilization. Amer. Soc. Agron., Madison, Wisc.

Nowakowski, T. Z. 1962. Effects of nitrogen fertilizers on total nitrogen, soluble nitrogen, and soluble carbohydrate contents of grass. J. Agr. Sci. 59:387-392.

Pettit, R. D., and R. E. Fagan. 1974a. Influence of nitrogen and irrigation on carbohydrate reserves of buffalograss. J. Range Manage. 27:279-282.

Pettit, R. D., and R. E. Fagan. 1974b. Influence of nitrogen on irrigated buffalograss yield and protein content. J. Range Manage. 27:473-476.

Phillipson, J. 1964. A miniature bomb calorimeter for small biological samples. Oikos 15:130-139.

Reid, R. L., and G. A. Jung. 1973. Effects of elements other than nitrogen on the nutritive value of forage. p. 395-435. *In:* D. A. Mays (Ed.) Forage Fertilization. Amer. Soc. Agron., Madison, Wisc.

Rodgers, J. D., and T. W. Box. 1967. Seasonal protein content of four Southern mixed prairie grasses. J. Range Manage. 20:177-178.

Rogler, G. A., and R. J. Lorenz. 1957. Nitrogen fertilization of northern Great Plains rangelands. J. Range Manage. 10:156-160.

Smith, D. 1969. Removing and analyzing total nonstructural carbohydrates from plant tissue. Res. Rep. No. 41, Res. Div., Univ. Wisconsin, Madison.

Sullivan, J. T. 1962. Evaluation of forage crops by chemical analysis. A critique. Agron. J. 54:511-515.

Uresk, D. W., and P. L. Sims. 1975. Influence of grazing on crude protein content of blue grama. J. Range Manage. 28:370-371.

Waite, R. 1958. The water soluble carbohydrates of grasses. IV. The effect of different levels of fertilizer treatment. J. Sci. Food Agr. 9:39-43.

Waite, R., and J. Boyd. 1953. The water soluble carbohydrates of grasses. I. Changes occurring during the normal life-cycle. J. Sci. Food Agr. 4:197-203.

White, L. 1973. Carbohydrate reserves of grasses: A review. J. Range Manage. 26:13-18.

Wight, J. R., and A. L. Black. 1972. Energy fixation and precipitation use efficiency in a fertilized rangeland ecosystem of the northern Great Plains. J. Range Manage. 25:376-380.

Wilson, J. R., and C. W. Ford. 1973. Temperature influences on the in vitro digestibility and soluble carbohydrate accumulation of tropical and temperate grasses. Aust. J. Agr. Res. 24:187-198.

Influences of Brush Conversion and Weather Patterns on Runoff from a Northern California Watershed

MICHAEL D. PITT, ROBERT H. BURGY, AND HAROLD F. HEADY

Highlight: Sixteen years of data were evaluated to determine the influence of annual weather patterns and a brush conversion project on subsequent runoff from an 86.2-ha watershed. Grassy vegetation released 39% more total runoff than did woody vegetation. Total runoff for each hydrologic year was directly proportional to total precipitation, regardless of vegetative cover. However, runoff as a proportion of total precipitation increased 59% following conversion of woody to grassy vegetation, and most closely correlated with March cover.

Unfortunately, brush conversion also drastically increased the number of soil slips and sediment discharged from the watershed. All major landslides occurred in the vicinity of streams when the root systems of woody vegetation along these streams began to decay. Leaving this streambank vegetation intact may have prevented some of the undesirable results of brush conversion on the watershed.

Literature describing watershed management practices typically concludes that reduction of woody vegetation cover, by cutting or other means, results in increased water yields (Burgy and Papazafiriou 1974). Studies as early as 1900 in Switzerland, the Colorado Wagon Wheel Gap Study (Bates and Henry 1928), the Coweeta studies in North Carolina (Hewlett and Hibbert 1961; Hibbert 1969), studies in South Africa (Pereira 1962), forestry and hydrologic research in Oregon (Rothacher 1965), California (Rowe 1948; Biswell and Schultz 1958; Rowe 1963; Bentley 1967; Lewis 1968), Ohio (Harrold et al. 1962), West Virginia (Reinhart et al. 1963), and many others, representing thousands of acres of watersheds and many years of records, all demonstrated the impacts of woody plant reduction in increased water yield.

However, total amounts of increased water yield following conversion from brush to grass are highly variable and unpredictable, and depend not only upon the change in vegetative type, but also upon annual weather patterns (Rowe and Reimann 1961). Where long-term weather records are available, average annual precipitation is usually considered a reliable parameter for predicting water yield (Branson et al. 1962). However, many climatic factors other than average annual precipitation also influence runoff. High levels of either storm intensity or duration may produce runoff, while low intensity storms, not exceeding soil infiltration capacity, may produce no runoff at all. Rainfall distribution over time also affects water yield, as storms separated by periods of clear weather produce maximum interception capacity at the beginning of each shower, with a corresponding decrease in runoff. Temperature regimes during both storms and clear weather exert additional impacts on total water yield. Intercepted moisture becomes more susceptible to evaporation when temperatures are high during periods of clear weather. This evaporation in turn produces a higher moisture holding capacity in the vegetation, thereby increasing interception capacity during the next storm and ultimately reducing runoff.

These variable climatic factors must be separated from the effects of watershed management techniques before evaluating the success of such techniques. Observed changes in runoff following brush conversion projects may result from different weather patterns as well as the reduction in woody vegetation. Therefore, this study evaluates the relative influences of annual weather patterns and a brush conversion project on 16 years of runoff from a northern California watershed.

Authors are assistant professor of range ecology, University of British Columbia, Department of Plant Science, Vancouver, B.C., Canada V6T 1W5; professor of water sciences and civil engineering, University of California, Department of Land, Air, and Water Resources (LAWR), Water Science and Engineering Section, Davis 95616; and professor of range management, University of California, Berkeley 94720.

Manuscript received April 1, 1977.

Location and Methods of Study

The study was conducted at the Hopland Field Station, which is owned and operated by the University of California and is located in Mendocino County in the central portion of the coast mountain ranges. The experimental area, known as Watershed II, is an 86.2-ha drainage basin with a west-facing orientation draining into the Russian River. Elevations range from 183 to 396 m. Soils on the watershed are approximately 1 meter thick overlying sandstone and shale rock of the Franciscan Formation. This formation is extremely shattered and jointed, with intrusions of basic rock and interlaced with faults, very typical of the coastal mountain ranges (Gowans 1958; Burgy and Papazafiriou 1974).

The study began in 1952 when the watershed was fenced and a weir erected for measuring runoff. Other instrumentation to measure precipitation, soil moisture, and groundwater levels, and a settling basin to measure sedimentation were also installed. The vegetative composition of Watershed II prior to brush conversion included 5.2 ha of open grassland; 19.8 ha of mixed grass and deciduous oak trees (*Quercus lobata*); 50.6 ha of black oak (*Quercus kellogii*), live oaks (*Quercus agrifolia, Q. wislizenii*), blue oak (*Quercus douglasii*), and madrone (*Arbutus menzeisii*); and 9.3 ha of brush composed principally of chamise (*Adenostoma fasciculatum*) (Pitt 1975).

The years 1955 through the summer of 1959 marked the first or calibration period of brush conversion. Throughout this calibration period, botanical composition, cover, and standing crop were estimated twice a year; once immediately before the onset of rapid plant growth in February, and again during summer dormancy in June. Precipitation and runoff were sampled monthly. The second, or treatment period of brush conversion on Watershed II, when woody vegetation was converted to grassy vegetation, began in December, 1959. The trees were killed by applying 2,4-D amine in surface cuts circling the base of the tree trunks. This procedure required approximately 4 months and concluded in April, 1960. Deciduous trees treated early in the winter generally did not come into leaf the following spring. Deciduous trees treated later in the winter did come into leaf the following spring but typically shed these leaves by September, 1960. The evergreen madrone and live oaks lost their leaves gradually and were bare within a year following treatment. During the second year after treatment, many small limbs fell; and within 3 years following treatment, many of the small tree trunks also rotted and fell. By the end of 1964, over 50% of the trees had fallen and a heavy litter lay on the ground limiting access for both men and livestock.

July 1969 marked the beginning of the third or stabilization period of brush conversion, initiated by burning the watershed to remove the extensive build-up of decaying woody vegetation. Firing procedures utilized two crews beginning at the top of the watershed and firing downhill around the periphery. When the crews reached the bottom of the watershed, a safe, burned boundary strip encircled most of the watershed. Center firing occurred before the perimeter fire completely enclosed the watershed. Within one hour of the firing, the major portion of the burning, with excellent fuel consumption, was complete. Vegetation sampling continued until the stabilization period of brush conversion terminated in June, 1973. Runoff and sedimentation were sampled only through the end of the 1970 hydrologic season.

Results and Discussion

Brush conversion undoubtedly increased runoff from Watershed II, as the formerly intermittent stream draining the center of the watershed became perennial immdiately following herbicidal treatment of the woody vegetation. However, some of this observed increase in runoff (Table 1)[1] may have resulted from different weather patterns following brush conversion as well as the reduction in woody vegetation. Therefore, simple comparison of average runoff before and after brush conversion may lead to conclusions that confound the influences of brush conversion and annual weather patterns.

Table 1. Annual runoff (cm) and precipitation (cm) through June 1 of the hydrologic year, and the corresponding runoff/precipitation ratios (%) on the grazing unit designated as Watershed II, Hopland Field Station.

Hydrologic year	Runoff (cm)	Precipitation (cm)	Runoff / Precipitation (%)
1954–1955	4.44	63.09	7.0
1955–1956	40.64	129.39	31.4
1956–1957	6.32	74.62	8.5
1957–1958	69.22	152.20	45.5
1958–1959	13.69	65.25	21.0
1959–1960	6.63	64.92	10.2
1960–1961	17.25	77.85	22.2
1961–1962	23.16	78.56	29.5
1962–1963	31.88	102.56	31.1
1963–1964	11.33	60.71	18.7
1964–1965	37.67	109.30	34.5
1965–1966	23.62	79.45	29.7
1966_1967	34.64	106.17	32.6
1967–1968	22.61	77.09	29.3
1968–1969	57.15	127.00	45.0
1969–1970	48.77	112.90	43.2

Figure 1 illustrates the relationships among total runoff, total precipitation, and runoff as a percentage of total precipitation. Runoff and precipitation both decreased during the treatment period immediately following brush conversion on the watershed. During the stabilization period of brush conversion, both runoff and precipitation increased, although precipitation was only slightly higher than the average prior to brush conversion.

The trend in runoff as a percentage of total precipitation, however, increased much more than either runoff or precipitation increased throughout the study of Watershed II. Obviously, grassy vegetation subsequent to brush conversion produced greater amounts of runoff as a percentage of total precipitation than did woody vegetation prior to brush conversion (Fig. 1). Indeed, analysis of variance for runoff/precipitation ratios as a function of brush conversion periods on the watershed produced differences significant at the 20% level of significance ($F = 2.12$). While annual runoff averaged 39% more during the stabilization period than during the calibration period of brush conversion, the ratio of runoff to total precipitation increased 59% between these same two periods. In contrast, total precipitation increased only 3.73% between the calibration and stabilization periods of brush conversion. Therefore, in both absolute and relative terms, grassy vegetation released a higher proportion of precipitation as runoff than did woody vegetation.

This relationship of runoff to total precipitation became particularly important during high rainfall years. Runoff from Watershed II exceeded 40 cm only during the hydrologic years ending in 1956, 1958, 1969, and 1970 (Table 1). Average runoff for the years 1955 through 1970 inclusive equaled 27.94 cm while total rainfall averaged 92.46 cm. During the high runoff years of 1956, 1958, 1969, and 1970, however, total rainfall equaled 129.39, 152.20, 127.00, and 112.90 cm, respectively (Table 1). Furthermore, the amount of runoff as a function of total rainfall increased geometrically. The runoff/precipitation ratios for the hydrologic years ending in 1955 through 1970 averaged 27.5%. Alternatively the runoff/precipitation ratios for the high runoff years of 1956, 1958, 1969, and 1970 equaled 31.4, 45.5, 45.0, and 43.2%, respectively. Runoff through June 1 during these hydrologic years averaged 53.95 cm, 93.1% higher than the average runoff year during the study of Watershed II.

In contrast to runoff, total precipitation during these years of 1956, 1958, 1969, and 1970 averaged 130.35 cm, only 40.8% higher than the average precipitation through June 1 for the hydrologic years ending in 1955 through 1970 inclusive. Therefore, increasingly greater proportional quantities of runoff emanated from increasing quantities of total precipitation. The runoff/precipitation ratios for the years 1956, 1958, 1969, and 1970 averaged 41.3%, 50.2% higher than the average runoff/precipitation ratio throughout the study on Watershed II. Obviously total rainfall, as influenced by the intensity, duration, and separation of individual storms and ambient temperature patterns during and between these storms, significantly influenced total runoff from Watershed II, regardless of the vegetative cover.

Influence of Weather Patterns on Runoff

Results obtained from step-wise multiple regression of runoff on 76 weather variables (Pitt 1975) illustrate that runoff depends primarily on total precipitation (Table 2).[2] Total rainfall through June 1 of the hydrologic year entered the regression equation

[1] The hydrologic year begins October 1 and extends through September 30. Only minor quantities of runoff and precipitation occurred from June 1 to the beginning of the next hydrologic year. Virtually all precipitation was discharged from the watershed during each hydrologic year.

[2] The first five weather variables entering the regression equations in Table 2 are listed from left to right in order of their respective appearance in the step-wise regressions. Direction of influence (positive or negative) and the coefficients are included with each weather variable.

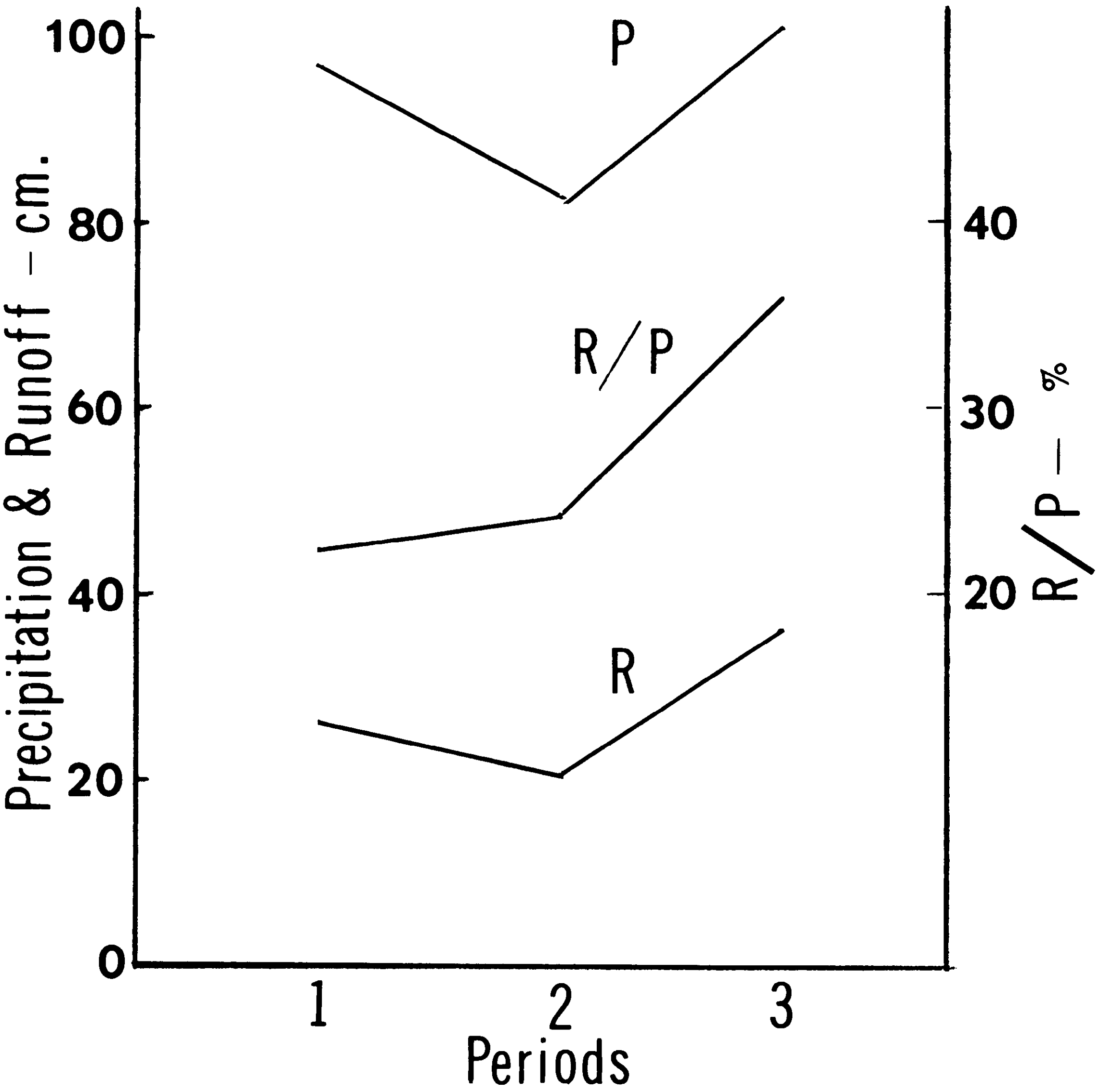


Fig. 1. *Runoff, precipitation, and runoff/precipitation ratio through June 1 of the hydrologic year as a function of the conversion period. (1) Calibration. (2) Treatment. (3) Stabilization.*

first, and by itself correlated with runoff through June 1 with an r^2 of 0.92. The negative correlation of runoff through June with total precipitation in April and May is possibly associated with increased evapotranspiration of annual vegetation during this period of rapid plant growth. High rainfall during these 2 months often produces virtually no runoff from watersheds in that region of California.

Runoff through March 1 of the hydrologic year also highly correlated with total precipitation, particularly during the months of December, January, and February (Table 2). The negative correlations of runoff through March 1 with numbers of days below freezing in October and increasing mean minimum temperatures in October, likely indicate cold weather with no rain, and an extended summer with no rain, respectively. Both these regressions of runoff on weather variables and the following regression equations (Table 3) of runoff on standing crop and cover utilized only those data (Table 4) collected after brush conversion (1960–1969 inclusive) so that results were not

Table 2. Summary of results obtained from step-wise multiple regressions of runoff through both March 1 and June 1 of the hydrologic year on weather variables.

Runoff	Constant	Weather variables					r^2	F
Runoff through June 1	10.0	0.7 Precip. year	−1.0 Precip. A, May	0.3 Precip. 0	−0.2 < .6cm SONMAM	0.2 M. max. ONMA	.99	832.5[1]
Runoff through March 1	9.9	0.6 Precip. DJF	−0.2 < .6cm SON	−3.5 <0°C 0	0.7 Precip. SON	−0.4 M. min. 0	.99	260.7[1]
Runoff through June 1	−12.5	0.6 Precip. year					.92	96.5[1]

[1] Significant at 0.01.

Table 3. Simple regressions of runoff through both March 1 and June 1 of the hydrologic year on cover and standing crop at the March 1 and June 1 sampling dates on Watershed II, Hopland Field Station, during the years 1960 through 1969 inclusive.

	r^2	F
March runoff = 1.03 + 0.19(March cover)	.20	2.07
March runoff = 5.20 + 0.36(March standing crop)	.15	1.44
June runoff = 5.96 + 0.15(June cover)	.08	0.70
June runoff = 2.38 + 0.28(June standing crop)	.25	2.67
June runoff = 0.43 + 0.27(March cover)	.33	3.91[1]
June runoff = 6.80 + 0.44(March standing crop)	.18	1.82

[1] Significant at 0.10.

confounded with the different runoff potentials of predominantly brushy versus predominantly grassy vegetation. Following conversion, this annual, grassy vegetation dominated all treated areas of the watershed, and permitted virtually no reinvasion by woody plant species.

Influence of Annual Vegetation on Runoff

The regressions of runoff on standing crop and cover produced relatively low coefficients of determination as simple r^2 values ranged from .08 to .33. The largest coefficient of determination resulted from the regression of runoff through June 1 on cover at the March sampling date. This relationship suggests a delayed influence of annual vegetation on runoff rather than an immediate calendar effect. Indeed, only this particular regression of runoff on vegetational parameters produced results significant at the 10% level of significance.

These regression analyses of runoff on vegetational parameters excluded data collected in 1970, which can therefore be used to "test" the predictive accuracy of the regression equation of June runoff as a function of March cover. From Table 3 June runoff equals 0.43 + 0.27 × March cover. Cover in March of 1970 equaled 54.53%. Therefore, the regression equation predicts 38.48 cm of runoff through June 1 of 1970, a value which compares reasonably well with the observed 48.77 cm through June 1 of 1970. However, since total precipitation is such a dominating factor in terms of runoff, this equation relating March cover to runoff through June 1 should be applied very cautiously.

Managerial Recommendations

Brush conversion not only augmented runoff from Watershed II but also drastically increased the number of soil slips and resulting sediment discharged from the watershed. Relatively stable top soils prevailed on the watershed prior to brush conversion treatments. No massive soil movements occurred during the calibration period of brush conversion, even under heavy precipitation (Burgy and Papazafiriou 1974). However, 61 soil slips occurred during the 10 years immediately following brush conversion. Only five of these slips occurred during the period of 1960–1964, while 18 slips were observed in 1964–1965, 15 in 1965–1968, and 17 in 1968–1969. The remaining six soil slips occurred in 1969–1970 (Burgy and Papazafiriou 1974). Although the rate of soil slips has recently declined, two new slips were observed in the spring of 1974. These slips were relatively small, however, and may represent natural slides very characteristic on clay soils found in the Franciscan Formation.

All of the major landslides occurred in the vicinity of streams (Fig. 2), and in most cases bank cutting preceded the slips. The bulk of these slips did not occur until 5 years following brush conversion, when the root systems of the dense, woody vegetation along stream banks began to decay. Once these roots released their hold upon the top soil, which often reached moisture saturation during the winter months, the total number of land slips in each time period was directly proportional to the total precipitation in that time period (Burgy and Papazafiriou 1974). These land slips produced such enormous quantities of sediment that measurement activities were discontinued. Sedimentation from Watershed II averaged approximately 400 tons per year during the calibration period, but increased to 4,000 tons per year following brush conversion. Intense storms occasionally washed 100 tons of sediment per hour from Watershed II following brush conversion.

The precise economic impacts of brush conversion on Watershed II remain unquantified. However, repeated soil slips

Table 4. Runoff through March 1 of the hydrologic year, standing crop (oven dry g/ft²) and foliar cover (%) at the March 1 and June 1 sampling dates on Watershed II, Hopland Field Station, during the years 1960 through 1970 inclusive.

Year	March runoff (cm)	March cover	June cover	March standing crop	June standing crop
1960	4.27	27.90	27.19	1.76	7.30
1961	12.12	44.61	43.65	4.49	27.98
1962	17.32	34.07	33.90	5.56	20.28
1963	17.60	41.58	30.15	6.44	30.91
1964	10.06	29.77	14.69	8.34	26.91
1965	34.29	23.36	18.39	7.41	33.32
1966	21.72	22.01	17.18	3.00	29.74
1967	24.51	46.35	43.58	11.90	28.52
1968	16.64	45.29	40.50	20.08	46.90
1969	50.06	60.89	39.45	13.51	34.92
1970	44.42	54.53	36.31	12.79	16.79

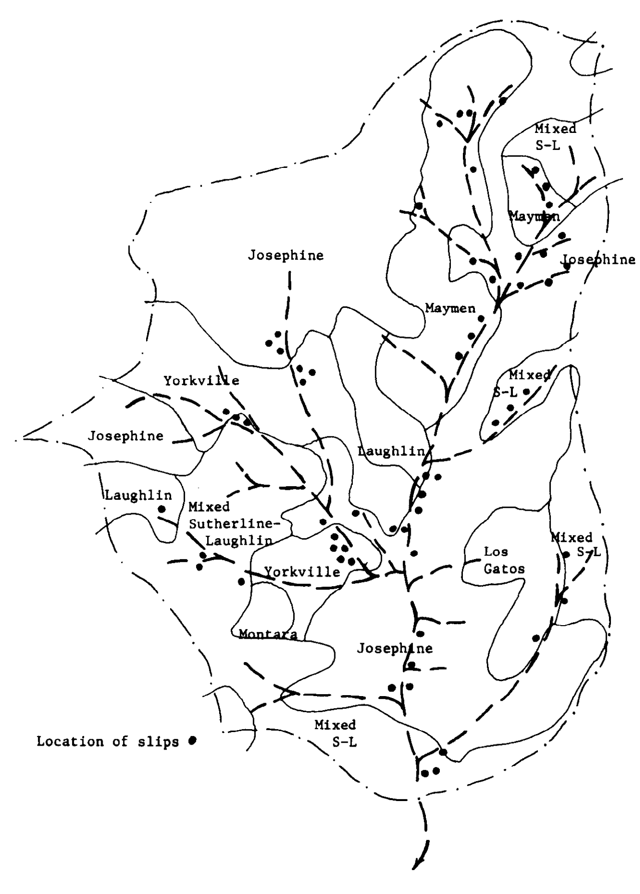


Fig. 2. Main soil series and location of soil slips on Watershed II, Hopland Field Station. (From Burgy and Papazafiriou 1974.)

certainly detract from long-term forage production potentials, while subsequent siltation may reduce runoff quality and values for downstream agricultural enterprises. Since most of the soil slips began on the steep slopes adjacent to the stream banks draining the center of the watershed, one implication is that total brush conversion may have been undesirable. Retaining some dense, riparian vegetation intact during brush conversion programs serves to minimize the unwanted side effects of slippage and sedimentation (Lewis and Burgy 1964). However, since these dense, woody sites contributed a very large proportion of the total forage increase following brush conversion (Pitt 1975), leaving them intact would also detract from the benefits of brush conversion prjects. The appropriate balance of these positive and negative results of brush conversion certainly depends upon managerial objectives in any particular regional locale.

Summary and Conclusions

The influences of brush conversion, herbage productivity, and annual weather patterns on runoff emanating from Watershed II, Hopland Field Station, were investigated during the years 1955–1970 inclusive. Grassy vegetation following brush conversion produced approximately 59% more runoff as a percentage of total precipitation than did woody vegetation prior to brush conversion. Once this grassy vegetation became established however, the relative degree of cover and standing crop from one year to the next exerted only negligible influences on total runoff from the watershed. The coefficients associated with cover and standing crop in the simple regression equations for runoff (Table 3) never exceeded 0.44, indicating that a unit increase in either cover or standing crop produces less than a unit increase in runoff. Interestingly, both cover and standing crop positively correlated with runoff, suggesting that increasing cover and standing crop of grassy vegetation produce greater amounts of runoff. However, these relationships among runoff, cover, and standing crop actually represent associations with the overwhelming influence of total precipitation, which positively correlated with all three of these variables (Pitt 1975).

Indeed, total precipitation rather than temperature and rainfall patterns was primarily responsible for annual variability in total runoff emanating from Watershed II subsequent to brush conversion. The first four variables entering the step-wise multiple regression equation of runoff through June 1 on weather patterns all describe amounts of rainfall as opposed to temperature patterns. Although periodicity and intensity of storms as well as temperature patterns certainly influence total water released from any watershed, the single variable, total precipitation through June 1, described 92% of the variability in annual runoff from Watershed II.

In addition to increased runoff, brush conversion at this site drastically increased sedimentation and soil slippage in the vicinity of streams, particularly after the root systems of the dense, woody vegetation on these slopes decayed. Leaving some stream bank vegetation intact may have minimized that undesirable result of brush conversion on Watershed II.

Literature Cited

Bates, C. G., and A. J. Henry. 1928. Forest and streamflow experiments at Wagon Wheel Gap, Colorado. U.S. Weather Bureau Monthly Weather Rev., Suppl. No. 30.

Bentley, J. R. 1967. Conversion of chaparral areas to grassland: Techniques used in California. U.S. Dep. Agr., Forest Serv., Agr. Handbook No. 328. 35 p.

Biswell, H. H., and A. M. Schultz. 1958. Effects of vegetation removal on spring flow. Calif. Fish and Game 44:211-230.

Branson, F. A., G. F. Gifford, and J. R. Owen. 1972. Rangeland hydrology. Soc. Range Manage., Range Sci. Ser. No. 1. 84 p.

Burgy, R. H., and A. G. Papazafiriou. 1974. Vegetative management and water yield relationships. Proceedings, 3rd Int. Seminar for Hydrology Professors, Purdue Univ., July 18-30, 1971. p. 315-331.

Gowans, K. D. 1958. Soil survey of the Hopland Field Station. Calif. Agr. Exp. Sta.

Harrold, L. L., et al. 1962. Influence of land use and treatment on the hydrology of small watersheds at Cashocton, Ohio. U.S. Dep. Agr. Tech. Bull. 1256. 194 p.

Hewlett, J. D., and A. R. Hibbert. 1961. Increases in water yield after several types of forest cutting. Int. Ass. Sci. Hydrology. Pub. No. 6:5-17.

Hibbert, A. R. 1969. Water yield changes after converting a forested catchment to grass. Water Resources Res. 5:634-640.

Lewis, D. C., and R. H. Burgy. 1964. The relationship between oak tree roots and groundwater in fractured rock as determined by tritium tracing. J. Geophys. Res. 69:2579-2588. June.

Pereira, H. C. 1962. Hydrological effects of changes in land use in some South African catchment areas. East Africa Agr. Forestry J., Vol. 29. 131 p.

Pitt, M. D. 1975. The effects of site, season, weather patterns, grazing, and brush conversion on annual vegetation, Watershed II, Hopland Field Station. Univ. of California. Unpublished PhD Thesis. 281 p.

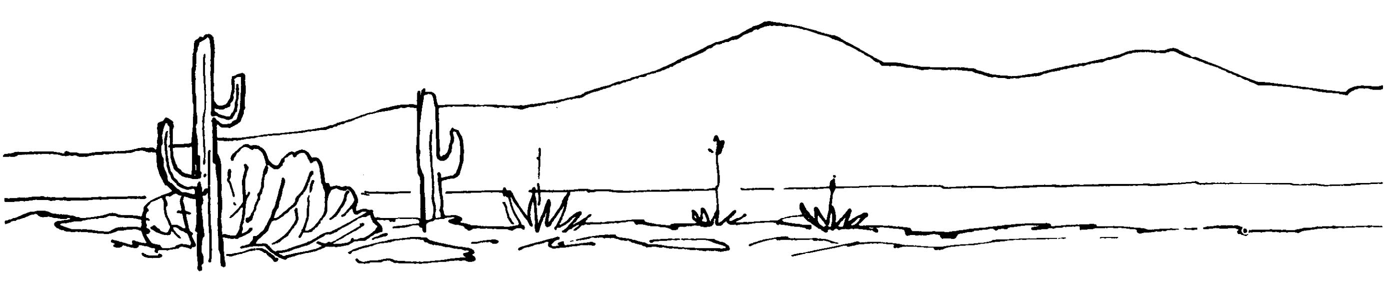
Reinhart, K. G., A. R. Eschner, and G. R. Trimble. 1963. Effect on streamflow of four forest practices in the mountains of West Virginia. U.S. Forest Serv., Northeast Forest Exp. Sta. Res. Pap. NE-1. 59 p.

Rothacher, J. 1965. Streamflow from small watersheds on the western slope of the Cascade Range of Oregon. Water Resources Res. 1:125.

Rowe, P. B. 1948. Influence of woodland chaparral on water and soil in central California. U.S. Dep. Agr., Forest Serv., in cooperation with State of California, Dep. Nat. Resources, Unnumbered Pub.

Rowe, P. B. 1963. Streamflow increases after removing riparian vegetation from a southern California watershed. J. Forestry 61:365-370.

Rowe, P. B., and L. F. Reimann. 1961. Water use by brush, grass, and grass-forb vegetation. J. Forest. 59:175-181.



Vegetative Responses of Some Great Basin Shrub Communities Protected against Jackrabbits or Domestic Stock

BARBARA RICE AND MARK WESTOBY

We surveyed the vegetation at 19 locations inside and outside 12 exclosures built at various times in Curlew Valley, northern Utah. The exclosures were in semidesert shrub vegetation and included several communities definable by a dominant perennial shrub distribution having sharp boundaries. At the level of the individual quadrat, there was no correlation between the density of any of the abundant annuals and the percentage of the soil surface that was bare, or covered by rock, dead plant matter, or cryptogam crust. The communities as defined by dominants arranged themselves in the order winterfat, shadscale, shadscale and perennial grasses, sagebrush, black sage. These communities are known to be found on progressively less xeric sites. The changes which resulted from protecting samples of these communities from grazers were fairly consistent within each community, but differed among communities; and moreover these changes were not correlated with a trend from more to less xeric sites. Protection against sheep, with or without protection against jackrabbits, did not have very many effects even over 15 years: halogeton generally decreased; peppergrass increased where present; winterfat increased in vigor but not in density where it was dominant. Other dominant shrubs and perennial grasses did not respond to protection. Protection against jackrabbits had no consistent extra effect on the parameters studied. The classical concept of range succession is that recovery from overgrazing moves a community through secondary succession parallel to a gradient towards relatively more mesic conditions. On the whole, this concept has not been useful in interpreting the results of excluding grazers from these semiarid shrublands.

It is generally accepted that vegetation on many semiarid rangelands has changed during the last century, partly because of poor grazing practices (Martin 1975). A number of reports document shifts from grassland to shrub-dominated vegetation in New Mexico (Buffington and Herbel 1965) and central Utah (Christensen and Johnson 1964). Vale (1975) suggested that northern Great Basin semiarid ranges may always have been dominated by shrub species. Under continued grazing pressure vegetational change in northern Nevada may be toward annual grasses and forbs replacing desirable browse species (Robertson and Kennedy 1954).

Studies of grazing successions are frequently based on comparisons of protected and grazed vegetation, and results vary considerably. Stoddart et al. (1975) state that secondary succession should follow the same sequence as primary succession, although the process may be extremely slow. On some Arizona ranges the shrub component continues to increase, regardless of grazing treatment (Smith and Schmutz 1975). Gardner (1950) found an increase in grass cover on protected areas in New Mexico, but little difference in floristic composition after 30 years. In Texas Smeins et al. (1976) recorded little change in plant composition within an exclosure protected for 25 years, and Reardon and Merrill (1976) found that litter production was greater under continuous light grazing than under no grazing. In western Colorado, Turner (1971) found little response to protection which could be clearly attributed to livestock exclusion, although an increase in litter and moss cover within exclosures was attributed to the lack of trampling. However, Robertson (1971) reported that 30 years' exclusion of livestock on a Nevada sagebrush-grass range resulted in an increase of shrub, forb, and grass cover.

In Curlew Valley, northern Utah, different range scientists have at various times built exclosures against livestock, and sometimes against jackrabbits. The exclosures are spread over a range of vegetation types along a slope and have been protected from 6 to 15 years. They provide an opportunity to study differences between protected and unprotected vegetation and also the relation of those differences to variation among different vegetation types. In this paper we report results of a vegetation survey designed to investigate those matters.

Study Area

Curlew Valley runs north from the shore of the Great Salt Lake across the Utah/Idaho border. Vegetation ranges from sagebrush (*Artemisia tridentata*) types in the north to saltbush types (*Atriplex* spp.) in the south and at lower elevations. Total year-round precipitation ranges from 150–200 mm in the south to 350–400 mm in the north. Most falls in the winter, a substantial portion as snow. Besides decreasing precipitation, another probable cause of changing vegetation down the valley is the increasing salinity of soils left behind by Pleistocene Lake Bonneville during its retreat. Attempts to define the correlation of soil properties with plant distribution in the study area have not been successful (Mitchell et al. 1966).

Gates et al. (1956) show that abrupt changes in soil chemistry do not necessarily induce concomitant, or consistent, shifts in vegetation. Even the relatively strong patterning in winterfat and shadscale vegetation types is apparently independent of soil salinity (Mitchell et al. 1966), although salinity would seem the strongest factor operating on distribution in the area.

A sketch-map of the part of the valley in which our studies were located is shown in Figure 1. The Wildcat Hills, on the east in Figure 1, rise in the center of the valley. The lowest point on the east-

Work was done while the authors were research assistants, Ecology Center, Utah State University, Logan 84332; supported in part by NSF Grant GB 15886 to the US/IBP Desert Biome. Reprints from Westoby, School of Biological Sciences, Macguarie Univ., North Rye, N.S.W. 213, Australia.

Authors appreciate the help of J. Chesney, A. H. Holmgren, F. H. Wagner, and N. E. West.

Manuscript received April 17, 1977.

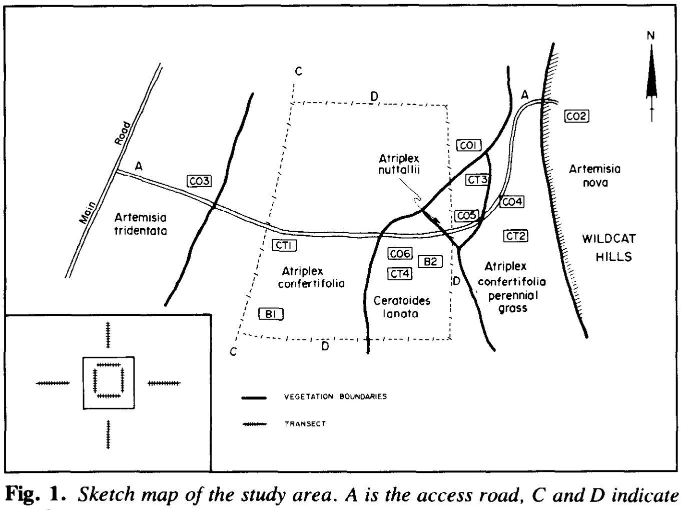


Fig. 1. *Sketch map of the study area. A is the access road, C and D indicate relevant fences, small rectangles with two- or three-digit names are exclosures. Further explanation in text.*

west road A lies at about B. The dominant shrubs are mapped over the area. This mapping is not exact but serves to show which shrubs dominate the vegetation of particular exclosures. For example, exclosure CO3 is dominated by sagebrush. To the east on the map, the road A turns north under a sharp slope upwards to the Wildcat Hills. Thus exclosure CO2 lies higher than the others, on coarser soils, and is dominated by black sage (*Artemisia nova*). Exclosure CT2 lies at the mouth of a small valley into the Wildcat Hills, and its soil is also coarser, presumably derived from material washed out of the valley.

What is known of the grazing history of the area is as follows. (We are grateful to Dr. N. E. West for this information.) From 1869–1914, Kelton, a few miles south, was a major railhead for shipping stock. Over this period the study area probably was grazed intensely by sheep being driven to Kelton and held waiting for shipment. After 1919 the main east-west railway route shifted south of the Great Salt Lake, and Kelton was no longer used. More recently the valley to the south of the study area has been grazed in winter under Bureau of Land Management permit. In the study area itself, the area west of the fence C has been grazed year-round by cattle. The center of the valley, bounded by fence C and fence D, was privately owned and used as a lambing ground until 1969. Since then it has not been grazed. The corridor between Fence D, on the west, and the slope of the Wildcat Hills, on the east, is the route through which sheep are driven south in early winter to use the grazing in the lower valley, and north again in spring. While there is no fence restraining sheep to the east, the absence of dung indicates that they do not usually have time to spread up onto the high ground.

The area shown in Figure 1 has been much used since the 1950's for various studies of range ecology. The exclosures shown there have mostly been established in order to protect from defoliation individual plants whose physiology was being studied. Those exclosures prefixed CO were established in 1956 (Cook 1971); except for CO1 they were made proof against jackrabbits (*Lepus californicus* only in this area) in 1957. The studies in them ended in 1969; the protection of CO2 and CO4 against jackrabbits has lapsed since then (Westoby 1973). Exclosures prefixed CT were established in 1966 (Coyne 1969; Trlica 1971). None of these were made jackrabbit-proof. Those prefixed B were established in 1968 (Bjerregaard 1971) and were made jackrabbit-proof.

Methods

Data Collection

Data were collected at a total of 19 "locations." These were inside each of the 12 exclosures and close by, but outside, seven of them—exclosures B1, CO1, CO2, CO3, CO4, CO5, and CO6. Locations in exclosures are referred to by the suffix P (e.g. B1P) and those outside by the suffix U (e.g. B1U). The inset in Figure 1 shows the arrangement within and outside the exclosures. Four 30-m transects were placed at each location. At 1.5-m intervals along each transect, twenty 0.1 m^2 (50 cm × 20 cm) quadrats were sampled. Within each quadrat percent cover and rooting density of shrubs were recorded. The soil surface was described as percentages of bare soil, cryptogam cover (algal crust), and litter; plant bases were considered litter. For perennial grasses, a cover value was recorded for each individual whose center lay inside the quadrat. Percent cover for each such individual was estimated as if it lay entirely inside the quadrat. Individuals some part of which fell inside the quadrat were not recorded if their center was not inside.

At each end of the quadrat, two 10 cm × 20 cm areas were marked off with wire. The densities of annual species were recorded in these two subquadrats.

These data were collected between May 6 and 12, 1973. At this date all annuals had germinated but most had not flowered. Identification was therefore speculative at the time the data were collected. In most cases the species were given arbitrary names and successfully identified later. In one case, however, seedlings of two *Descurainia* species were given the same arbitrary designation, and these data could not be properly separated afterwards. Generally they occurred together only in the Wildcat Hills, while over the rest of the area *Descurainia pinnata* was found.

