10-79

NATIONAL ACADEMY of SCIENCES

I, II, III

PHASE I INTERIM REPORT

ON WILD AND FREE-ROAMING HORSES AND BURROS

A Report Prepared by the

Committee on Wild and Free-Roaming Horses and Burros

Board on Agriculture and Renewable Resources

Commission on Natural Resources

National Research Council

NATIONAL ACADEMY OF SCIENCES

Washington, D. C. October 1979

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NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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CHAPTER 1

EXECUTIVE SUMMARY

1. The Wild and Free-roaming Horses and Burros Committee sponsored by the National Academy of Sciences has met four times since June 28, 1979. The Committee is subdivided into three subcommittees, the first dealing with equid biology, the second with the effects of equids on various parts of the ecosystem, and the third with the legal and political, the economic, and the sociological aspects of land management pertaining to equids.

2. Since the creation of the Committee, its subcommittees and individual members have engaged in a number of Committee related activities. Among other things, they have surveyed the published literature, reviewed intradepartmental documents, reports, and other forms of fugitive literature, examined and analyzed data from the files of the Bureau of Land Management and the Forest Service, interviewed numerous experts on various equid-related issues, conducted a public hearing, flown with BLM personnel during equid census activities, studied court cases, and visited BLM and Forest Service offices.

due around Dec 1980

3. This is an interim report on those activities, which thus far have resulted in a partially completed assessment of knowledge on wild and free-roaming horses and burros, and descriptions of nine proposed research projects to fill gaps in current knowledge.

4. Although numerous options are possible, the Committee has concentrated on assessing knowledge relevant to intermediate-intensity management for allocating herbage to several herbivorous species, since that is the general level of management found in current programs.

* 5. Although there are strong and conflicting opinions about the impact of wild equids on plant communities, only a small number of studies has been conducted to measure that impact, and the results have been less than definitive.

6. The digestive patterns of equids and ruminants have yet to be compared conclusively because few data exist on

the consumption and digestibility patterns of equids subsisting on rangeland forage.

7. Consideration is given to blood assays as indices of the equid nutritional plane and the nutritional adequacy of their forage.

8. Because factual data are virtually nonexistent, theoretical consideration is given to the possibility of interspecific competition between wild horses and cattle and the role such competition might play in the development of site-suitability criteria.

9. Since few data exist on the impact of equids on range hydrology, a research project is needed to determine their effects on water infiltration, water run-off, and riparian zones.

10. Studies of other animals suggest that it may be possible to suppress fertility in wild mares through the use of endocrine implants that would remain effective for a number of years.

11. Several drugs, especially etorphine (M99), have been used successfully to subdue captive equids.

12. The major political subject needing study is how scientific information is used in decision making.

13. A number of economic and sociological studies should be conducted, including (a) an evaluation of the wild-horse adoption procedure and its success, (b) an evaluation of control and management techniques, (c) a determination of the optimal numbers of wild horses and burros and alternative management strategies for maintaining populations, (d) an evaluation of the costs of existing legal regulations and restrictions, and (e) a determination of public attitudes, values, and preferences regarding wild equids.

14. Although roughly twice as many projets will eventually be proposed by the Committee, nine are recommended at this time: (a) habitat preference and use; (b) grazing impact on plant communities; (c) food consumption rates and nutrition; (d) nutrition, condition indices, and reproduction; (e) blood assay; (f) hydrologic impact; (g) riparian zone impact; (h) contraception; and (i) public attitudes.

15. The design for Projects 1, 2, 3, 5, 6, and 7 should involve analysis of the impact of grazing by horses alone, cattle alone, and combined horse and cattle grazing, each at moderate and heavy intensities. In addition, Projects 2 and 6 should include control plots where no grazing is allowed.

Projects 1 and 7 should utilize plots of about five to six square miles and involve wild equids. Projects 2, 3, and 6 should utilize plots ranging from about 100 to 320 acres and can involve domestic horses. Project 5 should be carried out in conjunction with both the large- and small-scale projects. The foregoing projects, with the suggested variations, should be replicated three or four times, perhaps once in each of three or four states.

16. The projects listed above would place their emphasis on horses and cattle. Similar designs could be set up for burros and cattle. Sheep could also be added in various ways to the project designs, as could wild ruminants, but in each case would greatly increase the required number of experimental activities.

17. Projects 4 and 8 can be conducted in small enclosures with domestic horses.

18. Project 9 should be conducted with survey techniques and an appropriately designed sampling scheme to ascertain the views of the general public as well as those of diverse interest groups.

CHAPTER 2

INTRODUCTION

This interim report is submitted in partial compliance with the Public Rangelands Improvement Act of 1978 and a 1979 contract between the U.S. Department of the Interior and the National Academy of Sciences (NAS). Both the Act and the contract direct the National Academy of Sciences to impanel a committee to assess the state of knowledge relevant to the management of wild and free-roaming horses and burros, to design a research program that will provide the additional information needed by the Department's Bureau of Land Management (BLM) to design sound management programs, to review and oversee the research program during its two years of existence, and to prepare a final report on the research program. The state-of-knowledge assessment and the design of the research program were designated Phase I of the undertaking and originally were to be completed by October 31, 1979.

A Committee on Wild and Free-roaming Horses and Burros was impanelled in June 1979, and in July the Committee asked and was given an extension of time to complete Phase I. The Committee proposed to submit an interim state-of-knowledge assessment on October 31 along with designs for certain research projects which should span two horse-breeding seasons. That interim assessment and the designs for nine research projects form the content of this interim report. The Committee will submit the completed assessment and remaining research designs on or before December 31, 1979.

CHAPTER 3

COMMITTEE OPERATING PROCEDURES

The contract sets out the areas of knowledge considered important to the development of a sound horse and burro management program and therefore requiring consideration in the state-of-knowledge assessment and the design of a research program. These are as follows:

a. Inventory--population estimates, techniques, indexes.

b. Wild horse and burro population dynamics--herd size, sex and age classes, reproduction rates, survival mortality for adults and foals, natural controls, and other population controls.

c. Forage requirements--comparisons to wildlife and livestock.

d. Impact of wild horses and burros on the public rangelands--interrelationship of wild horses and burros with habitat, fish, wildlife, recreation, water and soil conservation, and domestic livestock grazing.

e. Socioeconomic relationships of population control and management.

At its first meeting on June 28 and 29, 1979, the Committee developed a range of subtopics under the five subject areas above. These were divided into three general categories:

1. The demography and ecology of horses and burros, with primary attention to environmental influences, both physical and biotic, that affect these equids.

2. The effects of horses and burros on various components of their environments, especially vegetation, domestic animals, wildlife, and watersheds.

3. The legal and political, the economic, and the sociological issues that pertain to horse and burro management.

These categories were assigned to three subcommittees, respectively:

1. Walter Conley, Chairman
   Francisco Ayala
   Lee Eberhardt
   Patricia Moehlman
   Ulysses Seal

2. John Malachek, Chairman
   John Artz
   Gerald Gifford
   J.W. Swan
   Frederic H. Wagner

3. Walter Johnston, Chairman
   Gail Achterman
   Sally Fairfax
   Stephen Kellert

The subcommittees then set about the task of gathering state-of-knowledge information from a variety of sources.

Subcommittee 1

Subcommittee 1 has conducted a preliminary literature search by examining research reports, unpublished theses, impact statements, and popular literature. Other literature cited in these documents was then traced and cross-referenced. The search revealed that the available literature on the biology of wild equids was incomplete or shallow in some respects, irrelevant to the Committee's purposes in others, and quite complete in still others. In its effort to be comprehensive, the subcommittee consulted Wildlife Review (1936 to the present), the Denver Library (U.S. Fish and Wildlife Service cooperating), and BIOSIS (Biological Abstracts: 1969-present). BIOSIS alone produced over 15,000 citations and associated codes (1969-1979) keyed to the single word "equidae." These citations were obtained and individually screened. Broad subject categories were created, and all citations were listed under appropriate categories. (These files are available at New Mexico State University.) Other computer-based reference sources that were searched included Medline (Index Medicus) and Dialog through the Lockheed system. Science Citation Index and the bibliographies of individual articles were also consulted.

Since Bureau of Land Management (BLM) and U.S. Forest Service (USFS) files contain considerable amounts of field data, representative samples of that data were sought by just identifying agency units that had a history of intense horse or burro activity, or were likely to have information concerning economic and social considerations. Other criteria, such as regional horse and/or burro collection corrals, intense public interest in wild free-roaming horses and burros, general completeness of available records, historical extent of available records, history of research programs, and adequacy of land use plans were also applied.

Agency units thus identified were visited by subcommittee members, personnel were interviewed, and records were copied and grouped for cataloging and evaluation. These agency units included the BLM offices in Phoenix, Arizona; Palomino, Nevada; Susanville, California; Vale, Oregon; Lakeview, Oregon; Burns, Oregon; Salt Lake City, Utah; Pryor Mountains, Montana; and Rock Springs, Wyoming, and the USFS offices at Modoc, California, and Jicarilla, New Mexico. Interviews were conducted during late August and early September 1979, with the exception of Jicarila. In addition, the entire BLM records file previously located at the Denver Center was obtained, reviewed, copied where pertinent, and returned. All these data have been centralized at New Mexico State University.

The literature search of Subcommittee 1 was as complete as possible within the time available, and the search of the formal literature appears to have been essentially adequate. Although the file of unpublished data has not yet been fully analyzed, it appears that the state of the art as reflected in the efforts of the agency units is adequately represented.

L.L. Eberhardt of Subcommittee 1 visited four BLM District offices (Burns, Vale, Lakeview, and Challis) for the purpose of gaining preliminary knowledge of BLM census procedures. His twenty pages of notes and 300 to 400 photographs, combined with a considerable mass of BLM census data and lenghy statistical analyses, will be the basis for the evaluation of BLM census procedures in the final Phase I report. This document file (currently at New Mexico State University) remains to be catalogued and reduced. However, a moderately thorough review indicates that: (a) validation of census methodology is best accomplished via a research program if the decision is to proceed; and (2) such an effort might not be merited, with the exception of an evaluation of past census programs and data produced. Recent Subcommittee 1 efforts have concentrated on designing research projects for the other subjects under its purview. The Subcommittee's progress as of October 31 is summarized in Table 1.

Subcommittee 2

Subcommittee 2 set forth its areas of concern as follows:

TABLE 1 Progress Summary from Subcommittee 1

	State of Knowledge Assessed Yes/No*	Research Proposed Yes/No*	Research Design Complete Yes/No*	Comments
Census	No	Yes	No	Pending review by Eberhardt, Conley, and outside experts.
Immobilization	Yes	No	N/A**	State-of-the-art deemed adequate.
Genetics	No	Maybe	No	Pending review of Seal and Conley by Ayala.
Nutrition (in part)	Yes	Yes	Yes	As pertains to Subcommittee I, includes behavior sampling scheme.
Contraception	Yes	Yes	Yes	Includes behavior sampling scheme.
Site Suitability/ Competition (Part 1--Horse/Cow)	Yes	Yes	Yes	Relates strongly to nutrition project.
Ass Competition with Bighorn Sheep	No	Yes	No	Complete except for write-up (interlocks with horse/cow study).
Reproduction/Demographics	No	Yes	No	About 80 percent complete.
Behavior (General)	No	Yes	No	In progress.
Survival Patterns	No	Maybe	No	Write-up to include rationale for "no progress."
Equid Interactions with Other Species	No	Maybe	No	Birds, small mammals, other "wildlife" besides bighorn sheep.

* A "no" response indicates partial completion, not "no progress."

** N/A = not applicable.

1. Range plant-community impacts of wild free-roaming horses and burros (WFRHB) and associated livestock and native ungulates, including:

a. Seasonal levels of forage-plant utilization (by species) under known stocking rates and species of grazing animals.

b. Effects of specified levels and seasons of grazing and other forms of herbage removal upon (1) plant morphology, (2) carbohydrate reserves, (3) primary production, (4) plant reproduction, (5) plant vigor, and (6) plant survival/mortality.

c. Differential effects of various grazing animal species on the above plant characteristics, elicited by different animal-specific grazing behaviors.

d. Long-term changes in range condition (i.e., range trend) under known intensities, seasons, and classes of grazing use by livestock and wild ungulates.

2. Watershed impacts of WFRHB and associated wild and domestic grazers.

a. Infiltration rates as related to season and intensity of grazing, species of grazer, and vegetation type.

b. Riparian zone responses to WFRHB and associated grazers in terms of water quality (sediment, bed load, fecal coliforms, temperature, total dissolved solids, dissolved oxygen) and channel stability characteristics.

c. Infiltration-rate recovery modes and models for grazed watersheds.

d. Application of the Universal Soil Loss Equation (USLE) for use on grazed watersheds.

3. Range nutrition and feeding ecology of WFRHB and associated domestic and native ungulates.

a. Seasonal dietary botanical composition as related to kinds and amounts of forage available.

b. Daily quantity of forage consumed by WFRHB as related to animal body size, physiological status (i.e., maintenance, growth, reproduction, lactation), and other kinds and amounts of available forage.

c. Nutritional value of diets consumed on rangelands in relation to animals' demands and as affected by season, kind, and amount of available forage in terms of

(a) chemical composition (primarily N, P, and fiber components), and (b) digestibility and digestible energy content.

d. Energy budgets of WFRHB in terms of (a) energy consumed in relation to energy demand for maintenance, growth, reproduction, and lactation, and (b) special energy demands for locomotion and thermoregulation.

e. Development and validation through such techniques as (a) fecal analysis for diet determination, and (b) in vitro digestibility methods appropriate to equine species.

4. Water requirements of WFRHB.

a. Comparative water economies.

b. Seasonal watering behavior, including drinking frequencies and distances traveled to water.

Potential over-lap or joint responsibility is apparent between Subcommittees 1 and 2 in the following areas:

1. Habitat selection by WFRHB and associated ungulates.

2. Competition and other forms of species interaction.

3. Nutrition of WFRHB as related to reproduction, particularly undernutrition.

4. Techniques for assessing nutritional status by means of blood biochemistry.

The literature search on the impacts of animals on plant communities is approximately one-half complete as this is written. Review of watershed-related material is also about one-half complete. Study of material on nutritional aspects is approximately one-third finished.

Subcommittee 3

Subcommittee 3 divided its area of concern into three topics: (1) legal and political issues, (2) economic considerations, and (3) sociological aspects.