Data Analysis

In the Results section, besides presenting the basic data on vegetation properties of the 19 locations, we describe results of analyzing the data in three ways.

First, we studied the distribution of herbaceous species in the 0.1-m^2 quadrats with respect to their relation to soil surface properties and the percentage cover of half-shrubs and whole shrubs, by correlation of these factors for all 1,520 quadrats. Second, we ordinated the 19 locations to find the main directions of variation in vegetation composition over the whole study area, in order to see whether changes in vegetation after exclusion were consistently related to their direction of variation. A Bray-Curtis ordination method was used (Bray and Curtis 1957). Third, we considered the specific effects of protection by comparing particular pairs of samples (grazed and ungrazed) at locations which probably had similar shrub dominants before undergoing different grazing histories.

The basic data which come out of a vegetation study take the form of a table, with species along one side, locations along the other, and a measure of the abundance of each species at each location in each cell of the table. Such a table contains too much information for the main patterns to be readily apparent. Ordination is one of several methods for reducing such a data table to a simpler picture, but without discarding too much information in the process. The first step is to convert the basic data table to a similarity table. This is a table with the list of locations along both sides. Each cell of the table contains a measure of how different two locations are. The diagonal contains zero values, and the matrix is symmetrical about the diagonal.

Various measures of how different two locations are can be used. The results we present used percentage similarity, obtained by summing over all species the smallest abundance of each divided by the sum of its abundances in the two sites.

The similarity matrix can be used in various ways. In ordination procedures the locations are arranged along a few axes (usually two, so that the resulting figure can be shown on a page) in such a way that distances between locations in the arrangement are as close as possible in proportion to the differences between them in the similarity matrix.

We carried out several Bray-Curtis ordinations and a principal components ordination. In Bray-Curtis ordination axes are defined by choosing very dissimilar sites as endpoints; principal components ordination uses measures of how much variance between sites is explained to choose axes. For our data all analyses gave similar results. Gauch and Whittaker (1973) describe and assess the merits of different ordination methods.

Before carrying out ordinations, we reduced somewhat the basic data table. First, we removed those species which occurred in only a few locations because the mathematics of ordination make two locations appear similar if they both lack the same species as well as if

Table 1. Vegetation composition as percentage cover and densities at the 19 locations studied. Locations are arranged with similar ones adjacent. Zero values indicate cover of less than 0.05%.

Measure of abundance / Species	Location																		
	CO2U	CO2P	CT2P	CO3U	CO3P	B1U	B1P	CT1P	CO1U	CO1P	CO4U	CO4P	CO6U	CO6P	CT4P	B2P	CO5U	CO5P	CT3P
Percent cover																			
Artemisia nova	26	25																	
Artemisia tridentata		1	6	9	10							2	3	0.1	1	0.1			
Atriplex confertifolia		0.1				12	19	20	6	7	8	9	0						
Ceratoides lanata						0.3			0			2	16	25	21	29			
Atriplex nuttallii														0.3			18	15	22
Chrysothamnus viscidiflorus	0.4	2	8																
Grayia spinosa	1	0.1	5																
Artemisia spinescens						2					1	2							
Kochia americana											0.3	0.8							
Rooting density/m²																			
Artemisia nova	5	4																	
Artemisia tridentata			0.3	1	1							0.3	2		0.5	0.3			
Atriplex confertifolia			0.3			4	5	3	2	2	2	1	0.1						
Ceratoides lanata						0.3			0.1			1	19	21	23	27			
Atriplex nuttallii																	49	28	42
Chrysothamnus viscidiflorus	0.3																		
Grayia spinosa	0.3	0.1	0.1																
Artemisia spinescens						1				0.4	0.3								
Kochia americana										2	2								
Malcolmia africana	4	1	1						0.3		11	1	3		4	15	94		313
Halogeton glomeratus			69	150	53		141	21	701	247	558	2	285		25	2	88		26
Descurainia spp.	19	71	5	75	129	23	32	2	15	77	0.3	12	16	19	9	2	3	4	5
Cryptantha sp. (annual)	3	1	4	3	2	13	31	3	7	25	11	7	13	2	3	4	45	3	21
Bromus tectorum	20	21	95	673	776	164	225	62	642	609	446	232	7	5	55	7	34	466	84
Lepidium perfoliatum						45	4	558		7	9	72							

they have the same species. Thus too many zero values in the table can produce misleading results. Second, we divided all percentage cover values in the table by the largest single percentage cover, and all densities by the largest single density. This has the effect of making species measured by cover (shrubs and perennial grasses) of roughly equal importance in the ordination to species measured by density (annuals).

Results

Vegetation Composition

Table 1 shows the vegetation composition of the 19 locations studied. On the basis of the dominant shrubs, the locations fall into six subjectively recognizable communities. These correspond to the types indicated in Figure 1. They are communities dominated by sagebrush, shadscale, winterfat (*Ceratoides lanata*), Nuttall saltbush (*Atriplex nuttallii*), black sage, and shadscale-mixed shrub-grass community.

Of the minor perennials, white sage (*Kochia americana*) and bud sage (*Artemisia spinescens*) were found exclusively in certain shadscale communities on the east side of the valley. *Phlox hoodii* and rabbitbrush (*Chrysothamnus viscidiflorus*) occurred in all full-shrub communities. *Grayia spinosa* was found in sagebrush with black sage communities. Pricklypear (*Opuntia polyacantha*) was found occasionally in all communities.

Of the herbaceous species, three of the most important, halogeton (*Halogeton glomeratus*), *Malcolmia africana,* and cheatgrass (*Bromus tectorum*), are introduced. Halogeton was found in all communities except those dominated by black sage, but reached its greatest abundance in certain shadscale and winterfat communities. *Malcolmia africana* was also found in several communities, including those dominated by black sage, but only reached great abundance in Nuttall saltbush communities. Cheatgrass was found in all communities, but was most abundant in sagebrush communities, where it formed an almost continuous understory.

Of the native herbaceous species, the annual *Cryptantha* was found in moderate amounts in all communities, never reaching the abundance of halogeton, cheatgrass, or *Lepidium perfoliatum.* The latter was found only in shadscale communities. *Lepidium densiflorum* was found only in winterfat communities. *Allium nevadense, Phlox longifolia,* and *Gilia inconspicua* were virtually restricted to black sage communities.

By far the most important perennial grass was squirreltail (*Sitanion hystrix*). It occurred in all six communities, but rarely exceeded 10% cover; it did not compare with the dominant shrubs in abundance. Indian ricegrass (*Oryzopsis hymenoides*) was less common. Sandberg bluegrass (*Poa sandbergii*) equalled squirreltail in importance in the black sage community.

Correlation between Herbaceous Species and Microscale Properties

We attempted to determine the microscale habitat preferences of the more abundant annuals and of perennial grass seedlings by correlating their density in individual quadrats with factors that might be expected to influence their densities, such as the percentages of the soil surface covered with litter, a cryptogam crust, or bare ground, and the shrub cover over the quadrat.

We plotted scattergrams of densities against these factors, after appropriate transformations (square root for densities, angular for percentages). None of these scattergrams showed any consistent patterns. Accordingly we did not calculate correlation coefficients.

Ordination

Figure 2 shows the results of a typical Bray-Curtis ordination. In this figure, locations which were similar (as measured by percentage similarity) are close together, while very different sites are far apart. The dotted lines separate sets of locations

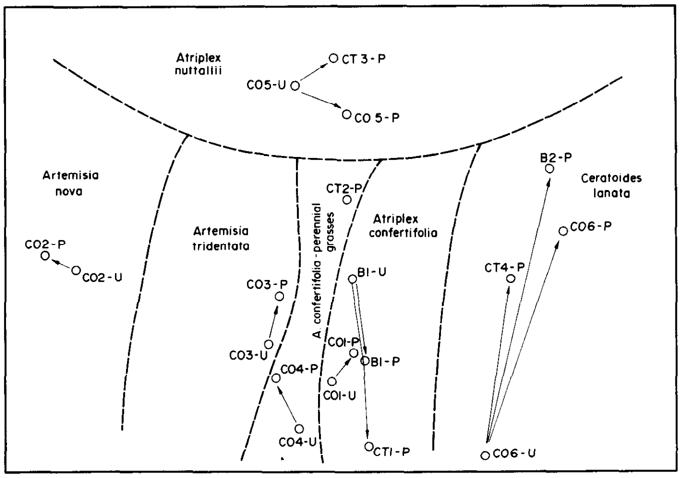


Fig. 2. *Results of a two-dimensional Bray-Curtis ordination of sample sites. The closer two sites on this figure, the more similar was their vegetation. Arrows go from grazed sites to protected sites with the same dominants, and therefore indicate the directions of change after protection. Further explanation in text.*

dominated by different perennial species or species-combinations. The main sequence of these subjectively recognizable communities, from left to right, is black sage, sagebrush, shadscale-mixed shrub-grass, shadscale, and winterfat. This is the same sequence as is found typically in Curlew Valley going towards lower elevations and more saline soils. The ordination has placed the Nuttall saltbush communities to one side of this main sequence, though these are normally found interspersed in a mosaic with the winterfat communities. Although surrounded by shadscale-mixed shrub-grass community, exclosure CT2P is dominated by sagebrush and rabbitbrush. This may be due to its position on coarse alluvial soils washed down from the Wildcat Hills.

Just as two sites with different vegetation would occur in different places in a two-dimensional ordination such as Figure 2, a change in the vegetation of one site would cause it to change its position, and the direction of the move would indicate the nature of the change which had occurred.

Therefore on Figure 2 we have drawn arrows from locations which are unprotected to those which have the same perennial dominants and which have been protected from large herbivores to various degrees and for various times. These arrows represent in length the amount of vegetation change suggested, and in direction the nature of the change.

First, it is clear that within each subjectively recognizable community the effects of protection from herbivores are reasonably consistent. Second, however, the trends were different in each community. Even in two communities with a good deal in common, the shadscale (*A. confertifolia*) and the shadscale-mixed shrub-grass communities, the effects of herbivore exclusion moved the composition of the vegetation in directly opposite directions.

In particular, the trends that resulted from herbivore exclusion apparently did not bear any regular relation to the main trend of vegetation variation along the topographic-rainfall-soil salinity gradient. Thus the effect of protection on the shadscale-dominated communities was not to make them more like the more mesic sagebrush-dominated communities. Similarly, protection did not make sagebrush-dominated communities more like the more diverse black sage-dominated communities.

Specific Effects of Protection

Table 2 describes what is known of the history of protection of the 12 enclosures. It is of course hard to guarantee that a fence is jackrabbit-proof. We tested this by estimating the standing crop of pellets inside and outside each exclosure during 1973 (Table 2). Westoby and Wagner (1973) found in a nearby area that the standing crop of pellets was 2–3 times as great as a yearly deposition rate which can be calculated from literature values. Therefore it is assumed here that the standing crop of pellets can reasonably be used as a crude estimator of jackrabbit grazing pressure at a location over the last 2–3 years. If the 95% confidence limits of pellet density inside and outside an exclosure do not overlap, the exclosure has probably provided effective protection since 1969. Non-overlap of confidence limits is a conservative test for the difference between means (Sokal and Rohlf 1969). The two peaks of jackrabbit density in Curlew Valley during the history of these exclosures have been in 1959–61 and in 1970–72. From the data presented in Table 2, it is possible to decide which exclosures were rabbit-proof during those peaks.

It might be thought that exclosures which had been protected against sheep grazing but not made rabbit-proof would be subject to heavier jackrabbit use than the community at large; but the pellet counts show no evidence of this. However, a higher rate of pellet deposition may have been counteracted by a

Table 2. History and characteristics of some exclosures in Curlew Valley up to 1973.

Vegetation type	Exclosure name	Sheep-proof since	Jackrabbit pellets per m^2 (95% confidence limits) Inside	Jackrabbit pellets per m^2 (95% confidence limits) Outside	Dates definitely jackrabbit-proof
Atriplex confertifolia	CO1	1957	34 ± 28	155 ± 148	Never
	CT1	1966	29 ± 17	28 ± 13	Never
	B1	1968	1 ± 1	29 ± 37	1968–1973
Artemisia nova	CO2	1957	24 ± 31	30 ± 39	1958–1969
Artemisia tridentata[1]	CO3	1957	29 ± 26	92 ± 52	Never
Atriplex confertifolia and perennial grasses	CO4	1957	73 ± 52	57 ± 31	1958–1969
	CT2	1966	53 ± 52	54 ± 49	Never
Atriplex nuttallii	CO5	1957	19 ± 11	125 ± 51	1958–1973
	CT3	1966	99 ± 31	131 ± 90	Never
Ceratoides lanata[2]	CO6	1957	0 ± 0	155 ± 148	1958–1973
	CT4	1966	70 ± 17	90 ± 47	Never
	B2	1968	3 ± 4	92 ± 34	1968–1973

[1] Area grazed by cattle.
[2] Sheep grazing in this community stopped in 1969.

higher rate of decomposition inside the exclosures, resulting from a more uneven (less trampled) soil surface and a denser herb layer (Flux 1967).

From Table 2 various comparisons among specific locations can be identified which allow us to explore the effects of particular kinds of protection in different communities. The effects of protecting against jackrabbits specifically can be seen by comparing B1P with CT1P in shadscale communities, and B2P with CT4P in winterfat communities. Notice that sheep are absent from both sides of these comparisons. The effects of protecting against both sheep and jackrabbits can be seen by comparing CO2P with CO2U in black sage communities, CO4P with CO4U in shadscale-perennial grass communities, CO5P with CO5U in Nuttall saltbush communities, and CO6P with CO6U in winterfat communities. The effect of excluding cattle can be seen by comparing CO3P with CO3U in sagebrush communities.

For each of these pairs of locations, we compared the value of all measured quantities by t-test after appropriate transformation. We do not show the detailed results of these tests here, although mean values are shown in Table 1. The results are summarized in Table 3, where a + means that protection caused a significant ($P < .05$) increase in the parameter, 0 means there was no change, a − indicates a significant decrease under protection, and a blank means that the value was zero in both locations being compared.

In interpreting Table 3 it should be borne in mind that 1 in 20 contrasts would be expected to show a "significant" change

Table 3. Herbivores excluded and the resulting increase (+), decrease (−), or no change (0) in vegetation parameters from plant communities subjectively defined by their dominants. Blanks indicate that the species was absent from both locations being compared. Increases and decreases defined at $P = .05$.

Measure and species or other parameters	Rabbits		Sheep				Sheep and rabbits				Cattle
	Atriplex confertifolia	*Ceratoides lanata*	*Atriplex confertifolia*		*Atriplex nuttallii*	*Ceratoides lanata*	*Ceratoides lanata*	*Artemisia nova*	*A. confertifolia* perennial grass	*Atriplex nuttallii*	*Artemisia tridentata*
Percentage cover											
Chrysothamnus viscidiflorus								0			
Artemisia nova								0			
Artemisia spinescens									0		
Artemisia tridentata		0				0	0	0	0		0
Atriplex confertifolia	0		+	0		0	0	0	0		
Atriplex nuttallii					0		0			0	
Ceratoides lanata		+	0	0		+	+		+		
Grayia spinosa								0			
Juniperus osteospermum								0			
Kochia americana									0		
Opuntia polyacantha				0				0			
Phlox hoodii								0			
Sitanion hystrix	0	0	−	0	0	0	0	0	0	+	0
Poa secunda			0	0			0	0	0	+	0
Oryzopsis hymenoides		0	0	0		0		−	0		
Bare soil	0	−	0	0	−	0	0	0	−	−	0
Littered soil	0	0	0	0	0	0	0	−	0	+	−
Cryptogam-crusted soil	0	+	0	0	+	0	0	0	+	+	0
Rock								0	0		+
Density											
Chrysothamnus viscidiflorus								0			
Artemisia nova								0			
Artemisia spinescens			−						0		
Artemisia tridentata		0				0	0		0		0
Atriplex confertifolia	0		0	0		0	0		0		
Atriplex nuttallii					0					−	
Ceratoides lanata		0	0	0		0	0		+		
Grayia spinosa								0			
Kochia americana									0		
Opuntia polyacantha				0				0			0
Phlox hoodii								0			
Allium nevadense								0			0
Bromus tectorum	+	−	−	0	+	+	0	0	−	+	0
Cryptantha nana								0			
Cryptantha sp. (annual)	+	0	−	0	0	0	0	0	0	0	0
Cymopteris longipes								0			
Descurainia spp.	0	−	0	0	0	0	0	+	+	0	+
Delphinium nelsonii								0			
Brigeron pumilis								0			
Camilina microcarpa	0										
Gilia polyclador								−			
Halogeton glomeratus	+	−	+	−	−	−	0		−	−	−
Lepidium montanum								+			
Lepidium perfoliatum	−		+	+					+		
Lepidium densiflorum		+				−	−				
Malcolmia africana		+		0	+	0	−	0	−	−	
Phlox longifolia								−			
Ranunculus testiculatus		0				0	−		0		
Rumex acetosella											0
Sphaeralcea collina								0	0		

randomly. Thus we would expect as many as 9 of the +'s and −'s in Table 3 to be spurious. Conclusions must be based on repeated patterns. rather than on single comparisons.

Looking first at the effects attributable specifically to excluding rabbits, we see that there were no changes in particular species which were repeated in both the communities for which we have data. In some cases where there was a significant increase in one community, there was a significant decrease in the other. These results are documented in more detail by Westoby (1973).

There seem to be two species consistently affected by the exclusion of sheep but not jackrabbits. *Lepidium perfoliatum* increased consistently in the *Atriplex confertifolia* communities in which it was found. Halogeton decreased in most cases, although in one case in a shadscale community it had increased. This increase was smaller and less significant ($P < .05$) than the decreases ($P < .0005$). This situation may be explained by the fact that the "unprotected" half of this comparison had not been grazed by sheep for 3 years before the data were collected. Perhaps the response of halogeton to sheep exclusion is a rapid one.

In the winterfat community, winterfat has increased in percentage cover but not in rooting density as a result of sheep exclusion; that is, the individual plants have increased in vigor, but not in number.

Considering now the effects of excluding both sheep and jackrabbits, we see first that some of the patterns found when sheep alone were excluded are confirmed. *Lepidium perfoliatum* increased where it was present, *Halogeton* usually decreased, and winterfat increased in percentage cover but not in density where it was a dominant. Interestingly, winterfat increased in density as well as percentage cover in the shadscale-perennial grass community where it was not a dominant. *Malcolmia africana* seemed to decrease when both sheep and jackrabbits were excluded, but this was contradicted by increases found when either sheep or jackrabbits were excluded separately.

Across all kinds of exclusion, the percentage of soil with cryptogam crust tended to increase, and the percentage of bare soil to decrease correspondingly. This was presumably the result of trampling pressures being removed.

Conclusions and Discussion

From these results we drew the following conclusions:
1) Although the communities in the study area have sharp boundaries as defined by the dominants, ordination arranged them as a series dominated by winterfat, Nuttall saltbush, shadscale, sagebrush, and black sage. These communities occur on progressively less saline soils, at higher elevations, and commonly under higher rainfall. Adjacent communities in the series tend to have annual species in common.
2) The vegetation changes in these communities which result when they are protected against domestic stock, jackrabbits, or both are different among communities. These changes do not tend to move the communities either higher or lower along the environmental progression described.
3) Protection against grazers tended to increase the percentage of the soil surface covered with cryptogam crust, and conversely to decrease the percentage of bare soil. This presumably resulted from the absence of trampling.
4) At the level of the 20 × 50 cm quadrat, there appeared to be no correlation between soil surface properties (percentages of litter, cryptogam crust, etc.) and the abundance of any of the common annuals or perennial grass seedlings.
5) In most communities the following tendencies of particular species either to increase or decrease under protection were found: *halogeton* tended to decrease; peppergrass (*L. perfoliatum*) to increase where present; winterfat plants increased in vigor where it was a dominant (i.e. there was an increase in percentage cover but not in density).
6) Protection from jackrabbits had no consistent effects.
7) A number of plant species which might have been expected to respond to protection did not do so. The other abundant annuals besides halogeton and peppergrass (*Malcolmia africana, Bromus tectorum, Descurainia* spp., and *Cryptantha* sp.) did not show a consistent response. Perennial grasses did not respond, either in percentage cover, density, or the number of seedlings present. The dominant perennial shrubs, with the exception of winterfat, did not increase under protection.

Three general points can be made from these conclusions. First, the difficulties of intepreting exclosure experiments should be emphasized. Our results from cold deserts are much like those documented for warm, arid zones (Smeins et al. 1976; Smith and Schmutz 1975), indicating common problems over different types of rangelands. While quadrats can be replicated inside and outside an exclosure, it is unusual to have replicated exclosures; that is, replicated samples of the original vegetation subjected to an exclosure treatment. Moreover, in most cases including this one, the sample protected is arbitrarily rather than randomly chosen from the original vegetation. Other factors complicating interpretation in this study are the varied history of the exclosures, and the varied history of grazing patterns to which the areas outside the exclosures have been subjected.

Second, even given these reservations about the imperfections of the "experimental design," we feel we can conclude that any changes which ensue on protection in these communities are at best slow, and probably almost nonexistent. With the exception of winterfat, none of the dominant shrubs or the perennial grasses responded to protection even after periods of 15 years. This must mean either that these populations were not reduced by intense grazing earlier, or that the concept of the grazing succession is not meaningful in these semiarid shrublands, or that recovery has been prevented by some new factor such as *Halogeton* invasion.

Third, we conclude that those changes which do occur after protection are not correlated with changes occurring along the gradient from relatively xeric to relatively mesic sites which dominates the distribution of communities over the area. Again, this is in conflict with the classical concept of range succession (Stoddart et al. 1975).

Literature Cited

Bjerregaard, R. S. 1971. The nitrogen budget of two salt desert shrub plant communities of Western Utah. PhD Diss., Utah State Univ., Logan. 100 p.

Bray, R. J., and J. T. Curtis. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecol. Monogr. 27:325-349.

Buffington, L. C., and C. H. Herbel. 1965. Vegetational changes on a semi-desert grassland range from 1858–1963. Ecol. Monogr. 35:135-164.

Christensen, E. M., and H. B. Johnson. 1964. Presettlement vegetation and vegetational change in three valleys in Central Utah. Brigham Young Univ. Sci. Bull. Biol. Ser. IV, No. 4. 16 p.

Cook, C. W. 1971. Effects of season and intensity of use on desert vegetation. Utah Agr. Exp. Sta. Bull. 382. 57 p.

Coyne, P. I. 1969. Seasonal trends in total available carbohydrates with respect to phenological stage of development in eight desert range species. PhD Diss., Utah State Univ., Logan. 164 p.

Flux, J. E. C. 1967. Hare numbers and diet in an alpine basin in New Zealand. Proc. N. Z. Ecol. Soc. 14:27-33.

Gardner, J. L. 1950. Effects of thirty years of protection from grazing in desert grassland. Ecology 31:44-50.

Gates, D. H., L. A. Stoddart, and D. W. Cook. 1956. Soil as a factor influencing plant distribution on salt-deserts of Utah. Ecol. Monogr. 26: 155-175.

Gauch, H. F., and R. H. Whittaker. 1972. Comparison of ordination techniques. Ecology 53:868-875.

Martin, S. C. 1975. Ecology and management of south-western semidesert grass-shrub ranges: the status of our knowledge. U.S. Dep. Agr., Forest Serv. Res. Pap. RM-156. 39 p.

Mitchell, J. E., N. E. West, and R. W. Miller. 1966. Soil physical patterns in the shadscale zone of northwestern Utah. Ecology 47:627-630.

Reardon, P. O., and L. B. Merrill. 1976. Vegetative response under various grazing management systems in the Edwards Plateau of Texas. J. Range Manage. 29:195-198.

Robertson, J. H. 1971. Changes on a sagebrush-grass range in Nevada ungrazed for 30 years. J. Range Manage. 24:397-400.

Robertson, J. H., and P. B. Kennedy. 1954. Half-century changes on northern Nevada ranges. J. Range Manage. 7:117-121.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco. 776 p.

Smeins, F. E., T. W. Taylor, and L. B. Merrill. 1976. Vegetation of a 25-year exclosure on the Edwards Plateau, Texas. J. Range Manage. 29:24-29.

Smith, D. A., and E. M. Schmutz. 1975. Vegetative changes on protected versus grazed desert grassland ranges in Arizona. J. Range Manage. 28: 453-458.

Stoddart, L. A., A. D. Smith, and T. W. Box. 1975. Range Management. 3rd edition. McGraw-Hill Book Co., Inc., New York. 532 p.

Trlica, M. J., Jr. 1971. Defoliation and soil moisture regime effects on plant regrowth and carbohydrate reserve utilization and storage in eight desert range species. PhD Diss., Utah State Univ., Logan. 122 p.

Turner, G. T. 1971. Soil and grazing influences on a salt-desert shrub range in western Colorado. J. Range Manage. 24:31-37.

Vale, T. R. 1975. Presettlement vegetation in the sagebrush-grass area of the intermountain west. J. Range Manage. 28:33-36.

Westoby, M. 1973. Impact of black-tailed jackrabbits (*Lepus californicus*) on vegetation in Curlew Valley, Northern Utah. PhD Diss., Utah State Univ., Logan. 164 p.

Westoby, M., and F. H. Wagner. 1973. Use of a crested wheatgrass seeding by black-tailed jackrabbits. J. Range Manage. 26:349-352.

Molybdenosis: A Potential Problem in Ruminants Grazing on Coal Mine Spoils

JAMES A. ERDMAN, RICHARD J. EBENS, AND ARTHUR A. CASE

Highlight: Copper-to-molybdenum ratios in all but two sweetclover samples collected on spoil at eight coal mines in the Northern Great Plains ranged from 0.44:1 to 5:1. Ratios of 5:1 or less in forage are reported to cause molybdenosis, a nutritional disease occurring in molybdic regions of the world. Therefore, if the major forage on coal-mine spoils is sweetclover or other species with similar Cu:Mo ratios, molybdenosis may be expected to occur in cattle and sheep grazing in these areas.

Molybdenosis is a copper-deficiency disease which occurs particularly in cattle and sheep and which is caused by the depressing effect of molybdenum (Mo) on the physiological availability of copper (Cu) (Dye and O'Harra 1959; Clawson et al. 1972; Case 1974). Characteristic symptoms in cattle are scouring, weight loss, depigmentation, reproductive impairment, and even death. Calves are most susceptible, and early symptoms are often irreversible. Although there appears to be no evidence that nonruminants suffer from Mo toxicity, various osteodystrophic conditions may occur in horses fed on high Mo forage over an extended period of time (Dye and O'Harra 1959).

Sweetclover (*Melilotus officinalis* and *M. alba*) is known to be a Mo accumulator, as are many other legumes; it is abundant and widespread on many coal mine spoils in the Northern Great Plains. Legumes are recommended in seed mixture used for land reclamation because of their nitrogen-fixing capability. Sweetclover is considered to be an especially effective plant for spoil-bank stabilization. This species is highly nutritious for livestock, ranking with other cultivated legumes in forage value, and is considered by some ranchers to be superior in productivity and nutritional quality to several of the native grasses in the Northern Great Plains (Miles 1970).

The availability of Mo to a plant is strongly affected by soil pH (Alloway 1973). Its availability is therefore enhanced by the more alkaline conditions that prevail in much of the West. Webb and Atkinson (1965) reported that 5 ppm Mo in forage is the approximate upper level tolerated by cattle, although more recently values as low as 2 ppm have been considered important in Mo-induced hypocuprosis in cattle (Alloway 1973; Thornton 1977. Others believe that it is not the concentration of Mo alone, but the ratio of Cu to Mo, that is the common cause of molybdenosis. The disproportion of these elements ranges from abnormally low levels of Cu and moderately high concentrations of Mo (distinguished as hypocuprosis or "peat scours") to unusually high concentrations of Mo with normal Cu levels (distinguished as molybdenosis or "teart disease"). These two conditions of element imbalance may, for convenience, be termed molybdenosis. A recommended Cu:Mo ratio for cattle is about 6:1, whereas a ratio of less than 2:1 will most likely cause molybdenosis symptoms to develop (Dollahite et al. 1972). Sheep are somewhat more tolerant of Mo (Dye and O'Harra 1959), although ratios of less than 5:1 have caused swayback disease in lambs as well as bovine hypocupraemia in Britain (Alloway 1973).

Authors are botanist and geologist, U.S. Geological Survey, Denver, Colorado 80225, and veterinary toxicologist, College of Veterinary Medicine, University of Missouri, Columbia 65201.

Authors thank T. F. Harms and C. S. E. Papp, who performed the copper and molybdenum analyses, respectively, and P. Guest, who provided the soil pH measurements.

Manuscript received April 20, 1977.

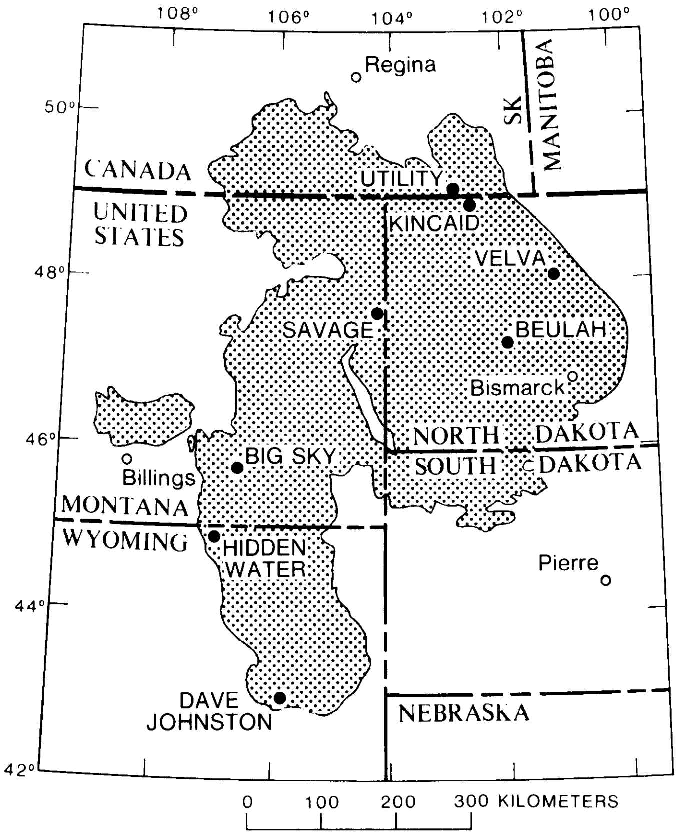


Fig. 1. *The Northern Great Plains coal province, showing locations of the eight surface mines sampled for sweetclover and associated spoil material. Map adapted from Whitaker and Pearson (1972); U.S. Geological Survey (1974).*

Native soils may contain sufficient Mo to cause molybdenosis in range livestock in some areas of the United States, particularly in Nevada and California (Kubota 1975). The replacement or alteration of native soils with spoil materials from mining operations can lead to more widespread molybdenosis problems, as was demonstrated in connection with a clay mine operation in Missouri (Ebens et al. 1973). The development of coal resources in the Northern Great Plains, particularly by surface mining, led us to examine the Cu:Mo ratios in samples of sweetclover that grew on spoils from eight coal mines in this region.

Methods

We conducted the field work during late summer of 1974. Samples of sweetclover and associated soil and/or spoil material were collected from 10 randomly selected sites (in which sweetclover could be found) at each of eight surface mines scattered throughout the Northern Great Plains (Fig. 1). A sample of spoil material or a spoil-soil mixture (where topsoiling had been attempted) was collected to a depth of about 20 cm. The sweetclover sample consisted of the above-ground portion of a plant growing within 1 m of the soil sample. Composite samples were collected from an area as large as 10 m^2 when single plants were not large enough. Although we wished to sample only yellow sweetclover (*Melilotus officinalis*), at the Big Sky and Utility mines this species had matured to the point where only stems remained and the later-maturing white sweetclover (*M. alba*) was sampled instead. Both species occurred at most mines, yellow sweetclover appearing to be the more abundant.

Samples of sweetclover were first dry-ashed at 450°C for 24 hours. Cu and Mo analyses of the ash were performed using atomic absorption spectrophotometry and thiocyanate methods, respectively (Reichen and Ward 1951; Nakagawa 1975). Because many reports on

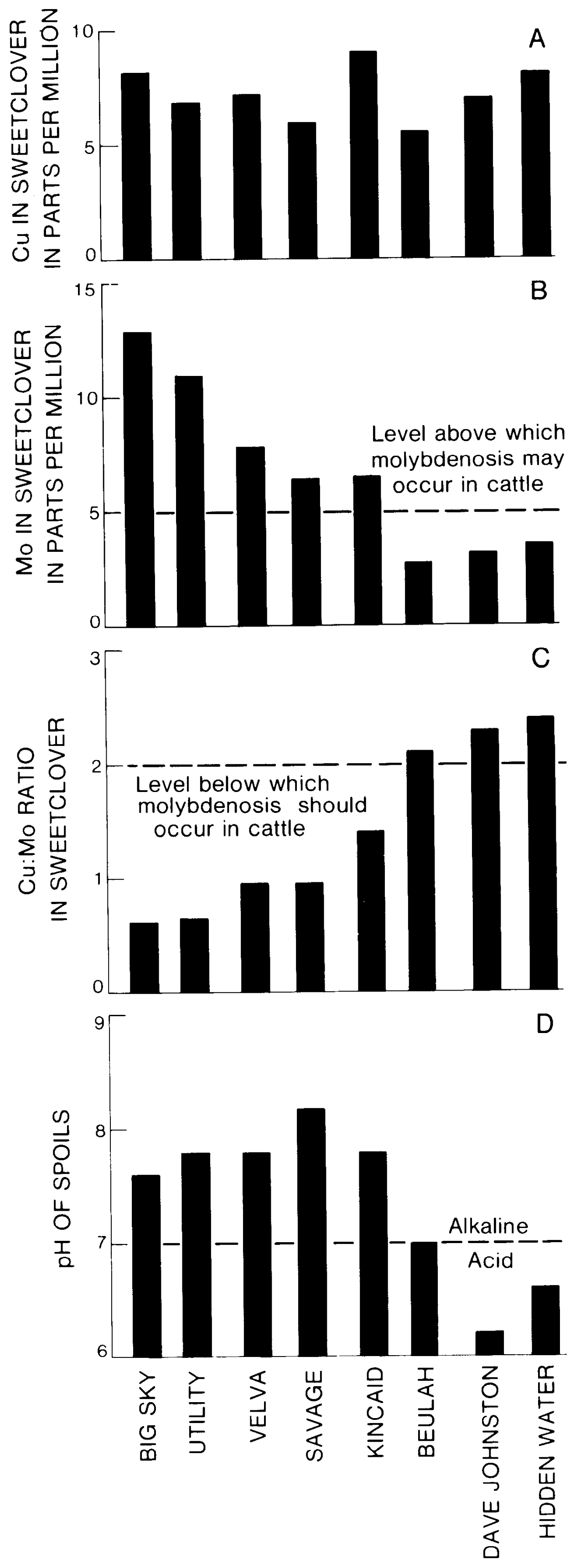


Fig. 2. *Mean copper (A) and molybdenum (B) concentrations in sweetclover, Cu:Mo ratios in sweetclover (C), and pH values of associated spoil materials (D) at eight surface coal mines in the Northern Great Plains. Each mean is based on 10 randomly selected samples.*

element concentrations in sweetclover are given on a dry-weight or moisture-free basis (see, for example, Furr et al. 1975), we converted the element concentrations that were reported by the analysts on an ash basis to a dry-weight basis. Samples of spoil materials were ground to pass through an 80-mesh sieve. Soil pH was measured using a hydrogen ion-specific glass electrode in a water-saturated paste.

Results

An analysis of variance procedure, which tested the differences between and within mines, demonstrated significant differences ($P < 0.05$) between the mines for all variables represented in Figure 2 (Cu, Mo, and Cu:Mo ratios in sweetclover, and pH in spoils). The Cu levels in sweetclover, however, were not very different between mines, and are about normal for forage (Dye and O'Harra 1959). The Mo levels and Cu:Mo ratios in sweetclover indicate that the potential for molybdenosis exists to varying degrees at all mine spoils that we sampled.

Duncan's multiple range test showed that the means for Mo fall into two groups. One group represents samples from the Beulah, Dave Johnston, and Hidden Water mines: the Mo averages range from 2.6–3.4 ppm. Spoil samples from these three mines were slightly acid or neutral. The second group of means ranged from 6.4–13 ppm Mo (Fig. 2); these concentrations are considered unusually high for typical forage and are all above the critical level of 5 ppm for Mo. Moreover the Cu:Mo ratios for samples from the mines in this group are below the conservative critical 2:1 ratio. Samples of spoils from these five mines were definitely alkaline, which probably accounts for the higher levels of Mo in the sweetclover.

The data indicate that the Mo concentrations in sweetclover growing on coal mine spoil banks at the mines studied are sufficiently high to induce metabolic imbalances in cattle and possibly in sheep and native ruminants at subclinical, if not acute, levels, assuming the animals were to feed predominantly on this or similar legumes. The low Cu:Mo ratios that we observed are in accord with those found in a recent study of reclaimed coal spoils in western North Dakota (Bauer et al. 1976). In mine areas where molybdenosis may be a potential problem, wholesome pasturage can be established by avoiding molybdenum-accumulating plant species, or by minimizing access to the fresh forage, which can cause greater injury than properly cured hay (Barshad 1948; Miller et al. 1970). Molybdenum-induced Cu imbalances in the diet may be corrected by treating the livestock with either copper sulfate or copper glycinate, although the latter treatment can produce undesirable side effects.

It may be difficult to prevent the development of hazardous geochemical environments in some surface-mining operations. But with the proper management of reclaimed areas, mining and agriculture can be compatible.

Literature Cited

Alloway, B. J. 1973. Copper and molybdenum in swayback pastures. J. Agr. Sci. 80:521-524.

Barshad, I. 1948. Molybdenum content of pasture plants in relation to toxicity to cattle. Soil Sci. 66:187-195.

Bauer, A., G. W. Gee, and J. E. Gilley. 1976. Physical, chemical and biological aspects of reclamation of strip-mined lands in western North Dakota, final report. North Dakota Agr. Exp. Sta. 605 p.

Case, A. A. 1974. Toxicity of various chemical agents to sheep. J. Amer. Vet. Med. Ass. 164:277-283.

Clawson, W. J., A. L. Lesperance, V. R. Bohman, and D. C. Layhee. 1972. Interrelationship of dietary molybdenum and copper on growth and tissue composition of cattle. J. Anim. Sci. 34:516-520.

Dollahite, J. W., L. D. Rowe, L. M. Cook, Dan Hightower, E. M. Bailey, and J. R. Kyzar. 1972. Copper deficiency and molybdenosis intoxication associated with grazing near a uranium mine. Southwestern Vet. 9:47-50.

Dye, W. B., and J. L. O'Harra. 1959. Molybdeosis. Nevada Agr. Exp. Sta. Bull. 208. 32 p.

Ebens, R. J., J. A. Erdman, G. L. Feder, A. A. Case, and L. A. Selby. 1973. Geochemical anomalies of a claypit area, Callaway County, Missouri, and related metabolic imbalance in beef cattle. U.S. Geol. Surv. Prof. Paper 807. 24 p.

Furr, K., G. S. Stoewsand, C. A. Bache, W. A. Gutenmann, and D. J. Lisk. 1975. Multielement residues in tissues of Guinea pigs fed sweetclover grown on fly ash. Arch. Environ. Health 30:244-248.

Kubota, J. 1975. Areas of molybdenum toxicity to grazing animals in the western states. J. Range Manage. 28:252-256.

Miles, A. D. 1970. Sweetclover as a range legume. J. Range Manage. 23: 220-222.

Miller, L. R., A. L. Lesperance, V. R. Bohman, and E. H. Jensen. 1970. Toxicity of inorganic and organic forms of molybdenum to the bovine. Western Section, Amer. Soc. Anim. Sci., Proc. 21:213-218.

Nakagawa, H. M. 1975. Atomic absorption determination of silver, bismuth, cadmium, cobalt, copper, nickel, lead, and zinc in calcium and iron-rich geologic material. *In:* F. N. Ward (Ed.) New and Refined Methods of Trace Analysis Useful in Geochemical Exploration. U.S. Geol. Surv. Bull. 1408: 85-96.

Reichen, L. E., and F. N. Ward. 1951. Field method for the determination of molybdenum in plants. U.S. Geol. Surv. Circ. 124. 4 p.

Thornton, I. 1977. Biogeochemical studies on molybdenum in the United Kingdom. *In:* W. R. Chappell and K. Petersen (Eds.) Proceedings of the Symposium on Molybdenum in the Environment, Vol. 2. Marcel Dekker, Inc., New York.

U.S. Geological Survey. 1974. Stripping coal deposits of the Northern Great Plains, Montana, Wyoming, North Dakota, and South Dakota. U.S. Geol. Surv. Misc. Field Studies Map MF-590. 1 sheet.

Webb, J. S., and W. J. Atkinson. 1965. Regional geochemical reconnaissance applied to some agricultural problems in Co. Limerick, Eire. Nature 208:1056-1059.

Whitaker, S. H., and D. E. Pearson. 1972. Geological map of Saskatchewan. Sask. Dep. Mineral Resources and Sask. Res. Counc. 1 sheet.