The legal and political literature on federal land use planning, multiple-use decision making, wildlife management, and public land history has been reviewed, including manual search of the Index of Legal Periodicals. All civil cases filed under the Wild and Free-roaming Horses and Burros Act of 1971 have been carefully studied with the assistance of

Paul N. Smyth, Office of the Solicitor, U.S. Department of the Interior. Particular attention has been given to the role scientific information has played in policy making.

The state-of-knowledge assesent of economic considerations is based on a literature review addressed to the following topics:

1. Livestock and range economics, with attention focused on the economic characteristics of individual firms in states affected by wild horses and burros.

2. Economic studies (chiefly input-output studies) depicting the structure of livestock-dependent communities and regions, and the impact of possible changes in these structures.

3. Economic valuation of fish and wildlife values, with emphasis on game species of wildlife and possibly wild horses and burros, with the focus on recreation and tourism.

4. Literature on the economic facets of public lands management, including multiple-use and multiple-goal management.

The literature was identified through (1) computerized literature searches, on selected keywords, of the NTIS, USDA/CRIS, and ENVIROLINE reference files, (2) examination of the collection of the library of the Department of Agricultural Economics, University of California, Davis (which includes items listed in the Giannini Library of Agricultural Economics, University of California, Berkeley), and (3) personal discussions with range and resources economists at three land grant universities. The institutions, dates of meetings, and experts involved were the following:

University of Wyoming (September 4-5, 1978)

Richard M. Adams, Associate Professor, Agricultural Economics

David S. Brookshire, Assistant Professor, Economics

W. Gordon Kearl, Professor, Agricultural Economics

Utah State University (September 17, 1978)

E. Bruce Godfrey, Associate Professor, Economics

Darwin B. Nielsen, Professor, Economics

John Workman, Associate Professor, Range Sciences

New Mexico State University (September 20, 1978)

John Fowler, Assistant Professor, Agricultural Economics

James R. Gray, Professor, Agricultural Economics

As of September 27, the literature review was judged to be about three-quarters complete, with Topics 1 and 2 near completion and Topics 3 and 4 comprising a majority of the new entries in the annotated bibliography to be appended to the final report. With few exceptions, the literature search has involved state and national publications of the 1970s. District and planning unit reports and publications are not included.

With respect to sociological issues, the work of Subcommittee 3 has included:

1. A traditional literature search, including bibliographies and indices, and a computer search; and

2. Letters, telephone contacts, and visits with public and private organizations and individuals.

The literature search was based on a list of relevant key words for certain critical time periods, defined as 1956-59, 1968-72, and 1976-79. These were periods when equid legislation was being passed or amended in Congress, and hence when public opinion would have been most in evidence. The search was not confined to these time periods but concentrated primarily on them.

The following sources were searched manually:

Wildlife Review

Keyword Index of Wildlife Research

Conservation and Wildlife Bibliography

Dissertation Abstracts International (Social Sciences and Biological Sciences)

General Science Index

Biological and Agricultural Index

Bibliography of Wildlife Theses

Environment: A Bibliography of Social Science and Related Literature (EPA)

Wild, Free-Roaming Horses - An Annotated Bibliography

Wild, Free-Roaming Burros - An Annotated Bibliography

Natural Science Research Reports - 1973-May, 1978, South-West Region, National Park Service

Card Catalogues at Yale University

Bibliographies of references uncovered by the search

In addition, a computer search was conducted of the entire data bases of NTIS, Current Research Information Service, Envirolines, and Environmental Publications Bibliography. Popular and scientific journals, books, government documents, and master's and doctoral theses were covered.

A lack of useful published material made it necessary to contact various state and federal agencies as well as private conservation organizations to ascertain the available information on public perceptions, attitudes, and understanding of the wild horse and burro issue. This search focused on the past 25-year period. In addition, a great deal of anecdotal information was collected, as well as transcripts from various public meetings.

Contacts were made with 34 agencies and organizations, including BLM, the National Park Service (NPS), the Fish and Wildlife Service, and the Forest Service. Letters requesting information at the state and district level were sent to all BLM state offices and to all state fish and game departments which deal with wild horses and burros. Some 19 private organizations and interest groups were contacted by letter or phone. After careful initial investigation, the Washington offices of five organizations--BLM, NPS, the Humane Society of the United States, the Fund for Animals, and the American Horse Protection Association--were visited to inspect files and interview relevant personnel. Finally, nine academics and other persons with special expertise were consulted. Correspondence and clipping files were identified as potential sources of raw data.

Conclusion

The full Committee has met four times:

June 28-29, 1979 at Salt Lake City, Utah;

July 6-7, 1979 (including a one-day public hearing) at Reno, Nevada;

September 6-8, 1979 (including attendance at a symposium on "The Ecology and Behavior of Feral Equids" at Laramie, Wyoming); and

October 27-28, 1979 at Las Cruces, New Mexico.

In addition, a number of subcommittee or partial subcommittee meetings have been held at various sites. The Committee plans to continue with its operations in November, and expects to complete Phase I by the first of December. Since much remains to be done, it should be clearly understood that the views stated in this interim report are subject to revision. They should not be considered the final views of the Committee.

CHAPTER 4

STATE-OF-KNOWLEDGE ASSESSMENT

Perspective

This Committee is firmly committed to the position that resource management programs require a solid base of factual information. Thus, in its assessment of existing information related to the management of the wild and free-roaming horse and burro populations, it has attempted to focus on those topics needed for management of wild horses and burros and to prescribe research in areas where an adequate data base does not exist. However, the Committee has had to take account of two general considerations.

First, the Committee has had to recognize that, in an era of diverse and changing values, several management alternatives can be envisaged for either a given piece of land at different points in time or for different pieces of land at the same time. Thus, it is possible to manage rangeland (1) primarily for forage allocatin to livestock, (2) for allocation of vegetation to a diversity of herbivores, (3) for herbivores as well as for various other purposes, or (4) according to user preference. Each of these alternatives requires a different kind of management and therefore has somewhat different information needs.

Second, the Committee has had to recognize that there is a wide range of management intensities for the various uses named above. For example, it is possible to conceive of at least four levels of management intensity for alternative (2):

(a) The historical minimum that may have characterized the era before the National Environmental Policy Act, the Federal Land Policy and Management Act, the National Forest Management Act, and the Wild and Free-roaming Horse and Burro Act. Vegetation was largely allocated to livestock, and stocking decisions were based on grazing histories and greater or lesser knowledge of range conditions and trends.

(b) The more contemporary pattern of allocating forage to a variety of species on the basis of careful inventories of range conditions and trends, site-suitability criteria, and concern for animal health. This level of management is possible with relatively little understanding of the relationships linking the status of vegetation, soil, and water resources to grazing pressures, and the responses of animals to different range conditions. It is largely an empirical approach which detects and responds to change but has limited ability to predict change.

(c) Elaboration of (b) through substantial understanding of the nutritional, physiological, and behavioral mechanisms linking animal response to vegetation and plant response to herbivores. This approach permits more insightful planning and decision making, and allows some degree of qualitative prediction.

(d) The systems approach, which recognizes that wild equids and domestic livestock exist in complex ecological systems involving climate, vegetation, soils, and smaller animals. Ultimately, a change in any part of the system elicits changes in the other parts. Predicting the changes in all parts of the system that would result from different management decisions is a management ideal now coming closer to reality through the use of simulation models which depict each entity in the system as a variable, the processes by which variables change, and the constraints affecting the rate of change. Such models require massive amounts of data which, formulated as functional equations expressing the process rates as functions of the constraints, are coded into computer programs.

Clearly, each of the levels of management intensity outlined above demands different amounts of information. Each involves successively greater understanding of the system involved and therefore has greater data requirements.

Each of the four management alternatives, then, could utilize one of these four different intensities. In all, there would then be sixteen different combinations, each with somewhat different data needs. Given the limited time available, however, the Committee found it necessary to confine its data analyses to less than all sixteen different possibilities. Without in any way intending to suggest which is the most appropriate choice, the Committee has concentrated its efforts on intensities (b) and (c) of alternative (2) because these seem to be the current management emphases in federal and state agencies.

HORSE AND BURRO BIOLOGY

Information Needs

Allocating herbage to equids, other wild herbivores, and livestock is a problem because it is necessary to determine allowable levels of herbage removal and to maintain each animal population at a density that keeps herbage removal within the allowable limits. Each land unit has the potential ability to produce a certain amount of forage usable by herbivores. The Committee considers it a desirable goal to maintain the resource base in order to perpetuate its productive capacity and conserve soil and water resources.

Maintaining the vegetation in the desired condition implies removal of a certain allowable level of herbivorous forage. If the vegetation is currently in a desirable condition, a certain amount of cropping by animals will aid in perpetuating the condition. If the vegetation is not in the desired state, a smaller amount of removal, no removal at all, or some positive improvement practices may be necessary to restore the vegetation.

The attempt to determine whether vegetation is or is not in desirable condition should be made on the basis of several different kinds of biological information:

1. The maximum amount of vegetation that can be produced in an area.

2. The present condition of vegetation in an area in relation to its potential maximum.

3. Desired vegetation condition.

4. The level of forage removal that will maintain or achieve the desired condition.

5. The proportion, or amount, of forage to be allocated to horses/burros.

6. The number of horses/burros to be maintained on the land unit in good health, and the size of the populations necessary to maintain adequate genetic variability.

This number is determined both by theoretical genetic considerations and by dividing the individual-animal consumption rate into the amount of forage allocated to equids. It also requires knowledge of equid forage and habitat preferences.

Although 1 and 2 are types of information essential to decision making they are considered to be within the state of the art of contemporary range ecology. Therefore, the Committee does not suggest further research in this direction.

Item 4 above is also considered to be within the state of the art of range management as far as livestock and wild ungulates are concerned, but the amount of horse/burro removal compatible with the desired condition of forage land is not well understood. Hence, this subject falls within the Committee's concern respecting needed research.

Items 3 and 5 above are actually decision-making points. Item 6 is also a decision-making point closely related to Item 5, since it requires knowledge of the consumption rates, forage and habitat preferences, and genetics of wild horses and burros. Items 3, 5, and 6 are also considered to be within the Committee's purview.

Once a decision is made on the appropriate numbers of horses/burros, the problem becomes one of population management. A given population will need to be reduced to, maintained at, or allowed to increases to the desired level and then held at approximately that level by periodic removal, reproductive inhibition, or both. There is evidence that some burro populations tend, in effect, to self-limit their numbers, and therefore may not need external control. But the apparent general tendency for wild horse populations to increase to the point of permanently damaging range land suggests that some form of population control is likely to be needed. Even with respect to this species, however, there may be times or areas in which it is desirable to allow it to experience natural, short-term fluctuations. Population management efforts require information on:

- The validity and precision of different census methods;

- Better knowledge of horse/burro demography so that annual rates of increase can be translated into annual rates of removal;

- Information on appropriate population-control measures, whether through removal of animals or through the use of contraceptive methods.

In all, the minimum data needs for management level 2(b) include information on:

1. Horse/burro impacts on vegetation, soils, hydrology, wildlife, and livestock.

2. Horse/burro forage consumption rates, forage and habitat preferences, competition with other herbivores.

3. Population size as disclosed by reliable census methods.

4. Demographic and genetic characteristics.

5. Appropriate handling and population-control measures.

The Committee believes that these areas of information should be given highest priority.

Management level 2(c), in addition to the information requirements already mentioned, requires information on the following aspects of equid biology:

1. Equid nutrition, including continuing assays of managed herds.

2. Equid physiology.

3. Equid social and herd maintenance behavior.

4. Regular inventories of range conditions and trends in managed areas.

Since regular monitoring of the nutritional condition of managed herds and assessment of the status of their range is likely to be difficult and expensive, later parts of this paper discuss the possibility that certain types of easily measured blood and behavioral criteria could be used as indices of nutritional condition. These blood tests and observations, utilized periodically in managed horse/burro herds to determine their nutritional condition, might in turn reflect the nutritional adequacy of the vegetation (though not necessarily the composition of the plant community) for equids. This information might in turn prove useful in predicting demographic performance. Such information could be used to guide decisions on the appropriateness of present management efforts and point the way to needed modifications. These issues are explored in the sections that follow.

State of Knowledge

Range Plant-Community Impacts

In general, wild and free-roaming horse and burro populations in the western United States affect geographical areas with the following plant associations or community types: pinyon-juniper, sagebrush-bunchgrass, salt-desert shrub, ponderosa pine, and hot-desert shrub, areas with the last being primarily the domain of burros. While these classifications are general and considerable physical, climatic, and vegetational variations may exist within a particular type, they offer a general scheme for discussing and analyzing the relationships between wild horses/burros and plants. Recent symposia and publications have dealt with the ecology and management of several of these areas (e.g., Gifford & Busby 1975, Clary 1975, Springfield 1976, Martin 1975, Currie 1975, USU-CNR 1979).

In view of the scope and alleged severity of the impact of grazing horses and burros on western rangelands, the problem has been studied surprisingly little, although general statements by recognized range management experts warn of a severe and growing problem. Box (1977) observes that rangelands in many areas are seriously overgrazed and the environment degraded. He cites the burros in the Death Valley area and the wild horse herds in the Rock Springs, Wyoming, area as posing threats to the habitat of native ungulates. Similarly, Cook (1975) suggests that, under the Wild and Free-Roaming Horse and Burro Act of 1971, horses and burros living in areas where a year-round forage supply is unavailable will be limited only by disease and starvation. Before that would occur, however, range deterioration would be prevalent and would lead to reduced carrying capacity for wild ruminants and domestic livestock.

Comments like the foregoing are generally based on years of professional experience and may indeed depict reality. However, the fact remains that few pertinent data are generally available. Until such data become available, professional judgments are certain to remain controversial, whether made by scientists or rangeland managers.

A majority of the studies on grazing impact have dealt with burros. Hanley and Brady (1977) reported that burros in the lower Colorado River Valley of California and Arizona overgrazed ranges near the river but that plant utilization, principally on browse species, decreased to light or moderate at distances greater than 2.5 km from the river. They found that the canopy cover of Amrosia dumosa was reduced from 2.26 to 0.04 percent by burro over-use and that no particular plants acted as increasers or invaders under heavy burro use. Carothers et al., (1976) also concluded that feral burros have a pronounced ability to upset plant community stability. Their studies in the lower reaches of the Grand Canyon showed that total vegetative cover on an impact plot was reduced to 20 percent, compared to 80 percent on a control plot. They also found that the total number of vascular species was reduced from 28 to 19. In a similar vein, Koehler (1974) stated that foraging by a population of 107 to 120 burros led to the degradation of nearly 10,000 acres of rangeland in Bandelier National Monument in New Mexico.