Increasing Rangeland Forage Production by Water Harvesting

H. A. SCHREIBER AND G. W. FRASIER

Highlight: Effects of additional water, provided from adjacent water-collecting areas, on forage production of blue panicgrass (*Panicum antidotale* Retz.) were assessed. Applying paraffin for water repellency of runoff areas increased water for use on the collecting areas. In this 3-year study, more than 2,000 kg/ha/year forage was harvested with rainfall of less than 130 mm and collecting-area runoff from 14 summer events in 1974 and from 18 summer events each in 1975 and 1976. Forage production from control plots averaged only 200 kg/ha/year the second and third years. Forage yield was increased about 16-fold over that of the control using a waxed-soil runoff area two times the crop growing area. Adjusting yields for the size of the bare runoff areas, the average yield increase for the system was still five times greater than that which would have been obtained from an uninterrupted planting of grass. Water-use efficiencies for this technique were comparable to those for irrigated grass.

The semiarid and arid regions of the United States encompass a large portion of our rangelands and produce much of our red meat. Concern is increasing that, unless we approach maximum utilization of the rangeland forage resources, economic pressures may cause an overall reduction in meat production (Box 1974; Long 1974). One means of maintaining meat productivity is to increase forage production in these areas. Limited natural rainfall may be more effectively used by collecting runoff water from specially prepared areas and concentrating this water on a crop area. This may result in more efficient use of water for increasing forage production. This method, commonly called "runoff farming," was developed over 4,000 years ago and consisted of collecting runoff water from higher areas with characteristically low infiltration rates for application to small fields in valleys (Evenari et al. 1961). Evans et al. (1975), rediscovering the technique, showed the feasibility of collecting water from impermeable highway surfaces for increased forage production. Recently, researchers have investigated various materials and methods for increasing runoff (Cooley et al. 1975). These methods consist primarily of covering the soil surface with a membrane or chemically sealing soil pores. However, most of these water-harvesting methods are relatively expensive for collecting water for crop production. Only a limited number of methods, like land forming and water-repellent soil treatments, have potential for being adapted to runoff-farming applications.

Many native range grasses that evolved under limited moisture conditions are not capable of efficiently utilizing water quantities that might occur with various water-harvesting treatments (Paulsen and Ares 1962; Martin and Cable 1975). One range grass, blue panicgrass (*Panicum antidotale* Retz.), will survive periods of low seasonal rainfall (80 to 250 mm) that often occur in arid lands, but can respond to over 500 mm of water (Wright 1962). This grass can compete on range sites with native perennials but when cultivated, fertilized, and irrigated has yielded over 30,000 kg/ha/year near Tucson, Ariz.

In this paper we report results of a 3-year study conducted to assess the effect of water harvesting on production of blue panicgrass. By coupling more available water with a higher fertility level, the productivity of specialized areas of our rangelands could be significantly increased.

The authors are soil scientist and research hydraulic engineer, respectively, with the Agricultural Research Service, U.S. Department of Agriculture. The former is with the Southwestern Watershed Research Center, Tucson, Arizona, and the latter is with the U.S. Water Conservation Laboratory, Phoenix, Ariz.

The authors thank Raymond Brown, Candido Ballesteros, Loel Cooper, and John Griggs, for assistance of field work and acknowledge with thanks Gary Richardson, Agricultural Research Service biometrician, in Fort Collins, Colorado, for statistical assistance.

Methods and Materials

A series of small test plots was established on a recently developed sandy loam alluvial terrace (2% slope) created in part from old mine spoils. These plots were located 6.5 km west of Tombstone, Ariz., on the lower part of the Walnut Gulch Watershed. There were no confining layers within 5 m (17 ft) of the surface, and gravel increased with depth. The plots were enclosed with a 6-cm high metal border buried 2 cm below ground. Grass plots (3 × 3 m) were seeded with blue panicgrass on June 24, 1974, at a rate of 4.5 kg/ha. After seeding, the plots were sprinkle irrigated with 8 mm/day for 2 weeks to insure seedling emergence and a stand of grass. All grass plots were fertilized before seeding with triple superphosphate, ammonium nitrate, and agricultural limestone at a rate of 33, 23, and 450 g/m² (300, 200, and 4,000 lb/acre), respectively.

A total of 36 plots were installed in a randomized block design with three replications of treatments. The treatments were three lengths of runoff areas and four runoff to crop-growing-area ratios of 0:1, 1:1, 2:1, and 3:1. The 0:1 plots had no runoff-contributing area and were used as the controls. The remaining plots had metal-bordered runoff areas that were 3 m wide and either 3, 6, or 9 m long. The water collected from the runoff area was retained within the cropped area by using a 6 to 18 cm metal border. The three runoff-area treatments were: bare soil (cleared and smoothed), waxed (cleared, smoothed, and waxed), and grassed (cleared and seeded with blue panicgrass like the crop area). On the cleared and smoothed areas, all vegeta-

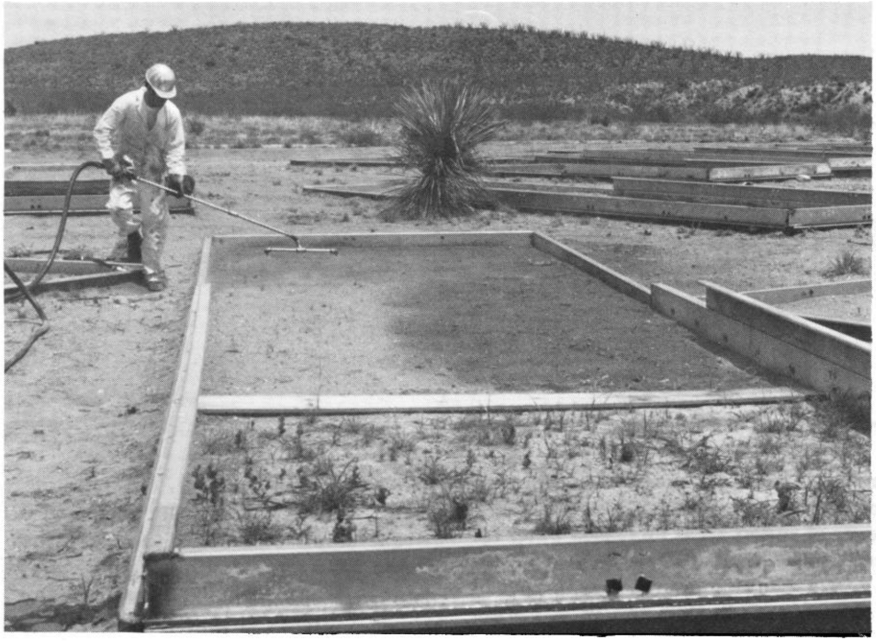


Fig. 1. *Liquid paraffin being applied to runoff area on July 11, 1974. The plot has a 3:1 runoff to cropping area ratio.*

tion was removed and the soil surface smoothed and compacted with a smooth steel-drum lawnroller. For the wax treatment, refined paraffin wax (128–135 AMP) was heated to 100°C and sprayed on cleared and smoothed soil surfaces at a rate of 1.1 kg/yd^2 , as described by Fink et al. (1973) (Fig. 1). One year later, on July 9, 1975, ammonium nitrate, triple superphosphate, potassium chloride, and magnesium sulphate were applied at rates of 30, 33, 11, and 13 g/m^2 (270, 300, 100, and 120 lb/acre), respectively.

Rainfall for the 1974 growing season was normal until early August (Table 1) and provided sufficient water for adequate growth on all plots. However, because of an August drought, all plots were harvested on August 26, 1974, even though flower emergence was not uniform among treatments. Rainfall after the cutting date was minimal, and no further harvests were attempted in 1974, although residual available water provided some additional growth on the plots with the larger runoff-contributing areas. This growth and the early 1975 spring growth froze without producing any harvesting vegetation, which essentially depleted the soil water as evidenced by the absence of growth on any plots before the 1975 summer rainfall. The 1975 and 1976 summer precipitation was more uniformly distributed than that of 1974, and the latter year's rainy seasons were longer. Smith and Schreiber (1974) found that the mean amount of rainfall was 7.6 mm (0.3 inch) with a median of 4.3 mm (0.17 inch) for each of 30 events per growing season. At the study location, although all years had typical rainfall distributions, there were only 14, 18, and 18 events per growing season June 1 to September 30 for the 3 years, respectively.

The 1975 harvest was made in December, after all plots had depleted the available soil water and frost had killed all top growth. Eighteen rainfall events were recorded prior to harvest with a total depth of 123 mm (4.84 inches) in 1976. Unlike either preceding year, two events exceeded 25 mm, but the calculated runoff (discussed later) was lowest in 1976.

In May 1976, a small laboratory rainfall simulator covering a 1-m^2 area was used to estimate runoff efficiencies from the wax runoff areas by spraying water onto the catchment surface at a constant rate from a 150-cm height. The runoff water was collected at the lower edge of the test area by a small tube connected to a vacuum pump, which deposited the runoff water in a plastic precalibrated chamber. The spray rate was determined by placing a pan cover over the test area for a predetermined time and measuring the water collected. The pan was then removed and the water sprayed directly on the catchment. The water was sprinkled at a rate of 4.5 to 5 cm/hour, until a total of 1 cm of water was applied. This corresponded with the quantity and intensity of many of the precipitation events in the Southwest.

Table 1. Monthly rainfall, estimated runoff, and potential water available for plant growth on forage plots during three growing seasons.

			Runoff (mm)		Potential water (mm)[1]					
					Waxed plots			Bare soil plots		
Year	Month	Rainfall[2] (mm)	Waxed plots	Bare soil plots	1:1	2:1	3:1	1:	2:1	3:1
1974	June	3.6	2.6	0.6	6.2	8.8	11.4	4.2	4.8	5.4
	July	103.6	91.6	22.2	195.4	287.2	379.0	125.8	148.0	170.2
	Aug.	22.1	21.1	8.0	43.2	64.3	85.4	30.1	38.1	46.1
	Sept.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	129.3	115.3	40.8	244.8	360.3	475.8	160.1	190.9	221.7
1975	June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	July	66.2	56.2	18.0	122.4	178.6	234.8	84.2	102.2	120.2
	Aug.	14.5	11.5	3.3	26.0	37.5	49.0	17.8	21.1	24.4
	Sept.	47.8	43.5	16.0	91.3	134.8	178.3	63.8	79.8	95.8
	Total	128.5	111.2	37.2	239.7	350.9	462.1	165.8	203.1	240.4
1976	June	8.9	7.9	2.7	16.8	24.7	32.6	11.6	14.3	17.0
	July	99.0	88.0	30.8	193.0	281.0	369.0	135.8	166.6	197.4
	Aug.	14.9	9.1	2.1	24.0	33.1	42.2	17.0	19.1	21.2
	Total	122.8	110.8	35.6	233.8	338.8	443.8	164.4	200.0	235.6

[1] Potential water = (rainfall) + runoff: crop growing area ratio × runoff).

[2] Since grass plots had no runoff as supplemental water, precipitation equalled water available for grass growth in 1974 and 1975. Runoff could have occurred in 1976, but no estimates could be made.

Results and Discussion

The rainfall simulator was used to evaluate the runoff efficiency of the waxed runoff area in May, 1976. Results indicated that the runoff per event from waxed plots could be expressed as:

$$\text{Runoff (mm)} = \text{Rainfall (mm)} - 1.0. \quad (1)$$

Using the results from Frasier (1975), the runoff of the bare soil plots per event could be expressed as:

$$\text{Runoff (mm)} = [\text{Rainfall (mm)} - 2.2] \times [0.4]. \quad (2)$$

Table 2 presents the calculated quantities of runoff for the waxed and bare-soil plots for each season. There was no apparent runoff from the grass plots, because no rainfall event exceeded the soil infiltration capacity.

The potential water available for plant growth is the rainfall plus the water collected from the runoff area.

This is expressed mathematically as follows:

$$\text{Potential water (mm)} = \text{Rainfall (mm)} + [\text{Runoff: crop-growing ratio} \times \text{runoff (mm)}]. \quad (3)$$

Table 1 shows the monthly potential water available for plant growth from each of the test areas.

The average forage yields for 1974 (Table 2) did not differ statistically among all treatments because of the uncertain effect of the residual soil water remaining after sprinkle irrigation of all plots. The forage yield differences between and within the 1975 and 1976 seasons, when the plant growth was totally dependent upon natural rainfall, were significant ($P = .05$). Contrasting production in 1976 with that of 1975 indicated that production increased with time as stands became more established. Yields of the best 1975 plots from waxed runoff areas increased slightly, if at all, in 1976. This suggested that these grass stands were already in equilibrium with the climatic and soil factors by the end of 1975. In 1976, yields from plots with larger runoff ratios in the bare and grassed runoff areas increased 2 to 2.5 times over that found in 1975. With an equal amount of rain and less calculated total runoff, this increase might be attributable to the runoff penetrating deeper into the soil profile, or to the age of the stand. Yields were almost five times greater for plots receiving runoff water from waxed areas than those for the control for the 2:1 ratio of runoff: crop area treatment on the complete system unit area basis. Forage yields for plots from the waxed runoff areas sometimes decreased as the ratios of treatment: crop growing area increased from 2:1 to 3:1. Possibly this was a chance result of some undetermined nutritional deficiency or of leaching of the existing nutrients by the increased water.

Table 2. Average forage yield (kg/ha) from plots as affected by the size of the runoff area and soil surface treatments.

Year	Runoff-crop growing area ratio	Runoff areas: Waxed		Bare soil		Grass	
1974	0:1	–	–	–	–	961	(961)
	1:1	954[1]	(1909)[2]	623	(1246)	534	(1068)
	2:1	646	(1932)	588	(1755)	401	(1203)
	3:1	284	(1136)	560	(2338)	273	(1093)
1975	0:1	–	–	–	–	186	(186d)d[3]
	1:1	666	(1333)bc	268	(536)d	216	(433)d
	2:1	973	(2920)a	227	(683)cd	140	(421)d
	3:1	484	(1939)b	237	(949)b	123	(494)d
1976	0:1	–	–	–	–	227	(227)e
	1:1	771	(1543)c	493	(986)cde	292	(583)de
	2:1	998	(2993)a	539	(1616)c	317	(951)cde
	3:1	650	(2602)a	553	(2211)b	327	(1308)cd

[1] Yield expressed for total area including crop-growing area and runoff area.
[2] Yield expressed only for the crop-growing area.
[3] Means within a year followed by similar letters are not significantly different ($P = 0.05$). Yields of 1974 are shown for comparison with following year. Statistical differences in 1974 water and rainfall cannot be determined because data applied is a combination of unmeasured irrigation.

Dividing the average yield of each plot (Table 2) by the potential available water for each treatment, the average yield of blue panicgrass herbage per millimeter of water was 1 to 3 kg/ha for waxed runoff areas and 1 to 2 kg/ha per millimeter of water for the bare soil runoff areas for 1975. The only source of water was precipitation and runoff during this year. Variation in water-use efficiency among plots for the size and types of the runoff areas could be related to the different depths of soil water storage between treatments and to plant responses to varying degrees of drought. Maximum runoff would result in proportionately less surface evaporation and more evapotranspiration from plants, as compared with crop-growing areas receiving no runoff water. Plant responses to drought might also be a factor if prolonged desiccation caused irreplaceable loss of photosynthetic tissue, thereby resulting in a less capable system to manufacture dry matter.

Our results compared favorably with some other studies of irrigated blue panicgrass. Erie et al. (1965) reported an average seasonal consumptive use of 1,328 mm (52.3 inches) with 630 mm (24.8 inches) of the water being used during July, August, and September. Their yields for a 2-year study were 7,160 kg/ha (6,378 lb/acre) the first year and 3,775 kg/ha (3,362 lb/acre) the second year for an average yield of 5.4 and 2.8 kg/ha per millimeter of water for the 2 years, respectively.[1] The application of additional water by water-harvesting techniques permits a water-use efficiency of the same order of magnitude as that for irrigated blue panicgrass.

Summary and Conclusions

A 3-year study was conducted to evaluate the possibility of increasing forage production by increasing the available water for plant growth by runoff farming (water-harvesting) techniques. Although the study was conducted on soil not generally suited for optimum growth, our results indicated that average per hectare yield was about five times greater than the control for an area receiving less than 130 mm (5.1 inches) of precipitation during the growing season. These results are significant, since two-thirds of the area

Fig. 2. *Stand of blue panicgrass in a 1:1 runoff to cropping area plot on August 6, 1976. Within 2 weeks, this plot produced more than 1,500 kg/ha of ovendry forage.*

[1] Personal communication with L. J. Erie of unpublished data.

was used only for collecting water and did not contribute any forage. Additional studies are needed to further evaluate different types of runoff treatments and grasses and to develop methods for managing this type of system for optimum forage production.

Literature Cited

Box, T. W. 1974. Increasing red meat from rangeland through improved range management practices. J. Range Manage. 27:333-336.

Cooley, K. R., A. R. Dedrick, and G. W. Frasier. 1975. Water harvesting: state of the art. p. 1-20. *In:* Proceedings of the Watershed Management Symposium, Amer. Soc. Civil Eng. (Irrig. and Drain. Div.), Logan, Utah, Aug. 11-13, 1975.

Erie, L. J., O. F. French, and K. Harris. 1965. Consumptive use of water by crops in Arizona. p. 24-25. Arizona Agr. Exp. Sta. Tech. Bull. 169.

Evans, C. E., D. A. Woolhiser, and F. Rauzi. 1975. Opportunity for harvesting water from and along highways in rangeland areas of Wyoming. p. 293-301. *In:* G. W. Frasier (Ed.) Proceedings of the Water Harvesting Symposium, Phoenix, Ariz., Mar. 26-28, 1974. ARS W-22.

Evenari, M. L., L. Shanan, N. Tadmor, and Y. Aharoni. 1961. Ancient agriculture in the Negev. Science 133:979-996.

Fink, D. H., K. R. Cooley, and G. W. Frasier. 1973. Wax-treated soils for harvesting water. J. Range Manage. 26:376-398.

Frasier, G. W. 1975. Water harvesting for livestock, wildlife, and domestic use. p. 40-49. *In:* G. W. Frasier (Ed.) Proceedings of the Water Harvesting Symposium, Phoenix, Ariz., Mar. 26-28, 1974. ARS W-22.

Long, R. W. 1974. Future of rangelands in the United States. J. Range Manage. 27:253-255.

Martin, S. C., and D. R. Cable. 1975. Highlights of research on the Santa Rita experimental range. p. 51-57. *In:* Arid Shrublands—Proceedings of the Third Workshop of the U.S./Australia Rangelands Panel, Tucson, Ariz., Mar. 26–Apr. 5, 1973.

Smith, R. E., and H. A. Schreiber. 1974. Point processes of seasonal thunderstorm rainfall 2. Rainfall depth probabilities. Water Resour. Res. 10(3):418-423.

Wright, L. N. 1962. Effects of management practices in forage yield and percent protein in blue panicgrass, *Panicum antidotale* Retz. Agron. J. 54:413-416.

White-tailed Deer Preferences and Hunte Success under Various Grazing Systems

P. O. REARDON, L. B. MERRILL, AND C. A. TAYLOR, JR.

Highlight: Preferences of white-tailed deer to various grazing management systems now being tested at the Texas A&M University Agricultural Research Station, Sonora, were evaluated on the basis of deer density and economic returns from hunting. Hunter success was evaluated on the basis of several factors. White-tailed deer definitely preferred a rangeland grazed under a system which included a systematic rotational deferment, and the more frequent the deferment the higher the preference. Hunter success was directly related to deer density, time during the season hunted, brush management, and type of grazing system utilized. Results from this study indicates that good livestock grazing management can also be good big-game range management.

Any landowner who has white-tailed deer (*Odocoileus virginianus*) or other game animals knows or should know their economic importance. However, very few landowners whose major source of income comes from livestock think they can afford to actually "manage" for their wildlife. This may stem from the misconception that good wildlife-range management is not good livestock-range management. Even though the requirements for managing certain wildlife species such as game birds may be different than for livestock, range management for the white-tailed deer and most other big game species in Texas is essentially the same as for livestock. However, when large acreages of rangelands are completely cleared and converte "improved" pastures, they could lose much of their value white-tailed deer habitat.

Many factors such as quality and quantity of game anim type of commercial lease, prices charged, and number hunters will affect income from wildlife to landowners. success of any wildlife management program, which inclu harvest of excess animals on a commercial basis, is measu primarily from two viewpoints, the hunter's and the la owner's. The hunter's viewpoint, of course, includes chances for harvesting some game animals, i.e. hunter succe The landowner's viewpoint includes obtaining maximum s tained net economic returns. To be a consistently succes wildlife manager requires skill plus knowledge about requirements, habits, and preferences of wildlife such as white-tailed deer (Brothers and Ray 1975).

Most landowners manage their rangeland primarily domestic livestock, thus leaving game animals to take what t can, when they can. This may create severe competition available food between livestock and white-tailed deer. competition increases, available forage decreases and c reproductive rates, body size, and antler quality are redu correspondingly (Teer et al. 1965; Thomas 1966). Since white-tailed deer generally spends most of its life near the pl it was born, it seldom has a choice as to the type or conditio the rangeland it occupies. However, if white-tailed deer ha choice, they definitely would prefer certain rangelands management systems over others (Merrill et al. 1957; Pas and Hicks 1970).

Since the landowner's primary objective is to obtain m mum sustained income, he must develop management progr

---

The authors are assistant professor, Texas A&M University Agricultural Research and Extension Center at Uvalde; professor in charge, and research associate at the Texas A&M University Research Station at Sonora.

This report is Technical Article 13199 from the Texas Agricultural Experiment Station. The authors gratefully acknowledge the cooperation of L. B. Blankenship and L. W. Varner in this study.

Manuscript received March 2, 1977.

Table 1. Income from hunting program on Sonora Research Station, 1971–75.

	1971	1972	1973	1974	1975	Average
Number of hunters	59	97	80	60	60	71
Days of hunting offered	8	8	6	6	6	7
Deer harvested	45	54	44	30	40	43
Hunting fee per day ($)	26.00	28.00	35.00	35.00	40.00	32.80
Net income per deer harvested*	51.00	81.07	105.34	115.50	98.78	90.34
Net income per acre	.66	1.26	1.34	1.00	1.14	1.08

* Expense items used in figuring net income are "out-of-pocket" expenditures only.

to improve both the livestock and wildlife habitats. This is not always an easy task since there is such a wide variation in rainfall patterns, hunter preferences, landowner preferences, present habitat and deer herd conditions, location of ranch, and many other factors. Present research comparing various grazing management systems at the Texas A&M University Agricultural Research Station at Sonora, Tex., offers an excellent opportunity to study some of these factors. Objectives of this research were to identify or determine: (1) preferences of white-tailed deer to different grazing management systems; (2) factors affecting hunter success (hunter success in this paper is defined as the percent of hunters harvesting at least one deer during a 2-day hunt).

Study Area and Methods

This study was conducted on the Texas A&M University Agricultural Research Station at Sonora, Tex. The station is located in the Edwards Plateau or Hill Country region of Texas, midway between Rocksprings and Sonora on State Highway 55. The Sonora Station is operated under various research projects designed to gain information concerning both livestock and wildlife habitat improvement.

Seven grazing management systems are being compared under current projects. They include four separate Merrill grazing systems under various brush management methods, a 7-pasture short duration system, and continuous year-long grazing at two stocking rates.

The Merrill grazing system includes three herds of livestock on four pastures with each pasture being grazed 12 months, then rested 4 months. One Merrill system has been root-plowed and seeded to native grasses, one has been aerial sprayed, and one has had the brush thinned or grubbed out with a bulldozer. The other Merrill system has had no brush control. The 7-pasture system has had no brush control and has 7 pastures and one herd of livestock which is moved to a new pasture every 3 weeks. Therefore, each pasture is grazed 3 weeks then rested 18 weeks. The two continuously grazed pastures are never rested and have received no brush treatment. All systems are grazed with cattle, sheep, and goats at a ratio of 60-20-20, and stocking rates were maintained as listed in Table 2. All pastures are approximately 80 acres in size and are separated by low fences, which permit deer to move freely between pastures and choose the grazing management system or habitat they prefer.

Table 2. Livestock stocking rates, deer densities, and hunting revenues from seven systems of grazing at Sonora Research Station, 1971–75.

Grazing system	Livestock stocking rate (acres/AU)	Deer* density (acres/deer)	Hunting* revenues (income/acre)
Moderate-continuous	16.0	18 c	$ .82 b
Heavy-continuous	11.9	20 c	.59 b
Merrill:control	16.0	15 b	2.25 a
Merrill:aerial-sprayed	12.8	16 b	.88 b
Merrill:front-end grubbed	12.8	16 b	.62 b
Merrill:rootplowed	12.8	15 b	.79 b
7-pasture short duration	10.7	10 a	1.79 a

* Numbers in a column not followed by the same letter differ significantly at the 5% level.

Other than brush treatment, there are very few basic differences between pastures. They are all included in one major range site. There are some vegetative differences which are a result of the grazing system.

White-tailed deer preferences for the various grazing management systems were evaluated by two basic methods: (1) making periodic nighttime and early morning census counts in each pasture to determine deer densities; (2) setting up an actual commercial day-hunting enterprise to estimate income to each grazing system. Significant differences were determined by analysis of various procedures.

All harvested deer were recorded according to the pasture where they were taken. Carcass data such as weight, age, sex, body, and antler characteristics were also recorded. Estimated hunting income to each grazing system was determined annually from the average value of each harvested deer times the actual number of deer harvested in that system. Average value of each harvested deer was based on total hunting income divided by the number of deer harvested. Net income figures are based on the gross income minus only "out-of-pocket" expenditures. "Out-of-pocket" expenditures included expenses such as annual depreciation of deer blinds, truck mileage, labor costs, and all maintenance expenses. An effort was made to distribute hunters on all pastures to equalize hunting pressure and chances of harvesting a deer. General information about the hunting program on the Sonora Station, the number of hunters, number of deer harvested, and income per deer and per acre is given in Table 1. Hunting occurred only on weekends and all hunters were allowed to take their legal limit of deer (three deer) if possible.

Conclusions concerning hunter success were drawn by running regression analyses and correlating data such as annual rainfall, deer density, fawn crop, time hunted, and grazing system to the number of deer harvested.

Results and Discussion

Preference of White-tailed Deer for Various Grazing Systems

When deer were given a choice, they preferred grazing management systems that Merrill et al. (1975) had reported to be best for livestock (Table 2). The highest deer density was found in the 7-pasture system (Table 2). This was not surprising since these pastures are grazed by domestic livestock only 6 to 9 weeks per year and also receive the most frequent rest. It should also be noted that the 7-pasture system maintained this high deer density even though it also supported the highest concentration of livestock. Deer densities were not significantly different among the four Merrill systems, although both continuously grazed pastures had significantly lower deer populations. This supports the idea that deer do prefer to stay in pastures which are periodically deferred and indicates that the more frequent the deferment the higher the preference for this system.

Maximum income per acre, which was highest in 1973, was a function of the number of hunters and the price they were charged and not necessarily hunter success or number of deer harvested (Table 1). In 1974 the number of hunters was less than in 1973. This reduction was necessary since deer census counts made prior to the 1974 hunting season indicated that the overall deer population was down. Therefore, it was necessary to reduce the numbers of hunters to obtain a desirable deer harvest.

The highest economic returns, which were a result of number of deer harvested or hunter success, came from the Merrill and 7-pasture system which have had no brush treatment (Table 2). There was no significant difference among the other treatments.

At first glance, the low incomes from the Merrill systems which were either sprayed, grubbed, or rootplowed seem to indicate that brush control was detrimental to the deer habitat. However, the deer populations in these pastures remained relatively high (Table 2). This indicates that brush treatment lowered hunter success but not necessarily deer densities. Observations have shown that deer utilize cleared areas during darkness and uncleared pastures during daylight. This emphasizes the importance of careful planning in any brush clearing operation. Leaving strips or motts of brush will not only provide the cover and food necessary for wildlife, but will also make the area more huntable, and improve hunter success.

Factors Affecting Hunter Success

The major factor contributing to hunter success in this study was deer density. There was a positive correlation between deer density and hunter success. Alternating high then low deer densities on the whole ranch were evident from 1971 through 1975, but were not statistically correlated to previous or present year's rainfall since rainfall was above average (average is approximately 23 inches) in all years. Previous or present year's fawn crop was also not correlated to hunter success.

Another factor affecting hunter success in this study was the time the person hunted during the hunting season (Table 3). Hunter success was always highest on the first two weekends. This is probably because in central Texas the white-tailed deer's breeding activities (when male deer are most easily killed) usually begin during October or November and then slow down by the third weekend of hunting season. Also, by the third weekend most deer have become very wary of hunting activities.

Since deer tended to prefer certain grazing systems over others and since high deer density was related to hunter success, it can be concluded that landowners who are interested in improving their rangelands while increasing big game and livestock revenues can set up grazing management systems which accomplish both objectives. The type of system employed will be determined by such criteria as present ranch facilities, range conditions, climate, and type of livestock management utilized. By setting up a system with a rest period long enough to improve range conditions and frequent enough to maintain high deer densities a landowner can expect to increase both hunter success and total income.

Table 3. Hunter success by weekend from 1971–75 on the Sonora Research Station.

Year	Hunter success (%) by weekend*		
	1st weekend	2nd weekend	3rd weekend
1971	63	50	44
1972	52	58	18
1973	48	52	32
1974	46	23	15
1975	48	61	31
Average	51	52	26

* Hunter success is defined as the percent of hunters harvesting at least one deer during a 2-day hunt.

Conclusions

Results from this study show that good livestock-range management can be good big-game range management. High hunter success was attributed to high deer density and deer density was attributed to the type of grazing system utilized. Highest deer densities and economic returns came from grazing systems which included a systematic deferment and the more frequent the deferment, the higher the deer preference for that system. Care should be taken in planning and carrying out any rangeland brush management. Clearing out extremely large areas may reduce hunter success even though it may not reduce deer density. Thus, with careful planning, rangeland resources can be managed to increase returns from both livestock and big game animals.

Literature Cited

Brothers, A., and M. E. Ray. 1975. Producing quality whitetails. 1st ed. Wildlife Services Publications, Laredo, Tex. 245 p.

Merrill, L. B., J. G. Teer, and O. C. Wallmo. 1957. Reaction of deer populations to grazing practices. Texas Agr. Prog. 3:10-12.

Merrill, L. B., C. A. Taylor, Jr., P. O. Reardon, and J. R. Stewart. 1975. Economic comparison of grazing systems at Sonora. *In:* Rangeland Resources Res. Texas Agr. Exp. Sta. Consol. PR-3341:57-58.

Passey, H. B., and V. M. Hicks. 1970. Grassland restoration. Part VI. Effects on wildlife. U.S. Dep. Agr., Soil Conserv. Serv. 34 p.

Teer, J. G., J. W. Thomas, and E. A. Walker. 1965. Ecology and management of white-tailed deer in the Llano Basin of Texas. The Wildlife Society. Wildlife Monogr. No. 15.

Thomas, J. W. 1966. Carrying capacity and overpopulation problems in Texas deer herds. The white-tailed deer—its problems and potentials. Prceedings of conference offered by the Dep. of Wildlife Sci., Texas Agr. Extension Serv., College of Agr., Texas A&M Univ. p. 42-54.

Phenology of the Aerial Portions of Shadscale and Winterfat in Curlew Valley, Utah

NEIL E. WEST AND JUAN GASTO

Highlight: Phenological development of aboveground portions of shadscale and winterfat was observed for 7 years in Curlew Valley, Utah, and graphically related to patterns of precipitation and temperature. The considerable variation in year-to-year phenology should be noted by those taking data in other basic and applied studies. Preset dates for livestock management actions that ignore yearly phenological differences could result, in some years, in the plants being used during phenological states that are susceptible to damage by browsing. Seed set cannot be counted on every year, complicating one of the assumptions of rest-rotation grazing.

Explanations of various rangeland plant phenomena often require an understanding of the phenological course of development of the organisms under study. For example, transpiration rates of desert plants are only partially explained by soil moisture depletion. Loss of ephemeral leaves sharply cuts transpiration losses by cold-winter desert shrubs during summer drought (Moore et al. 1972). Productivities are often inferred from what are thought to be peak standing crops (Holmgren and Brewster 1972). However, if the periods of growth were better defined, one could more accurately gauge when peak standing crop occurs. Nutritive values also vary with phenological stages. Sampling of materials on a preset date for several years may result in collection of materials in radically different phenological stages.

Management plans are dependent on plant development. Desert ranges are best suited for livestock utilization during the dormant periods. Although desert plants commonly provide more palatable and nutritious forage during their periods of growth, the plants can withstand much less grazing pressure and have high mortality rates if grazed at that time (Cook 1971). If phenological patterns and their likely variations due to climatic differences were more completely known, we could better adjust livestock use to avoid excessive damage by grazing.

Although some data are available on the phenology of the aboveground growth of cold winter desert and semidesert species, particularly sagebrushes, (Morton and Hull 1975) only Wein and West (1972), Wallace and Romney (1972), Tueller et al. (1972), and Ackerman and Bamberg (1974) have included phenology of perennial chenopods in published reports. These prior studies have all been located in drier and warmer environments than the northern Great Basin and conducted over only 1 to 3 years. Characterization of phenological variation over longer periods was needed for a variety of basic and applied research projects being conducted in the northwestern Great Basin.

Since the data we collected in response to these needs are of possible direct use by others and illustrate some principles applicable elsewhere, we present here the results of our phenological monitoring of shadscale [*Atriplex confertifolia* Torr. and Frem. (S. Wats.)] and winterfat [*Ceratoides lanata* (Pursh) J. T. Howell] between 1966 and 1973 in Curlew Valley, northwestern Utah.

The climate, vegetation, and soils at the study location near the north end of the Great Salt Lake have been described by Mitchell et al. (1966). Fernandez and Caldwell (1975) provided further descriptions of the study area and have reported on belowground phenology of the same species at the same site during 1972 and 1973.

Methods

Twenty individuals of each species were randomly selected from pure stands and permanently marked for observation. Sample plants were located within exclosures that have excluded livestock and rabbit grazing since 1967.

Phenological observations were made at least once every 2 weeks from March through October. Observations were more frequent during periods of rapid change. Three different sets of plants in close proximity to each other on the same site were used to minimize the possible effects of accumulated observer disturbance. The first set was observed from 1966 to 1968. A second set was selected and observed in 1969 and 1970. Data were not taken in 1971, but a third set of 10 plants of each of the two species was observed during 1972–1973.

A random set of 10 twigs in all possible portions of each plant's crown was selected and marked with colored plastic tape using coding techniques previously described by West and Wein (1971). Phenophases and numerical codes used to denote them are given in Table 1. Graphs of phenological progression were drawn using the methods described by West and Wein (1971). Since the phenological status was recorded on an ordinal scale, as discrete, noncontinuous variables, only graphical comparisons of averages were made because parametric statistical analysis was inadvisable.

Meteorological data were collected continuously at the study site. Data missing due to malfunction or disturbance of equipment were obtained by the Thiessen polygon method, using the nearest three U.S. Weather Service stations (Wisler and Brater 1959). Mean weekly air

Authors are professor and former Rockefeller Foundation graduate fellow, respectively, Department of Range Science, Utah State University, Logan 84321. The junior author's current address is Colegio de Graduados, Escuela de Agricultura, Universidad de Coahuila, Saltillo, Coahuila, Mexico.

This study was begun under financial support of the Utah Agricultural Experiment Station, of which this is Journal Paper No. 2206. Later data and all of the analyses upon which this report is based were carried out as part of the US-IBP Desert Biome with support from National Science Foundation Grant No. GB-15886. Support for Gasto's part of the study was provided under a Rockefeller Foundation Fellowship.

Ray Barney, Dave Innes, Lee Camp, Marcee Fareed, and Carol Gunn collected parts of the data. Bob Bayn reduced the data and prepared the figures. The interpretations are the authors' responsibility.

Manuscript received April 15, 1977.

Table 1. Phenophases and the numerical codes used to denote them.

Score	Phenophase
1	Winter dormancy
2	Leaves regreening, apical leaf buds swelling
3	Twigs elongating
4	Floral buds developing
5	Flowers opening
6	Fruit developing (male flowers dying)
7	Fruit disseminating
8	Summer dormancy beginning, leaves turning grey-green
9	Leaf buds swelling after late summer or early fall rains
10	Twig elongation after late summer or early fall rains

temperatures (at 1.5 meters above the ground in a standard shelter) and annual cumulative precipitation values were graphed from October 1, preceding the growing period.

Results

The phenological progressions observed in each of the years are graphically summarized in Figure 1. The concomitant weekly average air temperatures and cumulative precipitation values are given immediately below. Average temperatures and cumulative precipitation data (over the 8-year sequence) are indicated by the thinner, identical line within each year's graph. The current year's values are highlighted by shading below the thicker line.

We encountered a variety of climatically different years. Phenological patterns were correspondingly unique. Visual inspection of the graphs and consideration of the original data support the following generalizations.

Winterfat generally undergoes a slower progression of phenophases than does shadscale. When the full sequence of phenophases was truncated due to adverse conditions, then winterfat phenology was more arrested than that of shadscale. Both species evidenced accelerated development during warmer than average spring periods, whereas colder than average spring conditions were associated with delayed progression of phenophases. Drier than average years truncated phenological development, with noncompletion of reproductive phases. Low or zero seed set was noticeable during such years.

Total winter precipitation was apparently of major importance in influencing a full progression of phenophases, although warmer and/or drier than average spring or summer conditions were seen to cancel some of the effects of above average winter precipitation. Rainfall after June did little to either prolong or fulfill the potential course of phenophases. One warmer, wetter than average August-September period (1968) was associated with a pattern of some individuals beginning to grow and flower a second time.

The date of first appearance of given phenological stages varied considerably (Table 2). For instance, the average date of initial twig growth in the spring had a range of 35 days for shadscale and 47 days for winterfat over the 7 years observed. The average date of first flowering (phase 5) had a range of 44 days for shadscale and 29 days for winterfat. The respective standard deviations were 20 days for shadscale and 15 days for winterfat. Shadscale dispersed seed (phase 7) in 6 out of 7 years, winterfat in 5 out of 7 years.

Root growth in these shrubs begins slightly before aboveground morphological developments appear and continues after there is visible change in the aerial portions of these plants (Fernandez and Caldwell 1975). This more prolonged belowground activity is understandable because of the more moderate microenvironment of the soil compared to the atmosphere and the connection of root growth with the near year-round transpiration and photosynthesis carried on by these species (Caldwell et al. 1978).

These species in Curlew Valley began their aboveground phenological development later and had their phenophases

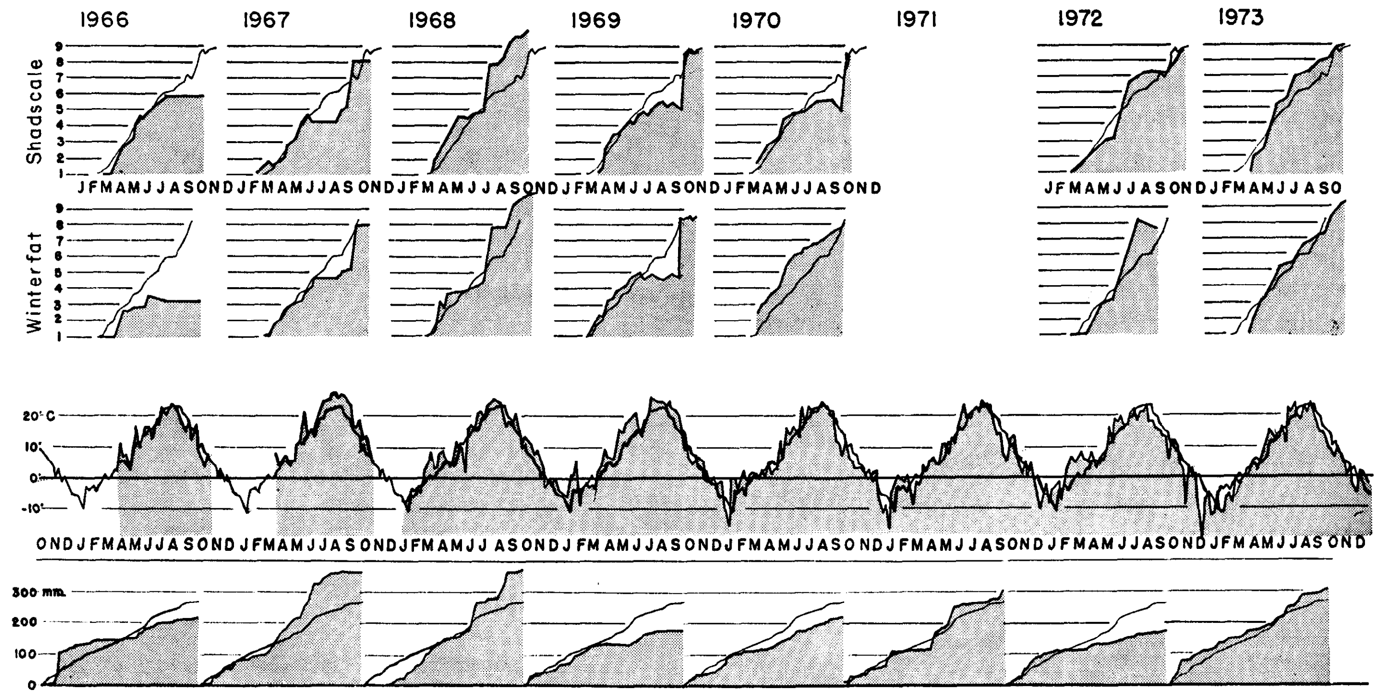


Fig. 1. *Population averages for phenological progressions by shadscale and winterfat in Curlew Valley, Utah, for the years indicated. Description of phenophases and coding are given in Table 1. Next to bottom row of graphs indicates average weekly temperatures (°C) for each year (thick line and shading) and 8-year average (thin line). Unshaded areas lack temperature data. Bottom row of graphs indicates cumulative precipitation (mm) for each year beginning Oct. 1 (thick line and shading) and 8-year average (thin line).*

Table 2. Mean date (± days standard deviation) of first observed occurrence of each phenophase each year and over the 7 years for each species. (Phenophases described in Table 1.)