Atleast part of the burro's ability to adapt to the relatively harsh environment of the desert Southwest is due to the broad spectrum of plant species it will use as food. Koehler (1974) reported that the bark of cholla cactus had been stripped from the base of the plant to three feet above ground, and that Yucca plants, although spiney-tipped, had been completely destroyed by burros.

Although burros apparently prefer green grasses and forbs when they are available (Hansen and Martin 1973, Woodward and Ohmart 1976), virtually all researchers have remarked on the highly opportunistic feeding habits of burros and their ability to utilize plants and plant parts not usually considered as forage. Ohmart (1975), for example, observed burros removing branches of palo verde (Cercidium microphyllum) as large as 1.5 inches in diameter and up to 6 feet in length. In their comprehensive review of literature on equine nutrition, Robinson and Slade (1974) observe that donkeys may have a higher capacity for digesting crude fiber than either horses or cattle, and that feral equines of both species can survive on diets deficient in total nitrogen as well as specific amino acids. These physiological capacities contribute to the burro's (and to some extent, the horse's) adaptability to low-quality forages.

Comparatively little work has been reported on the grazing impact of horses. Stoddart et al. (1975) state that, under overstocking conditions, horses can and will crop herbage (presumably grasses) more closely than any other range herbivore because they have upper as well as lower incisors. Arnold (1978) also emphasize the ability of horses to crop vegetation closely.

A relatively large number of studies report the botanical composition of horse diets, and in a number of cases, those of sympatric domestic and wild ungulates. Most of these (Hansen et al., 1977, Hubbard and Hansen 1976, Hansen 1976, Salter 1978, Salter and Hudson 1979, Vavra and Sneva 1978, Olsen and Hansen 1977) emphasized that grasses constitute the major part of horse diets on a yearly basis. These findings have led several authors to infer a high degree of dietary overlap between horses and cattle (Olsen and Hansen 1977, Hubbard and Hansen 1976, Hansen et al., 1977).

Some caution is necessary in making such an inference, however. In the first place, almost all of these studies have relied on fecal analysis to determine diet, and there is some reason to believe that highly digestable plants, particularly forbs, are not uniformly represented in fecal fragments, especially where ruminants are concerned (Slatter and Jones 1971, Smith and Shandruk 1979). Second, few of the studies have tried to quantify the forage available for consumption. Dietary overlap does not directly imply competition unless food resources are limited. In this connection, Salter and Hudson (1979) noted that horses were highly ubiquitous in their distribution over several major plant community types in their study area, and that there was little concurrent overlap in horse and cattle distribution even though fecal analysis showed that two-thirds of the time their diets were composed of the same plants.

In view of limited information on the specific grazing impacts of horses, in particular, and considering that most ranges occupied by wild horses are also grazed extensively by other domestic and wild ungulates, the Committee plans to explore the extensive literature on the grazing impact of large animals in general. The benchmark review monograph by Ellison (1960) is believed to cover the literature prior to 1960 adequately. Some 270 references are cited in that paper, and it is organized on the basis of plant community types, including those utilized by horses and burros. The Ellison paper, along with pertinent papers on specific studies, will form the basis of this portion of the review, which will be contained in the Committee's final report.

Forage Requirements of Equids and Other Large Herbivores

An accurate assessment of daily forage requirements (or voluntary forage intake) is critical on two counts. Dry-matter intake is the basis for determining consumption rates of several important nutrients, including calories, protein, and phosphorus. In addition, estimates of daily dry-matter requirements of the individual animal (kg. of forage per animal per day) enter into the calculation of stocking rates and the range-grazing capacities of animal populations.

Theoretically, equids are less limited than ruminants are by the configuration of their digestive tract in the amount of forage they can turn over per unit of time. Janis (1976) contends that cecal digestion is superior to ruminant digestion in dealing with high-fiber forage, provided that intake is not limited by the actual quantity of forage available. In other words, equids may have a competitive advantage over ruminants in situations where a critical nutrient (e.g., nitrogen) is present in low concentrations in the available forage. While equids apparently can compensate by turning over a large volume of material, the through-put rate of ruminants is limited by the capacity of the rumen and the rate of fermentation there. Generally speaking, fermentation rates decline markedly when ruminant diets consist of high-fiber, low-nitrogen forage.

The management implication of this difference is that horses may be capable of consuming more forage per unit of body weight than are cows. Hence, the animal unit requirement for forage (Stoddart et al., 1975, define an animal unit as a 454-kg cow or her equivalent) may be greater for horses than for equivalent-sized cows, especially where the forage is of poor nutritional quality. Some grazing-capacity assessments for cows and horses have apparently gone forward on this assumption.

But the existing literature offers little foundation for this assumption, although it does not directly refute it. Koehler (1978) stated that burros on Bandelier National Monument each consumed approximately 11 pounds of forage daily. Heady (1975), speaking of exchange ratios for various animal species on rangelands, stated that " . . . if the food eaten is reasonably the same for both species being compared, the ratio of metabolic weights gives the exchange." He used the widely accepted inter-species mean of body weight raised to the fractional exponent of 0.75 to define metabolic body weight. Using this procedure, a 1,000-lb. (454 kg) horse and a 1,000-lb. cow both have metabolic body weights of 98, and both are equal to 1.0 animal units. Practically speaking, however, such exchange ratios are strongly affected by the kind of range, the age and health of the animals, and the kinds of forage consumed. Hence, they appear to offer little basis for comparing animals so dissimilar as cattle and horses.

Another approach is to compare animal species on the basis of recommended nutrient standards, such as those issued by the National Research Council for horses (NAS 1973) and cattle (NAS 1976). Direct comparisons on an energy basis are not possible because the tabular values listed for horses are in terms of digestible energy and those for cattle are in terms of metabolizable energy. However, it is possible to make the comparison on the basis of total digestible nutrients (TDN).

If a 400-kg mare and 400-kg cow, both in the last 90 days of gestation, are used as examples, the recommended TDN levels are 3.72 kg per head daily for the mare (NAS 1973) and 4.00 kg per head daily for the cow (NAS 1976). This assumes that forage diets supply 4,000 kcal of digestible energy per kg of TDN for horses, as suggested by Fonnesbeck (1968). Thus, cows would require some 7.5 percent more TDN than wild mares of equivalent size and physiological condition. The main deficiency of this approach (or for that matter, one based on energy considerations) is that there is no direct way of translating TDN quantities into quantities of forage dry-matter consumed. The latter quantity is what interests the range manager most when it is necessary to allocate a fixed forage resource among various grazing animal populations. Given a lower digestive efficiency in equids than in ruminants, especially on highly fibrous diets, a horse presumably would consume more pounds of forage in order to extract its required quantity of TDN (or energy) than would an equivalent-sized ruminant. Obviously, this question requires further research, particularly with respect to the mid- and low-quality forages found on rangelands during much of the year.

Blood Assays as Possible Indices of Horse and Burro Nutritional State.

Assays of blood samples may offer possibilities for (1) evaluating the nutritional conditions of individual animals, and (2) using an animal's condition to indicate the nutritional adequacy of the range it inhabits (Seal, 1977). The evaluation of individual animals may include determining their nutritional condition in terms of recent food intake (protein and calories) and a determination of the quality of that intake during recent months. One may also evaluate specific nutritional deficiencies, and the physiological effects of various techniques for capturing and handling horses.

The literature relating nutritional status to the breeding capability of mares is extraordinarily sparse (Sutton et al., 1977; Ellis and Lawrence, 1978; Belonje and van Niekerk, 1975). A study in South Africa (van Niekerk and van Heerden, 1972) compared two groups of mares (one kept on pasture, the other kept on pasture with supplemental grain) in terms of heat, occurrence of ovulation, and successful conception. The pasture grass had a protein content of approximately 3.2 per cent, while the supplements were 12 to 15 per cent protein. Six of the eight animals maintained on grass alone exhibited heat, but only two of these ovulated. Both also conceived. In contrast, all seven of the group maintained on grass plus supplement exhibited heat and ovulation, and six of six served conceived. The supplemented animals gained 53 kg over the 53 days of the study, whereas the unsupplemented animals did not gain weight. The starting weight was 370 kg. These data, like those for other species, suggest that variations in nutritional intake can affect ovulation rate. Reproduction rates are also affected by spontaneous abortion, stillbirth, lactational failure, and loss of foals too weak to nurse properly; however, quantitative studies addressing these points do not appear to be available (Ginther, 1979a).

Nitrogen intake and absorption by horses can be assessed by measuring plasma urea nitrogen concentration (Fonnesbeck and Symons, 1969; Reitneur and Treece, 1976; Owen et al., 1978). Fonnesbeck and Symons studied diets whose protein content ranged from 8.3 percent to 16 percent. The correlation of plasma urea nitrogen with apparent nitrogen absorbed was $r = 0.78$. There were indications of variations in plasma protein, sugar, and cholesterol concentration depending on diet. There was no direct correlation, however, except that diets with the highest soluble carbohydrate content resulted in the lowest concentrations of cholesterol.

At some seasons of the year, protein content may fall below 8.3 percent because of range conditions. In order to determine nutritional adequacy in natural habitats, therefore, it would be necessary to study the effect of diets with as little as 3 percent protein. Serum protein and hemoglobin levels decrease when protein and calorie intake diminish, as found with domestic animals maintained on pastures without supplementation (Owen et al., 1978). There are no controlled experimental data available on the effects of very low protein intake in horses, however.

The effects of fasting on ponies for periods of up to 9 days have been described (Baetz and Pearson, 1972; Wensing et al., 1975; Gronwall, 1975; Baetz, 1976). These studies describe increases in bilirubin, cholesterol, phospholipids, free fatty acids, triglycerides, other serum lipids, pyruvate, lactate, and α_1-globulin. Serum urea, phosphorus, and magnesium decreased.

Several of these assays make it possible to distinguish fasting from relatively reduced food intake. There are also differences between ponies and larger breeds of horses, including Morgans and thoroughbreds (Robie et al., 1975). Ponies apparently maintain higher triglyceride levels in cold weather and are also more vulnerable to fasting hyperlipemia than the larger breeds. These results suggest the desirability of analyzing data from wild animals in terms of season and lipid metabolism. However, there is no evidence that season has an impact on serum urea nitrogen unless the animals are on pasture without supplementation (Owen et al., 1978).

Studies of hemotology and blood chemistry are available for burros (Brown and Cross, 1969; Yousef et al., 1971) and domestic horses. In addition, there have been several careful studies of water metabolism in the burro under desert heat conditions (Yousef et al., 1970, 1971). Data for newborn and young foals are also available (Kitchen and Rossdale, 1975; Medeiros et al., 1971).

Studies of the zebra (Seal et al., 1977) provide evidence that equids are similar to other mammals in the way their blood responds to trauma or disease. Blood proteins which increase during any disease or as the result of tissue injury are called acute phase reactants. The response pattern of each protein is characteristic, and studies of human beings have demonstrated a quantitative protein relationship to myocardial infarction, surgery, and various infectious diseases. Measurement of such proteins as fibrinogen, haptoglobin (Allen and Archer, 1971; Spooner and Miller, 1971), and perhaps C-reactive protein provide simple yet powerful methods for assessing the clinical condition of animals without undertaking a full spectrum of diagnostic procedures. Earlier exposure of healthy animals to various infectitious diseases can be detected by readily available seriological assays.

Detection of the effects of handling, exercise (Hensely, 1978; Kennan, 1979; Lucke and Hall, 1978; Kizywanek et al., 1976; Rose et al., 1979; Snow and MacKenzie, 1977 a and b), and sustained chasing and capture is a matter of concern to all those involved in the capture and transporting of wildlife (Harthoorn, 1976). Increased hormone secretion by the adrenal cortex and medulla (Anderson and Aitken, 1977) are considered to be physiologic responses to such disturbances. This increase in hormones is commonly referred to as a "stress indicator." A study of horses comparing different handling techniques (Kirkpatrick et al., 1979) found no differences in serum cortisol concentrations and concluded that the techniques were minimally stressful in terms of their impact on serum corticoid levels. A more sensitive technique for detecting the effects of different levels of muscular exertion in horses appears to be measurement of creating phosphokinase (CPK) activity (Anderson, 1976), uric acid (Kennan, 1979) and bilirubim (Hensely, 1978). The enzyme CPK is a sensitive indicator of significant muscle trauma. Animals in initially poor condition tend to show increases in serum CPK after graded levels of exercise.

If animals are being lost, particularly after prolonged chases or during their initial time in the corral, the possibility of metabolic acidosis resulting from exertion (Harthoorn and Young, 1974) needs to be considered. This condition has been well-documented by Harthoorn in zebras in a long series of studies in Africa. He describes as effective a treatment which consists of giving the animal a liter of electrolyte solution with 1000 mEq sodium bicarbonate added. This treatment decreased blood pH and, more importantly, resulted in survival. There are now available pH meters suitable for field use which diagnose the problem.

Other techniques for evaluating animal condition include autopsy (direct measurement of rump fat thickness as well as gross and microscopic tissue evaluation), estimation of fat thickness by ultrasonic measurement (Westervelt et al., 1976), and measurement of body weight in relation to age and bone growth. Extensive data on the growth of domestic horses from about 140 days of gestation up to maturity is available. Most strains of domestic horses appear to attain about 45 percent of their mature weight at six months, 65 percent at 12 months, and about 80 percent at 18 months. Thoroughbreds, quarterhorses, and Arabians reach 83 percent of height at the withers at about six months, 90 percent at

12 months, and 95 percent at 18 months.

Habitat Preference, Use, and Interspecific Competition.

In order to make decisions for a given land unit on the amount of forage to be allocated to horses/burros, livestock, and wildlife, and on the numbers of each type of animal to be allowed to graze on the land unit, it is important to know more than forage preferences and forage consumption. Several patterns of interaction can occur between these groups and thus influence decision making:

1. The different groups may select mutually exclusive habitats with the result that they do not affect each other's populations even though they may have similar forage preferences. No interspecific competition occurs in this situation.

2. The different groups may have overlapping habitat preferences but, through behavioral interaction, separate into discreet habitats. If competition is gauged by what a species is capable of in the absence of the other, this could be classed as competition if forage in one of the habitats became limiting to the species occupying it.