Species	Year	Phenophase code								
		2	3	4	5	6	7	8	9***	10***
Shadscale	1966	18 Apr. ± 2	5 May ± 3	22 May ± 18	30 June ± 23	25 July ± 8	**	**		
	1967	*	30 Apr. ± 4	29 May ± 10	15 June ± 9	26 June ± 12	6 Sept. ± 5	18 Sept. ± 0		
	1968	2 Apr. ± 8	16 Apr. ± 10	15 May ± 7	15 June ± 6	3 July ± 5	18 Sept. ± 0	27 July ± 0		
	1969	5 Apr. ± 0	21 Apr. ± 4	21 May ± 6	1 June ± 9	5 July ± 22	29 Aug. ± 6	21 Sept. ± 0	31 Aug. ± 4	18 Sept. ± 0
	1970	10 Apr. ± 9	30 Apr. ± 13	8 May ± 7	18 May ± 6	28 June ± 5	5 Aug. ± 11	7 Oct. ± 5		
	1972	20 Apr. ± 17	20 May ± 25	24 May ± 16	17 June ± 14	21 Aug. ± 47	16 Sept. ± 21	5 Aug. ± 56		
	1973	19 Apr. ± 0	11 May ± 0	22 May ± 5	1 June ± 9	17 June ± 20	6 Oct. ± 15	2 Oct. ± 47		
	Mean	11 Apr. ± 10	20 Apr. ± 14	19 May ± 12	11 June ± 20	7 July ± 22	1 Sept. ± 21	11 Sept. ± 36		
Winterfat	1966	17 Apr. ± 0	25 May ± 19	17 June ± 38	**	**	**	**		
	1967	7 Apr. ± 6	1 May ± 4	9 June ± 4	21 June ± 5	20 July ± 0	5 Sept. ± 4	18 Sept. ± 0		
	1968	28 Mar. ± 3	8 Apr. ± 11	14 June ± 6	21 June ± 9	11 July ± 11	10 Oct. ± 0	26 July ± 0	29 Aug. ± 0	18 Sept. ± 0
	1969	*	20 Apr. ± 2	26 May ± 13	5 June ± 8	23 June ± 11	6 Aug. ± 3	24 Sept. ± 20		
	1970	28 Mar. ± 0	18 Apr. ± 0	2 May ± 0	24 May ± 9	10 June ± 10	14 Aug. ± 0	12 Oct. ± 0		
	1972	22 Apr. ± 9	14 May ± 14	3 June ± 0	2 July ± 0	31 July ± 0	**	31 July ± 0		
	1973	19 Apr. ± 0	2 May ± 0	28 May ± 6	9 June ± 8	15 July ± 16	3 Oct. ± 0	2 Sept. ± 32		
	Mean	8 Apr. ± 10	29 Apr. ± 18	28 May ± 21	7 June ± 15	38 June ± 20	27 Aug. ± 23	10 Sept. ± 31		

* Some plants already in phase 2 when sampling began.
** Not observed.
*** Regreening after summer dormancy was only observed in nonfruiting individuals in 1968.

spread out over a longer period than populations observed elsewhere (Wallace and Romney 1972; Wein and West 1972; Tueller et al. 1972; Ackerman and Bamberg 1974). The other sites were warmer and drier than Curlew Valley, however. Sites with greater amounts of and more consistent late summer-early fall precipitation probably have second periods of reproductive activity occurring more routinely (Wein and West 1972).

The practical implication of this study for other researchers is that to ignore phenology when plant data are gathered for other purposes, is to confound the results seriously. The range manager should also be alert to yearly differences in phenological patterns. For instance, if livestock were turned in or gathered up at prescribed calendar dates, variable vegetation responses should be expected since time of range readiness varies considerably among years.

Seed production cannot be counted on every year. Rest-rotation grazing plans assume that seed will develop during the rest year. Under desert conditions seed production is not dependable. Thus, if the "rest" year is dry and hot, no seed production is likely and no reproductive benefits from rest will occur.

Studies such as this can yield insights into the effects of climatic conditions on phenological development. Many years of data collection from various sites will be necessary, however, before we can begin to predict phenological consequences of antecedent climatic conditions on salt desert shrubs, such as Blaisdell (1958) has done for major species on a sagebrush-grass range.

Literature Cited

Ackerman, T. L., and S. A. Bamberg. 1974. Phenological studies in the Mojave Desert at Rock Valley (Nevada Test Site). p. 215-226. *In:* H. Lieth (ed.) Phenology and Seasonality Modeling. Spring-Verlag, New York.

Blaisdell, J. P. 1958. Seasonal development and yield of native plants on the upper Snake River Plains and their relation to certain climatic factors. U.S. Dep. Agr. Tech. Bull. 1190. 68 p.

Caldwell, M. M., R. S. White, R. T. Moore, and L. B. Camp. 1977. Carbon balance, productivity, and water use of cold-water desert shrub communities dominated by C_3 and C_4 species. Oecologia (Berlin). 29:275-300.

Cook, C. W. 1971. Effects of season and intensity on use of desert vegetation. Utah Agr. Exp. Sta. Bull. 483. 57 p.

Fernandez, O. A., and M. M. Caldwell. 1975. Phenology and dynamics of root growth of three cool semi-desert shrubs under field conditions. J. Ecol. 63:703-714.

Holmgren, R. C., and S. F. Brewster, Jr. 1972. Distribution of orgaic matter reserves in a desert shrub community. U.S. Dep. Agr., Forest Serv. Res. Pap. INT-130. 15 p.

Mitchell, J. E., N. E. West, and R. W. Miller. 1966. Soil physical properties in relation to plant community patterns in the shadscale zone of northwestern Utah. Ecology 47:627-630.

Moore, R. T., R. S. White, and M. M. Caldwell. 1972. Transpiration of *Atriplex confertifolia* and *Eurotia lanata* in relation to soil, plant, and atmospheric moisture stresses. Can. J. Bot. 50:2411-2418.

Morton, H. L., and H. M. Hull. 1975. Morphology and phenology of desert shrubs. p. 39-46. *In:* D. N. Hyder (ed.) Arid Shrublands. Soc. Range Manage., Denver, Colo.

Tueller, P. T., A. D. Bruner, and J. B. Davis. 1972. Ecology of Hot Creek Valley—vegetation and soil responses to underground detonation. Univ. Nevada Agr. Exp. Sta. Rep. NVO-409-1. 131 p.

Wallace, A., and E. Romney. 1972. Radioecology and ecophysiology of desert plants at the Nevada Test Site. TID-25954. Oak Ridge Tenn. U.S. A.E.C. Technical Information Center. 439 p.

Wein, R. W., and N. E. West. 1972. Phenology of salt desert plants near contour furrows. J. Range Manage. 24:299-304.

West, N. E., and R. W. Wein. 1971. A plant phenological index technique. BioScience. 21:116-117.

Wisler, C. O., and E. F. Brater. 1959. Hydrology. 2nd ed. John Wiley and Sons, New York. 408 p.

Nonstructural Carbohydrate Depletion in Snowberry (*Symphoricarpus oreophilus*)

MELVIN R. GEORGE AND C. M. McKELL

Highlight: Nonstructural carbohydrate (NC) concentrations in defoliated snowberry (*Symphoricarpus oreophilus*) plants were compared over two seasons with trends of NC concentrations in untreated plants. Nonstructural carbohydrate concentrations in small roots and stems of defoliated plants decreased slowly from the time of initial defoliation. The NC concentrations in large roots and root crowns remained stable until prolonged, intense defoliation caused a significant decrease in NC concentrations in these plant parts. NC concentrations in stems, large roots, and root crowns decreased significantly before plant death. The decrease in NC concentrations in large roots and root crowns coincided with an increase in NC concentrations of stems prior to leaf production. Defoliated plants did not produce new stems after defoliation began and stem mortality during dormancy was great. NC concentrations apparently were inadequate to support the entire plant through dormancy. Nonstructural carbohydrates remaining in dead plant parts constitute an unused portion of the carbohydrate reserves.

Changes in carbohydrate reserves in response to various intensities, seasons, and durations of defoliation have been studied in several plants (Cook 1966; Donart and Cook 1970; Trlica and Cook 1971; Menke 1973; Willard and McKell 1973). Defoliation during periods of normal reserve depletion often induces more serious reserve depletion. In general, defoliation that is too heavy or too frequent results in decreased nonstructural carbohydrates (NC). Most defoliation and clipping treatments on snowberry (*Symphoricarpus oreophilus*) failed to reduce NC concentrations below that measured during leaf production. Frequent, intense defoliation would be expected to cause NC to decrease to concentrations lower than those measured during leaf production in untreated plants. Defoliation treatments by Donart and Cook (1970) and Willard and McKell (1973) apparently were not sufficiently intense to accomplish a permanent reduction in NC concentration. In these studies, partial to total replenishment of reserves was achieved after the treatments were imposed, but before dormancy began. Recovery from defoliation implies that snowberry's carbohydrate pool may be greater than the amount of NC used during the normal annual cycle. An estimate of the size of the carbohydrate reserve pool might be obtained by determining how much of the extractable NC can be depleted during continuous defoliation. In 1973 and 1974 a depletion study of NC in snowberry was conducted in Logan Canyon, Utah, to determine the trend and ultimate level of NC concentration present in defoliated and untreated shrubs.

Assistant professor, Natural Resources Management Department, California Polytechnic State University, San Luis Obispo 93407; and professor of range science, Utah State University, Logan 84322.

Manuscript received May 2, 1977.

Methods and Materials

Fifty-six snowberry plants of similar size were selected for the study. Twenty-eight of these plants were defoliated by hand picking all of the leaves. After the initial leaf removal on June 1, 1973, leaf regrowth was removed every 2 weeks on June 15, June 29, and July 13. Leaves were not replaced in 1973 after the fourth defoliation. The defoliated plants produced leaves the following spring and defoliation was resumed on May 15, 1974, followed by defoliations on May 30 and June 15.

Four plants were sampled on May 26, 1973, before defoliation began. After defoliation, four defoliated plants and four untreated plants were sampled on June 7, June 17, and August 3, 1973; and May 1, June 8, and July 15, 1974. Stem production by defoliated plants was observed as an indicator of plant vigor. Stem mortality was determined by ocular estimate.

Defoliated and untreated plants were excavated to a depth of 61 cm and representative sub-samples of stems, small roots (less than 6 mm in diameter), large roots (greater than 6 mm in diameter), and root crowns were collected. On each collection date, plant material was frozen in dry ice and taken to the laboratory where it was stored in a freezer until it was freeze-dried. The freeze-dried plant samples were ground in a Wiley Mill through a 40-mesh screen and stored in desiccators.

The NC was extracted from the ground plant samples using 0.2 N sulfuric acid as described by Smith et al. (1964). This method hydrolyzed NC to reducing sugars, which were analyzed using the dinitrosalicylic acid method (Luchsinger and Cornesky 1962). Glucose was used as a standard. The product of this procedure has conventionally been called total available carbohydrates but this term is a misnomer, according to Stoddart et al. (1975) and George (1976).

Data were subjected to analysis of variance and Duncan's new multiple range test (Duncan 1955) was used to separate means where a significant difference occurred ($p < 0.05$).

Results and Discussion

Nonstructural carbohydrate concentrations in small roots and stems of defoliated plants were depressed initially and were reduced significantly in all plant organs by the time of plant death (Fig. 1). Nonstructural carbohydrate in stems from untreated plants increased from a minimum of 5.6% on May 26 to a maximum near 12% in August. Stems from defoliated plants had only about 5% NC in August; whereas a maximum of 7.5% was found on May 1, 1974. This was followed by a decrease to 3.3% on June 8, 1974. The NC on this date was significantly lower than the NC measured on May 26, 1973, just before defoliation began, thus illus-

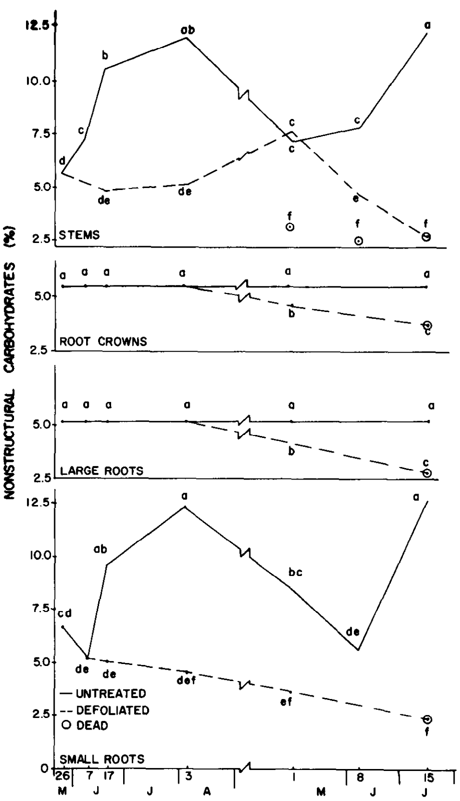


Fig. 1. *Mean NC concentration for four plant parts from defoliated and untreated snowberry plants in 1973 and 1974. Means with the same letters are not significantly different at the 5% level of probability.*

trating that NC in stems can be significantly decreased below the usual NC minimum reached in untreated plants during leaf production. During this study there was no stem production by the defoliated plants, but stem production did occur in the untreated plants.

The NC in large roots and root crowns from untreated plants maintained stable concentrations between 5 and 5.5% throughout the defoliation study in 1973 (Fig. 1). However, the NC in the large roots and root crowns from defoliated plants deviated from these normal concentrations on May 1, 1974, when NC dropped significantly to 4.1% for large roots and 4.4% for root crowns.

Small roots from untreated plants had a minimum NC concentration of 5.2% on June 7, 1973, and increased to a maximum near 12.5% in August (Fig. 1). The NC concentration in small roots from defoliated plants decreased from the beginning of defoliation until plant death occurred over a year later. However, the NC concentration within small roots did not decrease significantly from the NC minimum measured on June 7, 1973, until plant death occurred.

Nonstructural carbohydrates in stems, root crowns, large roots, and small roots collected in the second season on July 15 when the plants were dead were significantly lower than the lowest concentrations measured near the time defoliation was begun. The NC for stems, root crowns, large roots, and small roots from dead plants was 2.6, 3.4, 2.6, and 2.3%, respectively (Fig. 1). An estimated 60 to 75% of the defoliated stems died during winter dormancy. The NC in these dead stems on May 1 was 3.3%. More stems were dead on June 8 and the NC at this time was 2.5%.

Several important results were measured or observed while monitoring NC concentration in untreated and defoliated snowberry plants. The NC concentrations in stems and small roots fluctuated more and sooner than the NC concentrations in large roots and root crowns. Nonstructural carbohydrates in defoliated plants can be decreased below the depressed concentrations measured during leaf production in untreated plants. Of particular importance is the fact that NC was not replenished in severely defoliated plants, so they entered dormancy with depressed reserves. Finally, the observed lack of stem production after several defoliations and the high stem mortality during winter dormancy were important indicators of the effect of defoliations.

The fluctuation of NC concentrations in small roots and stems indicates the probable use or translocation of enough of the reserve carbohydrate pool in each of these plant parts to cause a change in concentration. This is probably because of the close proximity of these plant parts to the major sites of use. Stoddart et al. (1975) suggested that reserves nearest the place of use would be most readily available. Other researchers have shown marked depletion of carbohydrate reserves in tissue adjacent to expanding buds and shoots (Siminovitch et al. 1953; Woods et al. 1959; Priestly 1960). Coyne (1969) and Trlica and Cook (1971) showed that NC concentration in small roots was more responsive to change than NC concentration in crowns of big sagebrush and black sagebrush. The NC concentration in large roots and root crowns was relatively stable, indicating that the net use of the reserve carbohydrate pool was not gr enough to change the NC conce tration. If this reserve pool is gr enough, its contribution to metaboli may be quite important without signi cantly decreasing the NC conce tration. NC in large roots and r crowns could act as a "margin safety" to excessive carbohydrate u in the plant.

The defoliation in this study w frequent and intensive as a means depleting carbohydrate reserves in t subject plants. Snowberry has be clipped in other studies with little lor term effect on NC concentratio Donart and Cook (1970) found tl plants clipped once during leaf pı duction at 90% would replenish part their small root reserves by late Ju Willard and McKell (1973) monito NC concentrations in small roots, la roots, and root crowns when th simulated several grazing systems varying the time of clipping. The o clipping regime that significantly duced NC concentrations in large ro from snowberry was clipping on Ju 15 for five consecutive years.

In this study, NC concentration large roots and root crowns of untrea plants remained relatively stal throughout the year. The NC conce tration in large roots and root crowns defoliated plants did not decre significantly unless defoliation pressu was prolonged. This would indic that NC was used in respiration in t large roots and root crowns or that N was transported to support NC requi ments in small roots and stems. The N concentrations in stems and small ro did not decrease significantly i mediately after defoliation began. T large roots and root crowns, with larger reserve pool, may have helped maintain the NC concentrations small roots and stems. Initially tl could be accomplished without measu ably lowering NC concentrations large roots and root crowns, but t carbohydrate demands of dorman and mobilization of reserves to supp spring production might eventua cause a significant reduction in N concentrations in larger roots and r crowns. Although stem NC concent tion is maintained in live stems, li stem biomass decreased as stems di during the 1974 season. Ogden a Loomis (1972) found a similar situati in *Agropyron intermedium*. They fou equal concentrations of water-solut carbohydrates in roots from clipped and unclipped plants, but less water-soluble carbohydrate quantities in roots of clipped plants. This suggests that root biomass may decrease because of clipping, while carbohydrate concentrations remained stable.

Carbohydrate depletion may be responsible for the lack of stem production in defoliated plants, but other explanations should also be considered. Stem production would not occur if the buds were injured or killed by defoliation. Although new stems were not produced following defoliation, the terminal and lateral buds functioned in leaf replacement within 3 weeks after each defoliation until dormancy in 1973 and plant death in July, 1974. Although the objective of defoliation was to deplete carbohydrate reserves, plant morphology cannot be ignored when interpreting the effects of defoliation.

Continuous defoliation eventually results in plant death. From the beginning of defoliation, NC concentrations followed a decreasing trend in two storage organs until a plant part died. The decrease in NC to the range of critical concentrations can be a contributing cause of death. However, death could have occurred because of other reasons brought about by defoliation.

The NC concentration measured in dead plant material is difficult to interpret in terms of plant functions. Whether some of this reserve material could have been used under normal circumstances is not known, but it does represent a considerable loss to the plant. The isolation of carbohydrate reserves from the food transport system of shrubs deserves further study.

Summary and Conclusions

In continuously defoliated snowberry plants, NC concentrations in small roots and stems decreased slowly from the time of initial defoliation. The NC concentrations in large roots and root crowns remained stable until prolonged, intense defoliation eventually caused a significant decrease in NC concentrations in these plant parts. NC concentrations in stems, large roots, and root crowns decreased significantly before plant death. The decrease in NC concentration in large roots and root crowns coincided with an increase in NC concentration in stems just prior to leaf production. This indirect evidence seems to indicate that mobilization of carbohydrates in the stems is supported by NC in the large roots and root crowns. However, other carbon sources in the stems may have supported the increase in NC in the stems. The defoliation treatments also depressed plant vigor, as indicated by the lack of stem production after defoliation began and the high stem mortality suffered during dormancy. The depressed NC concentrations in stems and small roots at the beginning of dormancy appeared to be a good indicator of lowered plant welfare.

Nonstructural carbohydrate concentrations in dead plant parts represent an unused portion of the carbohydrate reserves. Although the carbohydrates in dead plant parts may be extractable using routine laboratory procedures, they appeared to be unavailable for plant use. In shrubs where stem dieback is common, such isolation may represent a great loss to the general vigor of plants and ecosystem productivity.

Literature Cited

Cook, C. W. 1966. Carbohydrate reserves in plants. Utah Agr. Exp. Sta. Resources Ser. 31. 47 p.

Coyne, P. I. 1969. Seasonal trends in total available carbohydrates with respect to phenological stage of development in eight desert range species. PhD Diss., Utah State Univ., Logan. 164 p.

Donart, G. B., and C. W. Cook. 1970. Carbohydrate reserve content of mountain range plants following defoliation and regrowth. J. Range Manage. 23:15-19.

Duncan, D. B. 1955. Multiple range and multiple *F* test. Biometrics 11:1-42.

George, M. R. 1976. Distribution of carbon reserves in snowberry (*Symphoricarpus oreophilus*). PhD Diss., Utah State Univ., Logan. 73 p.

Luchsinger, W. W., and R. A. Cornesky. 1962. Reducing power by the dinitrosalicyclic acid method. Anal. Biochem. 4:346-347.

Menke, J. W. 1973. Effects of defoliation on carbohydrate reserves, vigor, and herbage yield for several important Colorado range species. PhD Diss., Colorado State Univ., Fort Collins. 311 p.

Ogden, P. R., and W. E. Loomis. 1972. Carbohydrate reserves in intermediate wheatgrass after clipping and etiolation treatments. J. Range Manage. 25:29-32.

Priestly, C. A. 1960. Seasonal changes in the carbohydrate resources of some six-year-old apple trees. East Malling Res. Sta. Annu. Rep. 1959. p. 70-77.

Siminovitch, D., C. M. Wilson, and D. R. Briggs. 1953. Studies on the chemistry of the living bark of the black locust tree in relation to frost hardiness. V. Seasonal transformations and variations in the carbohydrate: starch-sucrose interconversions. Plant Physiol. 39: 960-962.

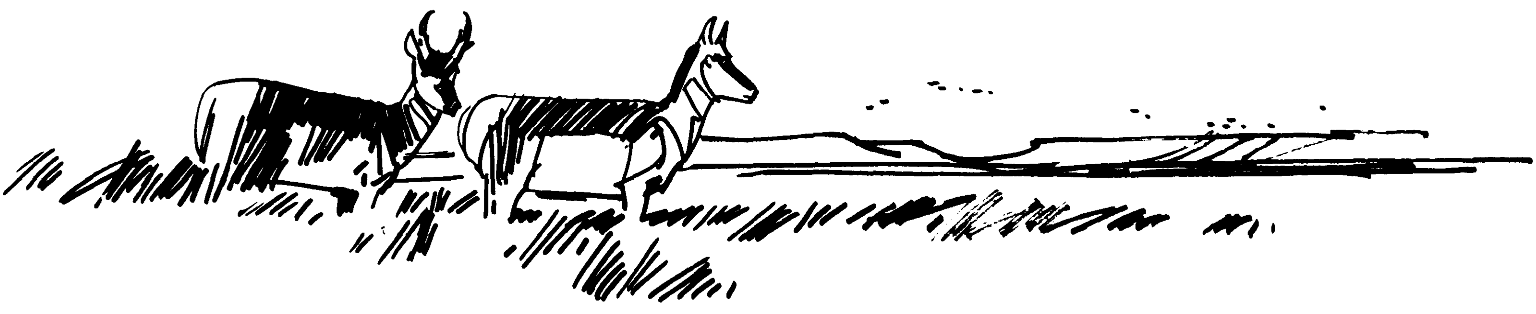
Smith, D., G. M. Paulsen, and C. A. Raguse. 1964. Extraction of total available carbohydrates from grass and legume tissue. Plant Physiol. 39:960-962.

Stoddart, L. A., A. D. Smith, and T. W. Box. Range Management. 3rd ed. McGraw-Hill Book Co., Inc., New York. 532 p.

Trlica, M. J., and C. W. Cook. 1971. Defoliation effects on carbohydrate reserves of desert species. J. Range Manage. 24:418-425.

Willard, E. E., and C. M. McKell. 1973. Simulated grazing management systems in relation to shrub growth responses. J. Range Manage. 26:171-174.

Woods, F. W., H. C. Harris, and R. E. Caldwell. 1959. Monthly variations of carbohydrates and nitrogen in roots of sandhill oaks and wiregrass. Ecology 40:292-295.



Successional Trends in a Ponderosa Pine/Bitterbrush Community Related to Grazing by Livestock, Wildlife, and to Fire

JAMES M. PEEK, FREDERIC D. JOHNSON, AND NED N. PENCE

Highlight: A ponderosa pine/bitterbrush community in the South Fork of the Salmon River, Idaho, was determined to be a seral stage of a Douglasfir/snowberry habitat type. An exclosure, erected in 1959 to evaluate effects of browsing on bitterbrush by big game, contained more kinnikinnik and less Idaho fescue than did the outside area. Bitterbrush density was similar outside and inside the exclosure, but twig production was 12 times greater outside. A combination of periodic natural fire prior to effective suppression starting in the 1940's, and livestock grazing were probably initially responsible for the secondary successional vegetation on the site. Subsequently, utilization by big game of this vegetation has served to maintain the productivity of the bitterbrush and retard succession to climax.

Bitterbrush (*Purshia tridentata*) is generally recognized as a component of climax dry forest and steppe habitat types in Idaho (Daubenmire and Daubenmire 1968; Steele et al. 1975). A 0.047-ha (one acre) big game exclosure established in 1959 on a big game winter range on the Buckhorn Bar, South Fork of the Salmon River of central Idaho has provided an opportunity to evaluate successional status of bitterbrush (*Purshia tridentata*) in relation to habitat type and land use practices. Two hypotheses were tested during this study: (1) bitterbrush was a seral species within a zootic-pyrrhic disclimax of a Douglasfir (*Pseudotsuga menziesii*)/snowberry (*Symphoricarpos albus*)-kinnikinnik (*Arctostaphylos uva-ursi*) habitat type (h.t.), and (2) foraging by mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) was contributing to maintenance of the existing bitterbrush stand outside of the exclosure.

U.S. Forest Service records, including history of the area, standing crop and annual productivity measurements of bitterbrush, and canopy coverage/composition measurements of the understory made in July 1976, form the basis for testing the hypotheses.

Study Area

Buckhorn Bar is underlain by granitic gravel substrate, approximately 100 m above current river level at an elevation of about 1,400 m. The surrounding canyon slopes are very steep, unglaciated decomposed granite. Climate is mild and relatively dry with an average precipitation about 620 mm at a river-grade station (Krassel R.S.) 10 km south of Buckhorn Bar. Temperatures seldom go below −10°C in winter and snow is rarely over a few centimeters deep. Mid-June to mid-September is normally without effective precipitation. The South Fork Salmon River canyon is dominated by forests of ponderosa pine and Douglasfir. Dry-lightning is common during the summer drought and the evidence of high fire frequency is easily read from the trees.

A savanna-like stand of uneven-aged ponderosa pine dominates Buckhorn Bar; the great majority of trees are mature and yellow-barked. In and around the exclosure there are about 245 trees/ha. Mean diameter breast high is 24 cm with the larger trees up to 91 cm. Two Douglasfirs of about 15 cm dbh were also present in the vicinity, but they were very rare on Buckhorn Bar. The understory of the general area was dominated by bitterbrush 0.9–1.8 m tall, rather widely spaced. Average stem age of bitterbrush was 26 (15–39) years based on annual ring counts of 13 randomly selected stems. Lesser amounts of snowberry, low huckleberry (*Vaccinium caespitosum*), wild rose (*Rosa woodsi*), and white spiraea (*Spiraea betulifolia*) form a very open low-shrub layer, while a few scattered Scouler willow (*Salix scouleriana*) and serviceberry (*Amelanchier alnifolia*) plants represent the tall shrubs. Graminoids, chiefly Idaho fescue (*Festuca idahoensis*), Junegrass (*Koeleria cristata*), and pinegrass (*Calamagrostis rubescens*) dominate a widely spaced ground layer which is rich in forbs.

The area had a history of fire as evidenced by fire scars on many pine trees, and charcoal on stumps and downfalls. Human use of the area dates back over 75 years, consisting primarily of domestic livestock grazing until the 1940's. Around 1940 the river bars were described by the District Ranger as "dust beds" from sheep and horse use. Grazing was sharply reduced in the late 1940's, and excluded in early 1960. Establishment of the current bitterbrush stand dates to the initial reduction of livestock grazing. Occasional selective cutting of larger insect-infested pine ceased in the early 1960's.

Method

Vegetation Sampling

Vegetation was sampled with a series of micro- and macroplots taken inside and immediately outside of the exclosure. Four lines were placed perpendicular to the sides of the exclosure at estimated mid-points from the corners. Ten 2 × 5-dm (0.2 m^2) plots were taken on each line both inside and outside with a plot interval of about 1.5 m between plots. A 2-m distance from the fence was maintained to prevent bias associated with the edge. A road-trail over 15 years old was by-passed by doubling the plot interval. Cover was estimated as outlined by Daubenmire (1959) using six cover classes, on plants rooted in the plots. This method is most reliable for low plants of relatively discrete habit. Taller shrubs, such as bitterbrush, often go unsampled, while cover estimates of rhizomatous grasses, such a pinegrass, are very inaccurate. To add depth to the vegetational

Authors are professors, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, and district ranger, Island Park Ranger District, U.S. Forest Service, Island Park, Ida.

Authors wish to thank students in the Wildland Ecology course, summer 1976, and Anita Cholewa for aid in taking field data. Monta Lazelle verified plant materials that were, for the most part, well past their prime. Dr. Doyle Anderegg, Department of Biological Sciences, University of Idaho, kindly identified the lichen. Dr. Charles Hatch reviewed statistical analyses.

This report was financed in part through McIntire-Stennis Project MS-22, the Stillinger Trust Foundation, and Forest, Wildife, and Range Experiment Station, University of Idaho, Paper No. 89, Forest Wildl. and Range Exp. Sta., Univ. of Idaho.

Manuscript received May 2, 1977.

description, cover was also estimated on two circular macro-plots of 375 m² inside and outside the exclosure. This system follows Daubenmire and Daubenmire (1968) as modified by Steele et al. (1975) and allows direct comparison with plot data published for most of the forest habitat types of Idaho and western Montana. The northern plot pair was chosen to represent medium bitterbrush density with typical ponderosa pine overstory dominance. The southern plot pair was judged typical of open areas with virtually no overstory shade and higher coverage of bitterbrush. Habitat types were determined using Steele et al. (1975). Voucher specimens of most plants were deposited in the Research Herbarium, College of Forestry, Wildlife and Range Sciences, University of Idaho (IDF). Scientific and common plant names follow Hitchcock and Cronquist (1973).

Parker 3-step transects (Parker 1951) were measured inside and outside the exclosure in 1959, 1964, and 1975. These provide direct estimates of vegetation change when grazing by big game is excluded.

Bitterbrush Sampling

Production of current year twig growth of bitterbrush was used as the index to productivity. Twigs were counted within 35 4-m² circular plots, inside and outside adjacent to the exclosure, following Shafer (1963). A regression equation of twig weight as a function of length was determined by clipping, measuring the length, oven-drying at 70°C for 24 hours, and weighing 68 twigs representing the range of lengths encountered on the site. Lengths of 100 unbrowsed twigs inside and outside of the exclosure were measured to nearest 0.5 cm. A mean weight per twig was obtained from mean leader lengths inside and outside the exclosure and multiplied by the mean number of twigs per m² to arrive at weight estimates for twig growth.

Standing crop of aerial shoots of bitterbrush was estimated by counting individual plants within the 4-m² plots. A crown cover estimate was made by measuring two diameters at right angles to each other across the canopy of each plant; and canopy area was determined using the formula

$$\alpha = \frac{\pi}{4} d_1 d_2$$

where α equals canopy area and d equals one diameter (cm) across the canopy of the plant. Ten whole plants representative of the variation in plants within the stand were measured, clipped at ground level, and weighed. A regression equation of weight of plant on its canopy area was calculated following Peek (1970). Calculation of standing crop was made by determining a mean canopy area for plants inside and outside the exclosure, converting to weight using the regression equation, and multiplying by stem density/ha. A significance level of $P = 0.10$ is used in all statistical tests unless otherwise specified.

Heights of all bitterbrush plants within the plots and percent of crown covered by the arboreal black lichen *Bryoria fremontii* Tuck, and number of dead plants were also determined.

Results

Present Vegetation

Table 1 summarizes micro- and macro-plot data and compares with the Douglasfir/snowberry habitat type-kinnikinnik phase and the ponderosa pine/bitterbrush habitat type-Idaho fescue phase from Steele et al. (1975). Steele et al. (1975) sampled 11 Douglasfir/snowberry stands and three ponderosa pine/bitterbrush stands in the central Idaho area. Both microplot and macroplot data reveal several remarkable differences in the vegetation outside and inside the exclosure. Idaho fescue, Junegrass, and intermediate oatgrass (*Danthonia intermedia*) declined dramatically inside. Pinegrass declined substantially in macroplots while remaining about the same in microplots. Other graminoids showed but small differences outside to inside. Figure 1, taken in July 1976, compares vegetation inside and outside the exclosure.

There were 31 species of forbs, most low in both cover and frequency in microplots and cover in macroplots both outside

Table 1. Summarization of species cover values and frequencies in microplots (0.1 m²) and macroplots (375 m²) inside and outside the Buckhorn Bar exclosure, and comparison with cover values for Douglasfir/snowberry and Ponderosa pine/bitterbrush habitat types.

Vascular plants	Macroplots Avg. cover % (+ = < 1%): Two plots Psme/Syal-Aruv: Outside	Inside	All plots[1] Avg. cover: Psme/Syal-Aruv	Pipo/Putr-Feid[3]	Microplots % cover • % frequency (+ = < 0.9%): Outside	Inside
Graminoids						
**Agropyron repens*	+	+	•	•	•	+•3
Calamagrostis rubescens	20	9	15	•	4•60	6•70
Carex geyeri	2	+	3	3	+•3	•
Carex rossii	+	•	•	1	+•8	1•5
Carex sp.					+•3	+•3
Danthonia intermedia	9	2	•	•	2•25	+•18
Festuca idahoensis	15	2	1	22	4•45	+•3
Koeleria cristata	2	+	1	1	1•23	+•8
Luzula campestris	•	+	•	•	•	
Poa sp.	+	+	•	•	+•15	+•10
Unknown grass					+•3	
Forbs						
Achillea millefolium	+	+	1	3	1•65	1•48
Antennaria microphylla	+	+	•	1	+•15	+•20
A. neglecta	+	+	•	•	2•23	+•5
A. stenophylla	•	+	•	•	•	•
Arenaria congesta	•	+	•	•	+•10	+•5
A. macrophylla	+	+	•	•	+•8	+•13
Calochortus eurycarpus	+	•	•	•	•	•
Campanula rotundifolia	•	+	•	•	•	•
Castilleja spp.	+	•	•	•	+•3	•
**Collinsia parviflora* (A)	+	•	•	•	+•10	•
Collomia tinctoria (A)	+	•	•	•	+•8	•
Epilobium angustifolium	+	+	•	•	+•8	+•8
E. paniculatum (A)	•	•	•	•	+•3	•
Fragaria virginiana	+	+	1	3	2•48	+•38
Gayophytum (A)	+	+	•		+•25	•
Gentiana affinis	•	+	•	•	+•5	•
Geum triflorum	+	+	•	•	+•3	+•3
Hieracium albertinum	15	3	•	•	3•63	1•28
Lotus purshiana (A)	+	•	•	•	+•20	•
Lupinus sericeus	+	+	•	•	+•3	+•3
Madia exiqua (A)	+	•	•	•	+•5	•
Microsteris gracilis (A)	•	•	•	•	+•8	•
Montia perfoliata (A)	•	•	•	•	+•3	•
Orthocarpus tenuifolius (A)	+	•	•	•	+•13	•
Penstemon procerus	+	+	•	•	+•15	+•8
Potentilla glandulosa	+	+	•	•	•	•
P. gracilis	+	+	1	•	•	•
Sedum stenophyllum	•	•	•	•	+•5	•
Solidago missouriensis	+	+	•	•	+•15	•
Trifolium longipes	+	•	•	•	+•3	+•3
Zig adenus venenosus	+	•	•	•	•	•
Shrubs						
Amelanchier alnifolia	+	+	1	0	•	•
Arctostaphylos uva-ursi	9	50	56	•	2•15	46•80
Physocarpus malvaceus	•	+	•	•	•	•
Purshia tridentata	50	38	15	22	+•3	+•3
Ribes irriguum	•	+	•	•	•	•
Rosa woodsii	3	3	•	•	+•10	2•25
Salix scouleriana	+	2	•	•	•	•
Shepherdia canadensis	+	+	•	•	•	•
Spiraea betulifolia	+	•	15	•	+•8	+•10
Symphoricarpos albus	3	9	26	3	1•28	3•45
Vaccinium caespitosum	2	+	•	•	1•18	1•13

* = Alien taxa.
(A) = annual.
[1] Steele et al. 1975.
[2] Psme/Syal-Aruv = Douglasfir/snowberry habitat types (Steele 1975).
[3] Pipo/Putr-Feid = Ponderosa pine/bitterbrush habitat types (Steele 1975).

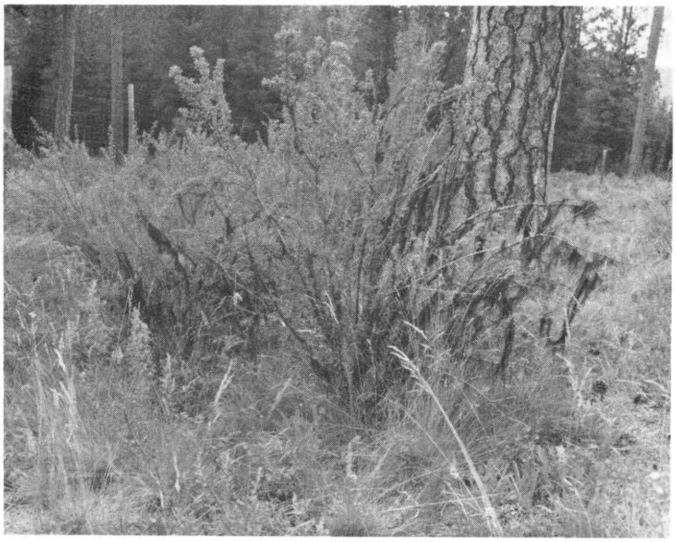


Fig. 1. *Comparisons of bitterbrush plants inside (left) and outside (right) of the Buckhorn Bar exclosure illustrating differences in black lichen occurrence.*

and inside. Most significant was the decline of hawkweed (*Hieracium albertinum*) inside, substantiating the seral role of this common forb in this habitat type.

Nine species of annuals occurred in plots outside of this exclosure, none with significant cover or frequency. Only one species, *Lotus purshiana*, appeared in plots inside the exclosure, testifying to the trend toward climax of the vegetation inside.

The most obvious difference in the outside/inside vegetation comparison occurred with kinnikinnik. Outside, kinnikinnik had a microplot frequency of 15% and a cover of 2%, while inside frequency and cover increased to 80% and 46%, respectively. Cover of this species in macroplots outside and inside were 9% and 50%, respectively. The average cover of bitterbrush remained about the same inside and outside the macroplots, while a few scattered tall and midsize shrubs including serviceberry, Scouler willow, and buffaloberry (*Shepherdia canadensis*) appear in small amounts. The trend toward snowberry domination at climax was shown by slight increases in its macroplot cover and larger increases in microplot cover and frequency. Low huckleberry (*Vaccinnium caespitosum*) may be a seral increaser on this habitat type, but it shows little change after 17 years of protection from browsing, suggesting a long-term role in the successional process.

Successional Trends

Parker 3-step data indicated downward trends of Idaho fescue and yarrow and upward trends of snowberry and kinnikinnik inside the exclosure (Table 2). Pinegrass declined both outside and inside, indicating a seral role following fire.

Bitterbrush showed similar trends in cover inside and outside of the exclosure, with highest coverage occurring in 1975. Alberta hawkweed, the most abundant forb in our outside plots, showed a strong upward trend outside in the Parker 3-step data. The 3-step data strongly imply that hawkweed was not an important early seral species but achieved an important role more recently.

Bitterbrush Standing Crop

The coefficient of determination for the regression weight of arboreal stems of bitterbrush on canopy area was 0.85, and the regression was significant at the 0.01 level of probability (Fig. 2). Regression coefficient derived separately from plants inside and outside the exclosure were not significantly different. Mean canopy area of 48 plants measured inside the exclosure was 3,956 ± 737 cm^2, and of 76 plants measured outside, 4,729 ± 1,005 cm^2. Standing crop of plants outside the exclosure was 157 ± 6.8 g/m^2, and inside 115 ± 7.5 g/m^2, or 73% of the weight of the outside crop (Table 3).

Stem densities per m^2 were similar inside (0.336 ± 0.022) and outside (0.325 ± 0.014) the exclosure. Plant heights averaged 88.37 ± 6.7 cm inside the exclosure and 80.95 ± 7.6

Table 2. Comparisons of vegetation (% cover) inside and outside the Buckhorn Bar exclosure in 1959, 1964, and 1975.[1]

	1959		1964		1975	
Vegetative cover	Inside	Out-side	Inside	Out-side	Inside	Out-side
Graminoids						
Calamagrostis rubescens	38	45	32.5	35.7	2	5.9
Carex geyeri	–	–	5	–	–	–
Festuca idahoensis	5.5	25	7	25	–	11.8
Koeleria cristata	–	–	–	7	–	–
Poa spp.	–	–	–	7	–	–
Forbs						
Achillea millefolium	2.8	–	–	–	–	–
Anemone sp.	2.8	–	–	–	–	–
Antennaria spp.	5.5	5	7	10.7	3.5	–
Eriogonum spp.	–	5	–	–	–	–
Fragaria virginiana	–	–	–	–	3.5	–
Heuchera sp.	2.8	–	–	–	–	–
Hieracium albertinum	–	–	2	–	4.5	29.4
Potentilla spp.	–		5		–	
Shrubs						
Arctostaphylos uva-ursi	2.8	5	23	3.6	33	–
Purshia tridentata	23	10	14	10.7	38	35.3
Rosa woodsii	11	–	2	–	2	–
Spiraea betulifolia	–	5	–	–	–	5.9
Symphoricarpos albus	7	–	2	–	13	5.9
Vaccinium caespitosum	–	–	–	–	–	5.9
Total plant cover	37	20	43	28	56	17
Moss	8	7	9	5	1	0
Bare soil	3	15	0	7	0	0
Litter	52	58	48	60	43	83

[1] Data are percentage cover values taken from Parker 3-step transects by U.S. Forest Service personnel. Records are on file at Krassel Ranger Station, Payette National Forest.

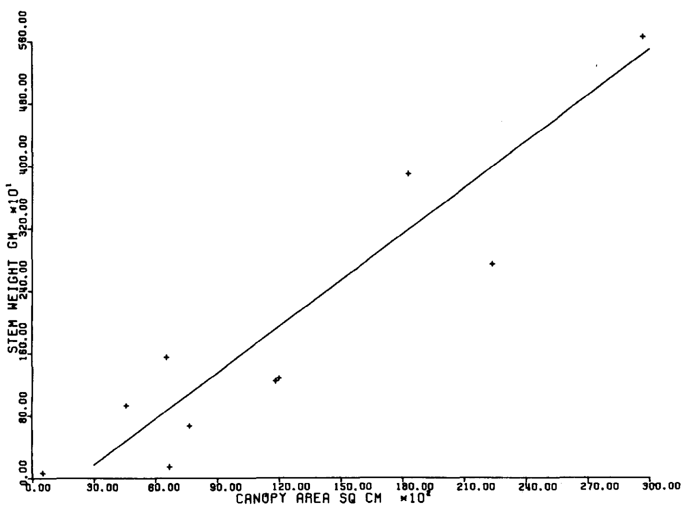


Fig. 2. *Regression of aerial stem weight of bitterbrush on canopy area. The regression equation is $Y = -383.47 + 0.1834X$. $r^2 = 0.85$. Data were collected in July 1976.*

outside the exclosure. In addition, an average of 16 ± 6% of the crown canopies of bitterbrush within the exclosure were covered with the common black tree lichen, while this palatable species was completely absent from bitterbrush outside (Table 3).

Dead stem densities averaged four times greater inside the exclosure than outside (Table 3). Thus the bitterbrush stand inside the exclosure was similar in density to that outside, but was uniformly taller, with more dead stems, greater black lichen coverage, and smaller canopy area. These factors indicated that bitterbrush vigor was deteriorating within the exclosure when compared with that existing outside.

Bitterbrush Production

Twig production was much greater outside than inside the exclosure, probably reflecting the stimulating effect of moderate browsing (Table 3). Approximately 12 times more twigs per m² were produced outside than inside, accounting for a similar disparity in weight production. Regression coefficients of twig weight on length derived separately for twigs inside and outside the exclosure were not significantly different. Twig lengths were significantly greater outside the exclosure (5.36 ± 0.65 cm) than inside (3.39 ± 0.56 cm). However, twig weights did not differ significantly. The regression of twig weight on length was significant ($P = 0.001$) and had a coefficient of determination of 0.889 (Fig. 3). The regression equations of Basile and Hutchings (1966), developed from twigs collected during plant dormancy, estimated twig weight at 62% of the estimates derived from collection during the growing season on the study area.

Table 3. Standing crop, productivity, height, dead stem density, and lichen coverage on bitterbrush inside and adjacent to the Buckhorn Bar exclosure, South Fork Salmon River, in July 1976. Confidence interval (CI) is 90%.

	Outside		Inside	
Cover	$\bar{X}$	CI	$\bar{X}$	CI
Stems/m²	0.325 ± 0.014		0.336 ± 0.022	
Canopy area per plant (cm²)	4,729 ± 1,005		3,956 ± 737	
Stem weight/m² (g)	157 ± 6.8		115 ± 7.5	
Plant height (cm)	80.9 ± 7.6		88.4 ± 6.7	
% canopy covered by lichen	0		16 ± 5.7	
Dead stems/m²	0.075 ± 0.032		0.279 ± 0.085	
Current year's twigs/m²	224.8 ± 20		19 ± 1.5	
Twig weight/m² (g)	14.36 ± 1.28		1.21 ± 0.96	

Discussion

To most observers, Buckhorn Bar appears to be an undisturbed area. Based on keys and descriptions provided by Steele et al. (1975), plus the insight of over 20 years' experience in forest typing, Buckhorn Bar was determined to be a Douglasfir/snowberry h.t.-kinnikinnik phase. However, this area will not key directly due to the paucity of Douglasfir, which could be considered accidental. Thus, the vegetation here could easily be taken to represent the ponderosa pine/bitterbrush h.t., Idaho fescue phase. The description of this habitat type (Steele et al. 1975, p. 32) and the occurrence map (p. 31) all support this conclusion. Only the constancy table (p. 173–174) provides insight to the discrepancy between the Buckhorn Bar vegetation and a ponderosa pine/bitterbrush climax.

In the climax condition, bitterbrush and Idaho fescue can be expected to disappear from Buckhorn Bar. Both are important winter forage species for big game in this area. Yarrow, Alberta hawkweed, the three species of *Antennaria*, and most small annual forbs, all are either seral or disturbance increasers in this type. Lack of low huckleberry in the Steele et al. (1975) data helps to establish the seral role of this shrub in this habitat type,

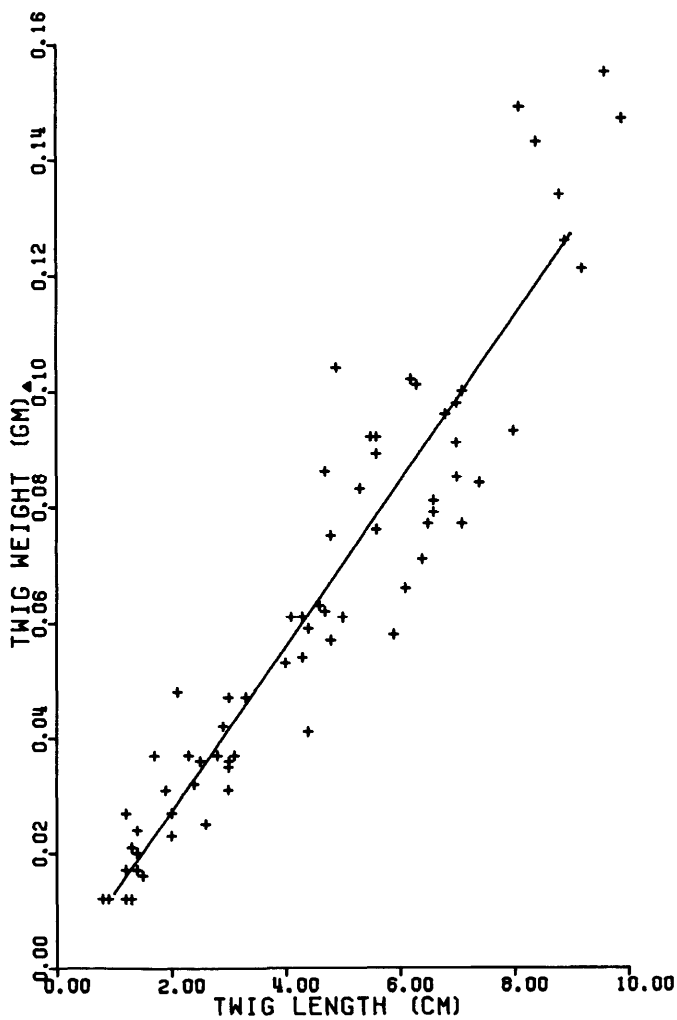


Fig. 3. *Regression of twig weight on length of bitterbrush. The regression equation is $Y = -0.001 + 0.014X$. $r^2 = 0.89$. Data were collected in July 1976.*

while our data show it to be slow in yielding to the advancing succession.

U.S. Forest Service utilization estimates for bitterbrush outside the exclosure from 1959 to 1975 averaged 60% of current growth removed (range 33–84%). The average fell within the maximum allowable annual utilization for bitterbrush as determined from clipping (Garrison 1953). It also appeared that this level of use had maintained bitterbrush in vigorous condition on Buckhorn Bar, while after 17 years of protection from browsing, the plants within the exclosure were less productive. These observations were the reverse of often anticipated results, since exclosures were often established as public relation tools to demonstrate detrimental effects of heavy browsing on preferred forage by big game.

A "browse line" was evident on black tree lichens outside the exclosure, where no lichens were present below 2.5 m, indicating the high palatability of this species. Also, the few ponderosa pine and Douglasfir seedlings available to big game in the vicinity showed heavy browsing and some mortality. Ponderosa pine regeneration was present inside the exclosure.

We hypothesize that the combination of periodic natural fire prior to effective suppression dating from the 1940's and livestock grazing were initially responsible for the secondary successional vegetation present on this site. Subsequently, utilization by big game has served to maintain the productivity of the bitterbrush, prevent establishment of conifer regeneration, and retain the seral community. Thus, we conclude that this is an example where browsing by a big game population has perpetuated a favorable food source.

Management alternatives to retain this situation must be considered if the balance between big game and the winter range is altered to allow succession to continue. Experimental burning may be considered to determine response of bitterbrush, usually a nonsprouter following fire (McKell et al. 1972). Selective logging to retain the savanna-like qualities of the site is a less-risky alternative (Stuth and Winward 1976). Livestock grazing at a controlled level of use on herbaceous forage, when use of winter game forage would be minimal, is also to be considered. The current population and mix of elk and mule deer should also be maintained through judicious regulation of harvest, with utilization of bitterbrush as one guide to adjusting seasons. If successional trends toward the climax Douglasfir/snowberry habitat type progress, the area will eventually become much less valuable as winter big game range. Heavier ground fuel a better fuel continuity will also develop with the more me vegetation and thus forest fires will be both hotter and m difficult to control.

Bitterbrush is seral on this habitat type, with its seral positi being effectively maintained by moderate browsing by deer a elk. Also, the ponderosa pine/bitterbrush community represe one successional stage of a Douglasfir/snowberry habitat ty The following plants appear to be important seral species on t Douglasfir/snowberry habitat type: Idaho fescue, intermedi oatgrass, three species of *Antennaria*, Alberta hawkwe lupine, wild rose, low huckleberry, and bitterbrush.

Caution must be exercised by field crews, and particula those training them for habitat-type work. In habitat-typir observations beyond the obvious indicator (or key) plants often needed. Crews should be able to read and interp constancy tables. In this instance, the numbers of mesic fo present is a positive, though subtle, indicator that the fo depauperate ponderosa pine/bitterbrush climax is an inapprop ate choice for classification.

Literature Cited

Basile, J. V., and S. S. Hutchings. 1966. Twig diameter-length-wei relationships of bitterbrush. J. Range Manage. 19:34-38.

Daubenmire, R. 1959. A canopy coverage method of vegetation analy Northwest Science 33:43-64.

Daubenmire, R., and J. B. Daubenmire. 1968. Forest vegetation of east Washington and northern Idaho. Washington Agricultural Exp. Sta. Te Bull. 60. 104 p.

Garrison, G. A. 1953. Effects of clipping on some range shrubs. J. Ra Manage. 6:309-317.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northw Univ. of Washington Press, Seattle. 730 p.

McKell, C. M., et al. 1972. Wildland shrubs—their biology and utilizati U.S. Dep. Agr., Forest Serv. Gen. Tech. Rep. Int.-1. 494 p.

Parker, K. 1951. A method for measuring trend in range condition on nat forest ranges. U.S. Forest Service, Washington, D.C. 26 p. (processe

Peek, J. M. 1970. Relation of canopy area and volume to production of t woody species. Ecology 51:1098-1101.

Shafer, E. L. 1963. The twig-count method for measuring hardwood d browse. J. Wildl. Manage. 27:428-437.

Steele, R., et al. 1975. Forest habitat types of central Idaho. Intermount Forest and Range Exp. Sta. 191 p.

Stuth, J. W., and A. H. Winward. 1976. Logging impacts on bitterbrus the lodgepole pine-pumice region of central Oregon. J. Range Mana 29:453-456.

THESIS: NEW MEXICO STATE UNIVERSITY

Effects of Type and Rates of Nitrogen Fertilizers on Blue Grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) Rangeland Production, by Kenneth Owen Fulgham, MS, Animal, Range, and Wildlife Science. 1972.

A study was conducted on the Fort Stanton Experimental Research Station in Lincoln County, New Mexico, to determine the effects of four types of nitrogen fertilizers applied at two rates on production of a blue grama rangeland.

Ammonium nitrate, ammonium sulfate, sulfur coated urea and urea were applied at rates of 40 lb of nitrogen per acre annually and 80 lb nitrogen per acre biennially.

Fertilization increased production for carruth sagewort, grasses and other forbs ($P < .01$) during the study. The drouth experienced during the study influenced plant composition and production. Production of other forbs increased from 1970 to 1971 while the carruth sagew and grass production decreased. This was a result of the decrea precipitation. Urea was the most effective nitrogen source over th years. The 80 lb nitrogen per acre rate was more effective the first y while the inverse was true the second year.

Inflorescence production was not significantly influenced by fert zation except that there was a significant response to the low rate urea in 1970 on blue grama culm heights. Crude protein was increa almost 1% for all fertilizer treatments combined when compared to control.

Salt Tolerance of Five Varieties of Wheatgrass during Seedling Growth

M. G. MOXLEY, W. A. BERG, AND E. M. BARRAU

Highlight: The salt tolerance of five relatively recently released varieties of wheatgrass was evaluated in a 6-week greenhouse study. Barton western wheatgrass (*Agropyron smithii* Rydb.) tended to be more sensitive to salinity than Arriba or Rosana western wheatgrass. Critana thickspike wheatgrass (*A. dasystachyum* [Hook.] Scribn.) tended to be more salt tolerant than the western wheatgrasses but was not as salt tolerant as Jose tall wheatgrass (*A. elongatum* [Host] Beauv.).

Salinity is a widespread problem in arid and semiarid regions. It is also a man-induced problem in soils where irrigation and rising water tables cause an increase in soluble salts. Of recent concern are the salinity problems associated with some coal mine spoils and processed oil shale wastes. One approach to the problem is to seed salt-tolerant species.

It would be desirable for the species selected to fit into the overall land use plan and pose minimum management problems. Thus in many cases, use of indigenous salt-tolerant species or selections within species would be preferred.

The purpose of this study was to determine the salt tolerance during the seedling stage of four recently released varieties of western and thickspike wheatgrasses. These species are native to extensive areas of the western United States. Tall wheatgrass, a species known to have outstanding salt tolerance, was used as a standard.

Materials and Methods

Five named varieties of *Agropyron*, representing three species, were obtained from Soil Conservation Service Plant Materials Centers. All have been released since 1970 except Jose tall wheatgrass, which was released in 1965 (Hanson 1972). The five varieties are identified as follows:

Variety	*Species*	*Common name*	*SCS center*
Arriba	*A. smithii*	western wheatgrass	Los Lunas, N. Mex.
Barton	*A. smithii*	western wheatgrass	Manhattan, Kans.
Rosana	*A. smithii*	western wheatgrass	Bridger, Mont.
Critana	*A. dasystachyum*	thickspike wheatgrass	Bridger, Mont.
Jose	*A. elongatum*	tall wheatgrass	Los Lunas, N. Mex.

The loam soil in which the grasses were grown was the A1 horizon from a Platner series (Aridic paleustoll). Two-liter paper pots with plastic liners were each filled with 2 kg of soil. The field capacity of this soil was 17% of the air-dry weight.

Six salinity treatments plus an untreated soil check were replicated three times. Salts were added in solution at a rate of 340 ml per pot at the time of planting. These solutions were prepared using mixtures of NaCl, $CaCl_2$, and distilled water in such proportions to maintain the sodium adsorption ratio at a constant level of 3. At this level, the sodium hazard is low and soil structure and permeability are maintained. One hundred ppm N and 50 ppm P were added to each pot.

After harvest a vertical cross section of the soil from one pot per salinity treatment per replication was sampled for electrical conductivity. The six salinity treatments were designed to obtain saturation extract conductivity values of 2, 4, 6, 10, 15, and 20 mmhos/cm; the average EC's of the soils from the six treatments were: 2.3, 3.8, 6.1, 9.3, 15.3, and 18.3, respectively. These values are close to the predicted values which will be used in the discussion to follow. The EC of the check soil was 0.68 mmhos/cm. Soils with saturation extract EC values of 4 mmhos/cm and greater are considered saline, EC values of 16 mmhos/cm and greater are extremely saline (Richards 1954). The study was planted on February 12, 1976, and harvested on March 25, 1976. All pots were watered twice daily in an effort to keep moisture levels close to field capacity. Soil moisture dropped no more than 20% below field capacity on the hottest days. During the third week all pots were thinned to 20 plants per pot. The study was harvested 6 weeks after planting. Tops were clipped 1 cm above ground level and were oven dried for 24 hours at 60°C prior to weighing.

Results

A comparison of above-ground dry matter yields (Table 1) shows Jose tall wheatgrass to be the outstanding producer of the five varieties tested. This was to be expected since the vigor and high salt tolerance of this species is widely recognized (Forsberg 1953; Dewey 1960; Rauser and Crowle 1963). Yields of Critana thickspike wheatgrass were similar to yields of Arriba and Rosana western wheatgrass at salinity levels of 4 mmhos/cm and greater. Barton western wheatgrass yielded significantly less than Critana thickspike wheatgrass at salinity levels of 4, 6, and 10 mmhos/cm. There were no significant differences in yield among the western wheatgrass varieties except that Arriba out-yielded Barton in the 6 mmhos/cm treatment.

Table 1. Yields of above-ground dry matter (g/pot) for five wheatgrass varieties as influenced by salinity treatments.

	Salinity treatments (mmhos/cm)						
Variety	Control	2	4	6	10	15	20
Jose	2.14a*	2.52a	2.36a	2.17a	1.58a	0.66a	0.36a
Critana	1.43b	1.47c	1.58b	1.26b	0.71b	0.24b	0.07b
Arriba	1.67b	1.86b	1.53bc	1.24b	0.61bc	0.16b	0.07b
Rosana	1.54b	1.77b	1.51bc	1.09bc	0.59bc	0.17b	0.07b
Barton	1.65b	1.66bc	1.30c	0.92c	0.54c	0.17b	0.02b

* Any two means within the same salinity treatment followed by the same letter are not significantly different at the 0.05 level.

The authors were research technician, associate professor, and researcher in the Department of Agronomy, Colorado State University, when the study was conducted. Present address of the senior author is Wyoming Department of Environmental Quality, Lander, Wyo.

This report is submitted as Colorado State University Experiment Station Scientific Series Paper No. 2233.

Manuscript received April 13, 1977.

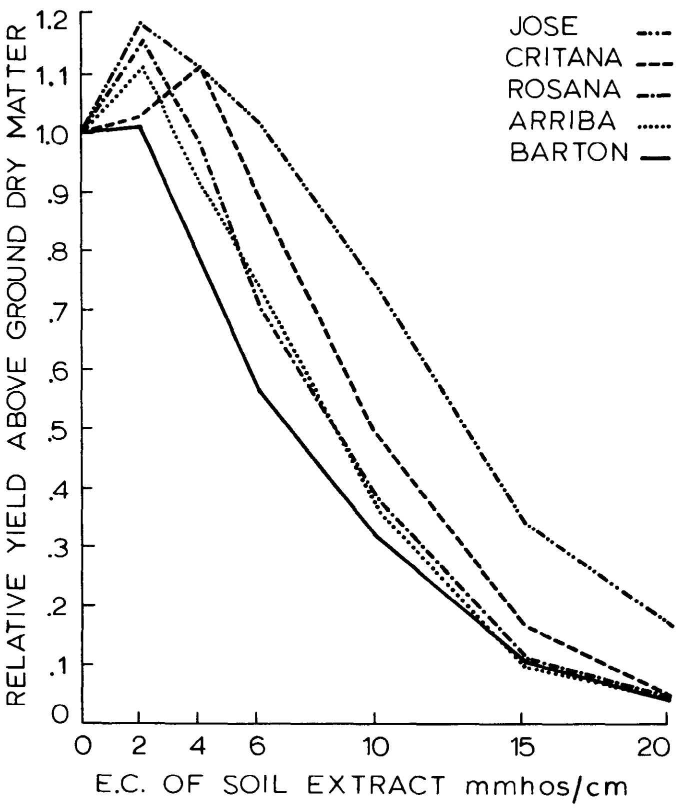


Fig. 1. *Relationships of relative yield of five wheatgrass varieties to electrical conductivity of soil extract.*

The yield of the roots as a function of the salinity treatments followed the same trend as the tops but the mass was slightly greater. The Jose variety produced about twice as much root mass as any of the other varieties. Root weights are not included in this report as we are not confident that all roots were recovered by the washing techniques used.

Dry matter yields are useful in pointing out differences in growth rates among varieties, but salt tolerance per se is best evaluated on the basis of relative plant yields when grown under saline as compared to nonsaline conditions. Thus relative yields were calculated and plotted for each variety at each salinity level using the yield of the control of that variety as the standard (Fig. 1).

When comparing relative yields, the greatest differences among varieties existed at the 6 mmhos/cm level where all varieties were significantly different (0.05 level) except Arriba and Rosana. Consistent trends in differences in salt tolerance among some varieties at EC's of 6 mmhos/cm and greater are apparent in Figure 1.

Salt tolerance can be compared using a salt tolerance index, which is the EC of the soil saturation extract at which yields are reduced 50% from the control (Richards 1954). Thus by using Figure 1, we can rank the five varieties in this study with their respective salt tolerance indexes as follows: (1) Jose, 13 mmhos/cm; (2) Critana, 10 mmhos/cm; (3) Arriba and Rosana, 8.5 mmhos/cm; (4) Barton, 7 mmhos/cm.

The salt tolerance of the western wheatgrass varieties in this study was considerably less than the salt tolerance of tall wheatgrass. This is in agreement with the findings of Forsberg (1953), who reported on seedling success and forage yields of these species in a field study. In contrast, Richards (1954) rated western wheatgrass high in salt tolerance. The latter rating was for productivity of western wheatgrass that was established under nonsaline conditions and then subjected to salinity treatments. Thus the reader is cautioned that salt tolerance indexes can be expected to vary with the stage of growth and environmental conditions, particularly moisture regime and type of salt.

In summary, Jose tall wheatgrass was considerably more salt tolerant than the western and thickspike wheatgrass varieties tested. Critana thickspike wheatgrass produced significantly greater relative yields at an intermediate salinity level (6 mmhos/cm) than the western wheatgrass varieties. The western wheatgrass varieties Arriba and Rosana produced greater relative yields than the Barton variety at the intermediate salinity level. At the higher salinity levels, differences among the western and thickspike wheatgrass varieties were less and generally not significant.

Literature Cited

Dewey, D. R. 1960. Salt tolerance of twenty-five strains of *Agropyron*. Agron. J. 52:631-635.

Forsberg, D. E. 1953. The response of various forage crops to saline soils. Can. J. Agr. Sci. 33:524-529.

Hanson, A. A. 1972. Grass varieties in the United States. U.S. Dep. Agr., Agr. Handbook No. 170. 124 p.

Rauser, W. E., and W. L. Crowle. 1963. Salt tolerance of Russian wild ryegrass in relation to tall wheatgrass and slender wheatgrass. Can. J. Plant Sci. 43:397-407.

Richards, L. A. (Ed.). 1954. Diagnosis and improvement of saline and alkali soils. U.S. Dep. Agr, Agr. Handbook No. 60.

Conflicting Vegetational Indicators on Some Central Oregon Scablands

J. EDWARD DEALY AND J. MICHAEL GEIST

Highlight: Two soil-vegetation sites were studied in central Oregon to determine why two conflicting plant indicators (antelope bitterbrush and low sagebrush), occurred on apparently uniform sites. Investigation showed that bitterbrush was not a reliable indicator of site conditions in the two study areas. Landscapes that appeared to be uniform were actually highly variable because of internal soil differences.

Knowledge of soil-vegetation relationships helps the range manager judge range condition, assess potential productivity, and determine appropriate species for use in range reseeding efforts when native plant cover has been depleted (Anderson 1956).

Site assessment is difficult where vegetative indicators conflict. We found conflicts with some central Oregon scablands.

Our investigation centered on determining why conflicting plant indicators occurred on an apparently uniform site. This situation was observed on two areas near Silver Lake in central Oregon. Scablands within the study areas generally support low sagebrush (*Artemisia arbuscula* Nutt.)[1] plant communities. Curlleaf mountainmahogany (*Cercocarpus ledifolius* Nutt.) and antelope bitterbrush (*Purshia tridentata* (Pursh) DC.), usually indicative of better sites, occur, however, as individuals or small groups within the margins of these scablands (Dealy 1971).

Study Areas

The two study areas are located on the upper edge of the Silver Lake winter range approximately 137 km (85 miles) south-southeast of Bend, Ore., and 8 km (5 miles) south-southwest of Silver Lake, Ore. (Fig. 1). Study area I (elevation 1,583 m, (5,200 ft) is situated on the Fremont National Forest at the toe of Hager Mountain (elevation 2,195 m, 7,200 ft), a volcanic cone rising out of an undulating plain primarily supporting ponderosa pine (*Pinus ponderosa* Dougl.) forest. Study area II (elevation 1,433 m, 4,700 ft) occurs 13 km (8 miles) west-northwest of study area I, on the Lakeview District, Bureau of Land Management, on a nonforested bench surrounding the Silver Lake valley.

The climate is continental with some marine influence from the west. Temperatures reach subfreezing levels during winter and highs of 32° to 41°C (90° tto 105°F) during summer. The growing season is 75 to 85 days in June, July, and August. Killing frost can occur during any month. Annual precipitation is approximately 38 cm (15 inches) with 50% in winter, 40% in spring and fall, and 10% in summer.

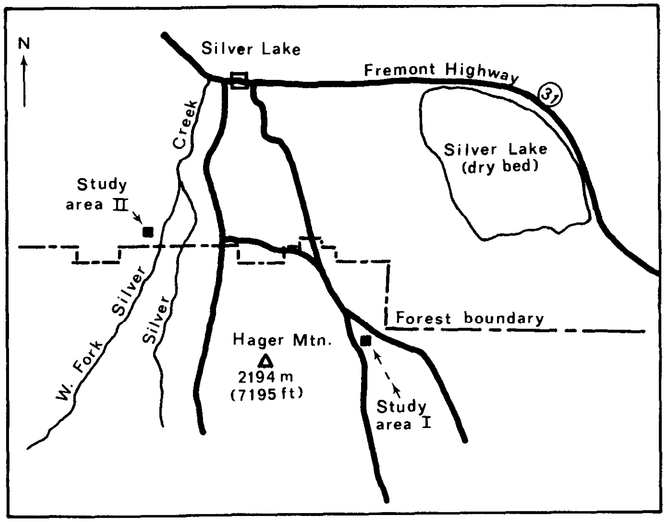


Fig. 1. *Study area locations near Silver Lake, Ore.*

Methods

Our methods were observational. Plants occurring at each study area were identified and listed in relation to their respective soils, which were described by standard survey methods (U.S. Department of Agriculture 1951). Soil pH was determined colorimetrically with a Truog soil reaction test kit.[2] Some supplemental soil investigations were also made to better define the diversity of conditions associated with observed vegetative patterns.

Results

Vegetation

Area I, a nearly level opening surrounded by ponderosa pine, contained a single shrub layer of low sagebrush with an understory of squirreltail (*Sitanion hystrix* (Nutt.) Smith) and prairie junegrass (*Koeleria cristata* Pers.). When a sufficient rise in microtopography occurred, Idaho fescue (*Festuca idahoensis* Elmer) replaced other grass dominants. Prominent perennial forbs included low pussytoes (*Antennaria dimorpha* (Nutt.) T. & G.), nineleaf lomatium (*Lomatium triternatum* (Pursh) Coult. & Rose), pink microsteris (*Microsteris gracilis* (Hook.) Greene), and scabland fleabane (*Erigeron bloomeri* Gray).

The authors are plant ecologist and research soil scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, La Grande, Oregon.

Manuscript received May 5, 1977.

[1] Plant nomenclature follows Hitchcock and Cronquist (1973).

[2] Mention of commercial products or companies does not constitute an endorsement by the U.S. Department of Agriculture.

Fig. 2. *Study area I with cutbank which illustrates the light colored intermittent indurated layer (right foreground) in soil associated with low sagebrush, and the finger of taller shrubs growing in the deeper soil lacking the indurated layer (right background).*

A finger of curlleaf mountainmahogany and antelope bitterbrush occurred within the low sagebrush opening (Fig. 2). One western juniper (*Juniperus occidentalis* Hook.), 1 m (3.28 ft) tall, was growing at the tip of the finger. Other vegetation associated with this finger included Idaho fescue, squirreltail, and an occasional bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith). Commonly occurring forbs were western yarrow (*Achillea millefolium* L.) and woolly sunflower (*Eriophyllum lanatum* (Pursh) Forbes).

Area II was also a low sagebrush flat with a grass layer primarily of Sandberg bluegrass (*Poa sandbergii* Vasey), Thurber's needlegrass (*Stipa thurberiana* Piper), and squirreltail (Fig. 3). Forbs included low pussytoes, nineleaf lomation, pink microsteris, and milkvetch (*Astragalus* L. spp.).

Individuals and small groups of antelope bitterbrush occurred within the low sagebrush flat just below the edge of the ponderosa pine zone. Beneath bitterbrush plants the grass layer was composed almost entirely of cheatgrass (*Bromus tectorum* L.) apparently due to past grazing; however, occasional remnants of Idaho fescue, squirreltail, bluebunch wheatgrass, and Thurber's needlegrass occurred. Forbs were rare under these shrubs. In Table 1 microsite vegetation is compared by study area.

Fig. 3. *General view of study area II showing the bitterbrush-low sagebrush mosaic of shrub vegetation.*

Table 1. Plant species comparison between study areas and soils.

Study areas	Low sagebrush	Bitterbrush
I	Low sagebrush	Antelope bitterbrush Curlleaf mountain-mahogany Western juniper
	Sandberg bluegrass Squirreltail Prairie junegrass Low pussytoes Nineleaf lomatium Pink microsteris Scabland fleabane	Idaho fescue Squirreltail Bluebunch wheatgrass Western yarrow Woolly sunflower
II	Low sagebrush Sandberg bluegrass Thurber's needlegrass Squirreltail	Antelope bitterbrush Cheatgrass Idaho fescue Squirreltail Thurber's needlegrass Bluebunch wheatgrass
	Low pussytoes Nineleaf lomatium Pink microsteris Milkvetch	

Soils

Area I soils were derived from alluvium apparently originating from Hager Mountain colluvium. This material was a mix of fines, gravels, and cobbles to 20 cm in size including basalt, andesite, pumice, ash, and obsidian. Area II soils were dominantly residual, derived from fractured basalt and andesite, with pumice and ash influence. The pumice and ash at both areas originated from Mt. Mazama or Newberry Craters (Allison 1945; Harward and Youngberg 1969).

In Figure 4, soils (A, B, C, D) associated with described vegetation are portrayed diagrammatically to scale with tentative horizon identification and horizon characteristics. Soils were not correlated with named soil series.

Area I, soil A, associated with low sagebrush, had grayish brown (dry colors are used throughout), loam surface material grading into brown, clay subsoil, with stone content increasing with depth. A prominent accumulation of medium and fine roots occurred on the surface of an indurated layer (C_m). The layer was quite hard, generally continuous at this location; it contained varying amounts of gravel and cobble-size coarse fragments. A gravelly loam layer underlay the indurated layer and resembled the subsoil at the same depth of soil B, which occurred under the finger of bitterbrush and mountainmahogany. The two soils were similar in color, texture, structural development, pH, and amount of coarse fragments in the upper horizons. They had weak platy surface structure and moderate subangular blocky subsurface structure. Soil B, under the finger, was deeper than A, horizons were thicker, and no cemented layer or rooting restriction was found. Drainage and root penetration were restricted by the indurated layer in soil A under low sagebrush (Fig. 5).

Additional soils data from a similar low sagebrush opening near area I showed a gravelly-clayey zone from 22–67 cm with an indurated layer from 65–75+ cm.

A second excavation under low sagebrush revealed a gravelly-clayey zone beginning at 12 cm, but no indurated layer was found. Two nearby soils associated with bitt·rbrush con-

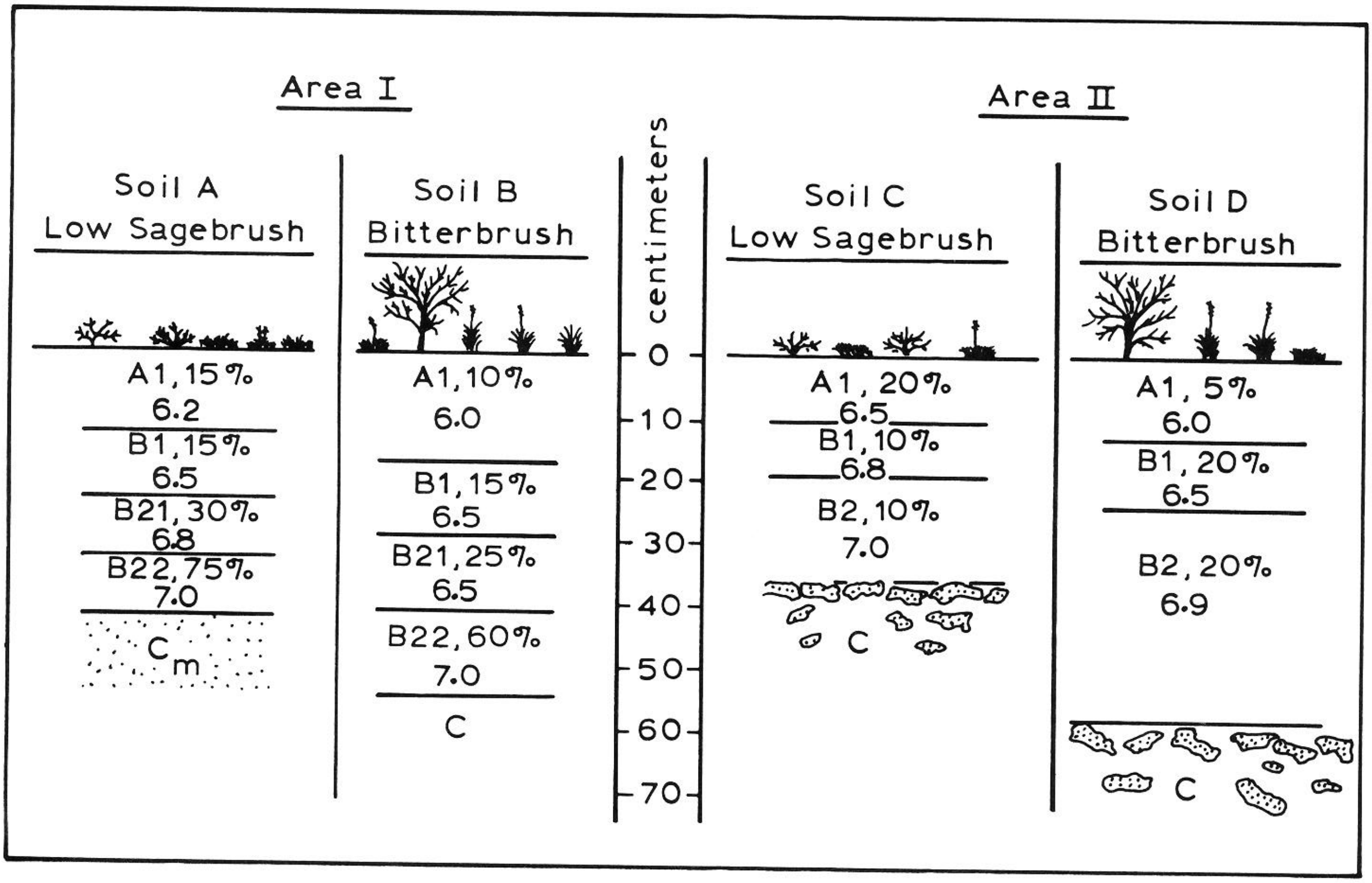


Fig. 4. *Scale diagram of soils A, B, C, and D occurring in the two study areas with tentative horizon designations, coarse fragment percentages, and pH values.*

tained gravelly-clayey zones at 35 cm in one case and at 38 cm in the other; neither contained an indurated layer.

In general, the indurated layer was variable in degree of cementation, thickness, and amount of horizontal fracturing. In some places it exhibited fine horizontal striations or bands of varied color. The upper surface of the layer was frequently coated by a thin, silicious sheet. The general color of the layer ranged from predominantly milky to yellowish brown with subtle milky markings. There were no surface soil or topographic indicators of presence or absence of the indurated layer.

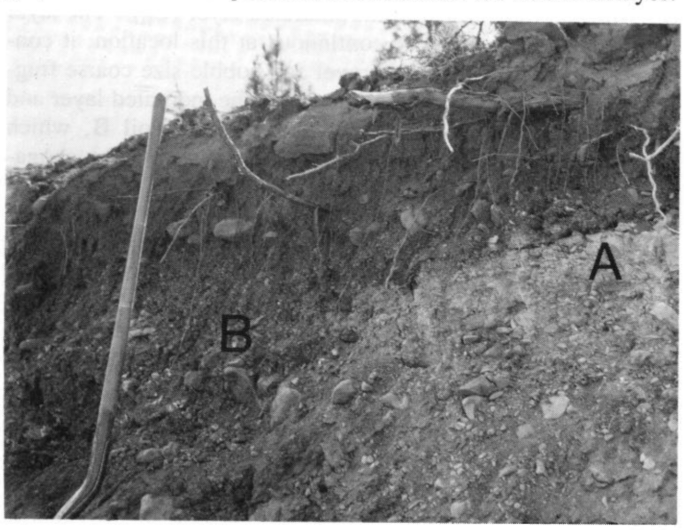


Fig. 5. *Study area I showing the discontinuity of the indurated layer from soil A to soil B.*

In area II under low sagebrush, soil C graded from a gray-colored gravelly loam at the surface to a brown clay in the subsoil (19–36 cm). Structure ranged from weak platy in the surface to moderate subangular or angular blocky in the subsoil. The two soils were similar in pH values. A broken indurated layer (Fig. 6) mixed with clay occurred from 36–69+ cm. Thin section microscopic analysis by the Oregon State University Soils Laboratory (report on file at the Range and Wildlife

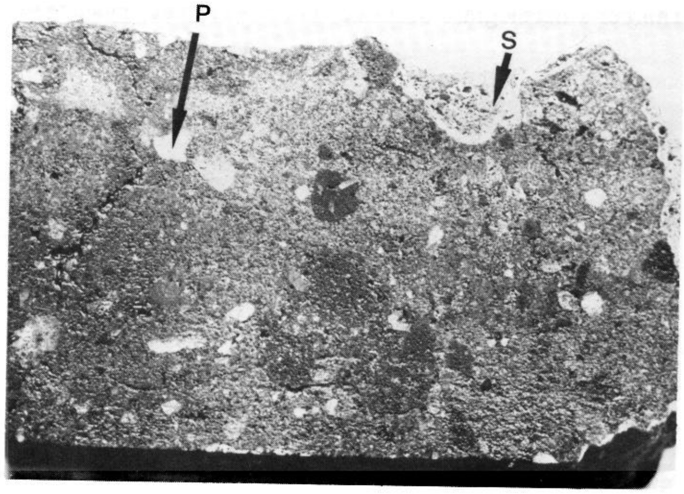


Fig. 6. *This photograph shows a portion of the indurated (cemented) layer from area II prior to thin section preparation. Dimensions are 4 cm × 2.5 cm. White material identified as silica (S) appears as a skin on the surface. White areas (P) are unweathered pumice particles bound by clays (dark color) and silica.*

Habitat Laboratory, La Grande, Ore.) showed this layer to be cemented by silica and clay. Fragments of the indurated layer ranged from gravel to cobble size and were tilted at varying degrees from horizontal. Roots showed a tendency to accumulate among the surface of the clayey-indurated zone, but accumulation was not as pronounced as in area I, soil A.

Under bitterbrush, soil D had gray surface color and loam surface texture; it graded into brown subsoil material with clay texture. Structure ranged from weak platy in the surface to moderate subangular blocky or moderate prismatic in the subsoil (24–58 cm). Roots extended through broken tilted indurated fragments mixed with clay from 58–72 cm. This latter material was similar to the 36–69 cm layer in soil C under low sagebrush, but better structure was present in soil D. The indurated layer exhibited less horizontal orientation under bitterbrush and occurred deeper than under low sagebrush.