3. The different groups may have overlapping habitat preferences and remain sympatric. If they have different forage requirements they are not competitors. If their forage preferences overlap but the animals are not present in sufficient numbers to deplete forage to limiting amounts, they will not become competitors. But if forage is reduced to the point of affecting the welfare of one or more of the groups, competition will occur.

Clearly, it is important to understand habitat preferences and uses, and whether competition is a possible reality, in developing criteria for site suitability. The comments that follow pertain only to possible competition between wild horses and cattle. (The subject of burro and wild ruminant competition is under review and will be discussed in the final Phase I report.)

Broadly viewed, habitat analysis and evaluation address two complementary sets of questions, the techniques for which are reviewed in de Vos and Mosby (1969). One set of questions addresses the structural characteristics of the habitat -- vegetation, topography, soils, and water. An extensive literature exists on the structural characteristics of the habitats of such diverse species as small mammals

(M'Closkey 1972, 1975, 1976, 1978; M'Closkey and Lajoie 1975; M'Closkey and Fieldwick 1975; Rosenzweig 1973; Rosenzweig and Winakur 1969; Conley et al., 1976; Lemen and Rosenzweig 1978); medium-sized mammals (Conley et al., MS); molluscs (Green 1971); a variety of birds and other taxa (Shugart and Patton 1972); and elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) by Sivinski (1979).

A second set of questions addresses the behavioral responses of various animals to their habitat. These questions involve aspects of the habitat that are required for such activities as feeding, breeding, parturition, escape, protection from weather, and others. Collectively, these are subsumed in the term "habitat selection." In establishing habitat suitability criteria for wild horses and burros, it is important to recognize that while there is some optimum which might appropriately be termed the "preferred habitat," the animals may be forced to occupy a suboptimum habitat due to habitat degradation, displacement by other species, or simply the absence of the optimum. This suboptimum habitat might be called the "subsistence habitat." (The parallel terms of animal response would be "habitat preference" and "habitat use." This distinction is made here because it cannot be assumed that an animal's presence in a given habitat necessarily implies that the habitat is an optimum one.

Since competition from other animals can profoundly affect a species' habitat use pattern and needs to be taken into account in forage allocation, it needs to be considered in some detail. By most definitions, interspecific competition is judged on the basis of two criteria (Milne 1961; Conley 1976):

(a) two species compete when they both use some resource that is present in short supply, and

(b) in using the resource they limit each other's population and fitness below what they would be in the absence of the other species.

The important point here is that two species can use the same resource and still not be competing -- that is, there is no competition unless joint use reduces the resource to the point of limiting each other's demographic performance.

This point seems to have escaped many of those who have written about animal competition. The extensive literature on dietary similarities among wild equids, domestic livestock, and wildlife often implies competition but without providing evidence of resource limitation or population effect. Various reports (Olsen and Hansen 1977; Hubbard and Hansen 1976; Hansen et al., 1977; Hansen and Clark 1977; Cole 1954; Hansen et al., 1973; Tueller and Lesperance 1970; Hansen and Reid 1975) provide important data on the biology of each species, assuming the efficiency of the measurement techniques used (Deardon et al., 1975; Hansen et all al., 1973; Todd and Hansen 1973; but see Keiss 1977, Smith and Shandruk 1979, Vavra et al., 1978). Such information, however, is not sufficient to demonstrate competition among the species even when the vegetation is surveyed (e.g., Jordan et al., 1979), much less so when it is not (e.g., Hansen 1976).

Two species may use more than one common resource. They may compete for one without competing for the other(s). An example was given earlier in which two species segregated between two habitat types because of behavior interactions without competing for food. There are also reports of this occurring between domestic animals and wildlife. Jeffrey (1963) and Mackie (1970) reported that the presence of cattle caused elk to leave areas which otherwise they would have continued to occupy.

These flexible patterns of resource use are explained by Hutchinson (1948) theoretical construct of the "niche" occupied by a species. In the absence of competition, a species occupies a broad portion of the resource spectrum which the species can tolerate. This is termed by Hutchinson the "fundamental" niche. In the presence of competitors, however, the species may restrict its habitat to a smaller part of the fundamental niche for which it is best adapted, the smaller part being termed the "realized" niche.

Circumstantial evidence of competition is revealed when a cpecies expands its use or occupancy of resources, after a competitor is removed. This expansion has been termed "ecological release" (Ricklefs 1973; Pianka 1974), and the concept has been utilized by various workers to infer competitive pressures (Ayala 1970; Koplin and Hoffmann 1968; Peterson 1973; Neill 1974, 1975; Rosenzweig 1973; Schroder and Rosenzweig 1975; Davis 1973; Simon 1975; Grant 1969, 1971; Morris and Grant 1972; Grant 1975; Crowell 1973; Crowell and Pimm 1976). Avoidance is more generally the response between competing species than outright aggression (Andrzejewski and Olszewaki 1963; Colvin 1973; Kikkawa 1964; Grant 1978), but exceptions exist, particularly under experimental conditions (Conley 1976).

It has long been recognized that "niche space" is a highly complex phenomenon, and that in any given circumstance only a portion of such a theoretical construct can actually be measured. This process, called "a partial analysis of niche" by Maguire (1967), has been followed by a number of recent workers.

The point of this discussion is that the concept of "niche space" is relevant to the problem of discerning and measuring competition between wild equids, livestock, and wildlife in order that it can be provided for in management plans. Since an essential criterion of competition is that it must have a population effect, its existence cannot be established absolutely without experimentally manipulating one species and ascertaining whether the other species responds.

If equids are competing with other species for food, the effect is presumably on nutrition and, ultimately, demographic performance. But, since equid demography is so conservative, a demographic change following experimental reduction of an apparent competitor would be difficult to measure in the time available for this proposed research program. The major hope is that a nutritional change could be detected through blood analysis, as described above, and that demographic results could be assumed. Research on the possible nutritional response is discussed in the section outlining the initial research projects.

If equids partition the habitat with other species through behavioral competition, this can readily be identified through experiment. Habitat use can be measured in both the presence and the absence of apparent competitors. Such experiments are also outlined in the section of this report on proposed research.

Equid Demography

A knowledge of horse/burro demography is clearly important to the development of management programs. If reproductive and survival rates are known, annual rates of increase or herd increments can be calculated, and herds maintained at desired levels by removing these increments or by some combination of removal and reproductive inhibition. For these reasons, demography is being given particular emphasis in the state-of-knowledge assessment. The review of the literature on demography was not completed at the time this report was prepared, but a complete review of the subject will be presented in the final report on Phase I.

THE EFFECTS OF WILD EQUIDS ON RANGE HYDROLOGY

Information Needs

The watershed impacts of wild equids are the results of activities which, in one way or another, affect the quantity, the quality, or the timing of water yields. Impacts may be measured either off-site or on-site, that is, in upland areas or directly in a water channel.

Grazing animals exert a significant influence on watershed ecology through their trampling of the ground and their consumption of protective ground cover. The results may include unwanted changes in characteristics (changes in coliform counts, nutrients, water temperature, sediment relationships, dissolved oxygen, dissolved solids) reduced stream-channel stability, increased overland flow, reduced soil moisture, and increased rill and inter-rill erosion. At the present time, given the state of the art in predictive wildland hydrology and the fact that grazing by horses and burros is a diffuse activity, it is often difficult to predict accurately the effect of management activities on changes of the kinds mentioned above. Most of the predictive tools now available are oriented toward stream-channel behavior and therefore are not particularly sensitive to specific plant-soil relationships within a watershed or to such variables as season, range condition, grazing intensity, or type of grazing animal.

An exception to this generalization is the deterministic model developed by Hawkins and Gifford (1979) which predicts infiltration rates of the ground by water as functions of grazing intensity and rest periods. Runoff volumes are estimated by linking predicted infiltration rates with projected watershed cover percentages and relating these two variables to a runoff curve number, a technique developed by the Soil Conservation Service. Another current tool is the Universal Soil Loss Equation (USLE) which was developed for agricultural lands in the eastern United States. Although widely used in wildland situations, however, the USLE lacks validation and needs modification. In general, the watershed impact of horses and burros needs to be identified and compared with the impact of domestic livestock and, possibly, selected wildlife species. Models should then be developed that will correctly predict watershed behavior under future management schemes.

State of Knowledge

The impact of wild and free-roaming horses and burros on watershed values has been described frequently in the past, but quantifications of the impact are few. Typical descriptions include "increased erosion" and "muddy water holes." Significant changes in erosion rates are usually associated with increased surface soil disturbance, reductions in ground cover, increased soil compaction, reduced infiltration rates, and increased overland flow. In many cases, judgments of hydrologic behavior are based on general ratings of range condition, the inference being that hydrologic behavior is "better" when range conditions are good than when they are poor or fair. This same logic is used to connect grazing intensity (heavy, light, or moderate) with hydrologic conditions. The relationship of grazing intensity to infiltration rates has recently been quantified by Gifford and Hawkins (1978). The data used in this analysis, however, were derived from studies of domestic livestock.

WILD EQUID MANAGEMENT TOOLS

Census

Substantial efforts are being made by the Committee to evaluate equid census methods, especially with respect to horses. Analysis of large amounts of BLM census data is nearly complete and will be summarized in detail in the final report on Phase I.

Contraception in the Horse

The purpose of this section is not to advocate contraception as a population-control measure in wild horse and burro management. Whether or not contraception is to be so used is a policy discussion outside the scope of the Committee's work. It is the purpose of the following discussion to point out the methods available if contraception were to be chosen as a management tool for use in particular situations. An evaluation of contraception could be performed with a relatively small sample of domestic horses during the next breeding season.

Fertility control or sterilization of the harem stallion has been suggested as one means of limiting the growth rates of wild horse populations. This approach is based on the premise that the females of a harem or band are inseminated only by the harem stallion and that this social structure is in some measure constant. In view of recent evidence reported by investigators in Wyoming and Montana, however, neither assumption appears valid. Several males have been observed breeding females in estrus, males sometimes change band affiliation, a given stallion may maintain dominance for only about four years, and some mares spend long periods of time outside a band. These considerations, plus the fact that reversible contraceptive techniques currently being tested for males would be effective for only six months, indicate that this approach may be neither practical nor effective. Finally, computer simulation of the population effects of female contraception indicates that it would have to be effective continuously for a period of five to seven years to provide useful results.

Artificial manipulation of the estrous cycle in horses (Ginther, 1979b) and other domestic animals has been restricted to relatively short-term applications. These have included: (1) synchronization of estrus and breeding for timed pregnancies, especially through artificial insemination; (2) treatment of infertility; (3) early induction of estrus and ovulation; and (4) suppression of estrus in feedlot cattle to reduce sexual activity. Long-term control of fertility has been intensively studied only in human beings, but there has been some recent work involving hormones and the use of mechanical devices to prevent conception in dogs and with hormones in a few wild species (Seal et al., 1976), inlcuding white-tailed deer (Matschke 1977a, b, c, Harder and Peterle 1974.

The types of long-term fertility control that might be applied to female horses inlcude: (1) the use of hormones, hormone analogues, or hormone antagonists; (2) the use of mechanical devices, such as intrauterine devices (IUD) or pessaries; and (3) surgical intervention. Surgery would be impractical under field conditions, however, because of the risk of infection and the surgical time required for each animal. Use of the IUD appears more practical because it would be effective indefinitely, could be recovered if necessary, and would not interfere with normal hormonal and behavior patterns. Use of the IUD also presents some problems, however. Individual fitting of the device is necessary because of variations in uterine size. Considerable skill is required to avoid injury or infection in placing the device, and in some species retention has been variable.

Although extensive information is available on the reproductive cycle of the mare and stallion (Ginther 1979, Rowlands et al., 1975), published data on the long-term effectiveness of contraceptive agents in horses are nonexistent. The literature on artificial control of the mare's estrous cycle is oriented toward synchronization of estrus, treatment of infertility, and early induction of estrus and ovulation (Ginther 1979b).

A report on melengestrol acetate (Zimbleman et al., 1970) found that this agent had no effect on the occurrence of estrus when administered intravenously. A rationale for the failure of this approach can be found in Ganjam et al., (1975), where it is demonstrated that there is little or no specific plasma-protein binding of pregesterone in the horse. As a result, the half-life of progesterone (and presumably other progestagens) in the animal is very short, that is, on the order of minutes. This would also explain why very large daily doses of progesterone have been required to inhibit estrus (100 mg/day) and ovulation (200 mg/day) in mares (Loy and Swan 1966).

Other compounds that have been tested for their contraceptive effect include chlormadinone acetate (Arbeiter and Jochle 1975) and an orally administered synthetic progestin, 17--allyl-estratiene-4-9-11, 17-01-3-one (Weber 1975). The latter compound (allyl trenbolone) may be suitable for use as an implant. It has been administered to pregnant horses with no apparent adverse effects.

Other contraceptive agents exist, some in the form of implants which release small amounts of the effective agent on a continuous basis for periods of up to five years. These agents have been effective in human beings in extended field trials, and they have been utilized in more than 400 animals involving a wide range of species (Seal et al., 1976). Given the view that contraceptive efforts involving male horses are likely to fail (Nelson 1979; Miller 1979), the implanting of contraceptive agents in mares would appear to be a more effective approach.

Implants can be installed in a short period of time under suitable field conditions. The females in a given herd could be rounded up and then restrained in a chute or with the use of drugs. The animals would be identified in some permanent fashion so that the implant's effectiveness could be monitored. It appears reasonable to think that implants with an effective period of five years can be obtained, but it would not require a full five years of study to determine the likely span of effectiveness.

Blood tests to measure the release rates of the compounds from the implants would enable us to project their effective lifespan. Establishing the effectiveness of the chosen compounds and implantation as the mode of administration is all that is necessary.

Studies designed to determine the effectiveness of this approach would include the use of captive mares with proven reproductive histories, installation of the implants, observation of the animals for signs of estrus, collection of blood samples, the use of rectal palpation to determine if ovulation has occurred, and bringing the mares together with a stallion to detect any behavioral responses characteristic of estrus. It is possible that estrous behavior might be elicited but not be followed by ovulation. It is also possible that insemination and ovulation might occur but that the condition of the fallopian tubes would prevent implantation of the ovum.

Blood samples taken during the studies would help to establish the effectiveness of the compounds and suggest possible alterations of dosage or the use of slightly different compounds. An acceptable compound would be one that was at least 95 percent effective in preventing pregnancy, would not cause abortion in a pregnant animal, and would not cause "significant" behavioral changes except those resulting from the mare's being in a continuous anestrus state.

If a decision is made to utilize contraception as a tool for managing the wild horse or burro population, it is recommended that studies be initiated to (1) establish an effective compound for mares, (2) determine an effective dosage, (3) test the use of silastic implants or similar materials offering an effective lifespan of five years or longer, and (4) monitor behavioral effects that might affect the social structure of the band.

Chemical Immobilization and Capture of Wild Horses

Veterinary practioners commonly have to deal with fractious horses (and other animals) which cannot be handled by standard techniques. This has resulted in the development of chemical tranquilizing and immobilizing agents, and much experience in the capturing of wild equids and in their restraint and handling in zoos and nature preserves has been gained (Seal et al., 1970; Harthoorn 1976; Haigh 1978; Fowler 1978). Utilization of these drug techniques requires considerable experience and is best accomplished by persons with adequate knowledge of horse physiology and anesthesiology. Many of the problems that have occurred in using these drugs have been caused by inexperienced or untrained personnel (Harthoorn 1976; Haigh 1978).

In general, chemical immobilization is not an efficient method of capturing wild horses initially, since it would take a long time to round up a whole herd this way. It is frequently more effective to utilize trapping, corralling, or herding techniques, after which the horses can be immobilized by drugs if necessary. Frequently it is not. Chemical immobilization is most useful when it is applied selectively by trained personnel and when it is appreciated that it is a time-intensive technique (Harthoorn 1976).

Long-distance immobilization of wild horses is done with dart guns whose range varies from 30 to about 100 yards. Retrieval of free-ranging wild animals hit by the immobilizing darts from the guns has been facilitated by the recent development of a small radio transmitter. This device, with a range of up to one-fourth mile depending upon terrain, makes it possible to locate the dart and hence the animal.

A large number of drugs that have been used to immobilize domestic horses have also been tested as possibilities in capturing wild equids. Discussion of these drugs can be found in several reference works, particularly those of Harthoorn (1974, 1976), who has done much of the work in developing techniques to capture zebras in Africa. It appears that two drugs can be used successfully, depending on the circumstances.

One is succinylcholine, a muscle relaxant which is neither a tranquilizer nor an anesthetic. Administered intramuscularly by way of a dart gun, it will immobilize an animal within five to ten minutes when used successfully. The suitable dose range for a particular population must be established from experience, since it can vary with the season of the year, sex, and age. There is a body of experience with this agent (Borchard et al., 1979) and in experienced hands the loss rate would probably run no more than 2 percent. Since respiratory arrest may occur in 20 percent of more of the immobilized animals, it is necessary to reach the animal quickly with whatever equipment is necessary to support respiration.

The other drug is etorphine (known as M99 in the United States and Immobilon in the United Kingdom). This is a morphine-type compound which is effective at low doses and acts as an immobilizing agent, analgesic, and anesthetic (Harthoorn 1976; Bogan et al., 1978; Hillidge and Gies 1978). An Antagonist known as M 50/50, or Revivon, reverses the immobilizing effects of M99. M99 appears to be the drug of choice for immobilizing wild equids in field circumstances. It is customarily used in combination with acepromazine. Effective doses of etorphine range from 5 to 10 mg per animal, rather than the higher amounts mentioned in textbooks. Equids have a wide tolerance for this compound, however, and as much as ten times the effective dose has been administered without fatal results. Horses have been known to recover spontaneously from a dose of etorphine within thirty minutes to two hours.

Xylazine (Rompun) should be avoided as a drug for capturing wild horses. Since both xylazine and etorphine are respiratory depressants, the combined effect of both is respiratory failure, which, if not treated promptly, results in death. Although xylazine sometimes has appropriate uses in clinical practice, its metabolic effects (rapid and severe elevation of glucose and urea levels) negate the use of blood samples to evaluate the nutritional status of an animal (Short et al., 1972; Eichner et al., 1979).

Most of the experience in chemical immobilization of horses has involved captive and domestic animals, but the efforts of a group at Washington State University appear likely to yield the experience necessary for using drugs to capture wild horses in the environments typically encountered in the western United States. Therefore, no additional work on chemical immobilization is recommended.

LEGAL AND POLITICAL ISSUES

The ultimate goal of this Committee is to prepare a research report that will assist decision-makers at the Bureau of Land Management and the Agriculture Department's Forest Service in making sound decisions on managing the wild horse and burro populations on federal lands. In order to achieve this goal, it is important for the Committee to understand the decision-making processes of the federal land management agencies and the legal and political constraints confronting federal land managers.

The legal and political literature on federal land-use planning, multiple-use decision making, wildlife management, and public land law history has been surveyed and listed in an annotated bibliography which will be appended to the final report on Phase I. The final report will discuss the history of the federal land-management agencies and the resources they manage, emphasizing the origin and importance of land ownership patterns and placing the wild horse and burro management program in the context of the agencies' management authority, their institutional structure, and their manpower and budget resources. In addition, the legislative history of the Wild and Free-roaming Horses and Burros Act of 1971 will be discussed in connection with a review of pre-1971 management of these animals under state estray laws and the 1959 federal law.

Table 2 contains a list of all civil law suits filed under the 1971 Act, along with brief descriptions of the legal issues in each case. Most of the lawsuits fall into two categories: (1) those challenging the need for wild horse and burro round-ups by federal agencies and the adequacy of the environmental impact statements relied upon by the Federal Government to justify those round-ups; and (2) those challenging the Federal Government's authority over the animals. The lawsuits reflect serious concern about the implementation of the Act both by those interested in protecting the animals and those interested in preserving state government control over them. The lawsuits also illustrate the serious disagreements among experts about such fundamental matters as herd size, population levels and trends, reproductive rates, and the impact of wild horses and burros on other animals, rangeland, and other natural resources. An analysis of the use of such information in the lawsuits and the reaction of the courts to this information will also be made.

As is shown in the bibliography to be attached to the final report, there is a substantial body of literature describing and analyzing the planning and decision-making processes of BLM and the Forest Service. In the final report these processes will be described in light of the agencies' new planning mandates from Congress and discuss the constraining effects of the agencies' single-purpose mandates as they affect efforts of multiple-use management. These constraints include the Endangered Species Act, the cultural resource program, and mining laws.

Table 2 Annotated Cases - Wild and Free-Roaming Horses and Burros Act

Reported Cases

1. Kleppe v. New Mexico, 426 U.S. 529 (1979) Constitutionality of the Act, particularly Federal authority to manage wildlife on public lands.

2. American Horse Protection Ass'n v. U.S. Dep't of the Interior, 551 F.2d 432 (D.C. Cir. 1977) Howe Massacre litigation - Issue -- whether ownership under state laws is to be determined by state or federal officials -- final decision is federal under S5 of the Act upholding Federal authority.

3. Roaring Springs Associates v. Andrus, 471 F. Supp. 522 (P. Or. 1978) Obligation of federal government to remove wild horses from unfenced private lands.

4. Sheridan v. Andrus, 465 F. Supp. 662 (D. Colo. 1979) (Craig, Colo.) Alleged improper taking by government of horses owned by plaintiffs.

5. American Horse Protection Ass'n v. Andrus, 460 F. Supp. 880 (D. Nev. 1978) (Palomino Corral and Nevada round-ups). Compliance with NEPA; legality of round-ups; humane conditions. (Appeal pending before Ninth Circuit.)

6. American Horse Protection Ass'n v. Kleepe, 6 ELR 20802 (D. D.C. Sept. 9, 1976) Legality of Challis round-up under the Act and NEPA.

7. American Horse Protection Ass'n v. Frizzell, 403 F. Supp. 1206 (d. Nev. 1975) (Stone Cabin round-up). Legality of round-up under the Act and NEPA and legality of state cooperative agreement.

Unreported or Pending Cases

1. State of Nevada v. U.S., Civ. No. R-79-185-BRT (D. Nev. filed 8/20/79). State seeks court-ordered gathering of horses back to 1971 census levels and a declaratory judgment that the state can manage the wild horse population itself without Federal interference.

2. State of Nevada v. U.S., Civ. No. R-78-0076 (D. Nev. 3/25/78) Jurisdiction of state versus federal government in ownership determinations. (Dismissed 3/28/79) (same issue as American Horse Protection Ass'n v. U.S. Dep't of the Interior.

3. National Animal Welfare League v. U.S. Dep't of the Interior, (Civ. No. F-77-93 E.D. Cal.) (burros in Saline Valley, Calif.) Legality of wild burro round-up program (bighorn conflict).

4. Humane Society of the U.S. v. Udall, Civ. No. 2158-68 (D. D.C. 1968). Challenge to Pryor Mt. round-up. Case dismissed when BLM stated it had no plans for a round-up.

The principal issue requiring primary research is how scientific information about wild animal populations and their relationship to land and water resources can be used in decision making. A study will be conducted to analyze the way in which horse and burro population data and needs are utilized in the multiple-use decision-making and planning process, with particular attention given to determining the amount of information which can be absorbed effectively by decision makers.

ECONOMIC CONSIDERATIONS

Information Needs

The NAS contract with BLM specifies that the research program should include investigation of the socioeconomic relationships involved in managing wild horse and burro populations on public rangelands. It is clear that economic studies can assist policy makers and managers by providing information about the changes in net benefits that may stem from different levels of management.

State of Knowledge

The literature on the economic impact of wild and free-roaming horses and burros is rather sparse, although range and ranch economics as a whole have a long-established history in many land grant institutions. From the mid-1950s through 1969 the Western Agricultural Economics Research Council (WAERC), comprised of the chairmen of the agricultural economics departments at land-grant universities in 11 western states, sponsored a Committee on the Economics of Range Use and Development. The WAERC committee issued a series of reports on a wide variety of range resource and management topics over that period. Range and ranch economics research still flourishes at several western universities despite the demise of WAERC, although the volume of research has probably decreased during the 1970s. Nonetheless, the annotated bibliography which will be appended to the final report contains many references to reasonably current studies. Ching (1978), and Nielsen and Workman (1971), contain extensive bibliographies on ranching and public land use in the western states.

Part of the impetus for the Public Rangelands Improvement Act of 1978 was concern that the public rangelands were producing at less than their potential. Several reports issued earlier in the decade, including the U.S. Public Land Law Review Commission's report <u>One Third of the Nation's Land</u>, study reports issued by the Stanford Environmental Law Society (1971) and the University of Wyoming College of Law (1970), a 1977 GAO study, Box et al., (1977), and papers from the 1977 Forum on the Economics of Public Land Use in the West (Ching, 1978). Recent studies of range improvement--for example, Burt (1971), Cordingly and Kearl (1975), Godfrey (1972), Olson et al., (1977), and Stevens and Godfrey (1972), provide information and propose methods for rangeland improvement which may be useful in cases where rangeland improvements occurr together with wild horse and burro populations and where the economic effect of the improvements must be considered in allocating rangeland resources.

Although economics literature on wild horse and burro issues is meager, theoretical methodologies which could be applied to the problem probably exist. Market and nonmarket valuation techniques have veen developed, although the latter are less refined and are still undergoing development. Non-market valuation and analysis for environmental and aesthetic values, including wildlife, are discussed in Krutilla (1972), Seneca and Taussig (1979), in Section 704. 129 (Recreation) of the recent U.S. Water Resources Council report (1979), and in Brookshire et al., (1979).

Hyde (1978), in a revision of a paper presented at the 1977 National Wild Horse Forum (Artz 1977), develops an approach for evaluating management alternatives qualitatively by comparing "consumer" benefits with management costs. The elements in Hyde's approach include:

1. The value of recreational viewing of horses and burros;

2. The "vicarious" value gained through the enjoyment of others or through knowing that wild horses and burros will be there whether a person ever sees them or not;

3. The value of animals removed from the rangelands and "adopted" by human beings;

4. The opportunity cost of domestic livestock and wildlife foregone because of competing wild horse and burro populations on public ranges;

5. The cost of managing wild horse and burro populations, including roundup, disposal, and legal and enforce-

ment costs; and

6. The cost of negative externalities imposed by wild horse and burro management on private individuals and economic units, such as unwanted grazing on private land.

Hyde recognizes the difficulty of quantifying the above elements, but urges that attempts to do so be made in demonstrative studies.

A second survey of the Wild and Free-roaming Horses and Burros Acts is by Godfrey (1979a and 1979b), the former being a project report and the latter a summary of the project report. In his summary Godfrey notes that "There are reasons why the capture and use of WFRHB need to be controlled but it is not obvious that the present laws result in efficient or equitable solutions." As to whether there is a solution, Godfrey has this to say:

> Most of the research that has been advocated by others is ecological, and must precede any economic evaluation of the WFRHB problem. However, a large portion of the work advocated by others will not answer the two basic questions faced by agency personnel: <u>How many WFRHB can be justifiably maintained and how can these numbers be most efficiently managed?</u>

Before these two basic questions can be answered, Godfrey says, attention must be paid to such major questions as (1) the value of, and the demand for, wild horses and burros, (2) evaluation of the adoption procedures and its success, (3) evaluation of control and management techniques, (4) analysis to determine the optimal number of wild horses and burros and management alternatives for maintaining populations at those levels, and (5) evaluation of the costs of existing regulations and restrictions. Godfrey's study, based on responses to a mail survey of BLM and Forest Service districts in ten western states, attempts to evaluate the economic costs of wild horse and burro management during the 1978 fiscal year and describes the reported impacts of the animals on other rangeland uses.

SOCIOLOGICAL ASPECTS

Information Needs

A 1976 report to Congress prepared jointly by BLM and the Forest Service on the administration of the Wild and Free-roaming Horses and Burros Act says that "greater public understanding of the wild horse and burro situation, plus public involvement in decisions concerning these animals, is vital to stated management goals." Thus, in order to determine appropriate management policies and strategies, to effectively and equitably allocate scarce resources, and to determine the need for greater public awareness efforts, it would seem that an empirical data on public attitudes, values, and preferences is needed.

What needs to be discovered, first is the relative worth of wild horses and burros to the various segments of the public concerned about them and their perceived role in a world of competing needs. The relative value of wild horses and burros to domestic livestock and wildlife should be determined by the recreational, aesthetic, utilitarian, ecological, scientific, and historical benefits associated with these animals.

Secondly, data should be obtained on the public's understanding and knowledge of horse and burro biology and its ecological effects, the multiple uses of public rangelands, legislative mandates, and the economic viability of the livestock industry.