Two other excavations near those in area II showed some similar soil profile characteristics and depth relationships, but no broken indurated layer was found within 70 cm of the soil surface under bitterbrush or 50 cm under low sagebrush.

Conclusions

Our investigations showed that neither bitterbrush nor curlleaf mountainmahogany were reliable indicators of site conditions in the study areas. Landscapes that appeared uniform from surface soil and topographic observations were actually highly variable because of internal soil variations. A thorough examination of both soil and vegetation is necessary before forage production or rehabilitation potentials can be predicted.

Under low sagebrush we found that a shallow, poorly structured, fine-textured (clayey) gravelly layer and/or presence of a shallow continuous, indurated layer restricted rooting of bitterbrush and mountainmahogany and prevented their occurrence. The latter two species, however, will grow where these influences are moderated by better subsoil structure in fine-textured horizons, fracturing of or lack of the indurated layer, or deeper, well-drained soil. The abundance of the species depends on the kind and degree of moderation. Internal soil differences in the two study areas were not indicated by pH tests in the field.

We are not implying that low sagebrush or sporadic bitterbrush occurrence is always tied to the same site factors discussed in this study. Rather, we encourage fieldworkers to look for other ecological influences. We can safely say that few single-factor, cause-effect relationships exist in nature, because a change in one factor is usually accompanied by one or more associated changes. Our attempt at untying this tenuous ecological web is only a beginning. We hope our future experiences and those of others will help to refine these interpretations.

The following is a first approximation guideline to the soil-vegetation relationships in the areas studied:

A. Expect low sagebrush without bitterbrush where rooting depth of shrubs is restricted by:

1. a continuous indurated soil layer near the soil surface, or
2. a broken indurated layer mixed with poorly structured, fine-textured material near the soil surface.

B. Expect spotty or patchy bitterbrush occurrence in low sagebrush stands where restrictive soils (described under A) are occasionally interrupted by:

1. comparatively deep, well-drained soil with moderate well developed structure, or
2. soil lacking a continuous indurated layer but having poorly structured, fine-textured material (with or without broken indurated fragments) in the lower subsoil only.

Be prepared for some digging if you want to develop a management plan or assess the reseeding potential of a site supporting scattered bitterbrush. Use soil exposures at roadcuts, gravel pits, pond sites, etc., for initial insights to profile features. Use a backhoe, if possible, to excavate trenches across visible vegetative changes. Hand excavated soil pits, dug with the aid of a crowbar to break through indurated layers, should also be situated across vegetative transitions. The knowledge gained should tell whether bitterbrush is indicating discontinuities in soil conditions or if the site will generally support a population of shrubs eliminated earlier by fire or other factors.

Literature Cited

Allison, I. A. 1945. Pumice beds at Summer Lake, Oregon. Geol. Soc. Amer. Bull. 56:789-807.

Anderson, E. William. 1956. Some soil plant relationships in eastern Oregon. J. Range Manage. 9:171-175.

Dealy, J. Edward. 1971. Habitat characteristics of the Silver Lake mule deer range. Pacific Northwest Forest and Range Exp. Sta., Portland, Ore. U.S. Dep. Agr., Forest Serv. Res. Pap. PNW-125. 99 p.

Harward, M. E., and C. T. Youngberg. 1969. Soils from Mazama ash in Oregon: identification, distribution and properties. Pedology and Quaternary Research Symposium, May 13-14, Univ. Alberta, Edmonton, Alta., Can. p. 163-178.

Hitchcock, C. Leo, and Arthur Cronquist. 1973. Flora of the Pacific Northwest. Univ. Washington Press, Seattle and London. 730 p.

U.S. Department of Agriculture. 1951. Soil survey manual. U.S. Dep. Agr. Handbook No. 18. U.S. Govt. Printing Office, Washington, Washington, D.C. 503 p.

THESIS: MONTANA STATE UNIVERSITY

Evaluation of Nitrogen Fertilization and Grazing Effects on a Porcupine Grass (*Stipa spartea* var. *curtiseta*) Community, by Leonard Roy Roath, MS, Range Science. 1974.

Evaluation of nitrogen fertilization and grazing treatments on a porcupine grass community was initiated on the Rohde-Langen Ranch, north of Glasgow, Montana, in 1970, to determine whether increased utilization of porcupine grass could be achieved.

Nitrogen fertilizer (ammonium nitrate) was applied at five rates, in 50-lb increments, 0–200 lb of actual nitrogen per acre. The 200 lb of nitrogen per acre treatment was applied as 600 lb of nitrogen per acre in 2-ft bands on 3-ft centers. An exclosure was established and moved each spring to create varying lengths of grazing deferment following initial fertilizer applications.

Porcupine grass yield did not respond significantly to nitrogen application. Wheatgrasses increased in yield and density with added nitrogen. The remaining vegetation demonstrated no uniform yield response to fertilization. Palatability of all species was greatly increased in the first season following fertilization but decreased substantially the following year. Extreme utilization adversely affected yield and cover of porcupine grass, but other species showed no uniform response.

A Comparison of the Line-interception and Quadrat Estimation Methods of Determining Shrub Canopy Coverage

THOMAS A. HANLEY

Highlight: The line-interception and Daubenmire's 0.1 m² quadrat estimation methods of determining canopy coverage were compared for four densities of big sagebrush in northwestern Nevada. Results indicated that the methods provide comparable estimates. The line-interception method is preferable to 0.1 m² quadrats where high levels of precision and confidence are required, but the 0.1 m² quadrat method may be preferable where lower levels of precision and confidence are acceptable. Fewer man-minutes of time are required by either method for one person working alone than for two people working together.

Canopy coverage is a frequently measured and useful parameter in range analysis. It serves as a criterion of relative dominance and the influence of plants on precipitation interception and soil temperature. Compared with other parameters, such as biomass or productivity, canopy coverage is relatively easily measured. Evaluations precise enough for research purposes generally do not require excessive field time.

A variety of methods have been devised for measuring plant canopy coverage, but advantages and disadvantages vary with types of vegetation sampled and degrees of confidence and precision[1] required. The line-interception method (Canfield 1941) is a frequently used technique for measuring canopy coverage of shrubs in the Great Basin. Kinsinger et al. (1960) compared results of line-interception, variable plot, and loop methods for shrub cover in Nevada and found the line-interception method to be the most accurate. However, it required an undesirably large sample size due to the variability between sample units (lines). Daubenmire (1959) compared results of the line-interception method and an estimation technique using 0.1 m² quadrat sampling for big sagebrush (*Artemisia tridentata*) and found that although the standard error of 0.1 m² quadrat sampling was high, the estimates obtained from 40–50 quadrats were nearly identical to those from 350 m of line-interception. He pointed out that much more time was required for the line-interception method than for the quadrats.

Quadrat sampling of canopy coverage usually involves a visual estimation of canopy coverage within a circular or rectangular plot, whereas the line-interception method involves measurement of the intercepted lengths of an "elongated plot without width." Advantages of quadrat sampling over linear and plotless techniques have been elaborated by Daubenmire (1959) and include (1) enhanced opportunity for comparison and correlation of more taxa, (2) evaluation of frequency, and (3) more complete information about the community as a whole. The principal advantage of the line-interception technique is that of direct measurement, as opposed to visual estimation, of the vegetation being sampled (Canfield 1941).

It was the purpose of this study to compare the precision and efficiency of the line-interception (Canfield 1941) and 0.1 m² quadrat estimation (Daubenmire 1959) methods for measuring Great Basin shrub canopy coverage in varying stands of shrub canopy cover. Canopy coverage, as used in this study, was defined as the percentage of the ground included in a vertical projection of imaginary polygons drawn about the total natural spread of foliage of the individuals of a species (Daubenmire (1968). Dead portions of the canopy were not included.

Methods

Four sites were selected for study. All were in northwestern Nevada, near Cedarville, California. Big sagebrush was the sole shrub component in three of the sites. Minor amounts of shadscale (*Atriplex confertifolia*) and greasewood (*Sarcobatus vermiculatus*) were present in the site with the lowest total cover. Big sagebrush canopy coverage ranged from approximately 8–48% over the four sites. The average shrub height was approximately 75 cm at each site.

Ten parallel 30-m lines, systematically spaced at 3-meter intervals, were used for the line-interception method. Forty 0.1 m² (20 × 50 cm) quadrats, systematically spaced at 1.5-m intervals along two parallel 30-m lines 3 meters apart, were used for the quadrat method: canopy coverage was estimated within six cover classes: (1) 0–5, (2) 5–25, (3) 25–50, (4) 50–75, (5) 75–95, and (6) 95–100%, with the midpoints of each class used in computing the mean. Such classes are believed to leave little chance for personal error in class assignments, yet yield rather fine differences when the results from a considerable number of small plots are averaged (Daubenmire 1959). Each site was sampled by both methods twice, once with one person working alone and once with two people working together. All measurements and estimates were made by the same person. The time required for each method was recorded each time. Thus, data from a total of 600 m of line-interception and 80 0.1 m² quadrats were obtained at each site sampled. The person conducting the

The author is wildlife biologist, U.S. Department of the Interior, Bureau of Land Management, Cedarville, California 96104. His present address is, College of Forest Resources, AR-10, University of Washington, Seattle 98195.

The author is grateful to Kathleen A. Hanley for her assistance with the field data collection.

Manuscript received May 23, 1977.

[1] As used in this report, the term *precision* refers to the size of deviations from the mean obtained by applying the sampling procedure repeatedly; the term *confidence* refers to the level of probability that the sample size will provide an estimate within a given precision.

sampling was already familiar with the use of both techniques. Therefore, data were not available concerning the amount of time necessary for training the observer; nor were data available concerning differences between individual observers.

Canopy coverage data were analyzed in a 4 × 2 × 2 factorial. The layout was a randomized complete-block design with each datum being the mean canopy coverage of ten lines or 40 quadrats. Blocks were sites, and factors were sampling methods and number of persons. An arcsine transformation ($\arcsin\sqrt{x}$) was used, because percentage or proportion data usually fit a binomial distribution (Steel and Torrie 1960; Zar 1974).

Results and Discussion

Highly significant (α = 0.001) differences were found between mean cover of sites, as was expected. No significant ($\alpha = 0.05$) differences were found between means of the two methods, the number of persons, or any interactions. Therefore, the line-interception and 0.1 m^2 quadrat methods, whether conducted by one person alone or two people together, yielded comparable results over the entire range of shrub canopy coverage sampled.

The data for the number of persons were pooled by method, and the sample size (number of lines or quadrats) and time required for one and two people to sample within two levels of precision and confidence were calculated (Table 1) using the pooled sample variances as estimates of the true population variances. Due to the greater variability between samples at low shrub density, much larger sample sizes would be required by both methods when the total canopy coverage approaches 10% than when it approaches 50%. The size of line-interception samples required are comparable to those reported by Kinsinger et al. (1960). In all cases the time required to sample within these levels of precision and confidence would be less for the line-interception method than for the 0.1 m^2 quadrat method. Two people working together would require more man-minutes of time than would one person working alone in most cases for either method. However, the numbers of samples, and consequently the time, required to sample within these levels of precision and confidence are undesirably high for both methods.

Daubenmire (1959) suggested that in such comparisons adequate sample

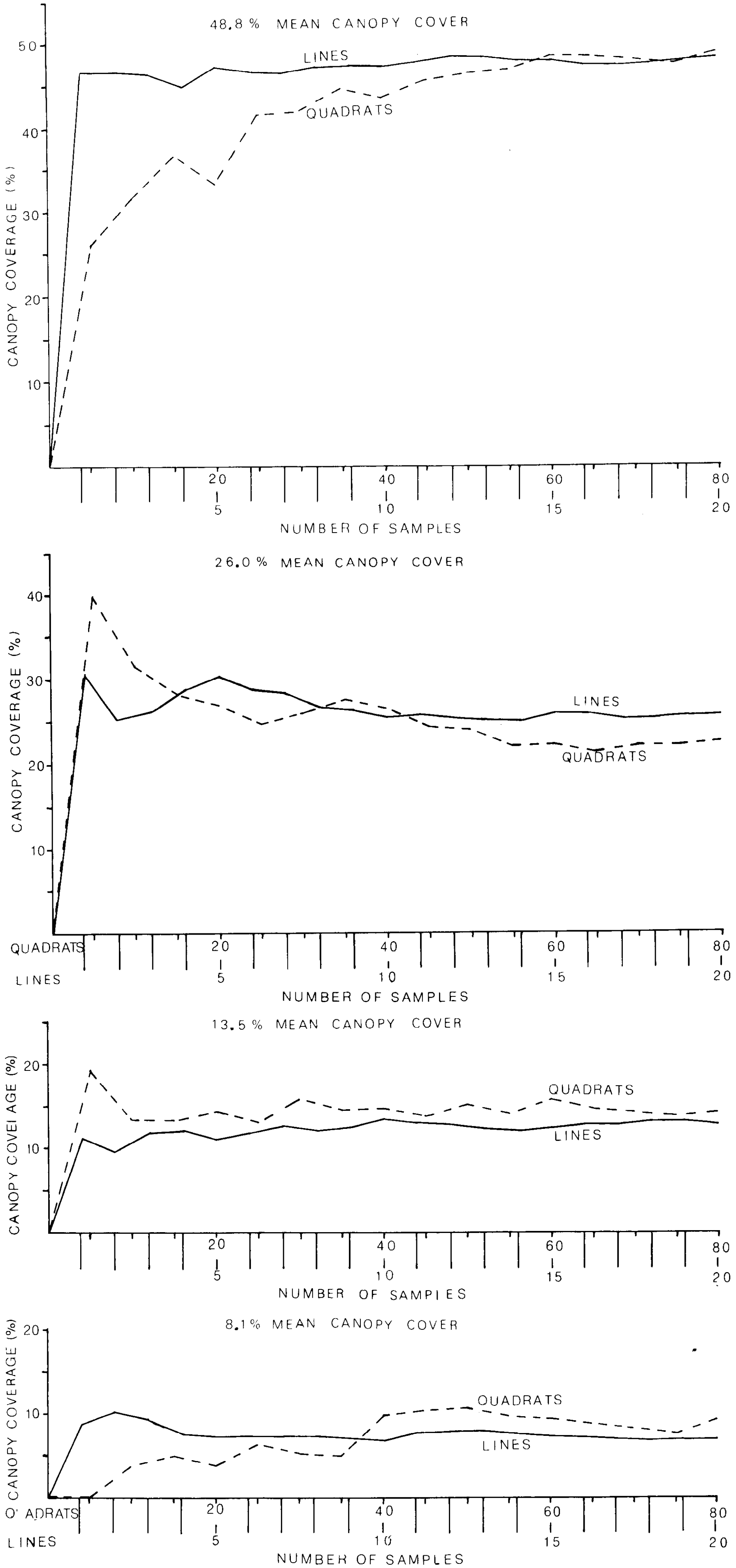


Fig. 1. *Change in mean canopy coverage with increasing sample size.*

Table 1. Comparison of mean ($\bar{x}$) big sagebrush canopy coverage, size of sample required (n), and man-minutes required for one person alone (t_1) and two people together (t_2) to sample within two levels of precision and two levels of confidence using the 0.1 m^2 quadrat and line-interception methods.

Cover at different locations	Within $\pm$ 0.10$\bar{x}$ and 0.95 confidence level: Quadrats (0.1 m^2)	Within $\pm$ 0.10$\bar{x}$ and 0.95 confidence level: Line-interception (30 m)	Within $\pm$ 0.20$\bar{x}$ and 0.90 confidence level: Quadrats (0.1 m^2)	Within $\pm$ 0.20$\bar{x}$ and 0.90 confidence level: Line-interception (30 m)
8.1% mean cover	$\bar{x}$ = 9.19%	$\bar{x}$ = 6.92%	$\bar{x}$ = 9.19%	$\bar{x}$ = 6.92%
	n = 2700	n = 115	n = 471	n = 19
	t_1 = 675	t_1 = 380	t_1 = 118	t_1 = 63
	t_2 = 1080	t_2 = 368	t_2 = 190	t_2 = 62
13.5% mean cover	$\bar{x}$ = 14.31%	$\bar{x}$ = 12.75%	$\bar{x}$ = 14.31%	$\bar{x}$ = 12.75%
	n = 1261	n = 80	n = 221	n = 14
	t_1 = 316	t_1 = 288	t_1 = 56	t_1 = 51
	t_2 = 380	t_2 = 288	t_2 = 68	t_2 = 52
26.0% mean cover	$\bar{x}$ = 26.44%	$\bar{x}$ = 25.48%	$\bar{x}$ = 26.44%	$\bar{x}$ = 25.48%
	n = 551	n = 36	n = 97	n = 6
	t_1 = 193	t_1 = 173	t_1 = 34	t_1 = 29
	t_2 = 248	t_2 = 196	t_2 = 44	t_2 = 34
48.4% mean cover	$\bar{x}$ = 48.56%	$\bar{x}$ = 48.17%	$\bar{x}$ = 48.56%	$\bar{x}$ = 48.17%
	n = 223	n = 6	n = 39	n = 1
	t_1 = 84	t_1 = 37	t_1 = 15	t_1 = 7
	t_2 = 112	t_2 = 36	t_2 = 20	t_2 = 6

sizes calculated on the basis of the standard error overestimate the amount of work needed to obtain a reasonable appraisal of the coverage of scattered shrubs. If this is true, then both methods may be of more practical value to range ecologists. The methods were therefore compared by a graphical procedure of plotting their means as cumulative functions of increasing sample size (Fig. 1). In each case, the line-interception mean appeared to stabilize earlier than the quadrat mean. The need for larger sample sizes at lower shrub densities appeared to hold true, especially for the 0.1 m^2 quadrat method. However, the argument that sample sizes greater than those involved in this study (20 30-m line-interception transects and 80 0.1 m^2 quadrats) are not needed to obtain a reasonable appraisal of big sagebrush canopy coverage appears to be plausible, especially for the line-interception method. A comparison of the time required for one person to sample ten 30-m line-interception transects versus 80 0.1 m^2 quadrats (Table 2) shows that comparable results may be obtained by the 0.1 m^2 quadrat method in slightly more than one-half the time required for the line-interception method.

These data and analyses therefore indicate that the line-interception and 0.1 m^2 quadrat methods are equivalent in accuracy of measuring canopy coverage of big sagebrush, but that the sample size and time required for adequate sampling affect the relative advantages and disadvantages of each in relation to the sampling objectives. Where a high degree of precision and confidence are required (where repeatability is very important), the line-interception method would be more advantageous than the 0.1 m^2 quadrat method; however, both methods would be very time consuming. Where a lower level of precision and confidence are acceptable (e.g., as in range inventories), the 0.1 m^2 quadrat method may be more advantageous than the line-interception method. In either case, no time (man-minutes) is saved by two people working together rather than one person working alone.

These conclusions are expected to be true for the range of shrub canopy coverage analyzed. The inverse relationship between adequate sample size and canopy coverage may be especially important for species with lower canopy coverage than that investigated in this study.

Table 2. Comparison of time (minutes) required for one person to sample ten 30-m line-interception transects versus 80 0.1 m^2 quadrats for big sagebrush canopy coverage.

Mean canopy coverage	10 lines	80 quadrats
8.1%	33	20
13.5%	36	20
26.0%	48	28
48.4%	61	30

Literature Cited

Canfield, R. H. 1941. Application of the line-interception method in sampling range vegetation. J. Forest. 39:388-394.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-64.

Daubenmire, R. 1968. Plant communities: a textbook in plant synecology. Harper & Row, New York. 300 p.

Kinsinger, F. E., R. E. Eckert, and P. O. Currie. 1960. A comparison of the line-interception, variable plot and loop methods as used to measure shrub-crown cover. J. Range Manage. 13:17-21.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481 p.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J. 620 p.

Blue Grama and Buffalograss Patterns in and Near a Prairie Dog Town

CHARLES D. BONHAM AND J. STEPHEN HANNAN

Highlight: Blue grama and buffalograss patterns differed in response to prairie dog mound building activities. While both species exhibited smaller pattern sizes within prairie dog towns compared to outside, but adjacent areas, the size of clumps and patches differed for the two species. Prairie dog activities caused a two-fold decrease in pattern size of blue grama by reducing size of clumps and patches. On the other hand, buffalograss patches were fragmented into small clumps which were not observed outside the town.

The black-tailed prairie dog (*Cynomys ludovicianus*) is a native of the Great Plains region of North America and has been studied extensively as to its role in grassland ecosystems. In particular, Osborn and Allen (1949), Koford (1958), and Bonham and Lerwick (1976) reported that definite vegetation patterns consisting of concentric rings occur within prairie dog towns. Several authors have also observed that vegetative composition within towns were related to prairie dog clipping of taller plants and feeding habits, as well as mound building activities (King 1955; Koford 1958; Lerwick 1974). While these kinds of specific differences have been noted, no attempt has been made to describe vegetation patterns within prairie dog towns on a quantitative basis.

Greig-Smith (1964) noted that spatial distribution of individual plants may be random, contagious, or regular. He further observed that plants are seldom randomly distributed. Then, pattern can best be defined as a departure from randomness (Kershaw 1958; Greig-Smith 1964) and can be subdivided into two categories: (1) contagious, which is characterized by clumping or aggregation of individual plants, and (2) regular, which is characterized by even or uniform spacing of individual plants as in an orchard. Contagious patterns in natural vegetation are much more common than are regular patterns.

One of the more obvious and most often encountered patterns in any vegetation type involves the morphology of the individual plant. Therefore, Anderson (1961) emphasized that the normal morphological pattern for a species should be determined and used as a basis to compare the performance of a given species under varying ecological conditions.

The present study was to measure pattern size for blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*) in and near a dog town and to relate any specific pattern sizes found to prairie dog mound building. Normal patterns, as defined by Anderson (1961), for both species were considered as those occurring outside, but adjacent to, the town. Effects of prairie dog activities on normal patterns for these species were then determined by comparing the clump and patch sizes found outside the town to those inside the town.

Authors are professor and graduate research assistant, Range Science Department, Colorado State University, Fort Collins 80523.

The research was supported by NSF Grant No. GB-35372 in cooperation with Colorado State Univ. Experiment Station (Contribution No. 2266) and with the Central Plains Experimental Range, Agricultural Research Service, U.S. Department of Agriculture.

Manuscript received July 28, 1976.

Site Description

The prairie dog town was located in the western part of the Central Plains Experimental Range, 50 km northeast of Fort Collins, Colo. Blue grama and buffalograss were the dominant species, and midgrasses such as western wheatgrass (*Agropyron smithii*) and needle-andthread (*Stipa comata*) were major associates. Perennial forbs were abundant and included scarlet globemallow (*Sphaeralcea coccinea*), plains Bahia (*Bahia oppositifolia*), locoweed (*Astragalus* spp.), and Brittons skullcap (*Scuttellaria brittonii*). Annuals included sixweeks fescue (*Volpia octoflora*), woolly plantain (*Plantago purshii*), tansyleaf aster (*Aster tanacetifolius*), and stickweed (*Lappula redowskii*). Cattle had moderately grazed the area during the spring for several years, before and during the study.

The soils of the site are from the Shingle series, which have textures varying from sandy loam to sandy clay loam in the top 6 inches, while subsoils are predominately a sandy clay loam. There were no significant diferences among chemical or physical characteristics of soils inside compared with those outside the prairie dog town (Lerwick 1974).

Methods

A method for pattern measurements suggested by Kershaw (1957) was used to obtain cover data for blue grama and buffalograss at 1-cm intervals along ten 12.8-m line transects. Each transect was divided into 256 basic units of 5 cm each and the total number of occurrences for blue grama and buffalograss in each of the units was recorded. Six of these transects were located within the prairie dog town while four transects were used to obtain data outside the town. In the latter area, transects were placed parallel and 15 m apart, while transects inside the town originated at the center of randomly selected burrows.

Percentage ground cover for each species was obtained by dividing the number of transect points at which the species was encountered by the total number of observation points on the transect and multiplied by 100. Data from each transect were grouped into basic data blocks, consisting of five consecutive points, for analysis. These blocks were then grouped into successively larger blocks for each separate analysis such that each block was twice as large as that in the preceding analysis and half as numerous. That is, the smallest block consisted of five basic data points and each successive set of blocks was formed by combining two adjacent basic units (Fig. 1).

Analysis of variance procedures were used to obtain estimates of mean squares for each block size (Greig-Smith 1952, 1964; Kershaw 1957). A trend in magnitude of mean squares as block size increases indicates that a decrease or increase is occurring in the variation of the data. This trend can be easily seen, if it exists, by plotting block size

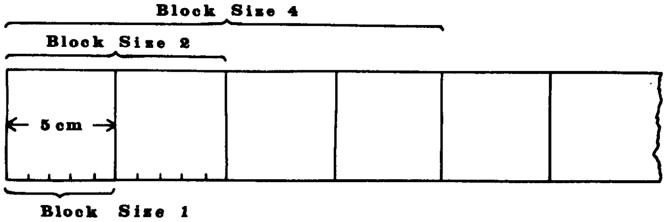


Fig. 1. *Method for combining blocks for mean square analyses.*

against mean square values for increasing block sizes. A peak occurs on the graph when a maximum of variation occurs between two adjacent blocks. This peak provides an estimate of the size of the clump or patch of the species as indicated by block size.

Results and Discussion

Sizes of Normal Patterns

The mean square procedure using block sizes has at least two limitations for the study of species patterns. One is the assumption of linearity of the pattern as block size increases, while the second occurs when blocks of data are formed. The latter procedure allows the measured scale to be, for example, either 1.6 m or 3.2 m in size. Yet, in reality, the size may be anywhere between the two. However, the procedure was useful to compare patterns inside versus outside the town.

The normal pattern for blue grama based on data outside the prairie dog town showed that peaks occurred at two different block positions (Fig. 2). This pattern that was independent of prairie dog activities was then used for comparison of pattern inside the town. The mean size of the smaller pattern for blue grama outside the town was indicated by a peak at block size 8 (0.4 m). This pattern size was related to the aggregation of blue grama clumps with a mean linear size of 0.4 m, while the peak at block size 64 corresponded to the blue grama patch mean size of 3.2 m.

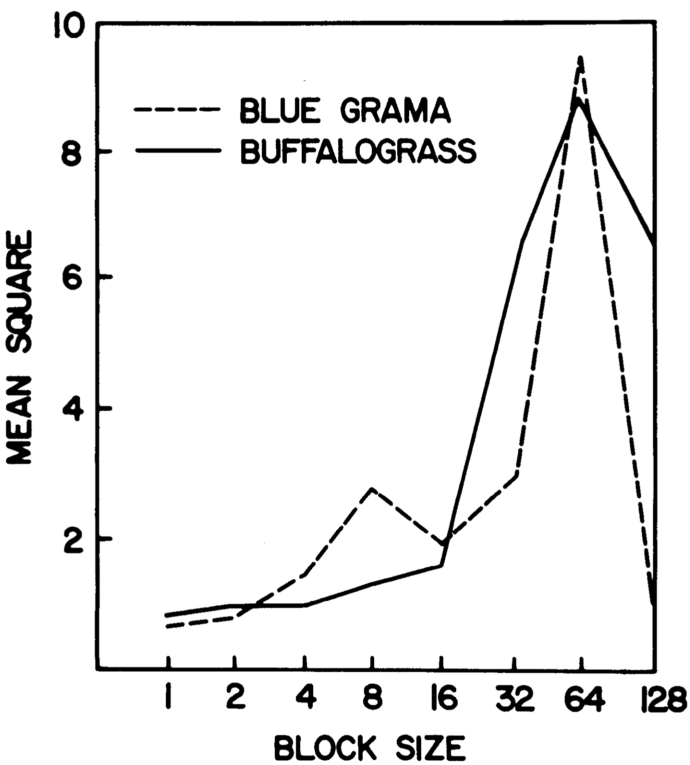


Fig. 2. *Mean square of blue grama and buffalograss cover values compared to sample block size outside the prairie dog town.*

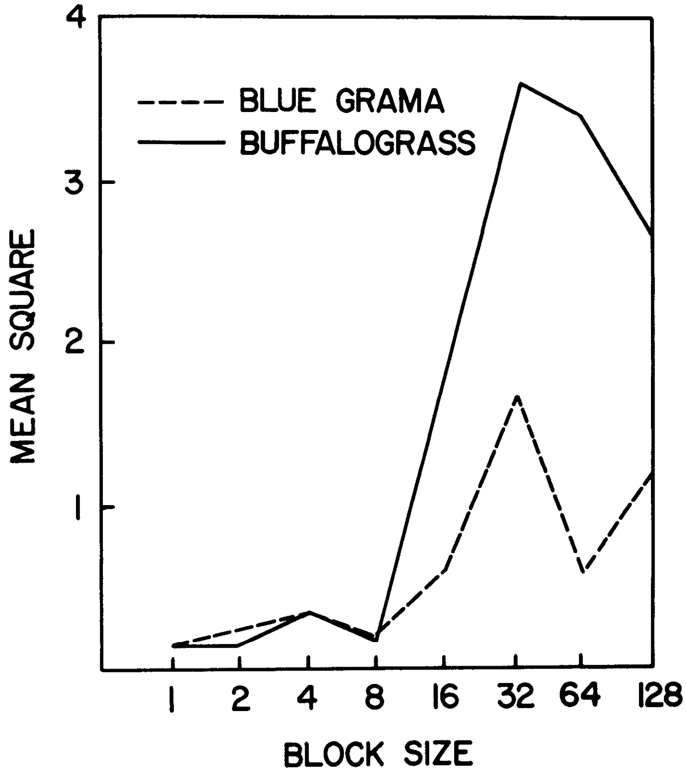


Fig. 3. *Mean square of blue grama and buffalograss cover values compared to sample block size in a prairie dog town.*

Pattern sizes for buffalograss outside the prairie dog town were indicated by one prominent peak (Fig. 2), which coincided with that of blue grama (3.2 m). Aggregated clumps of buffalograss also occurred naturally within larger patches of buffalograss.

Sizes of Patterns inside the Town

Blue grama cover inside the town gave two peaks on the mean squares versus block size graph, which corresponded to two morphological units, clumps and patches (Fig. 3). The smaller pattern size was indicated by a peak occurring at block size 4 (4 blocks of 5 cm each), which corresponded to the mean size of 0.2 m for blue grama clumps found near prairie dog burrows. These clumps were observed to occur within larger patches of blue grama indicated by a peak at block size 32 (1.6 m) (Fig. 3). This smaller pattern is attributed to the morphologically controlled way in which blue grama tillers.

Pattern measurements for buffalograss inside the town also gave peaks at two different block sizes and indicated pattern sizes for buffalograss were the same as those for blue grama (Fig. 3). That is, the pattern size indicated by a peak at block size 4 (0.2 m) is the mean clump size of buffalograss occurring in prairie dog towns while the larger pattern size at block 32 (1.6 m) is a measure of mean patch size.

Both blue grama and buffalograss cover inside the town generally increased as distance from the burrow increased. Furthermore, the occurrence of small clumps of blue grama and buffalograss near crater mounds were remnants of a once larger patch of blue grama or buffalograss sod. The prairie dog's habit of scratching topsoil from the area around burrows probably broke up larger patches of blue grama and buffalograss into smaller clumps.

Comparison of Pattern Sizes and Prairie Dog Activities

A comparison of pattern sizes for blue grama inside and outside the dog town revealed that two basic differences occurred (Figs. 2 and 3). The same small scale (0.2 m) pattern that was associated with clumps of blue grama near prairie dog burrows did not appear outside the town. Instead, the pattern size for clumps from the outside area was larger (0.4 m) and was considered to be the normal pattern for an area free of prairie dog mound building. Furthermore, there was a significant decrease ($P = .01$) in size of blue grama patches within the town (1.6 m) compared to outside the town (3.2 m). Therefore, prairie dog activities seemingly contributed to two-fold decrease in the size of both blue grama clumps and patches within the town through construction of crater mounds.

Buffalograss within the town aggregated into clumps within patches as was the case with blue grama. However, this aggregation was on a smaller level than that in the outside area which indicated that prairie dog mound construction also resulted in fragmentation of buffalograss patches into smaller units as was the case for blue grama (Figs. 2 and 3). However, the pattern size for buffalograss outside the town did not include a significant small scale pattern.

In conclusion, blue grama and buffalograss were affected in a morphologically similar way by prairie dog mound building activities. Both species displayed smaller pattern sizes inside the town compared to those pattern sizes in adjacent areas unaffected by prairie dogs. As pointed out previously, peaks occurring at given block sizes do not suggest an exact measurement of scale size, but rather are an estimate of that size. Therefore, the occurrence of peaks at the same block size for both species does not suggest a common, identical scale for clumps or patch size for the two species.

Literature Cited

Anderson, D. J. 1961. The structure of some upland plant communities in Caernarvonshire. II. The pattern shown by *Vaccinum mystillus* and *Calluna vulgaris*. J. Ecol. 49:731-738.

Bonham, Charles D., and Alton Lerwick. 1976. Vegetation changes induced by prairie dogs on shortgrass range. J. Range Manage. 29:221-225.

Greig-Smith, P. 1952. The use of random and contiguous quadrats in the study of the structure of plant communities. Ann. Bot., London, N.S. 16:293-316.

Greig-Smith, P. 1964. Quantitative Plant Ecology. 2nd Ed. Butterworths, London. 256 p.

Kershaw, K. A. 1957. The use of cover and frequency in the detection of pattern in plant communities. Ecology 38:291-299.

Kershaw, K. A. 1958. The investigation of the structure of a grassland community. I. The pattern of *Agrostis tenuis*. J. Ecol. 45:571-592.

King, J. A. 1955. Social behavior, social organization and population dynamics in a black-tailed prairie dog town in the Black Hills of South Dakota. Univ. of Michigan. Contrib. Lab. Vert. Biol. No. 67. 123 p.

Koford, C. B. 1958. Prairie dogs, white faces, and blue grama. Wildl. Monogr. 3. 78 p.

Lerwick, A. C. 1974. The effects of the black-tailed prairie dog on vegetative composition and their diet in relation to cattle. MS Thesis. Colorado State Univ., Fort Collins. 106 p.

Osborn, B., and P. E. Allen. 1949. Vegetation of an abandoned prairie dog town in tall grass prairie. Ecology 30:322-332.

Effect of Prescribed Fire on Bobwhite Quail Habitat in the Rolling Plains of Texas

J. DAVID RENWALD, HENRY A. WRIGHT, AND JERRAN T. FLINDERS

Highlight: Bobwhite quail preferred lotebush as loafing cover over all other woody plants, although honey mesquite was also used during summer months. Most (88.3%) lotebushes on the study area were resprouts of burned plants. During the first 5 to 6 years after burning, quail used large lotebushes that had escaped fire or were partially defoliated. Following fire, only 3.9 lotebushes/ha were available as cover for quail. Little covey movement was observed between seasons, indicating yearlong cover requirements were being met within a fairly small area. Before burning large pastures, at least 10 large honey mesquite and 4 large lotebushes per hectare in each primary rest area should be ringed with 7-m firebreaks to insure adequate cover for quail.

Authors are wildlife biologist, Bureau of Land Management, Roswell, New Mexico 82201; professor of range management, Texas Tech University, Lubbock 79409; and associate professor of range and wildlife resources, Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602.

This research was supported in part by the Forest Service, U.S. Department of Agriculture, through the Eisenhower Consortium for Western Environmental Forestry Research, and is published as Eisenhower Consortium Journal Series No. 16, and as Texas Tech University, College of Agricultural Sciences Publication No. T-9-167.

Manuscript received May 20, 1977.

Prescribed burning is a useful tool to manage tobosagrass (*Hilaria mutica*)-honey mesquite (*Prosopis glandulosa* var. *glandulosa*) communities for livestock production in the Rolling Plains of West Texas (Wright 1972), but its effects on bobwhite quail (*Colinus virginianus*) habitat have not been evaluated. Suitable habitat must contain some type of brush or woody cover where quail can rest most of the day (Robinson 1957; Casey 1965). Present burning prescriptions (Wright 1974) remove most cover because they are designed to eliminate dead mesquite stems and to top-kill resprouts of associated shrubs. Lotebush (*Ziziphus obtusifolia*) is a co-dominate with mesquite throughout the Rolling Plains and is the primary source of fall, winter, and spring cover for bobwhite quail in the Rolling Plains.

Fire has never been used extensively for quail management in Texas and has never been used in the Rolling Plains of West Texas, which is near the western edge of the bobwhite quail range (Jackson 1969). Jackson (1969) attributed this to the danger of fire plus the widely held belief that fire is a destructive force in grassland management. He believed that the only alternatives left to retard succession were discing or grazing even though he recognized the benefits of fire in increasing grass and forb production. Jackson (1969) reported one instance where a wildlife management area was burned by a wildfire covering 2,000 acres. Regrowth of plants in the burned area produced 15% more quail food than the unburned area with most of the unburned land decreasing in food production the following year. However, the loss of shrub cover in grasslands after fire may have offset any food benefits.

This study was conducted from November 1, 1973, to September 1, 1975, to determine the effects of a 7-year burning program on bobwhite quail habitat, particularly woody cover. Field work was directed at habitat measurements and quail population studies following prescribed burns.

Study Areas and Methods

The study area, which was sprayed with 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) in 1966, is on the Renderbrook-Spade Ranch, 32.2 km south of Colorado City, Tex., in Mitchell County. The area lies on the southwest edge of the Rolling Plains described by Thomas (Gould 1969). Average precipitation is 48.2 cm per year. Slopes range from 0 to 3% on a Stamford Clay (Typic Chromustert) soil. Vegetation is dominated by tobosagrass, buffalograss (*Buchloe dactyloides*), and annual broomweed (*Xanthocephalum dracunculoides*), with an overstory of honey mesquite and scattered lotebush.

Seven treatments and one control were used to evaluate the effect of fire on quail habitat. These included areas burned in 1969 (109.7 ha), 1970 (57.1 ha), 1971 (60.2 ha), 1972 (123.1 ha), 1973 (71.2 ha), 1974 (73.2 ha), 1975 (91.1 ha), and an unburned control (140.8 ha).

Bobwhite quail coveys were located using the territory-mapping technique (Overton 1971). Coveys were flushed at midday to identify plants used as loafing cover. Preliminary observations indicated that lotebush was a preferred loafing site and this study was undertaken to characterize the plants used by quail.

Thirty plants were selected in each of the seven treatment areas (1, 2, 3, 4, 5, 6, and 7 year-old burns) plus the control. Fifteen of the lotebushes selected were used by quail and 15 were randomly chosen. A volume figure for each plant was calculated by multiplying the mean height × width × length. Understory characteristics were recorded as light grass (< 50% herbaceous cover), heavy grass (> 50% herbaceous cover), light litter (< 50% ground cover), heavy litter (> 50% ground cover), and percent bare ground. The height and cover of vegetation adjacent to lotebushes used by quail which might have affected visibility or escape routes were recorded along a 1 m tansect in each of the four cardinal directions beginning at the edge of the lotebush canopy.

The minimum size of lotebush used by quail was identified by averaging the volume measurements of the two smallest plants used in each treatment area. Ages of closed-canopy resprouts used by quail were estimated by counting rings from the two largest stems of each plant. This aided in determining the age at which lotebushes would be of value to quail following fire. Volume measurements of mesquite trees were also taken to identify the size of tree used by quail.

Woody plant densities were recorded in each treatment and control using two 50 × 50-m plots. In addition, the density of woody plants within each primary rest area in covey home ranges was measured using one 50 × 50-m plot. Woody plant cover within home ranges was sampled with two 250-m line intercepts.

Home ranges and primary rest areas were mapped using the territory-mapping technique (Overton 1971) and results from re-trapping leg-banded quail.

Baited walk-in traps were used to capture quail. Each bird was tagged with a serially numbered aluminum leg band. Trapping data provided information on mortality, breeding success, and covey movements. All traps were baited with 150 gm of grain sorghum. When quail were captured, the amount of bait consumed was estimated and the estimate divided equally among the number of birds caught and subtracted from their weights.

Both parametric and nonparametric tests were used to evaluate the data. Spearmans Rho Test (Canover 1971:248) was used to determine the correlation of home range size with covey size and with woody plant density during different seasons to determine habitat suitability.

Results and Discussion

Habitat Measurements

Bobwhite quail used lotebush as loafing cover more than all other woody plants (Table 1). Differences in seasonal use of various plants appeared to be dependent on growth form. Winter use of lotebush may have been due to the closed, spinescent canopy (Fig. 1) that provided overhead concealment and protection from predators. It is generally agreed that there is no single cause for quail population fuctuations from year to year (Mosby and Overton 1950); however, the number of coveys that can be supported on any given unit of rangeland may be dependent on the amount of winter cover (Burger and Linduska 1967). In addition, winter cover may be selected which best protects coveys from climatic extremes. In grasslands there is no biotic protection in the community against environmental changes (Wiens 1974). The lotebush canopy retains large amounts of wind-blown litter which may create an insulated microhabitat favorable to quail during winter months.

Table 1. Number of each plant species (for total study area) used for loafing cover by bobwhite quail by season in Mitchell County, Tex., 1973–1975.