The third type of information needed concerns the public's preferences regarding alternative management strategies. Studies of predator control and endangered species protection indicate that a number of variables seriously affect public attitudes towards management and control. Among these variables are the species under discussion, the humaneness of the control methodology, the degree of control, the cost of management efforts, the competing forms of wildlife, the socioeconomic impact of noncontrol, and others. The variables affecting public attitudes on alternative horse and burro control strategies are much the same as those affecting predator control, and are related to such options as animal refuges, population-control efforts, adopt-a-horse programs, and others.

Information on the views of both the general public and special interest groups should be obtained. To some degree the values of the general public were influential in the passage of the Act and it would be a mistake to promulgate policy without at least considering the views of the general public. But special interest groups must also be specifically considered, since their economic and environmental concerns will be the ones most affected by management programs. These special interest groups include several groups within the livestock industry (particularly cattlemen), wildlife professionals, horse and burro advocates, wildlife conservation groups, and outdoor recreationists.

State of Knowledge

The state-of-knowledge assessment has demonstrated that empirical data on the sociological aspects of the wild horse and burro issue is sorely needed. Many interesting and provocative accounts of public opinion were found, but nearly all stemmed from hearsay, personal judgment, or bias. The only attempt to ascertain public attitudes on the issue empirically, as well as to determine the values associated with wild horses, was a 1975 masters thesis by Mark Edward Rey at the University of Michigan entitled "A Critique of the Bureau of Land Management's Program for Wild Horses and Burros in the Western United States." Rey sought to "define exactly which resource values associated with wild horses should be maintained." To determine public sentiment on the issue, he surveyed recreationists and other key groups in the Pryor Mountain area of Montana regarding their views on various wildlife species (including wild horses) and their assumptions about the benefits associated with wild horses. Although the methodology might have been more sophisticated, the study provides at least some insight into the topic and (except for a fairly limited study by the National Park Service on burros) is about the only empirical material on the subject. Some useful sociopolitical analyses have also been written, and these are summarized in the annotated bibliography to be appended to the final report.

CHAPTER 5

NEEDED EARLY RESEARCH

OVERVIEW

Time Constraints and Priorities

It is clear from the foregoing assessment that the present store of knowledge regarding horse/burro management leaves much to be desired. In order to fill the gaps in current knowledge, the Committee is contemplating 18 research projects for recommendation in the final Phase I report. Since Public Law 95-514 specifies that the research should carry through two horse breeding seasons, however, research designs for nine projects are set forth in the following pages. These are projects that should begin early in 1980 in order to cover the 1980 and 1981 breeding seasons. These are:

Project 1:	Habitat Preference and Use
Project 2:	Grazing Impact on Plant Communities
Project 3:	Food Consumption Rates and Nutrition
Project 4:	Nutritional Plane, Condition Indices, and Reproduction
Project 5:	Blood Assay
Project 6:	Hydrologic Impact
Project 7:	Riparian-zone Impact
Project 8:	Contraception
Project 9:	Public Attitudes

Additional projects that will be proposed in the final Phase I report are:

Project 10:	Demography
Project 11:	Census
Project 12:	Social and Maintenance Behavior
Projects 13-16:	Economics
Project 17:	Role of Scientific Information in Decision Making
Project 18:	Genetics

The first nine projects proposed here may be grouped according to their importance with respect to the management alternatives described at the beginning of the preceding assessment section.

Alternative 2 (b): Projects 1, 2, 3, 6, 7, 8, 9

Alternative 2 (c): Projects 4 and 5

Integration, Scale, and Geographic Distribution

Project 1 should be conducted on study plots of five to six square miles per experimental treatment (to be outlined shortly). The scientific observations to be made will include equid behavior and habitat measurement. Projects 2, 3, and 6 should be conducted on study plots ranging in size from 100 to 300 acres per experimental treatment. The scientific observations to be made include the ecological impact of grazing, animal feeding behavior and nutrition, and measurement of various watershed attributes. Thus, several disciplines will be needed, and the availability of researchers in these several disciplines will have to be considered in determining the location and design of the projects. In addition, Project 5 should be carried out in conjunction with Projects 1, 2, and 3, and therefore should be planned and designed in coordination with them. Project 7 is likely to need a study area somewhat similar in size to that needed for Project 1 but requires, of course, the presence of a riparian zone. Therefore, where possible (i.e., where scientists in both disciplines are available), Projects 1 and 7 should be carried out on the same sample plots.

The ideal integration of these projects is shown in the following scheme for a single replication:

Class of Animals	Grazing Intensity: Moderate		Grazing Intensity: Heavy	
Horses	Projects 1,5,7	Proj. 2,3,5,6	Projects 1,5,7	Proj. 2,3,5,6
Cattle	Projects 1,5,7	Proj. 2,3,5,6	Projects 1,5,7	Proj. 2,3,5,6
Horses and Cattle	Projects 1,5,7	Proj. 2,3,5,6	Projects 1,5,7	Proj. 2,3,5,6
Neither		Proj. 2,6		Proj. 2,6

Each of these experiments, however, should be replicated three or four times, perhaps once in each of three or four states. It is not essential that the large-scale (1,7) and small-scale (2,3,6) studies be combined at a single site, as shown here. If expertise for Project 1 but not for Projects 2, 3, and 6 exists in a single area, Project 1 could be replicated in one area and 2, 3, and 6 replicated elsewhere. But if expertise can be brought together in a single area, such integration would be desirable.

Priority in these projects is given to horses and cattle because the possibility of competition between the two, both behavioral and for forage, seems greatest. If funds permit, however, sheep should be included even though their addition to the above scheme would double the number of experimental activities at each experimental site. A similar increase would occur for each additional wild ruminant included in a project. The scheme could also be repeated with burros instead of horses, which would mean another increase in the number of experimental activities at each experimental site. Details of the individual projects follow.

PROJECT 1. HABITAT PREFERENCE AND USE

Rationale

As discussed above, it is necessary to understand the habitat preferences of equids and other large herbivores, and how their use of habitats is modified by interspecific competition among them in order to allocate rangeland properly and develop site-suitability criteria. Since habitat preferences and the distribution of different species may vary seasonally, it is desirable to initiate studies of this subject as early as possible. They should be conducted year-round throughout the period of this program.

Objectives

1. Determine patterns of habitat structure (vegetative, topographical, soil, water) utilized by feral equids and domestic bovids in the presence of, and the absence of, potential competitors (i.e., equids alone, equids and cattle, cattle alone).

2. Develop an appropriate multivariate statistical model that allows testing of the following null hypothesis: "there is no difference in utilization patterns between equids and bovids."

3. Use this statistical model to determine the probabilities of habitat patterns that can be used to develop site-suitability criteria for both equids and cattle.

4. Synthesize the results from 1 through 3 above with the nutrition program and evaluate the existence of, and potential for, competition between these two species.

Experimental Design

1. A single experimental block should be a large area containing wild horses or burros.

2. Such a block should be subdivided into six treatments cells about five to six square miles each and characterized by adequate habitat and topographic diversity. The six cells should also be characterized by having different animal populations, namely:

a. Cattle stocked at a level that allows the land to retain its long-term carrying capacity.

b. Cattle stocked at a level considered too high to sustain the long-term health of the vegetation.

c. Equids stocked at the level described in a.

d. Equids stocked at the level described in b.

e. Equids and cattle stocked as in a.

f. Equids and cattle stocked as in b.

These cells must be large and diverse enough to allow natural segregation of habitats. They must also contain sufficient numbers of animals to insure statistical reliability.

3. Sampling should be done according to a suitable random or stratified-random design to eliminate bias and should concentrate on (1) feeding and watering, (2) escape (from pests or other disturbances), and (3) parturition and care of newborn. For each of these categories, multivariable vectors representing characteristics of the habitat structure are to be obtained. The variables chosen for measurement should reflect local conditions and incorporate consideration of vegetative structure, aspect (topography), edaphic structure (in the broad sense), and availability of water or other special requirements. To facilitate location of the animals under observation, it is desirable to use telemetered individuals. As with the nutrition experiments, emphasis should be placed on observing breeding-age females in order to maximize the probability of detecting demographic effects, should they occur.

4. Preliminary measurements should be evaluated for variations, and sample sizes computed (e.g., Cochran 1977) for stated levels of precision. Statistical procedures should be similar to those used by workers cited above (e.g., M'Closkey, Shugart, Sivinski). Multivariate analyses that allow testing of null and alternate hypotheses, and projections to group membership, should be emphasized. Data sets should be divided so as to maximize predictability.

5. This entire experiment should be replicated three orfour times in as many states in order to support generalized statements about equid and bovid habitat preference and use patterns and the possible effects of competition between the species.

6. Blood assays (described in Project 5) should be made, and the reproductive condition of mares checked during the appropriate season.

List of Competent Investigators for Project 1

1. Dr. Fred Bunnell, University of British Columbia
2. Drs. Steve Carouthers and James Reichman, Flagstaff Museum
3. Drs. Denniston and Mark Boyce, University of Wyoming
4. Dr. Roger Hungerford, University of Arizona
5. Dr. Dale McCullough, University of California, Berkeley
6. Dr. Robert M'Closkey, University of Windsor (Ontario)
7. Dr. Robert Ohmart, University of Arizona

PROJECT 2. GRAZING IMPACT ON PLANT COMMUNITIES

Rationale

The 1978 Act states that a program of research should be developed that defines the phrase "excess numbers of animals." This can be interpreted from either the standpoint of animal welfare or the standpoint of range welfare. There appears to be little quantitative documentation of grazing by either horses or burros in the published literature. Although several studies have attempted to document plant utilization levels by burros (Koehler 1974, Carothers et al., 1976, Hanley and Brady 1977) and horses (Salter and Hudson 1979), grazing by other ungulates using the same range has often confounded the results. Furthermore, the attribution of specific levels of defoliation to specific numbers of animal days of grazing has not generally been made. In the absence of protracted studies (longer than five years) of range trends, such quantitative data on plant utilization levels are critically needed to address the question of excess numbers from the standpoint of the range plant community's stability.

It goes without saying that herbivores affect the physical structure and botanical compostion of the plant communities upon which they graze. However, the effect is not uniform across animal species because different animals exhibit different forage preferences, dietary habits, and grazing behavior. To plan effective management programs, the range manager needs to know more than merely which plant species are consumed or preferred by the animals grazing on that range and the extent of their dietary overlap. He must also understand the temporal and spatial patterns of such grazing, the relative degree of foliage removal from the major forage plants in the community, and which other parts of various plants are consumed. All of these factors contribute to the persistence or the demise of individual plants in a community and, ultimately, to changes in competitive relationships and community succession. Studies of these relationships among cattle and sheep are fairly extensive but there have been relatively few detailed studies of equid grazing, either alone or in a combination with other large herbivores.

Ideally, such studies should be long-term (>5 years) in order to evaluate successional changes in plant communities directly. However, it is possible to draw inferences from short-term studies if utilization patterns for individual plants are carefully monitored and related to published information on the physiological responses of these plants to various levels of defoliation. Such studies could also form the beginnings of longer-term investigations involving the monitoring of successional change.

Emphasis is given here to horse and cattle impacts because this appears to be the most prevalent problem throughout the West. This does not imply, however, that other domestic animals (e.g., sheep) should not be considered if they are important locally. Nor does it imply that burro-livestock or burro-wildlife interactions should not be considered.

Objectives

1. Determine grazing distribution patterns (habitat selection) of horses and cattle when grazed as single species or in combination. This objective is to be addressed in Project 1.

2. Within important habitat segments, determine for the major forage species:

a. Temporal level of utilization (percentage of current year's plant production removed).

b. Use of standing dead or previous year's (in the case of shrubs) plant material.

c. Plant parts utilized.

d. Frequency and timing of defoliation.

e. Amount of forage re-growth and its utilization.

Experimental Design

1. In contrast to Project 1, this project should be conducted in paddocks on the order of 100 to 320 acres in size. These can be small pastures temporarily or permanently fenced so that local environmental conditions can be adequately controlled. The actual size of these pastures will depend on the grazing capacity of the areas selected for study, the season, and the duration of grazing periods.

2. Domestic horses generally representative of wild types in the locale can serve as the experimental animals in studies of plant utilization patterns and rates, daily forage consumption rates, nutritional value and, to some extent, forage preferences. The representation of social units and sex-age structures typical of wild herds will obviously not be possible in such small-scale, highly controlled studies. However, major attention should be focused on reproductive females. Domestic livestock used in these studies should be typical of local conditions in terms of breed, sex, age, and reproductive status. For example, steers should not be used to represent lactating cows simply for the sake of technical expediency.

3. Grazing season(s) should also be typical of local conditions. If existing conditions, for example, include year-long use of sagebrush-bunchgrass range by horses and spring use by cows and calves, the studies should be designed to represent and sample these conditions adequately.

4. The variations in this project should be the same as those in Project 1:

a. Grazing by equids at carrying capacity.

b. Excessive grazing by equids.

c. Grazing by cattle (or sheep) at carrying capacity.

d. Excessive grazing by livestock.

e. Grazing by equids and livestock at carrying capacity.

f. Excessive grazing by equids and livestock.

In addition, there should be control pastures where no grazing occurs. Stocking rates should be determined through consultation with professional range managers and scientists (BLM, Forest Service, SCS, university scientists, extension specialists) who are familiar with problems and conditions in each particular study area. The pastures with both equids and livestock should be stocked so that the year-long level of grazing is on an equivalent animal-unit-month basis for the two species.

5. Where possible, grazing by native ungulates should be incorporated in the experimental design. This might be treated as a separate main effect, with appropriate blocks for a combination of horses (or burros), domestic livestock, and native ungulates, or it might be an alternate experimental design (e.g., split-plot) where separate blocks are not used. The use of tame, hand-reared animals in either of these designs would provide an avenue for highly controlled studies of equid-wild ungulate interaction. With the exception of bighorn sheep, tame animals have been used often in studies of various aspects of animal habitats (see, for example, Currie et al., 1977, McMahon 1964, Neff 1974, Reichert 1972, Smith et al., 1979, Wallmo et al., 1972, for studies on mule deer; Collins et al., 1977, for elk; and Schwartz and Nagy 1976, for pronghorn antelope). At minimum, range use by native ungulates should be monitored in any study location where their presence is significant. Attention should be focused both on social interaction with horses (or burros) as well as interaction mediated through food or water resources.