	Plants				
Season	Lotebush	Honey mesquite	Fourwing[1] saltbush	Annual broomweed	Catclaw acacia
Winter 1973	39	15	0	0	0
Spring 1974	30	21	0	0	0
Summer 1974	18	44	0	0	0
Fall 1974	28	11	5	0	0
Winter 1974	32	8	3	0	0
Spring 1975	14	0	0	0	0
Summer 1975	4	0	0	30	0

[1] Scientific name is *Atriplex canescens*.

Other characteristics of lotebush may have resulted in its selection as yearlong cover by quail. Understory measurements showed that 97.8% of the bushes used by quail had bare ground or light grass under the canopy, thus furnishing good visibility as well as secure dusting sites. Measurements of adjacent vegetation showed that grass height was significantly shorter near those lotebush plants that were used by quail than near those that were not used by quail.

Quail use of large mesquite on the study area during the dry summer of 1974 may have been due to the weather extremes during that season. Wiens (1974) observed that dry years in grasslands are typified by higher than average winds and temperatures, thus quail may have required a more open situation which supplied shade, cover, and access to cooler breezes found in large mesquite stands. Heavy use of broomweed during the summer of 1975 followed a spraying program during the spring. Coveys depended on broomweed once mesquite and lotebush were defoliated.

Lotebush is a highly volatile species and burns easily. Consequently, most (88.3%) of the lotebushes that were chosen randomly and considered typical of the burns had been burned and were recovering from the effects of the fire. The resprouts grew slowly for the first 3 years after burning, and then grew rapidly during the fourth and fifth years (Neuenschwander and

Fig. 1. *By the sixth growing season after burning, about 70% of the volume of burned lotebushes has recovered and the largest plants are used by quail. The plants are rigid and have a closed, spinescent canopy that provides overhead concealment from predators.*

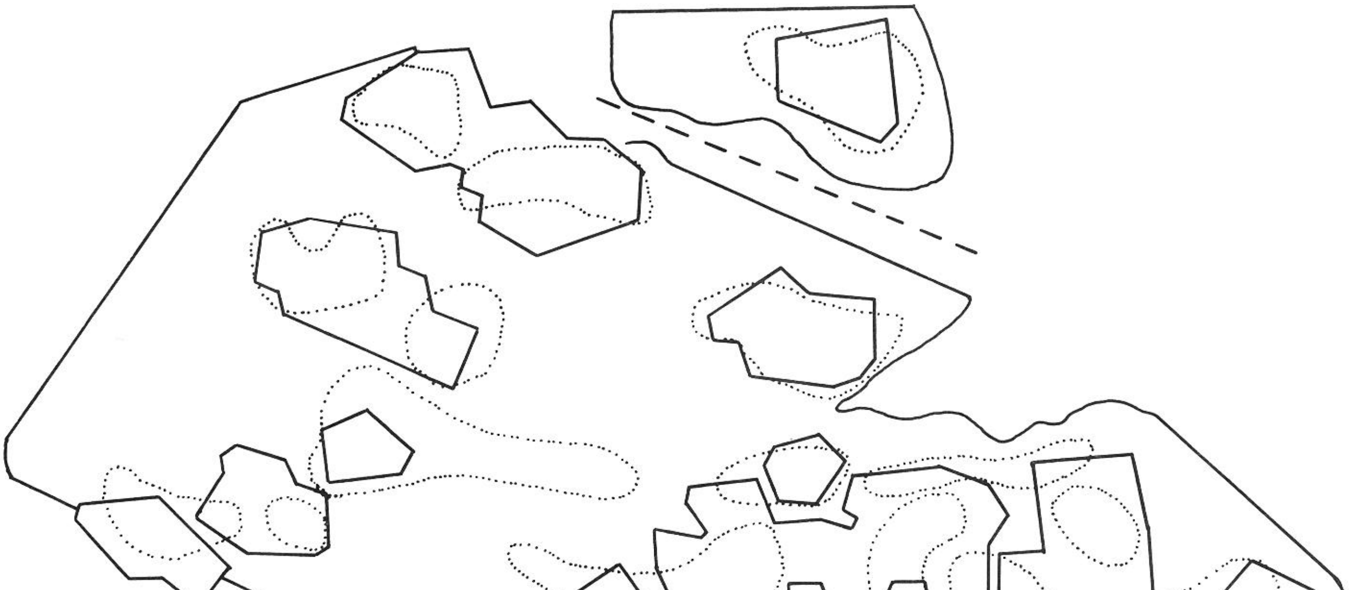


Fig. 2. *Map of the study area containing all ages of burns and showing the outside boundaries of composite home ranges (dotted lines) of bobwhite quail from June 1, 1974, to August 26, 1975, in Mitchell County, Tex. Area within dotted lines are concentrations of woody cover.*

Fig. 3. *A typical primary rest area of the Rolling Plains that would be preferred by bobwhite quail because it contains large mesquite trees and lotebushes.*

Wright 1973). By the sixth growing season after burning about 70% of the volume of burned lotebushes had recovered and the largest plants were being used by quail (Fig. 1). As expected, volume measurements of lotebushes in the control were greater than those in the burns with one exception. The 1971 burn had more bushes on higher ground where the fire did not carry well, thus randomly chosen plants in this burn tended to be larger than those in other treatments.

Hot fires (burning with a relative humidity of 20 to 40%, a wind of 13 to 24 km/hour, and air temperature of 21 to 26°C, and no green forbs in the understory vegetation) similar to the 1974 burn are most effective in reducing above-ground growth of lotebushes, though the plants are rarely killed (Scifres and Kothmann 1976). In this treatment all lotebushes burned in an April fire, but resprouting was evident by October. No coveys were observed loafing in this treatment area after the burn, though feeding birds were occasionally flushed. Burns during wet years (when green forbs were abundant) such as 1975 have the least effect on lotebushes, even though fire may reach the canopies of some plants. A burn in 1975 had a low intensity because annual forbs greened up early, winds were 10 to 13 km/hour, and relative humidity was 40%. This resulted in some bushes being defoliated and a few burned to ground level, but due to the patchiness of this "cool" burn, enough lotebushes survived to support resident coveys with no displacement.

Table 2. Home range and primary rest areas of bobwhite quail and average covey population by season from 1974–1975 in Mitchell County, Tex.

Season	Number of coveys	Home range (ha) Smallest	Largest	Mean	Primary rest area (ha) Smallest	Largest	Mean	Number of birds/covey
Summer 1974	12	2.2	13.9	7.2	0.4	3.7	2.1	9.1
Fall/winter 1974	13	1.1	3.4	1.9	0.4	1.1	0.5	6.1
Spring 1975	10	0.8	2.1	1.4	0.4	1.4	0.8	5.6
Summer 1975	15	0.7	2.8	1.7	0.3	1.5	0.9	14.8

Lotebushes used by quail averaged 3.8 m^3 and were significantly ($P < .05$) larger than plants randomly chosen. Only 11.8% of these plants had been burned and returned to a closed-canopy form. The rest of the plants had either escaped the fires or were partially defoliated. The two smallest plants used by quail had an average volume of 0.97 m^3, which we consider to be the minimum size for lotebush to be useful to quail.

Mesquite trees used by quail tended to be large, averaging 48.6 m^3. Low-growing, multiple-stemmed resprouts that resulted from burning were rarely selected by loafing quail when larger trees or lotebushes were available. Since fine fuel was too light around the base of most large trees for top-kill with fire, many older mesquite trees escaped fire and furnished loafing cover for quail during the warmer months. Trees that were 48.6 m^3 in size averaged 11.6 trees/ha on the burned treatments and 17.7 trees/ha on the unburned control.

The large number of lotebushes used by quail yearlong is of particular interest when related to woody plant densities following fire. Lotebush densities for burned treatments averaged 33.6 plants/ha. However, only 3.9 plants/ha were large enough to be used for loafing cover. Densities of lotebush in the control (18.4

Table 3. Percent woody cover in home ranges of bobwhite quail in Mitchell County, Tex., 1974–1975.

Season	Number of coveys	Home range Smallest	Largest	Mean
Summer 1974	12	7.11	30.30	14.77
Fall/winter 1974	13	3.84	30.30	12.01
Spring 1975	9	2.08	13.80	8.73
Summer 1975	16	1.36	10.54	4.35

plants/ha) were significantly lower than in the burns, but most (63.4%) were larger bushes and used as loafing cover by quail.

A composite map of bobwhite quail home range (Fig. 2) on various ages of tobosagrass burns shows that large areas remained unoccupied by coveys. These areas did not have concentrations of woody cover and did not appear to have space for travel lanes and dusting sites in the thick tobosagrass.

Large coveys of quail were always associated with mixtures of large lotebush shrubs and mesquite trees (Fig. 3) during the summer of 1974. At this time a positive correlation ($P < .05$) was noted between covey size and the density of mesquite in covey headquarters. Larger coveys appeared more active in daily movements. Coveys using dense stands of mesquite were occasionally seen moving about midday when coveys residing in areas of scattered trees were loafing. The dense blocks of mesquite may have acted as screening cover, allowing coveys to move about more confidently in any direction in search of food.

The 1974 fall and winter home ranges (Table 2) were much smaller than summer ranges. By comparison, winter home ranges averaged less than half (4.8 ha) of the 24 acres (9.7 ha) reported by Johnsgard (1973:422) as the average winter range for Texas and Missouri bobwhites, but equal to Kansas studies. More coveys were found in open grassland habitats which had only a few mesquite trees in the primary rest areas. The number of lotebushes suitable for cover in home ranges remained the same as for coveys in the summer of 1974, indicating a possible minimum number of lotebushes required for fall and winter cover. This number included two to three clones of lotebushes in the primary rest area plus three to five individual lotebush plants to serve as screening cover when coveys traveled through home ranges.

Observations recorded before covey break-up in the spring of 1975 showed that quail had moved back into areas of higher mesquite density. Home ranges averaged only 1.4 ha and covey size dropped to 5.6 quail/covey. Early spring rains increased the food supplies of forbs and insects and home ranges were apparently adequate for the smaller coveys.

Woody cover measurements in quail home ranges showed a wide variation within and between seasons (Table 3). The smallest percentages of cover were generally associated with covey home ranges on upland sites and the largest percentages were measured in home ranges on bottomland sites. Mesquite trees in bottomland sites are very fire tolerant, whereas mesquite on upland sites are moderately susceptible to fire (Wright et al. 1976). Lotebush, catclaw acacia (*Acacia greggii*), and algerita (*Berberis trifoliata*) made up more than half (63.4%) of the woody cover in home ranges on upland sites.

Management Implications for Quail

Management for bobwhite quail in honey mesquite-tobosagrass communities centers around the amount and type of woody plants necessary to maintain yearlong cover. Prescribed burning as outlined by Wright (1974) would generally benefit quail habitat if added precautions are taken. Fire has the greatest effect on mesquite resprouts which are the prime concern of ranchers and which are of little value to quail. Larger trees need no protection from fire unless they have been previously top-killed, then 7-m firelines should be dozed in circles with 30-m diameters around at least 10 large mesquite trees/ha for optimum summer cover. Once lotebush plants are burned it may take 6 to 7 years before they become useful to quail. By that time pastures should be burned again to increase production and utilization of tobosagrass (Wright 1972). In primary rest areas, 7-m firelines should be dozed in circles with 15-m diameters around at least four clones of lotebush or large individual plants/ha to insure optimum winter cover for quail.

Since lotebush is a clonal plant and some shrubs may be 9 m^3 in volume while others are very small, only 10 or 20% of the land on a ranch may be key cover areas for quail. Feeding areas, however, may cover 50 to 80% of the ranch. Thus preparing firelines for the protection of lotebush and mesquite plants from prescribed fire is biologically feasible and would leave only a small amount of unburned brush.

The cost to cut a fireline around each group of four clones of lotebush that contained mesquite plants would be $2.00 to $4.00. Prorated over the entire acreage for many such firelines within a section of land, this would be $.20 to $.80/acre, depending on amount of lotebush in the area. Since the life of the detrimental effects of fire on lotebush is 6 years or more, the cost for firelines can be further prorated to $.04 to $.14/acre/year plus interest. Hunting leases for quail cost from $.25 to $1.00/year in the Rolling Plains.

Literature Cited

Burger, G. V., and J. P. Linduska. 1967. Habitat management related to bobwhite populations at Remington Farms. J. Wildl. Manage. 31:1-12.

Casey, W. H. 1965. some speculations on the minimum habitat requirements of bobwhite quail. 19th Ann. Conf. S.E. Ass. Game and Fish Commissioners, Proc. 19:30-39.

Conover, W. S. 1971. Practical nonparametric statistics. John Wiley & Sons, New York. 462 p.

Gould, F. W. 1969. Texas plants—a checklist and ecological summary. (Revised). Texas Agr. Exp. Sta., College Station. 121 p.

Jackson, A. S. 1969. Quail management handbook. Texas Parks and Wildl. Bull. 48. 77 p.

Johnsgard, P. A. 1973. Grouse and quails of North America. Univ. of Nebraska Press, Lincoln. 553 p.

Mosby, H. S., and W. S. Overton. 1950. Fluctuations in the quail population of V.P.I. farms. Trans. N. A. Wildl. Conf. 15:347-355.

Neuenschwander, L. F., and H. A. Wright. 1973. Regrowth of lotebush (bluebush) after burning. Texas Tech Univ. Noxious Brush and Weed Control Res. Highlights. 4:14.

Overton, W. S. 1971. Estimating the numbers of animals in wildlife populations. p. 403-455. *In:* R. H. Giles (Ed.) Wildl. Manage. Tech. 3rd Edition. Wildl. Soc., Washington, D.C. 633 p.

Robinson, T. S. 1957. Climate and bobwhite in Kansas—1955. Trans. Kansas Acad. Sci. 59:209-212.

Scifres, C. J., and M. M. Kothmann. 1976. Site relations, regrowth characteristics, and control of lotebush with herbicides. J. Range Manage. 29:154-156.

Wiens, J. A. 1974. Climatic instability and the "ecological saturation" of bird communities in North American grasslands. Condor 76:385-400.

Wright, H. A. 1972. Fire as a tool to manage tobosa grasslands. Tall Timbers Fire Ecol. Conf., Proc. 11:103-167.

Wright, H. A. 1974. Range burning. J. Range Manage. 27:286-289.

Wright, H. A., S. C. Bunting, and L. F. Neuenschwander. 1976. Effect of fire on honey mesquite. J. Range Manage. 29:467-471.

Deer Mouse Preference for Seed of Commonly Planted Species, Indigenous Weed Seed, and Sacrifice Foods

RICHARD L. EVERETT, RICHARD O. MEEUWIG, AND RICHARD STEVENS

Highlight: Captive deer mice from pinyon-juniper, sagebrush-bitterbrush, and Jeffrey pine-ceanothus plant associations were fed a variety of shrub, grass, forb, and tree seeds. Mice ate or destroyed an amount of seed equal to approximately one-third their body weight daily. Seed of bitterbrush, singleleaf pinyon, balsamroot, and small burnet were the most preferred food items tested while seed of Utah juniper, smooth brome, fourwing saltbush, and big saltbush were least preferred. Planting valuable forage species whose seeds are not preferred by deer mice would appear to improve seeding success on sites where seed predation by deer mice is a problem.

Seed predation by the deer mouse (*Peromyscus maniculatus*) and other rodents has contributed to the failure of several seedings (Howard 1950; Spencer 1954; and Nord 1965). The deer mouse has been singled out as a major consumer of planted seed by Casebeer (1954), Kverno (1954), and Nelson et al. (1970).

Seeds are an important part of the deer mouse diet, especially in the fall and winter when insects and green vegetation are not available (Fitch 1954; Williams 1959; and Whitaker 1966). Seeds of forbs (Johnson 1961), grasses (Frischknecht 1965), and shrubs (Jameson 1952) are consumed at different times of the year, depending on seed availability and floristic composition. Seed size, odor, and nutrient content play an important role in food preference (Thompson 1953; Howard and Cole 1967; Lockard and Lockard 1971), but when food is scarce deer mice will take almost any food available. Deer mice are also opportunistic in their feeding habits and readily consume new foods (for example, planted seed) that appear on the site (Johnson 1961).

New methods of controlling deer mouse predation of planted seed should be developed. Recent restrictions on the use of poisons on federal lands (Evans 1974) and increased emphasis on the preservation of all nongame wildlife species make many control treatments unacceptable.

By understanding the food habits and preferences of the deer mouse we hope to develop techniques that reduce seed predation to an acceptable level and so improve stand establishment. Seed predation may be reduced if planted seed species are less preferred by the deer mouse than indigenous food or low-cost sacrifice foods. This paper presents information on deer mouse preference for seed species commonly planted on rangelands, indigenous weed seed, and possible sacrifice foods.

Authors are range scientist and research forester, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Ogden, Utah 84401, located at the University of Nevada-Reno; and research wildlife biologist, Utah Division of Wildlife Resources, located at Ephraim, Utah.

The authors wish to express appreciation for the materials and facilities provided by Dr. Darrell Foote (University of Nevada-Reno, Agricultural Experiment Station) and George Tsukamoto (Nevada Fish and Game Department). Preparation of this publication was supported by funds provided by the Intermountain Forest and Range Experiment Station and by Federal Programs for Wildlife Restoration W-82-R.

Manuscript received May 3, 1977.

Methods

Native deer mice were trapped in western Nevada and transferred to an animal holding room at the University of Nevada at Reno. There a series of feeding trials were run to determine deer mouse preference for various seeds and sacrifice foods.

Eight deer mice trapped in a sagebrush (*Artemisia tridentata*)-bitterbrush (*Purshia tridentata*) plant association were used in an initial feeding trial to provide baseline information on deer mouse preference for seed species commonly planted on rangelands. Seeds of 18 shrub, forb, and grass species were divided into two 9-species groups A and B (Table 1). Each seed group was provided separately to four mice in individual cages.

After the feeding trial, seed species from both seed groups were separated on the basis of deer mouse acceptance. Seed species that made up 10% or more of the deer mouse diet were grouped as primary seed species while those seed species consumed in lesser quantities were grouped as secondary seed species.

A second feeding trial was run to determine deer mouse seed preference within primary and secondary seed groups. Each seed

Table 1. Deer mouse food preference for commonly seeded species.

	Feeding trials[1]			
	1		2	
Common name	Seed group A % diet	Seed group B % diet	Primary seed % diet	Secondary seed % diet
Antelope bitterbrush	30.7^{a}		26.0^{a}	
Arrowleaf balsamroot	23.6^{ab}		16.1^{b}	
Small burnet		20.5^{a}	14.3^{b}	
Sainfoin	18.4^{b}		8.7^{c}	
Mountainmahogany	9.6^{c}		9.3^{c}	37.0^{a}
Serviceberry		15.7^{a}	10.2^{c}	
Lewis flax		16.3^{a}	4.7^{d}	
Stiffhair wheatgrass	13.8^{c}		4.5^{d}	
Big bluegrass		17.2^{a}	2.0^{e}	
Russian wildrye		10.7^{b}	3.5^{e}	24.0^{b}
Alfalfa		8.3^{b}		19.2^{c}
Green ephedra		3.5^{c}		7.4^{d}
Cicer milkvetch	2.4^{d}			3.1^{e}
Sheep fescue		3.0^{c}		4.6^{e}
Bulbous bluegrass	$.0^{e}$			2.6^{e}
Big saltbush		4.5^{c}		1.3^{f}
Fourwing saltbush	1.3^{d}			$.3^{f}$
Smooth brome	$.1^{e}$			$.7^{f}$

[1] Species in each column with dissimilar superscripts are significantly different ($p<0.1$).

Table 2. Deer mouse preference for select seeded species, indigenous forb, grass, and tree seed and alpha-napthylthiourea (ANTU)-treated bitterbrush seed.

Food source Common name	Feeding trials[1] 3 Indigenous forb and grass seed	 4 Tree seed and sacrifice food	 5 ANTU-treated bitterbrush seed
Seeded species			
Antelope bitterbrush	31.5^{a}	28.5^{a}	10.2^{b}
Arrowleaf balsamroot			11.7^{b}
Small burnet		20.6^{b}	11.5^{b}
Mountainmahogany	22.8^{b}		11.5^{b}
Serviceberry			4.3^{bc}
Russian wildrye	9.4^{cd}	4.3^{cde}	6.0^{bc}
Cicer milkvetch	7.3^{cde}	1.9^{de}	$.5^{bc}$
Big bluegrass	4.8^{def}		
Fairway wheatgrass	4.1^{ef}		
Sheep fescue	$.6^{f}$		
Smooth brome	$.1^{f}$		
Indigenous forb and grass species			
Prickly poppy	11.4^{c}		
Lambsquarters	3.1^{ef}		
Cheatgrass brome	2.9^{ef}		
Coyote tobacco	2.0^{ef}		
Tree seed			
Singleleaf pinyon		23.6^{ab}	40.5^{a}
Utah juniper		$.4^{e}$	
Sacrifice foods			
Barley (rolled)		10.2^{c}	
Lab Chow		8.5^{cd}	
Wheat (hulled)		2.0^{de}	

[1] Species in each column with dissimilar superscripts are significantly different ($p<0.1$).

group was provided separately to 12 mice: four each from sagebrush-bitterbrush, pinyon (*Pinus monophylla*)-juniper (*Juniperus osteosperma*), and Jeffrey pine (*Pinus jeffreyi*)-Ceanothus (*Ceanothus velutinus*) plant associations. For a continuum of food preference, seeds of mountainmahogany (*Cercocarpus ledifolius*) and stiffhair wheatgrass (*Agropyron trichophorum*) were included in both seed groups. Species in each seed group are identified in Table 1.

Third and fourth feeding trials were run to determine whether seed of weedy herbaceous species indigenous to disturbed rangelands or commercial sacrifice foods would reduce deer mouse consumption of desirable seed species (Table 2). Seeds of four indigenous weed species and eight commonly seeded species were provided to eight mice in the third trial. In the fourth trial, sacrifice foods (wheat (*Triticum sativum*), rolled barley (*Hordeum sativum*), and Lab Chow[1]), seeds of pinyon and juniper, and seeds of four commonly seeded species were provided to seven mice.

In the fifth and final feeding trial, we attempted to reduce deer mouse preference for bitterbrush seed by coating it (9% seed weight) with alpha-naphthylthiourea (ANTU)[2], a rodent pesticide-repellent (Passof et al. 1974). ANTU-treated bitterbrush seed and seed of seven previously tested seed species (Table 1) were provided to six mice in this trial.

In all feeding trials, mice were given 5 days to become accustomed to their new surroundings before the start of the test. Mice were provided with cotton nesting material and a surplus of water and Lab Chow. Lab Chow was removed from the cages during feeding trials in which it was not a test food.

Food choices were provided ''cafeteria style'' to each mouse in its individual cage. Seed or other food was placed in individual cubicles of a 12-cube ice tray. Food choices were kept separate and placement was made at random within the tray. We assumed that each mouse would make a large number of independent food selections during a feeding period and consumption of seed from any cubicle would reflect this independence. This assumption appeared reasonable from observations and because other food sources were taken before the preferred food was entirely consumed.

Each mouse was provided with 0.5 g of selected foods the first day, 1 g the second day, and additional 1 g increments until the fifth day when 4 g of each food item were provided. At the end of each daily feeding (4 p.m. to 8 a.m.), the food tray was removed. Dropped or displaced seed was rare; when it occurred, the food items were replaced in their proper cubicles. Feces and other foreign matter were removed from the seed remnants.

Total seed consumed was determined for each seed species at the end of each feeding period by taking the difference between the weight of seed offered and the weight of whole seed remaining. Empty hulls were separated from whole seed; but, for several seed species, this was only possible for small samples. In the latter case, weight of whole seed remaining was determined by weighing the seeds and empty hulls together and correcting for the empty hulls with this equation:

$$W = \frac{A}{1+(B \cdot C)}$$

Where:

W is the weight of whole seeds,

A is the combined weight of whole seeds and empty hulls,

B is the ratio of the number of empty hulls to the number of whole seeds, and

C is the ratio of hull weight to the whole seed weight.

The value of B for each lot of remaining seeds and hulls was estimated by taking a sample from each lot and counting the number of whole seeds and estimating the number of hulls from remaining fragments. The value of C for each species was estimated by weighing a number of samples of hulls and whole seeds.

Amount of each seed species consumed during the 5-day feeding trial was expressed as a percentage (percent diet) of the total seed (all species) consumed. Percent diet was used instead of seed weight to make comparisons among seed species to nullify differences in total seed weight consumed by individual mice. Percentages were generally in the 0% to 30% range and as such were transformed to arc sine

$$\sqrt{\frac{\%\ \text{Diet}}{100}}$$

before statistical treatment (Snedecor 1956).

In each feeding trial except the second, differences in total seed consumption (% diet) were statistically analyzed with a one-way analysis of variance. Propriety of the analysis is dependent upon the assumption that food selections were made independent of each other. Hopefully, departures from this assumption will have minor effects on the analysis. In the second trial, differences in food consumption were run in a 3 by 10 factorial statistical test to delineate seed preference within seed groups and among mouse populations. Hartley's sequential method of testing (Snedecor 1956) was used to determine which food source pairs were significantly different (*p* 0.1) in preference in each separate feeding trial.

Results

Deer mice showed a definite preference for certain seed species within each feeding trial. Without exception, the numbers of species whose seeds were eaten decreased as the amount of seed offered increased. Most of the deer mouse diet

[1] Use of trade or firm names is for reader information only, and does not constitute endorsement by the U.S. Department of Agriculture or the Utah Division of Wildlife Resources of any commercial product or service.

[2] This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

(65–70%) was made up of only three or four food sources in each feeding trial. Deer mice, however, preferred some variety in their diet. Total consumption of the most preferred seed rarely occurred when increased amounts of seed were offered, although amounts of seed of individual species were well below the nightly food intake of the mice.

Deer mice consumed or destroyed an amount of seed equal to 30% to 40% of their body weight each night when more than that amount of seed was available. Total food intake decreased when less preferred seed species were provided. Deer mouse seed consumption or destruction over a 5-day period was 174% of body weight when preferred primary seed species were offered and 137% of body weight when less preferred secondary seed species were offered in the second feeding trial. Mice consumed or destroyed an intermediate amount of seed (162% of body weight) over a 5-day period when primary and secondary seed species were provided together in the first feeding trial.

Consumption of individual seed species varied among feeding trials, depending upon other food sources available. The proportion of mountainmahogany and Russian wildrye seed in the diet increased by 20% to 30% when offered with less preferred secondary seed species in the second feeding trial (Table 1).

Deer mice from pinyon-juniper, sagebrush-bitterbrush, and Jeffrey pine-ceanothus plant associations did not differ significantly (p 0.05) in their preference for seed species commonly planted on rangelands. The ranking of seed species according to deer mouse preference (Table 3) shows the general consistency in preference for seed species among deer mouse populations.

Deer mouse food preference was consistent among feeding trials with minor exceptions. Deer mouse preference for some seed species did vary when new food items were made available. For example, seed of big bluegrass (*Poa ampla*) was preferred over seed of Russian wildrye in the first trial, but not in the third trial (Table 1) when fairway wheatgrass (*Agropyron cristatum*) and a variety of weed seeds were provided.

Seed of bitterbrush and pinyon were clearly among the most preferred of the tested foods. From 26% to 32% of the deer mouse diet consisted of bitterbrush seed when the seed was available. The high preference of deer mice for bitterbrush seed may account for the extreme predation of planted bitterbrush seed under field conditions as reported by Brown and Martinsen (1959), Holmgren and Basile (1959), and Nord (1965).

Table 3. Seed preference by deer mice from pinyon-juniper, sagebrush-bitterbrush, and Jeffrey pine-ceanothus plant associations.

	Preference ranking of seed species by deer mouse populations[1]		
Seed species	Pinyon-juniper	Sagebrush-bitterbrush	Jeffrey pine-ceanothus
Antelope bitterbrush	1	1	1
Arrowleaf balsamroot	2	3	2
Small burnet	3	2	3
Serviceberry	4	4	5
Sainfoin	5	5	6
Mountainmahogany	6	8	4
Lewis flax	7	6	8
Stiffhair wheatgrass	8	7	7
Russian wildrye	10	9	9
Big bluegrass	11	10	10
Alfalfa	9	11	11
Green ephedra	12	12	13
Cicer milkvetch	13	14	15
Bulbous bluegrass	15	13	12
Sheep fescue	14	15	14
Big saltbush	16	18	17
Smooth brome	17	17	18
Fourwing saltbush	18	16	16

[1] Ranking based on percent of deer mouse diet.

Pine-nut consumption varied, ranging from 24% to 40% of the diet (Table 2). Increased amounts of pinyon nuts were consumed when untreated bitterbrush seed was not available. Utah juniper (*Juniper osteosperma*), smooth brome, (*Bromus inermis*), big saltbush (*Atriplex lentiformis*), and fourwing saltbush (*Atriplex canescens*) seeds were the least preferred of the tested foods.

With the possible exception of prickly poppy (*Argemone munita*), seeds of indigenous forbs were not preferred food items of deer mice. However, deer mice preferred seed of indigenous forbs as much or more than seed of smooth brome, big saltbush, fourwing saltbush, bulbous bluegrass (*Poa bulbosa*), sheep fescue (*Festuca ovina*), fairway wheatgrass, and cicer milkvetch (*Astragalus cicer*) (Table 2).

Sacrifice foods provided were usually intermediate in deer mouse preference (Table 2). Rolled barley, the most preferred sacrifice food (10% of the deer mouse diet), was preferred over seeds of cicer milkvetch and Russian wildrye (*Elymus junceus*).

ANTU-treated bitterbrush seed made up only 10% of the diet instead of 26% to 32% for untreated seed (Table 2). When treated bitterbrush seed and pinyon nuts were offered together, deer mice preferred pinyon nuts.

All tested foods are listed in Table 4 in estimated order of deer mouse food preference. The order in which foods appear is based on preference rankings within and among individual feeding trials. Seed from mountainmahogany (*Cercocarpus ledifolius*), Russian wildrye, or both occurred in all feeding trials and served as a baseline for comparisons among trials.

Table 4. Deer mouse food preference for seeded species, indigenous forb, grass and tree seed, and sacrifice foods.

Common name	Food categories[1]	Scientific name
Antelope bitterbrush	(C)	*Purshia tridentata*
Singleleaf pinyon	(T)	*Pinus monophylla*
Arrowleaf balsamroot	(C)	*Balsamorhiza sagittata*
Small burnet	(C)	*Sanquisorba minor*
Sainfoin	(C)	*Onobrychis viciaefolia*
Mountainmahogany	(C)	*Cercocarpus ledifolius*
Serviceberry	(C)	*Amelanchier alnifolia*
Barley (rolled)	(S)	*Hordeum sativum*
Lewis flax	(C)	*Linum lewisii*
Stiffhair wheatgrass	(C)	*Agropyron trichophorum*
Lab Chow	(S)	
Prickly poppy	(I)	*Argemone munita*
Big bluegrass	(C)	*Poa ampla*
Russian wildrye	(C)	*Elymus junceus*
Alfalfa	(C)	*Medicago sativa*
Green ephedra	(C)	*Ephedra viridis*
Wheat (hulled)	(S)	*Triticum sativum*
Cicer milkvetch	(C)	*Astragalus cicer*
Fairway wheatgrass	(C)	*Agropyron cristatum*
Lambsquarters	(I)	*Chenopodium album*
Cheatgrass brome	(I)	*Bromus tectorum*
Coyote tobacco	(I)	*Nicotiana attenuata*
Sheep fescue	(C)	*Festuca ovina*
Bulbous bluegrass	(C)	*Poa bulbosa*
Big saltbush	(C)	*Atriplex lentiformis*
Fourwing saltbush	(C)	*Atriplex canescens*
Smooth brome	(C)	*Bromus inermis*
Utah juniper	(T)	*Juniperus osteosperma*

[1] Food categories are: (C) commonly seeded species, (T) tree species, (S) sacrifice foods, or (I) indigenous herbaceous species.

Discussion

Deer mouse preference among seed species and sacrifice foods was very apparent and generally consistent among feeding trials and mouse populations. Amount of a particular seed species consumed was dependent upon the amount and kinds of food sources available. Seeds of less preferred species were taken in greater quantities when more preferred seeds were not available. The amount of food consumed per unit of body weight declined, however, when less preferred seed species were offered. Selecting seed species less preferred by deer mice should reduce the rate of predation of planted seed.

Predation of desired seed species should be further reduced if seed species are selected that are less preferred by deer mice than indigenous weed seed. Seeding in heavy stands of vegetation where indigenous seed sources may reduce predation of planted seed is not recommended because of plant competition and cover for deer mice. Predation of planted seed may be reduced, however, on prepared sites where indigenous weed seeds exist and cover is reduced.

Providing sacrifice foods may also lessen predation of desirable seeded species (Evans 1974). Rolled barley, Lab Chow or wheat could be obtained at minimal cost and mixed with the desired species, but only seed species that the deer mice prefer less than the sacrifice food would be protected. Seedling competition from rolled barley or Lab Chow would not occur because they are incapable of producing plants. Rodent populations could increase, however, because of the sacrifice food source and present a problem to emerging seedlings at a later date.

Treating bitterbrush seed with ANTU reduced its consumption by deer mice. Even a slight reduction in deer mouse preference for desirable seed species may be of great benefit if indigenous seed such as pinyon nuts are available to bear the brunt of deer mouse seed predation.

Although deer mice showed definite preferences among seed of commonly seeded species, indigenous species, and sacrifice foods in the laboratory, the findings may not agree entirely with deer mice preference under field conditions. Differences in nutritional requirements of deer mice from season to season may change seed preferences.

Seed consumption in the field may differ from predictions based on seed preference because all seeds are not equally available. Indigenous seed species are not as readily available to the deer mouse as newly seeded species, in most instances, but the presence of deer mice on the site prior to seeding is conclusive evidence that some indigenous food sources are available.

Planted seed may be consumed regardless of deer mouse preference if deer mouse populations are high or planted seed is exposed to predation for a long time. Planting seed species that are not preferred by deer mice in late winter or early spring when mouse populations are low and the length of the predation period is reduced should increase the number of seeds available for establishment.

Research is needed to document deer mouse seed consumption under field conditions as has recently been done for some granivorous birds (Goebel and Berry 1976). Information on deer mouse seed preference will aid in explaining any differences in seed consumption that may occur.

Conclusions

Differences in deer mouse food preference should be considered in making choices among equally adapted and productive species for seeding. We should plant desirable species whose seeds are not preferred by deer mice, especially those species whose seeds are less preferred than indigenous weed seed. Treating desirable seed species with a repellent or providing sacrifice foods may also be expedient when economically feasible. Smooth brome, fourwing saltbush, bulbous bluegrass, sheep fescue, fairway wheatgrass, and cicer milkvetch would appear to be good species for seeding when adapted to a site where seed predation by deer mice is a problem.

Literature Cited

Brown, E. R., and C. F. Martinsen. 1959. Browse planting for big game in the State of Washington. Washington State Game Comm. Biol. Bull. 12. 63 p.

Casebeer, R. L. 1954. The use of tatramine in bitterbrush revegetation. J. Forest. 152:829-830.

Evans, J. 1974. Pesticides and forest wildlife in the Pacific Northwest. *In:* Symp. Proc. Wildlife and Forest Management in the Pacific Northwest. H. C. Black (Ed.). Sch. Forest., Oregon State Univ., Corvallis.

Fitch, H. S. 1954. Seasonal acceptance of bait by small mammals. J. Mammal. 35:39-47

Frischknecht, N. C. 1965. Deer mice on crested wheatgrass range. J. Mammal. 46:529-530.

Goebel, C. J., and G. Berry. 1976. Selectivity of range grass seeds by local birds. J. Range Manage. 29:293-295.

Holmgren, R. C., and J. V. Basile. 1959. Improving southern Idaho deer winter ranges by artificial revegetation. State Idaho Dep. Fish and Game Wildl. Bull. 3. 61 p.

Howard, W. E. 1950. Wildlife depredations in broadcast seeding of burned brushlands. J. Range Manage. 3:291-298.

Howard, W. E., and R. E. Cole. 1967. Olfaction in seed detection by deer mice. J. Mammal. 48:147-150.

Jameson, E. W. 1952. Food of deer mice, *peromyscus maniculatus* and *P. boylei*, in the Northern Sierra Nevada. Calif. J. Mammal. 33:50-60.

Johnson, D. R. 1961. The food habits of rodents on rangelands of Southern Idaho. Ecology 42:407-410.

Kverno, N. B. 1954. Development of better seed protectants. J. Forest. 52: 826-827.

Lockard, R. D., and J. S. Lockard. 1971. Seed preference and buried seed retrieval of *Dipodomys deserti*. J. Mammal. 52:219-221.

Nelson, J. R., A. M. Wilson, and C. J. Goebel. 1970. Factors influencing broadcast seeding in bunchgrass range. J. Range Manage. 23:163-170.

Nord, E. C. 1965. Autecology of bitterbrush in California. Ecol. Monogr. 35:307-334.

Passof, P. C., R. E. Marsh, and W. E. Howard. 1974. Alpha-naphthylthiourea as a conditioning repellent for protecting confier seed. *In:* Proc. Sixth Vertebrate Pest Conf., Anaheim, Calif. p. 280-293.

Snedecor, E. W. 1956. Statistical methods applied to experiments in agriculture and biology. Iowa State Univ. Press, Ames. 534 p.

Spencer, D. A. 1954. Rodents and direct seeding. J. Forest. 52:824-826.

Thompson, H. V. 1953. The use of repellents for preventing mammal and bird damage to tree and seed. Forest. Abstr. 14(2):129-136.

Whitaker, J. D., Jr. 1966. Food of *Mus musculus, Peromyscus maniculatus bairdi* and *Peromyscus leucopus* in Vigo County, Indiana. J. Mammal. 47:473-486.

Williams, O. 1959. Food habits of the deer mouse. J. Mammal. 40:415-419.

TECHNICAL NOTES

Effects of Two Wetting Agents on Germination and Shoot Growth of Some Southwestern Range Plants

S. MIYAMOTO AND J. B. BIRD

Highlight: Two soil wetting agents (linear sulfonate and alkyl polyethylene glycol ether) were evaluated on inhibition of germination and shoot growth of alkali sacaton, galleta, blue grama, and fourwing saltbush. Sacaton and galleta seeds were germinated in wetting agent solutions (185, 370, and 740 ppm by volume) as well as in sand and a water-repellent coal mine spoil sample treated with the wetting agents at rates equivalent to 23.5, 47, 94 liters/ha. Blue grama and saltbush were germinated only in the sand and spoil samples. Results indicate that in solution culture these wetting agents reduce germination, severely deter shoot growth of both sacaton and galleta, and cause nearly permanent injury to plumules of galleta seeds. Wetting agents applied to sand at the comparable rates cause only minor reduction in shoot emergence and growth of the tested grass species, presumably due to soil sorption of wetting agents. The wetting agents tested are potentially phytotoxic, especially the sulfonate compound to saltbush, but can improve shoot emergence when applied to water-repellent media.

One problem in revegetating coal mine spoils of the arid southwest is poor water infiltration induced by water-repellency (Miyamoto et al. 1977). A previous study shows that the use of wetting agents, especially a linear sulfonate compound, improves water infiltration into water-repellent mine spoils (Miyamoto 1977). Wetting agents are also effective for improving infiltration into water-repellent soils and peat media (e.g., Pelishek et al. 1962; Osborn et al. 1969). However, some wetting agents are toxic to plants (e.g., Endo 1969; Luxmoore et al. 1974; DeBano and Conrad 1974), while others may stimulate plant growth (Parr and Norman 1974). The study was thus made to evaluate inhibitory effects of two soil wetting agents on germination and shoot growth of alkali sacaton (*Sporobolus airoides*), galleta (*Hilaria jamesii*), blue grama (*Bouteloua gracilis*), and fourwing saltbush (*Atriplex canescens*).

Authors are assistant professor and technician, Texas A&M University, Research Center, El Paso.

Texas Agr. Exp. Sta. J. No. 13138. Contribution from the Texas A&M Univ. Research Center, El Paso and Texas Agr. Exp. Sta. This program is supported in part by a cooperative agreement between the Rocky Mountain Forest and Range Exp. Sta. U.S. Dep. Agr. and the Texas Agr. Exp. Sta., and is a contribution to the SEAM (Surface Environment and Mining) program.

Manuscript received February 28, 1977.

Materials and Methods

Two commercially available wetting agents, "Soil Pen"[1] (linear sulfonate) and "Water-In" (alkyl polyethylene glycol ether), were used. These compounds, especially "Soil Pen" improve water infiltration into water-repellent mine spoils consisting of coal fragments (Miyamoto 1977. The compound "Water In" was studied previously by Luxmoore et al. (1974) and DeBano and Conrad (1974), and is included here for comparison.

Four species (alkali sacaton, galleta, blue grama, and fourwing saltbush) were used for testing. Alkali sacaton and saltbush are used extensively for spoil revegetation in the arid-southwest, while galleta is used only to a limited extent.

Germination tests were conducted for sacaton and galleta by using a solution culture technique under greenhouse conditions (25 to 30°C). Seeds (100 each) were placed into petri dishes containing wetting agent solutions (185, 370, and 740 ppm by volume on an active ingredient basis) in amounts sufficient to wet the seeds; the solutions were changed every 3 days. No adsorptive medium except seeds was placed in the dishes in order to avoid possible sorption of wetting agents. Germination counts were made at 3, 7, and 14 days after seeding. Seeds were considered germinated when shoot or root exceeded the size of seeds. Shoot growth was traced by measuring the length of shoots. As a separate test, seeds germinated in the wetting agent solutions of 185 ppm were transferred into dishes containing distilled water, then the shoot elongation was traced for 3 weeks. Experiments were in triplicate, and the Student-Newman method was used for tests of significance.