6. Untilization patterns and rates hould be carefully measured as a basis for inferring plant community change. Utilization rates and levels should be closely related to extent of grazing use (in animal-unit-days or animal-unit-months). This approach necessitates careful quantification of growth (and re-growth) curves for ungrazed plants representative of the plant species being studied.

7. Findings on seasonal levels and rates of species

utilization should be related to published data, and inferences should be drawn as to the likely directions and rates of plant community change under various levels of grazing pressure. Examples of pertinent literature in this regard might include West (1968), Willard and McKell (1973), Pechanec and Steward (1949), West et al. (1972), Hyder et al. (1975), Smith (1967), Cook (1971), Ellison (1960), Laycock (1967). The recent bibliography by Vallentine (1978) should also be consulted.

8. The approach advocated here is viewed as yielding rapid but relatively imprecise answers to questions about grazing impact. An essential part of such a study is early establishment of permanent range-trend transects for both grazed and ungrazed pastures. If the experimental grazing experiments could be continued beyond the two-year limits imposed on this study, such transects would provide the long-term data necessary for ultimately determining the effects of wild horses and burros on plant community change. This research could be sustained beyond the initial two years with relatively small amounts of funds, and the potential pay-off is great.

List of Competent Investigators for Project 2

Since Projects 2 and 3 can be carried out together, the list that follows includes investigators who (with the one exception noted) could carry out both projects.

1. Drs. Reldon Beck and Joe Wallace, New Mexico State University

2. Dr. Robert Ohmart, Arizona State University (Project 2 only)

3. Dr. Randy Rossier, University of California, Berkeley

4. Drs. Michael Smith and Jim Waggoner, University of Wyoming

5. Dr. Larry Rittenhouse, Colorado State University

6. Dr. Martin Vavra, Oregon State University

PROJECT 3. FOOD CONSUMPTION RATES AND NUTRITION

Rationale

In addition to understanding the impact of grazing animals on plant communities, the range manager must also understand ecological limitations on animal reproduction. Various studies show the critical link between a plant community and the demographic response of an animal population. Considerable research has been conducted on how ecological conditions affect the nutrition and feeding of sheep and cattle (e.g., Cook and Harris 1967, Cook et al., 1967, Cook et al., 1953, Cook et al., 1962), mule deer (e.g., Dietz and Nagy 1976, Smith 1952, Smith 1959, Hansen and Reid 1975), and pronghorn antelope (e.g., Beale and Smith 1970, Mitchell and Smoliak 1971, Severson and May 1967, Severson et al., 1967). However, little comparable work has been done on either the wild horse or the burro under range conditions.

Virtually no information exists on the daily forage intake of wild horses. This information is critical for calculating grazing capacities under BLM's forage allocation system, and it supplies a quantitative perspective in any evaluation of a habitat's nutritional value. From an experimental and technical point of view, studies of the nutritional value (i.e., chemical composition) of range forage for grazing horses and studies on forage intake could logically proceed simultaneously. However, determining chemical composition has secondary priority and could be delayed or omitted if necessary. Studies of food habits should also be an integral part of such an inquiry, and such data are easily obtained in conjunction with work on nutrition and intake. All of these components are presented below as objectives, on the assumption that they will proceed simultaneously under a single experimental design.

Objectives

1. Determine seasonal botanical composition of diets in relation to kinds and amounts of available forage.

2. Determine daily forage intake as related to animal size and physiological status (i.e., maintenance, gestation, lactation) and to type and amounts of available forage.

3. Determine nutritional value of diet as related to animals' nutritional demands and as affected by season and types and amounts of forage available. Major

attention should be given to dietary N, P, digestable energy content, and fiber components according to the system of Van Soest (1967).

Experimental Design

1. Objectives in this study can be met through the use of domestic horses and tractable livestock (cows or sheep) as experimental subjects in the general experimental design set forth in Project 2.

2. Diets should be determined by a technique other than fecal analysis. Use of animals fitted with esophageal fistuale and cannulae, with subsequent microscopic analysis of fistual extrusa (reviewed by Theurer et al., 1976) is a valid technique that would be feasible under the constraints of the present design. Alternatively, a bite-count technique (Wallmo and Neff 1970) or suitable modification thereof would be appropriate if carefully controlled and validated with a proven procedure, such as the fistulated animal technique. These specifications do not preclude the use of fecal analysis procedures. Indeed, this study would provide an opportunity to validate the fecal analysis technique under field conditions. However, it should not be relied upon as the sole procedure in that its accuracy and precision are presently subject to question (Smith and Shandruk 1979, Vavra et al., 1978).

3. Diets should be sampled at least on a monthly basis during times when animals inhabit the particular range being studied. Detailed information on forage available (such as that derived from the "grazing impact" study) should be obtained in conjunction with dietary sampling.

4. Nutritional value of diets should also be studied on a monthly basis, and such studies could be linked with diet-analysis studies, as outlined under objective 1 above. Laboratory analysis of samples obtained either via fistula or by hand-plucking should include as a minimum: dry-matter, nitrogen (crude protein), phosphorus, gross energy, cell walls, cellular constituents, and lignin.

5. Additionally, estimates of forage digestibility should be obtained for ruminant species grazing with horses. This should be approached using in vitro techniques, preferably those of Tilley and Terry (1968). However, in vitro procedures have apparently not been perfected for equine species. Hence, a limited number of in vivo

digestion trials with horses will be required. This should be approached through trials that employ classical techniques where penned animals are fed controlled quantities and feces are totally collected. The major forage species constituting the seasonal diets of horses should be fed in mixtures approximating measured dietary botanical composition (from Objective 1, above). The major limitation of this approach is in harvesting suitable quantities of native forages for feeding trials. However, alternative methods, such as the lignin-ratio, appear undependable. These trials will offer an opportunity for development of in vitro procedures directly applicable to equine species. This technique development should be pursued, as the potential pay-off is large in relation to the small marginal investment of research time and funds.

6. Forage intake by the grazing animal should be measured by the procedures of Garrigus and Rusk (1939), described by the equation:

$$\text{Drymatter intake} = (\text{Fecal output}/100\text{-}\%\ \text{drymatter digestibility}) \cdot 100$$

7. Fecal output should be measured using total collection procedures, with animals wearing fecal collection bags. Alternatively, appropriate indigestible indicators (e.g., Cr_2O_3 or appropriate rare-earth compounds) can be used to estimate fecal output if adequately validated and quantitated.

8. Intake studies on horses should focus on the reproductive female and should be phased so that they cover the three major physiological phenophases: (1) maintenance, (2) gestation (especially the last trimester of pregnancy), and (3) lactation.

List of Competent Investigators for Project 3

See Project 2.

PROJECT 4. NUTRITIONAL PLANE, CONDITION INDICES, AND REPRODUCTION

Rationale

The nutritional condition of the female is considered to be of primary importance to estrus, ovulation, and survival of the offspring from conception to weaning. The rate at which offspring are produced is a critical demographic characteristic in estimating rates of population increase. If a link between levels of energy and nitrogen intake and reproductive success could be established, and if these levels of response could be predicted by measures of the condition of the animal, the ability to estimate reproductive rates from range conditions or the nutritional condition of the animals would be greatly enhanced.

Objectives

1. Determine the relationship between the nutritional plane of a mare and the probability that she will produce a foal.

2. Assess indices of animal condition for their ability to predict the relationship between nutrition level and reproductive success. Should some indices of animal condition prove to be successful predictors of reproductive rate they will be used to estimate reproductive rates in wild populations.

Experimental Design

1. Confine groups of 10 domestic mares annually for two years (or 15 to 20 for one year) in each of the nine blocks to be described below. Do not use ponies. Ideally, the study should run two years, since the given nutritional plane may have a cumulative effect. Reproduction in one year often reflects nutrition from a previous year, although acute nutritional deprivation can delay the onset of estrus or perhaps inhibit it completely if there is no improvement in food supply. The mares should range in age from four to ten years. (The age of onset of the estrous cycle is a separate question).

2. The nine feeding blocks are all possible combinations of three levels of energy intake and three levels of nitrogen intake. This nine-block design can be achieved in several ways.

a. Levels are set in absolute intake values for energy and nitrogen and not varied throughout the experiment. This is the simplest method. The advantage of such a constant feeding system is that a particular level of energy and nitrogen intake can be related directly to success in a particular stage of reproduction.

b. Three levels of energy simulating winter conditions are fed to three groups and then each of these three groups is divided into three groups and fed at high, medium, and low spring conditions. This design mimics the nine possible combinations of sequences involving a poor, medium, or high quality winter followed by a poor, medium, or high quality spring. The advantage of this design is that it simulates the real sequence of events in wild populations more accurately than the constant ration does.

The design included N as well as energy, however, it would contain 81 cells and hence would be too large to accomplish with reasonable effort.

c. Nutritional levels as some percentage of the NRC requirements for maintenance, gestation, and lactation. In this case, nutritional intake at a particular level would increase with gestation and lactation according to some percentage of the increment suggested by the NRC. The difficult aspect of this approach is establishing the nutrient levels. A guideline might be conditions existing on very good and very poor ranges, with an intermediate level included.

d. Nutritional levels are set as a precentage of dry weight, and the horses are fed ad libitum. This allows the horse to respond naturally to poor food by increasing its intake. Percentage of dry matter as a measure of nutritional level is more easily translated into range conditions than other measures used in previous designs. The horses will not be on a constant nutritional plane and the establishment of high, medium, and low nutritional levels will be difficult. However, some preliminary feeding trials might help to establish them.

3. The reproductive characteristics to be measured in order to establish the quantitative relationships between nutritional plane and reproductive success which can then be used for demographic models of specific ranges are:

a. Estrus (onset of behavior).

b. Ovulation rate (rectal palpation).

c. Number of estrous cycles (behavior and progesterone) before pregnancy-extended cycles (prolonged corpora lutea-life).

d. Conception.

e. Implantation rate (rectal palpation, PMSG, pregesterone), embryonic loss (PMSG, progesterone, urinary estrogens).

f. Foaling rate (count live, abortions, stillbirths).

g. Length of gestation (dates of breeding).

h. Parturition (independent or requiring assistance, duration at birth).

i. Weight of foal at birth.

j. Lactation behavior (ability to nurse, acceptance by mare).

k. Nutritional composition of milk (colostrum at two and six weeks, protein fat, carbohydrate).

l. Milk production (probably difficult to quantify).

m. Foal growth and behavior (weight weekly, withers height, etc. and simple estimate of activity level).

4. Condition measures (every two weeks) to establish measures which correlate with empirical intake data, general condition measurements, reproductive characteristics, and seasonal variation. This would allow evaluation of particular wild herds and assist demographic projections of population changes.

a. Hematology (CBC).

b. Chemistry:

Serum urea nitrogen
Glucose
Triglycerides
Serum protein and albumin
Uric acid
Bilirubin
Free fatty acids (NEFA)
CPK
Ketones
Haptoglobin
Transferrin

5. Behavioral sampling for the purposes of:

a. Determining activity levels so that nutritional levels can be accurately generalized to free-roaming populations whose activity levels are likely to be different.

b. Correlating differences in reproductive performance and condition to activity measures.

c. Comparing nutritional effects on activity.

Specific behavioral sampling:

When females in the experiment are mated, behavioral samples identical to those used in the contraceptive experiment will be recorded. These data will show how the nutritional plane affects the sequence of sexual behavior between stallion and mare.

Focal Animals:

The groups for this experiment will be composed of mares from each nutritional group with an experienced stallion.

Sampling Schedule:

The sampling should be conducted primarily during the breeding season so that good activity profiles are available for different phases of the breeding cycle.

Specific Behavioral Samples:

The behavior of animals is important to the determination and functioning of their social groups and to successful breeding. Since nutrition affects the reproductive success of the animal, it will be essential to measure the differences in behavior between nutritional groups to determine sensitive points in the reproductive levels. The effect of behavioral changes in individuals on the group's social dynamics can be monitored, and the ecological and management implications of these effects might be suggested.

Sampling Scheme:

Besides the activity and frequency of social behavior sampled by the FSP method, reproductive behavior needs to be sampled in detail.

Reproductive behavior can be divided into functional categories. These categories are necessary because a breakdown in the reproductive act can be assigned either to the mare or the stallion and the breakdown can be identified as having occurred at a particular phase of the reproductive act. The object of this sample will be to monitor the behavior of mares on different nutritional planes and their stallions to determine differences in each of these functional categories. The differences can then be related to failure at various stages of the reproductive sequence. Samples should be continuous focal samples. The time and intensity of the samples can be determined by the researcher. The continuous samples will record the occurrence of sexual behavior, with a time record. From these samples the rates of reproductive behavior can be calculated and tested against estimates for wild populations. Spacing data gives information on the distance between individual members of the groups. These data can be recorded at a time when the distances and identity of the individual animals are recorded. These samples would be taken at the beginning and end of all half-hour FSP samples. These data will allow a comparison not only of sexual states but also of dominance rank. Spatial displacements, usually a reliable indicator of relative dominance among individual animals, will be recorded as part of the continuous focal samples.

List of Competent Investigators for Project 4

1. Dr. H. F. Hintz, Cornell University
2. Dr. G. H. Stabenfeldt, Eastern Montana University

PROJECT 5. BLOOD ASSAY

Rationale

It has been suggested above that various blood characteristics could be used to provide sensitive and easily taken indices of nutritional plane. These could be used as both predictors of the animals' demographic performance and as indicators of range conditions. This project would involve routine blood sampling and assays on the experimental animals described in Projects 2, 3, and 4 to test their usefulness in determining ecological and nutritional characteristics.

Objectives

1. Systematically collect blood samples during habitat interaction studies from cattle and horses for hematological and chemical assays to provide independent evaluation of animal condition and establish correlates with range condition evaluation.

2. Systematically collect blood samples during range nutrition studies for blood assays to establish correlates with condition and known levels of food intake and utilization.

3. Systematically collect blood samples from mares in the reproductive performance study to establish correlates with condition, reproductive success, and mechanisms of reproductive suppression.

Experimental Design

1. At each sampling time, extract 50 ml of blood from the jugular vein of roped and pole-restrained animals, or from animals in chutes or from drugged animals. The procedures are well-known and are commented upon by Kirkpatrick (1979) in his article on restraint procedures for the evaluation of stress. If drugs are used it is important that they be identified and specified, since the various immobilization drugs have an impact on laboratory studies (but not genetic studies). In particular, Rompun (xylazine, Chemgro Corp.) should be avoided if clinical metabolic studies for evaluating condition are to be performed, since this drug results in a steady increase in blood urea and blood glucose for a period of four to six hours after its administration. It also would be desirable to collect samples from the animals as soon after capture and handling as possible and certainly prior to their being fed or transported to longer-term holding facilities. Blood sampling can be accomplished by either a veterinarian or a trained wildlife technician.