[1] The trade name is included here for the convenience of readers and does not imply endorsement by the author, Texas Agr. Exp. Sta. and the Forest Service, U.S. Dep. Agr.

Shoot emergence was determined for the four species by using two growth media: a coarse sand and a mine spoil consisting of coal fragments, both collected from the Fruitland formation in the Navajo Indian reservation. The coarse sand contained approximately 9% silt plus clay fraction. The coal-based spoil was poorly wettable, having a solid-water contact angle of 87° measured by the relative capillary rise method of Letey (1969). These materials were air dried and placed into greenhouse pots (10 cm ID, 12 cm deep). Seeds were placed at a depth of 1 cm. Thereafter, wetting agent solutions in the same concentrations as the solution culture experiments were applied to the surface in amount of 1.25 ml/cm². Equivalent rates of active ingredients were 23, 47, and 94 liter/ha (or 2.5, 5, and 10 gallons per acre, respectively). For blue grama and saltbush, only the highest rate was used. Pots were placed under greenhouse conditions (20–30°C for grasses and 15 to 25°C for saltbush) and

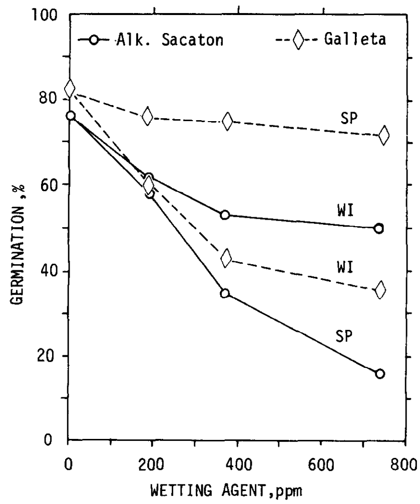


Fig. 1. *Germination of sacaton (solid lines) and galleta (dotted lines) seeds as influenced by the concentration of wetting agent solutions; SP = Soil Pen, WI = Water In.*

Table 1. The average shoot length (cm) of sacaton and galleta grown in distilled water, wetting agent solutions (185 ppm), and in distilled water following the growth in the wetting agent solutions.

Species and days after seeding	Distilled Water	Wetting agents		Distilled following wetting agents	
		SP	WI	SP	WI
Alkali sacaton					
5 days	1.0*	0.2 b	0.1 b	0.2 b	0.1 b
10	1.5 a	0.2 b	0.2 b	0.8 c	0.3 b
21	—	0.5	0.4	1.7	0.6
Galleta					
3 days	3.2 a	0.2 b	0.1 b	0.2 b	0.1 b
10	5.0 a	0.2 b	0.2 b	0.2 b	0.2 b
21	—	0.2	0.2	0.2	0.2

* Numbers followed by the same letter are not significantly different at 5% level between the treatment consisting of different growth media.

irrigated with tap water every 3 days at a rate of 1.25 cm. Seedling counts were made on the 7th and 14th days. Shoot length was also measured on the same days by arbitrarily taking ten shoot samples.

Results and Discussion

Germination of galleta seeds placed in distilled water started within 1 day and virtually finished within 3 days, whereas sacaton continued to germinate up to about 7 days. The germination of both species placed in wetting agent solutions was, however, slow, reaching an apparent plateau within 7 days, then increasing for approximately 5 to 10% for another week. Germination counts made at 2 weeks are shown in Figure 1. Increasing concentrations of wetting agents reduced germination. The germination of sacaton (solid lines) was reduced markedly by "Soil Pen" (SP), whereas galleta tolerated this wetting agent but was severely affected by "Water In" (WI).

Both wetting agents severely deterred shoot growth (Table 1). Table 1 also includes the situation where seeds germinated in wetting agent solution were transferred into distilled water and then the shoot growth was traced (the last two columns). The transfer was made on the 3rd and 5th day after seeding for galleta and sacaton, respectively. This transfer activated shoot growth of sacaton, but not of galleta. The incubation of galleta seeds in these wetting agent solutions for 3 days evidently causes a permanent injury to plumules.

Shoot emergence of galleta from the sand and the coaly spoil started 2 days after seeding and was virtually completed within one week, whereas blue grama and sacaton started emerging approximately 5 days after seeding and continued to emerge for about another 10 days. The emergence of saltbush was slower by several days. Emergence counts made at 2 weeks are given in Table 2. Application of wetting agents reduced emergence in sand, but increased emergence over the control in the mine spoil, except for saltbush. The emergence of saltbush was notably reduced by application of "Soil Pen."

Table 2. Shoot emergence and average shoot length as influenced by application of wetting agents to sand and soil.

Species and treatments	Application rate (liter/ha)	Sand	Spoil	
		Emergence (%)	Emergence (%)	Length (cm)
Alkali sacaton				
Control		77 a*	30 a	1.7 a
Soil pen	(47)	65 b	40 b	1.6 a
Soil pen	(94)	61 c	43 b	1.6 a
Water in	(47)	69 b	52 c	1.8 a
Water in	(94)	69 b	58 c	1.9 a
Galleta				
Control		80 a	35 a	4.8 a
Soil pen	(94)	74 b	58 b	4.8 a
Water in	(94)	72 b	52 b	5.0 a
Blue grama				
Control		75 a	28 a	2.8 a
Soil pen	(94)	72 a	56 b	2.1 b
Water in	(94)	75 a	43 c	1.9 b
Saltbush				
Control		22 a	13 a	4.0 a
Soil pen	(94)	6 b	8 b	2.6 b
Water in	(94)	21 a	12 a	3.5 b

* Numbers followed by the same letter are not significantly different at the 5% level from other treatments of different growth media.

Application of wetting agents to sand and spoil resulted in minor or no measurable reduction in shoot growth of the grass species (Table 2). (Since data from the sand were similar to those from the spoil, they are omitted.) Application of "Soil Pen," however, caused notable reduction in shoot growth of saltbush.

The above data point out that inhibitory effects are reduced when wetting agents are applied to sand and spoils. An observation similar to this is also reported by Endo (1969) and Luxmoore et al. (1974). The major reason is probably soil sorption of wetting agents (Valoras et al. 1969). The leaching of wetting agents by irrigation can be an additional reason, but probably a minor factor as compared to the sorption. If there were no sorption in our tests, wetting agent solution applied initially would have permanently damaged the plumules before leaching took place.

In conclusion, the tested wetting agents should be considered potentially toxic to germination and shoot growth. However, soil application of these wetting agents to the tested rates is not likely to severely deter germination and shoot growth, with a possible exception of saltbush.

Literature Cited

DeBano, L. F., and C. E. Conrad. 1974. Effect of a wetting agent and nitrogen fertilizer on establishment of ryegrass and mustard on a burned watershed. J. Range Manage. 27: 57-60.

Endo, R. M. 1969. The deleterious effects of two nonionic surfactants on the germination and growth of various grasses. p. 327-333. *In:* DeBano and Letey (Eds.) Water-Repellent Soils. Proc. of Symp. on Water-Repellent Soils. Univ. of California, Riverside.

Letey, J. 1969. Measurement of contact angle, water penetration time and critical surface tension. p. 43-48. *In:* DeBano and Letey (Eds.) Water-Repellent Soils. Proc. of Symp. on Water-Repellent Soils. Univ. of California, Riverside.

Luxmoore, R. J., N. Valoras, and J. Letey. 1974. Nonionic surfactant effects on growth and porosity of barley roots. Agron. J. 66: 673-675.

Miyamoto, S., A. Bristol, and W. L. Gould. 1977. Wettability of coal-mine spoils in northwestern New Mexico, Soil Sci. 123:258-263.

Miyamoto, S. 1977. Effects of wetting agents on water infiltration into water-repellent coalmine spoils. Soil Sci. (In Press).

Osborn, J. F., J. Letey, and N. Valoras. 1968. Surfactant longevity and wetting characteristics. Calif. Agr. March, 1969. p. 6-8.

Parr, J. F., and A. G. Norman. 1965. Considerations in the use of surfactants in plant systems: A review. Bot. Gaz. 126:86-96.

Pelishek, R. E., J. Osborn, and J. Letey. 1962. The effect of wetting agents on infiltration. Soil Sci. Soc. Amer. Proc. 26:595-598.

Valoras, N., J. Letey, and J. F. Osborn. 1969. Adsorption of nonionic surfactants by soil materials. Soil Sci. Soc. Amer. Proc. 33: 345-348.

BOOK REVIEWS

The Lands Nobody Wanted. A Conservation Foundation Report. By William E. Shands and Robert G. Healy. The Conservation Foundation, 1717 Massachusetts Avenue, N.W., Washington, D.C. 20036. 1977. 282 p. $14.50 cloth, $10.50 paper.

The Conservation Foundation, "a nonprofit research and communications organization dedicated to encouraging human conduct to sustain and enrich life on earth," initiated this review of Forest Service policy, programs, and management in the eastern United States in 1974. This book contains the Foundation's findings, as well as its recommendations for future management of the Eastern National Forests.

Early in the book, the authors point to the unique history surrounding the National Forests east of the 100th meridian. Movement of industry predominantly into the East at the turn of the century, along with unsuccessful farming attempts on marginal lands, resulted in the reduction in size and quality of the area's forests. Many cut-over lands were then abandoned and wildfire took its toll. Massive erosion and regrowth of poor quality vegetation resulted.

Although the Organic Act of 1897 was the founding legislation of the Forest Service, it was applied mainly in the West. Vast tracts of publicly owned land formed into National Forests for purposes of "protecting water flow and providing a continuous supply of timber for the United States." Although there were a few opportunities to establish National Forests in the East, the system did not really get a foothold there until passage of the Weeks Act in 1911. This law opened the way for the Federal Government to purchase lands to protect watersheds and return cut- and burned-over lands to productivity.

Since implementation of the Weeks Act, the eastern portion of the National Forest System has grown until today it consists of 50 National Forests, with some 24 million acres in 23 states. Still, this comprises only 13% of the total National Forest System, and the percentage of federal land within Forest boundaries is much less than in the West. Fragmented ownership patterns make workable land management planning difficult to achieve. Yet, the Eastern National Forests are under intensive environmental, economic, and recreational pressures, as evidenced by the fact that 174 million people live within a day's drive of some part of these public lands.

Taking all of this into consideration, the Conservation Foundation is "concerned that the Eastern National Forests are not receiving the special attention they need."

The authors base their recommendations for future policy and programs on two basic principles:

1) National Forests in the East should provide public benefits that cannot be supplied by private land, either because resources are unavailable or because economic incentive is absent; and,

2) Land managers should restore the National Forests as natural ecosystems, distinct from the man-made environments otherwise dominant in the East. The Forests and their products should be used only to the extent that this continuing process of restoration is not interrupted.

The Foundation gives special emphasis to land acquisition needs and priorities of the Eastern National Forests, encouraging increased congressional appropriation of Weeks Act funding and full use of Land and Water Conservation Fund Act dollars. The economic and social importance of public land in the heavily populated East is emphasized.

The Foundation offers suggestions for change in such areas as staffing, planning, compensation to private landowners, incentives, and legislation. The report points out that many changes are necessary if the Forest Service is to meet the challenges facing the National Forests in the East.

Range management and grazing have traditionally received minor consideration on the Eastern National Forests, with only about 15% of the area grazed by livestock. This amounts to only 1 million animal-unit months annually, or less than one-half of 1% of the range grazing in the United States. Most of this is in the southeastern States of Arkansas, Mississippi, and Louisiana.

These figures of actual grazing use contradict the fact that the Eastern National Forests, in reality, are large forage producers, averaging over 800 pounds per acre. A 1972 Forest Service study recognized this highly under-utilized resource, pointing out that Eastern Forests could support as much as four times the current grazing level.

Although grazing has been considerably underplayed on the Eastern National Forests, the Foundation points to two factors that could lead the Forest Service to intensify its eastern range management program. These are conversion of private idle lands back into crop production to help meet current world food demands and an increasing number of cattle being raised in the East.

The authors discuss some ideas that have been tossed around for years: better control of disease and parasite problems in the South, expansion of the forest understory as a grazing resource in the South, and the long-term grazing potential of the northern forests. They are also careful to point out potential problem spots, such as the value of forage to various wildlife, the possibility of damage to young trees, aesthetic impacts of fencing and other structures, damage to the water resource, and problems with herbicides and fertilizers.

The Conservation Foundation's book looks at the National Forests in the East with refreshing objectivity. The authors not only cite problems, but they offer some practical means of utilizing Eastern National Forest resources to the highest acceptable level, while allowing them to fill their very unique role.

The Chief of the Forest Service has recognized the Conservation Foundation report as having considerable importance and practical application to future policy and programs. This book is certainly "must" reading for anyone concerned with the future role of the National Forests in the East.—*Stan Tixier*, Milwaukee, Wisconsin.

Breeding Birds of North Dakota. By Robert E. Stewart. Tri-College Center for Environmental Studies, Fargo, North Dakota. 1975. 295 p. Illus. $18.50.

Robert E. Stewart is employed by the U.S. Fish and Wildlife Service as a staff ecologist at the Northern Prairie Wildlife Research Center, Jamestown, North Dakota. Extensive fieldwork by the author in every county of North Dakota and a comprehensive literature search have been combined to produce a well-documented account of the breeding birds of this Northern Great Plains state.

Environmental attributes of the state and the ecological relations of breeding birds and their habitats and associations are discussed in detail in the introductory chapters. Descriptive accounts are then given for the 196 bird species that are known to breed in North Dakota. Breeding range maps showing distribution in the state and frequency are provided for 165 species.

This book is a valuable reference for ornithologists interested in the Northern Plains. North Dakota hunters of waterfowl and upland game birds, people who like the outdoors, and those concerned with the effects of land use practices in the bird life of the state will find much useful information in the text.—*Meredith J. Morris*, Fort Collins, Colorado.

NEW PUBLICATIONS

ECOSCIENCE: Population, Resources, Environment, Third Edition, by Paul R. Ehrlich, Anne H. Ehrlich, and John P. Holden. W. H. Freeman and Co., 660 Market Street, San Francisco, Calif. 94104. 1977. 1,003 p. $39.95 cloth, $19.95 paper. The present edition, based on *Population, Resources, Environment,* is an attempt to provide a more thorough, up-to-date understanding of the population-resource-environment predicament and to discuss strategies for dealing with it. In format and emphasis it is quite different from the earlier book.

There is a brief introductory chapter designed to give the reader a capsule overview of the predicament of humanity, a framework into which the more detailed discussions that follow can be fitted. The first major section, consisting of three chapters, gives a detailed review of the physical and biological systems of Earth.

The second section covers population and renewable resources—land, soil, water, forests, and food. The coverage of all these topics has been updated and considerably enlarged from that in the second edition of *Population, Resources, Environment.* The third section covers energy and materials far more comprehensively than did previous books, with special attention paid to nuclear energy and other possible sources for the long term, as well as the potential of energy conservation.

The material on environmental disruption in the fourth section has been updated and includes more comprehensive coverage of carcinogens, mutagens, climate modification, and many other topics. The last section on social, economic, and political change, including the issue of population control, has likewise been considerably expanded.

Extensive footnotes with references to the technical literature document key points throughout the book. In addition, at the end of each chapter there is a brief list of references, Recommended for Further Reading, containing selections of the most generally useful works for further exploration of the topics in the chapter which precedes the annotated chapter bibliograhies.

LAND USE: Tough Choices in Today's World. Special Publication No. 22 by Soil Conservation Society of America, 7515 Northeast Ankeny Road, Ankeny, Iowa 50021. 1977. 454 p. $7.00. This is a publication of the proceedings of a National Symposium presented by the SCSA in Omaha, Nebr., in 1977. It presents 53 papers encompassing a comprehensive review of land use planning problems, implementation, experiences and the courts' reactions to those programs. The papers are presented by planners, natural resource specialists, attorneys, federal, state, and local governmental officials, landowners and laymen. Subjects deal with facing the tough land use choices: competition for land, preserving land for food and fiber production, providing for living space and natural space, federal and state involvement in land use planning, and a special section on the role of citizens, landowners, planners, elected officials, developers, attorneys, and the courts in the land use planning process.

Range Management Theses 1968–1975

Compiled and Edited by
REX D. PIEPER
New Mexico State University, Las Cruces

continuation

IOWA STATE UNIVERSITY

*Bernal, Javier. 1974.** Evaluation of carbohydrate reserves, field, and quality in three tropical grasses.
*Brotherson, Jack DeVon. 1969.** Species composition, distribution, and phytosociology of Kalsow prairie in Iowa.
*Bryan, William Barter. 1969.** Voluntary intake by grazing steers and digestibility trends of tall fescue and reed canary-grass as summer and fall-saved pasture.
DeWitt, Dennis Lee. 1973. Influence of nutrition on growth and body composition of steers.
Kennedy, Robert Kenneth. 1969. An analysis of tall-grass prairie vegetation relative to slope position, Sheeder Prairie, Iowa.
*Markland, Flave Eugene. 1968.** Influence of nitrogen and potassium on growth, chemical composition, and anatomical structure of *Agrostis palustris* Huds.
Richards, Mary Seitz. 1969. Observations on responses of prairie vegetation to an April fire in central Iowa.
Ryan, Michael Joseph. 1970. Nitrates in forage grasses as affected by time and level of nitrogen application.
Schaefer, Peter Brooks. 1973. Correlations between production and carcass characteristics of beef cattle.
Schmitt, Donald Peter. 1969. Plant parasitic nematodes and nematode populations in Kalsow Prairie.
*Stoneburner, Daniel Lee. 1970.** Forest-prairie boundary energetics and secondary succession.
Thomas, Adrienne Charlene. 1970. The cattlemen and the passage of the Taylor Grazing Act of 1934.

UNIVERSITY OF MONTANA

Aderhold, Michael W. 1972. The history, winter range, and current status of the Rock Creek, Montana, bighorn sheep herd.
Brunner, J. David. 1971. Primary production of a rough fescue ecosystem in western Montana.
Klumph, Samuel E. 1969. A study of the weight gains of cattle on provincial grazing reserves in central Alberta.
Knoche, Kenneth G. 1968. The ecology of the Rattlesnake Creek, Montana, mule deer winter range.
Lafferty, Ralph R. 1970. Effects of burn intensity of vegetal composition.
Majerus, Mark E. 1972. The response of root and shoot growth to decrease in soil water potential.
Marcum, Les. 1971. Vegetal development on montane fir clearcuts in western Montana.
Olson, Gary R. 1973. Range condition on abandoned croplands in north central Montana.
Ries, Ronald E. 1968. Herbage and timber production under a western Montana pine canopy.
Sindelar, Brian W. 1971. Douglas-fir invasion of western Montana grasslands.
Synder, Roy O. 1969. Forage competition between cattle and elk in the Gird Creek drainage of western Montana.
Taskey, Ronald D. 1972. Soils contamination at Anaconda, Montana: History and influence on plant growth.
Warner, Ralph A. 1970. Some aspects of browse production in relation to timber harvest methods and succession in western Montana.

UNIVERSITY OF NEVADA

Beeson, C. Dwight. 1974. The distribution and synecology of Great Basin pinyon-juniper.
Booth, D. Terry. 1974. Photographic remote sensing techniques for erosion evaluations.
Cole, Norman J. 1968. Mule deer utilization of rehabilitated Nevada rangelands.
David, J. Barry. 1971. Estimating plant production from soil and floristic correlates in Hot Creek Valley, Nevada.
Deibert, William Jerry. 1968. Mule deer condition and food habits on two Nevada ranges.
Delmas, Richard Emmett. 1971. Mule deer food habits and condition on the Ruby-Butte study area.
Everett, Richard L. 1974. Plant and soil water potentials in big sagebrush and shadscale communities.
Halvorson, Ronald M. 1974. ERTS-1 imagery for vegetation mapping and phenology detection in Nevada.
James, Alvin R. 1968. Establishing perennial shrubs and grasses on lands of the Pyramid Lake Indian Reservation.
Kipping, Karl L. 1968. Ground photographic techniques for range condition and trend analysis.
Lorain, Garwin E. 1970. 70 mm large scale aerial photography for range resources evaluation.
Pudney, Richard Alvah. 1972. Food preferences of mule deer on the Ruby-Butte study area.
Ratliff, Joe Michael. 1972. Remote sensing evaluations of phreatophytic vegetation in Nevada.
Rohwer, Gary Lamont. 1970. Blood composition of wintering Nevada mule deer (*Odocoileus hemionus hemionus*).
Savage, David E. 1968. The relationship of sage grouse to upland meadows in Nevada.
Seher, J. Scott. 1972. Color and color infrared aerial photography for waterfowl habitat evaluation.
Sheeter, Guy Richard. 1968. Secondary succession and range improvements after wildfire in northeastern Nevada.
Swanson, John David. 1972. Color infrared photography for analysis of vegetation changes in Hot Creek Valley, Nevada.
Tower, Jerald D. 1970. Vegetation stagnation in three-phase big game exclosures and its effects in determining forage utilization.
Wilkie, Charles Faye. 1966. Range condition and trend by frequency sampling.
Zamora, Benjamin Abel. 1968. *Artemisia arbuscula, A. longiloba,* and *A. nova* plant associations in central and northern Nevada.

NEW MEXICO STATE UNIVERSITY

Adi, Sora. 1969. The effect of nitrogen fertilization on chemical composition and in vitro digestibility of blue grama.
Aguirre, Edmundo L. 1971. Effects of watering treatments on emergence of plant species in soil collected from different desert grassland sites.
Allegri, Mario. 1973. Some effects of soil fertility on yield and composition of forage sorghum.
Alvarez, Claudio Arzola. 1972. Effects of soluble silica on in vitro digestibility of some range grasses and on the metabolism of albino rats.
Anderson, Bruce L. 1972. Growth response and deer utilization of fertilized browse.

Bekele, Ermias. 1972. Effects of clipping frequency and clipping height on greenhouse production of nitrogen-fertilized blue grama grass.

Boggino, Eloy J. A. 1970. Chemical composition and in vitro dry matter digestibility of range grasses.

Cordova, Francisco J. 1974. Chemical composition and in vitro digestibility of some browse and forb species of southern New Mexico.

Cox, Jerry R. 1974. Growth response of fertilized wavyleaf oak.

DeLaTorre, Raul. 1970. Chemical composition and digestibility of tobosa.

Fulgham, Kenneth O. 1972. Effects of types and rates of nitrogen fertilizers on blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) rangeland production.

Fraser, Joseph G. 1968. Some autecological characteristics of walking-stick cholla (*Opuntia imbricato* (Haw.) DC.) in New Mexico.

Fretes, Ruben A. 1969. A grassland survey of the departamento of Paraguari, Paraguay.

Germany, James C. 1969. Mule deer habitat preference on the pinyon-juniper ranges of Fort Stanton, New Mexico.

Hatch, Carl F. 1968. Chemical composition and nylon bag digestibility of range grasses.

Hills, Jack M. 1968. Intake and digestibility of range forage by Hereford and Santa Gertrudis cows.

Kelsey, R. Joe. 1971. Chemical composition and digestibility of unfertilized and nitrogen-fertilized blue grama.

Kiesling, Herman E. 1968. Intake and digestibility of tobosa (*Hilaria mutica*) by grazing steers.

Korzdorfer, Edward J. 1968. Seeding, furrowing, brush removal, and rabbit exclusion on creosotebush-infested sites.

Law, Lamont W. 1968. Ecotypic variation in seed and seedling characteristics in New Mexico galleta grass.

Leifeste, William F. 1971. Control of mesquite in southeastern New Mexico.

McDonald, Fred W. 1974. Response of oneseed juniper to nitrogen fertilization.

Meyer, William W. 1973. Effect of pH on the germination of burroweed (*Happlopappus tenuisectus*) at a constant osmotic pressure.

Nava, Guillermo. 1970. Occurrence of vegetation and emergence of species from surface soil collected on two southwestern desert range sites.

Perez-Garcia, Alberto. 1971. A vegetational survey of the Teseachic Ranch of the University of Chihuahua, Chihuahua, Mexico.

Rawlins, William J. 1973. Fire and clipping studies on campo grasslands of the Planalto Central of Brazil.

Rea, Kenneth H. 1972. Competitive relationships between cholla cactus (*Opuntia imbricata* (Haw.) DC.) and blue grama grass (*Bouteloua gracilis* (H.B.K.).

Reed, Jerry L. 1969. Effects of nitrogen fertilization on clipping, on production, and water usage in blue grama.

Rosiere, Randy E. 1973. Cattle diets on semidesert grassland.

Russell, J. William. 1973. Soil-plant-livestock-weather relationships of a range ecosystem: interactive timeshare regression and simulation model approaches.

Schickedanz, Jerry G. 1970. Vegetation and cattle response to nitrogen-fertilized rangeland.

Seefeld, Terry C. 1974. Effects of rest treatments on production and morphology of blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) rangeland.

Thetford, Frank O., Jr. 1970. Botanical and chemical composition of cattle and sheep diets on pinon-juniper grassland range.

Welsh, Richard G. 1972. Some ecological relationships between creosotebush (*Larrea tridentata* DC.) and bush muhly (*Muhlenbergia porteri* Scribn.).

Wile, William W. 1972. The effects of burning and nitrogen fertilization on the underground biomass and soil characteristics of a blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) rangeland.

Zambuk, Umaru Y. 1974. The germination responses of three semidesert grasses to temperature, moisture, and depth of planting.

NORTH DAKOTA STATE UNIVERSITY

Aalgaard, Ronald Bruce. 1973. Movements of the white-tailed deer (*Odocoileus virginianus*), in the prairie-marsh deer range of south-central North Dakota.

Abouguendia, Zoheir M. 1973. Net primary production and turnover in a mixed-grass prairie.

***Dodd, Jerrold Lowell. 1970.** Distribution and community and site relations of bluebunch wheatgrass in North Dakota.

***Dosland, John Gerald. 1969.** Studies relating to bud dormancy and auxin catabolism in *Euphorbia esula* L.

Green, Curtis Edward. 1969. Morphological variation in three ecotypes of *Agropyron smithii* Rydb. and *Bouteloua gracilis* (H.D.K.) Lag. ex Steud.

***Hegstad, Glen Dewey. 1973.** Vascular flora of Burke, Divide, Mountrail, and Williams counties.

***Johnson, Warren Carter. 1971.** The forest overstory vegetation of the Missouri River Floodplain in North Dakota.

***Keammerer, Warren Ray. 1972.** The understory vegetation of the bottomland forests of the Missouri River in North Dakota.

Kramer, James Lowell. 1973. Vegetation and soil responses to burning, mowing, and fertilization in the Schyenne National Grassland of North Dakota.

Lauenroth, William Karl. 1970. Dynamics of dry-matter production in a mixed prairie in western North Dakota.

***Lorenz, Russell James. 1970.** Responses of mixed prairie vegetation to fertilization and harvest frequency.

Martin, Larry Kennedy. 1973. Seasonal movements of white-tailed deer in North Dakota.

***Prasad, Rupi. 1968.** Morphological and developmental studies on the suppression of bud growth in *Euphorbia esula* L.

***Sanford, Richard Charles. 1970.** Skunkbush (*Rhus trilobata* Nutt.) in the North Dakota Badlands: ecology, phytosociology, browse production, and utilization.

Seiler, Gerald. 1973. Vascular flora of Richland, Ransom, and Sargent counties, North Dakota.

***Ward, Richard LeRoy. 1973.** A cytotaxonic study of the *Scirpus lacustris* L. complex in the Northern Plains States.

Willenbring, R. E. 1971. The vascular flora of Pembina County.

***Wolters, Gale Leon. 1968.** Characterization of the growing-season micro-environment of the mixed-grass prairie of southwestern North Dakota.

***Zaczkowski, Nicholas Kilian.** Vascular flora of Billings, Bowman, Golden Valley, and Slope counties, North Dakota.

OREGON STATE UNIVERSITY

Bauer, W. 1969. Evaluation of dry-weight-rank and microscopic point techniques for seasonal botanical analysis of two pasture mixes.

Crawford, James C. 1970. Taste responses in Columbia black-tailed deer (*Odocoileus hemionus columbianus* (Richardson).

Erickson, Lloyd Ronald. 1974. Livestock utilization of a clearcut burn in northeastern Oregon.

Findley, Roger Raymond. 1974. Changes in plant communities following rangeland brush control.

***Garcia-Moya, Edmundo. 1972.** A preliminary vegetation classification of the Tombstone, Arizona, vicinity.

Handl, William P. 1972. Influence of spring crested wheatgrass production on intake of grazing steers.

Hines, William W. 1971. Plant communities in the old-growth forests of north coastal Oregon.

***Johnson, James Russell. 1975.** Small scale photo probability sampling and vegetation classification in southeast Arizona as an ecological base for resource inventory.

Knothe, Kenneth P. 1969. Aerial photo interpretation of vegetation and soil surface features on the browse-grass rangeland in southeastern Oregon.

Markgraf, Peter M. 1970. Herbage production on three vegetation types in the High Desert of eastern Oregon.

Martin, Niels L. 1970. Development of a legend and key for ecological resource analysis in the 15-mile administrative unit, Malheur County, Oregon.

McDaniel, Kirk Cole. 1974. A comparative study of two land classification systems for use with remote sensor data.

Miller, Richard Frank. 1974. Spring, summer, and fall use by cattle and big game on foothill rangelands.

***Pettit, Russell D. 1968.** Effects of seeding and grazing on a clearcut burn in a mixed-coniferous forest stand of the Wallowa Mountain foothills.

***Pyott, William T. 1972.** Numerical classification of range vegetation and statistical analysis of its ecology.

Reece, Patrick Eldon. 1975. Autecology of three perennial grasses relative to microenvironmental modification following permanent defoliation of Wyoming big sagebrush.

Ross, George Franklin. 1974. The identification of selected vegetation types in Arizona through the photointerpretation of intermediate scale aerial photography.

Scandarani, Muhei-Eddin G. 1972. Range improvements.

Schrumpf, Barry J. 1968. Methodology for cuticular identification of selected eastern Oregon range plants.

*Schrumpf, Barry James. 1975. Multiseasonal-multispectral remote sensing of phenological change for natural vegetation inventory.

*Segura-Bustamante, Mariano. 1970. Ecology of bitterbrush (*Purshia tridentata* (Pursh.) DC.) in the Silver lake deer winter range, Oregon.

Sheehy, Dennis Patrick. 1975. Relative palatability of seven *Artemisia* taxa to mule deer and sheep.

***Stuth, Jerry W. 1975.** Livestock, deer, and logging interactions in the lodgepole pine-pumice region of central Oregon.

***Turner, Robert B. 1969.** Vegetation changes of communities containing medusahead (*Taeniatherum asperum* (Sim.) Nevski) following herbicide, grazing, and mowing treatments.

Van Zwoll, Wayne Cornell. 1975. Chemical analysis of three forage plants collected from pastures suspected of inciting acute bovine pulmonary emphysema.

***Wood, Benjamin W. 1971.** Response of Canada milkvetch (*Astragalus canadensis* var. *mortonii* (Nutt.) to range and forest improvement practices in northeastern Oregon.

SOUTH DAKOTA STATE UNIVERSITY

Benson, Lawrence A. 1973. Reflectance measurements for the detection and mapping of soil limitations.

Byers, Keith L. 1973. Evaluation of methods of reducing seed dormancy in switchgrass, Indiangrass, and big bluestem.

Cady, Howard G. 1972. Ecological succession along Missouri River Reservoirs as it relates to development of forest environment.

***Coffman, Charles D. 1972.** The biology of *Geomylichus geomydis* N. Sp. (Acari: Listrophoridae) from the plains pocket gopher, *Geomys B. Bursarius* (Shae).

Cogswell, Carolyn A. 1971. A characterization of four prairie grasses.

***Cogswell, Carolyn A. 1974.** Pine needle (*Pinus ponderosa*) abortive factor and its biological determination.

Doyle, John J. 1969. The effect of fertilization of a native lowland pasture on forage intake and nutritional value of diet selected by grazing sheep.

Graber, Cecil R. 1970. Pasture supplementation of beef cattle followed by drylot finishing with high-concentrate rations and antibiotic supplement.

Grenz, G. K. 1971. Effects of applied nitrogen and phosphorus on native grasslands in the northern Great Plains.

***Gross, Delmer F. 1974.** Improving water use efficiency of smooth bromegrass by selecting for regrowth.

Hamm, David C. 1973. Evaluation of cattle use of a deer winter range.

Hamm, Pauline E. 1972. Taxonomic composition, biomass, and trophic structure of grassland invertebrates at Cottonwood, South Dakota.

Hansen, Lloyd H. 1972. Effect of planting methods and seeding rates on the establishment of alfalfa under dryland and irrigation.

Harr, Douglas C. 1971. Interpretive potential of South Dakota wetlands.

Heil, R. 1972. Recognizability and reproductibility of air photo interpreted landscape units.

Hillman, Conrad N. 1968. Life history and ecology of the black-footed ferret in the wild.

Hoar, Donald W. 1969. Factors influencing urinary calculi in lambs.

Jacquette, Dale L. 1972. Tissue ammonium nitrogen in sheep tongue, liver, and kidney following death by ammonia intoxication.

Jense, Grant K. 1968. Food habits and energy utilization of badgers.

Jensen, Gerald L. 1967. Drought resistance of ponderosa pine and eastern redcedar on central South Dakota soils.

Kirkpatrick, William C. 1971. The effects of acute ammonia toxicity on certain hemogram parameters in sheep.

Kranz, Jeremiah J. 1971. A comparison of aspen and pine communities in the northern Black Hills.

Lengkeek, Venance H. 1974. The decomposition of organic matter in two mid-grass prairies in western South Dakota.

Lockert, R. A. 1974. Influence of growth stage, stubble height, and cutting frequency on the carbohydrate reserves and yield of switchgrass.

Mariam, E. K. 1972. Taxonomy of the *Agropyron intermedium* and *Agropyron trichophorum* complex.

Moore, Gary L. 1968. Chlorinated hydrocarbon residues in pronghorn antelope (*Antilocapra americana americana* (ORD) 1815) of South Dakota collected in 1966.

Morihara, Dennis K. 1974. Biological control of musk thistle (*Carduus nutans*) in South Dakota.

***Nearman, Lance J. 1973.** Insect biological control studies on Canada thistle (*Crisium arvense* (1.) Scop.) in South Dakota.

***Onstad, Charles. 1972.** An incrementally distributed mathematical model of a watershed.

Pfeiffer, Donald G. 1972. Effects of diethylstilbestrol on reproduction in the black-tailed prairie dog.

Renhowe, Bruce A. 1968. Food habits of the sharp-tailed grouse (*Pedioecetes phasianellus jamesi*).

Rodgers, David. 1972. The effect of range condition and season of grazing on the amount and quality of the diet selected by grazing steers.

***Schaber, Burton D. 1973.** Evaluation of the flea beetle (*Alica caduorum* Guer.) (Coleoptera: Chryelidae) as a control agent of Canada thistle (*Cirsium arvense* (1.) Scop.) in South Dakota.

Schenck, Theron E., III. 1971. Food habits of deer in the southern Black Hills as determined by the point technique.

Sheets, Robert G. 1970. Ecology of the black-footed ferret and the black-tailed prairie dog.

***Smolik, J. D. 1973.** The role of nematodes in a South Dakota grassland ecosystem.

Sorensen, James T. 1972. Germination and vegetative propagation of native prairie forbs.

Ternus, Gary S. 1968. Urea supplementation of high roughage rations for wintering calves.

Thaden, Ronald T. 1973. In vitro digestibility of diallel and polycross progenies of intermediate wheatgrass.

Weber, J. B. 1972. Intermediate wheatgrass seed production responses to fertilizer and cultural practices.

Wickstrom, Roger P. 1970. Interseeding as a grassland improvement practice in central South Dakota.

Wurster, Marvin. 1969. A comprehensive evaluation of three selected species of cultivated grasses.

Yelverton, Charles. 1974. Ammonia levels in maternal and fetal tissues and blood of urea-treated sheep.

(To be completed in the next issue.)

Statement of Ownership, Management, and Circulation

(Act of August 12, 1970, Sec. 3685, Title 39, United States Code)

1. *Title of Publication:* JOURNAL OF RANGE MANAGEMENT
2. *Date of Filing:* September 16, 1977.
3. *Frequency of Issue:* Bimonthly
4. *Location of Office of Publication:* 2760 West Fifth Ave., Denver, Colo. 80204
5. *Location of General Business Office:* Same
6. *Names and Addresses of:*
   Publisher: Society for Range Management, 2760 West Fifth Ave., Denver, Colo. 80204
   Editor: Rex D. Pieper, Dept. of Animal and Range Sciencies, New Mexico State Univ., Las Cruces, N. Mex. 88001
   Managing Editor: David A. Smith, 2760 West Fifth Ave., Denver, Colo. 80204
7. *Owner:* Society for Range Management, 2760 West Fifth Ave., Denver, Colo. 80204
8. *Known Bondholders, Mortgagees, etc.:* None
9. *For Completion by Nonprofit Organizations Authorized to Mail at Special Rates:* The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during preceding 12 months.
10. *Extent and Nature of Circulation*

	Avg. for 12 months	Actual for issue nearest filing date
A. *Total copies printed*	6,519	6,550
B. *Paid Circulation*		
1. Dealers, counter sales	0	0
2. Mail subscriptions	5,978	6,032
C. *Total paid circulation*	5,978	6,032
D. *Free distribution*	0	0
E. *Total distribution*	5,978	6,032
F. *Copies not distributed*	541	518
G. *Total*	6,519	6,550

I certify that the statements made by me above are correct and complete. —*David A. Smith,* Managing Editor.

You are cordially invited to join the Society for Range Management

the Society

. . . (founded in 1948) is a private, non-profit, professional association dedicated to advancing a comprehensive understanding of range ecosystems and the intelligent use of all range resources. The Society assists all who work with rangelands to keep abreast of new findings and applications in range management and strives to create a public appreciation of the benefits to be derived from proper range use.

Membership

. . . in the Society is open to anyone engaged in or interested in the study, management, or use of range ecosystems. Members—from more than 35 countries—include research scientists, ranchers, governmental agency administrators, advisory and technical assistance personnel, teachers, students, and people from the business community.

Meetings

. . . held on a regular basis by the Society and each Section, provide for a face-to-face exchange of technical information, ideas, and philosophies. The Society holds a major meeting each year in February, and Section meetings afford members an opportunity to examine applied range management methods and to discuss matters of immediate and local interest.

Publications

. . . include two bimonthly periodicals—*Journal of Range Management* and *Rangeman's Journal*—as well as special publications that are issued from time to time. Through these publications (which feature timely articles of general interest, research reports, management notes, viewpoints, book reviews, and news about Society members and activities) members are kept current on information pertinent to rangeland management and use.

SOCIETY FOR RANGE MANAGEMENT
2760 W. 5th Ave., Denver, CO 80204

FOR OFFICE USE ONLY No.							C/M	SEC	
RR	K	ID	SS	AP	D	JRM RJ	C	ZL	L

Please Print   Date ______________ 19 __

NAME ______________________________

ADDRESS ______________________________

____

MEMBERSHIP CLASS: Regular ☐ **Student** ☐ **Individual Sustaining** ☐ **Life** ☐

Dues paid herewith $ __________ are for calendar year 19 ____

I wish to be affiliated with the ______________________ Section

Membership solicited by ______________________

Make check, draft, or money order payable to SOCIETY FOR RANGE MANAGEMENT. Mail to the Society at 2760 West 5th Avenue, Denver, Colorado 80204.

Your cooperation is requested in completing the following information for our files. Please print.

Date of birth ______________________

Occupation (or Position Title) ______________________

Employer ______________________

Education (This information is for statistical purposes, not used on an individual basis.)

High School ☐ College(s)–Degree(s)–Major(s) ______________________

____

____

Applicants for Student membership please complete the following:

Name of school ______________________

Freshman ☐ Sophomore ☐ Junior ☐ Senior ☐ Graduate ☐

1978 DUES SCHEDULE

	Regular	Student	Individual Sustaining	Emeritus
ARIZONA Section	$23.00	$12.00	$34.00	$16.50
CALIFORNIA Section	23.00	11.00	33.00	16.50
COLORADO Section	21.00	11.00	31.00	14.50
IDAHO Section	22.00	12.00	32.00	15.50
KANSAS-OKLAHOMA Section	22.00	12.00	32.00	15.50
NEBRASKA Section	23.00	11.00	33.00	16.50
NEVADA Section	22.00	12.00	32.00	15.50
NEW MEXICO Section	22.00	11.00	32.00	15.50
NORTHERN GREAT PLAINS Section	23.00	13.00	33.00	16.50
INTERNATIONAL MOUNTAIN Section	22.00	12.00	32.00	15.50
PACIFIC NORTHWEST Section	22.00	12.00	32.00	15.50
SOUTH DAKOTA Section	22.00	12.00	32.00	15.50
SOUTHERN Section	25.00	15.00	35.00	18.50
TEXAS Section	23.00	12.00	33.00	16.50
UTAH Section	23.00	13.00	33.00	16.50
WYOMING Section	23.00	12.00	33.00	16.50
NATIONAL CAPITAL Section	21.00	11.00	31.00	15.50
MEXICO Section	24.00	14.00	34.00	17.50
NORTHCENTRAL Section	22.00	12.00	32.00	15.50
*Unsectioned**	22.00	12.00	32.00	15.50

Effective October 1977