2. Samples should be preserved for analysis by a single laboratory if at all possible in order to minimize interlaboratory variation, and procedures should be

established to document quality control, including reproducibility and accuracy. A very high degree of laboratory precision can be achieved in each of the assays listed below, and excellent procedures and equipment are available for achieving this precision.

3. Approximately 2 ml of the sample should be drawn into a tube containing EDTA (ethylenediaminotetraacetate) as an anticoagulant for hemotology. Approximately 5 ml should be drawn into a tube containing heparin for the preparation of red cells and plasma for molecular genetic studies, and approximately 5 ml should be drawn into Alsevier's solution for determining blood groups. The remainder of the sample should be placed in untreated tubes for the preparation of serum.

4. The following blood assays should be evaluated for their correlation with measures of animal nutritional condition, evaluation of range condition, measures of reproductive success, and estimation of the presence of disease:

a. Serum urea

b. Hematocrit and hemoglobin concentration

c. Serum protein concentration

d. Haptoglobin

e. Greatine phosphokinase

f. Triglycerides

g. Uric acid

h. Bilirubin

i. Free fatty acids and ketones

j. White cell count and differential

k. Transferrin

l. Various special clinical studies--serology.

PROJECT 6. HYDROLOGIC IMPACT

Rationale

It may well be that various grazing intensities at different seasons among different classes of grazing animals produce a variety of hydrologic responses. These responses should be explored and described in order to provide direction in formulating predictive tools for grazing hydrology.

Infiltration rates govern much of the hydrologic behavior of rangelands. Therefore, much can be gained simply by looking at spatial and temporal patterns of infiltration. On many rangelands, infiltration rates tend to recover somewhat during rest periods (no grazing) and also during the winter. The latter type of recovery is often attributed to freeze-thaw activity, among other things. The recovery process is also currently envisioned (Gifford and Hawkins, 1979) as being rather slow, certainly in excess of one year. The fact that infiltration rates appear to recover from grazing activity more slowly than vegetation has created a serious unknown in terms of hydrologic evaluation of modern grazing schemes, which employ various rest periods. In other words, long recovery times may reduce the prospects for improving watershed conditions through improved management. Therefore, if the recovery process could be adequately modeled--especially in terms of easily measured field variables--recovery rates could be readily estimated for specific plant-soil complexes and resultant watershed behavior patterns could be better represented.

The Universal Soil Loss Equation (USLE) is a tool that was initially developed for predicting rill and interrill erosion from farmlands east of the Mississippi River. Within the last several years, however, this technique has been extrapolated to areas throughout the western United States. At the current time, despite wide use by all land management agencies, the technique and modifications thereof remain almost completely unvalidated. It is important to hydrologic impact evaluation that the numbers generated through use of the USLE represent actual soil-loss potential rather than relative values bearing no resemblance to the real world. Hence, the accuracy of the equation needs to be scrutinized using field experiments. Such scouting during equid and livestock grazing would benefit both management of these animals and range hydrology.

Objectives

The following objectives should be addressed in connection with Projects 2 and 3.

1. Measure infiltration rates during critical runoff periods on selected sites representing different grazing intensities, various seasons of use, and various types of grazing animals (horses, burros, and domestic cattle).

2. Use the measured infiltration rates to infer hydrologic behavior and to modify existing predictive tools or construct new ones useful to practicing hydrologists, to a degree consistent with the limitations of the experimental design.

3. Construct an infiltration-recovery model suitable for use on areas grazed by horses, burros, and domestic cattle. The model should initially be consistent with the physical properties of soils and with the physical principles associated with known freeze-thaw phenomena. This modeling effort should then be utilized to formulate secondary models suitable for use by field hydrologists.

4. Validate, in conjunction with ongoing field infiltrometer studies, the model(s) developed under objective 3.

5. Evaluate the applicability of the USLE, or modifications thereof, for rangelands grazed at moderate and heavy intensities by horses, burros, and domestic cattle.

Experimental Design

The following observations should be made in conjunction with Projects 2 and 3.

1. Infiltration rates should be measured with a sprinkling type infiltrometer on plots large enough to sample the variability present in an area, particularly that associated with vegetation patterns (i.e., brush and interspace combinations). Rainfall application rates should be sufficient to exceed infiltration rates, and drop size and raindrop terminal velocities should approximate a natural storm of the intensity simulated.

2. Infiltration curves representing the duration of rainfall simulation should be constructed even though

primary emphasis is placed on final, "constant" infiltration rates at the end of a specified period.

3. Obtain sediment measures (or other water quality measures) from the infiltrometer plots. These data should then be utilized to develop comparative relationships among variables as well as to validate or modify the Gifford and Hawkins (1979) infiltration model and other predictive tools.

4. Construct an infiltration recovery model according to established principles of soil physics and soil mechanics as well as information from controlled laboratory studies. The model should be applicable to a wide range of soil textures and plant-cover conditions.

5. Validate the infiltration recovery model from the above infiltrometer studies.

6. Evaluate the USLE, or modifications thereof, for predicting erosion under moderate and heavy grazing by using standard erosion plots 6 X 72.6 ft. on 9 percent slopes. Where possible, the study should use rainfall simulators with known drop-size characteristics and drop velocities to ensure that data are available upon which to evaluate the question.

List of Competent Investigators for Project 6

1. Dr. Will Blackburn, Texas A. and M. University

2. Dr. John Buckhouse, Oregon State University

3. Dr. Fee Busby, University of Wyoming

4. Dr. Martin Fogel, University of Arizona

5. Dr. C. M. Skan, University of Nevada, Reno

6. Dr. Freeman Smith, Colorado State University

PROJECT 7. RIPARIAN-ZONE IMPACT

Rationale

The riparian zone, based on the variable source-area concept, is extremely important not only in terms of total watershed behavior but also in terms of its individual components--fish, wildlife, insects, vegetation, birds, soil, and so on. This study would concentrate on defining the impact of burros, horses, and cattle on hydrologic behavior and water quality, both of which affect all other components of the riparian zone.

Objectives

1. Determine, on a seasonal basis, suspended sediment, bedload, fecal coliforms, water temperature, total dissolved solids, dissolved oxygen content, and general channel stability of select portions of riparian habitat grazed by horses or burros or cattle.

2. Relate measured water quality and channel stability characteristics to the characteristics of the adjacent riparian habitat. Important characteristics would include percent vegetative cover, grazing intensity, and rest periods. Other important considerations include general behavioral characteristics of these animals with respect to use of the riparian habitat.

Experimental Design

The design of this study will depend to some extent on whether the grazing animals are utilizing springs, established water holes near wells, or live streams as a source of water. It would be desirable, if possible, to include riparian zones in relatively good condition rather than zones that have been heavily utilized.

In dealing with the impact of the animals on lakes, ponds, seeps, or springs, some sort of fencing scheme will have to be used that will, for all practical purposes, subdivide the watering site into zones representing various intensities of use. To avoid confounding water-quality data with intensity of use, the water source itself may have to be subdivided in a permanent way; this would eliminate, for example, the possibility that the impact on water in heavily used areas would be confused with the impact on water in lightly used areas. Where the above is impossible or impractical, replicated watering sites may have to be created that represent desired use levels. Each of these sites would be fenced to control access.

The same basic problems apply to rivers and streams, but stream geometry may further complicate the sampling procedures, especially with respect to water-quality characteristics. Fencing schemes will be necessary to define intensity of use. Water-quality sampling will have to be carried out on a "flow-through" basis, with samples taken as water enters a specific reach representing a given intensity of use and again as water leaves the reach. This scheme dictates that intensity of use must increase in a downstream direction rather than in a random pattern.

List of Competent Investigators for Project 7

Same as individuals listed for Project 6.

PROJECT 8. CONTRACEPTION

Rationale

Management of the wild equid population means having to deal with multiple populations of differing size, composition, and accessibility. If population control is desired and removal techniques cannot be used, long-term contraception programs may be an effective alternative. The studies proposed here will provide data on short-term effectiveness. Blood levels of compounds and measured rates of release will allow a projection of likely life.

Objective

Establish a method of reproductive inhibition in female horses and burros which (1) is at least 95 percent effective, (2) requires a single treatment or administration under field conditions, (3) will last at least five, and preferably 7, years, (4) is potentially reversible, and (5) will not adversely affect the health or behavior of the animal.

Experimental Design

1. Establish five experimental areas, each one involving five captive mares, as follows:

Control -- no treatment (placebo-vehicle)

Compound A -- estimated dose for 5 years

Compound A -- five times base dose

Compound B -- estimated dose for 5 years

Compound B -- five times base dose

Use nonpregnant breeding age females (four years or older), preferably of established reproductive status (either known to have cycled or been pregnant the past year).

2. Place implants intramuscularly early in the breeding season, if possible. Solid rod silastic implants should be given primary consideration. Use known amounts of drug in each implant.

3. Measure the following:

a. Reproduction

(1) Estrus. Does it occur, or is it completely suppressed (behavior and appearance of genitalia)?

(2) Ovulation. Determine by rectal palpation and progesterone.

(3) Breeding. Will the female accept the stallion (test)?

(4) Pregnancy. Determine by rectal palpation and hormones.

(5) Foaling.

(6) Foal heat.

If an agreed percentage of the animals becomes pregnant after implantation the trial is a failure and should be terminated.

b. Condition

(1) Hematology: CBC

(2) Chemistry:

Serum urea nitrogen	CPK
Glucose	Ketones
Triglycerides	Haptoglobin
Serum protein and albumin	Transferrin

Uric acid
Bilirubin
Free fatty acids (NEFA)

(3) Behavior

(a) Focal Animals: The groups for this experiment will be composed of stallions and mares. Stallions of different social rank (if multi-male groups are used) should be chosen as focal animals. Mares should be picked to include animals of different ranks in both the normal and treated (contraceptive) groups.

(b) Sampling Schedule: The sampling schedule should be intensified during the breeding season so that activity profiles are available for different phases of the breeding cycle.

(c) Specific Behavioral Samples:

Rationale: Behavior of animals is important to the determination and functioning of their social groups. Since contraception changes the hormonal activity of the animal and hormones are often linked closely with behavior, it will be essential to measure the differences in behavior exhibited by normal and contraceptive mares. The effect of behavioral changes in individuals on the group's social dynamics will be monitored, and the ecological and management implications of these effects can be suggested.

Sampling Scheme: Besides the activity and frequency of social behavior sampled by the FSP method, reproductive behavior must be sampled in detail. Reproductive behavior can be divided into functional categories. These divisions are established because breakdown in the reproductive act can be assigned either to the mare or the stallion and the failure can be assigned to a particular phase of reproductive interaction. Proceptive behavior is that which the female uses to make her reproductive condition known to the male. This behavior includes raising the tail, urinating with urination stance, and approach or spacing relative to the male. The male's response is termed attraction behavior. His approaches, spacing relative to the female, and mounting attempts signal his perception of her state. Finally, her acceptance of the male is termed reception and is evinced in either acceptance (or ultimate rejection) of mounting attempts.

The object will be to monitor the behavior of normal and contraceptive females and their stallions to determine differences in each of these functional categories. Differences can then be related to failure at various stages of the reproductive sequence.

Samples should be continuous focal samples. The time of the samples and their intensity can be determined by the researcher. The continuous samples will record occurrences of sexual behavior with a time record. From these samples the rates of sexual behavior can be calculated and tested against estimates for wild populations.

Spacing data gives information on the distance between individual members of the groups. These data can be taken at a time when distances and identity of individuals can be recorded. These samples should be taken at least at the beginning and end of all half-hour FSP samples. Since spatial relationships often give an indication of social relationships, these data will allow a comparison not only of sexual states but also of diminance rank. Spatial displacements, usually a reliable indicator of relative dominance between individuals, will be recorded as part of the continuous focal samples.

(d) The following hormone levels should be measured regularly:

(i) Blood levels of contraceptive

(ii) Progesterone

(iii) Mensure rates of release from device

List of Competent Investigators for Project 8

1. Dr. O. J. Ginther, University of Wisconsin
2. Dr. Jay Kirkpatrick, Eastern Montana University
3. Dr. B. W. Pickett, Colorado State University

PROJECT 9. PUBLIC ATTITUDES

Rationale

The joint 1976 BLM/Forest Service Report to Congress referred to earlier stated that "...greater public understanding of the wild horse and burro situation, plus public involvement in decisions concerning these animals, is vital to stated management goals." A two-year research effort is herewith proposed that could enhance agency understanding of public awareness, needs, attitudes, and preferences.

Objectives

1. Ascertain public attitudes and values associated with wild horses and burros in relation to wildlife and livestock.

2. Ascertain public benefits associated with wild horses and burros, as well as problems (social, economic) relating to these animals.

3. Ascertain public preferences among alternative management and control strategies.

4. Ascertain public knowledge of wild horse and burro biology and ecological impact, multiple use management of public rangeland, and legislative mandates dealing with the management of rangeland, including animals dependent on public lands.

Experimental Design

1. Conduct a national survey of the general public and special interest groups. A mail or telephone survey (rather than personal interviews) will minimize costs. At least three pretests of the interview questions should be required. Consultation with the contractor or a responsible designated project officer should follow two of the three pretests. One set of interview questions should cover public attitudes regarding the values and benefits associated with wild horses and burros. Attitude questions should also include questions on the socioeconomic problems of wils horse and burro management, range management, and related wildlife management issues. Additional questions should be devoted to alternative management and control strategies.

2. A second set of questions should cover public

knowledge and understanding of wild horses and burros, range management, and related factual matters. A third set of questions should cover the behavioral interaction of wild horses and burros with wildlife, livestock, and outdoor recreation activities. A final set of questions should cover the relevant sociodemographic characteristics of the respondents.

3. A separate survey should be developed for special interest groups. This survey should include all of the questions asked of the general public plus questions on matters of particular concern to special interest groups. For example, livestock producers should be asked questions about the socioeconomic impact of varying degrees of wild horse and burro management; horse and burro advocates should be queried as to alternative control strategies; wildlife professionals should be asked questions about perceived impacts on wildlife; etc.

4. The national sample should be randomly selected. A probability random sample is preferred, but if costs are prohibitive an area random sample should be employed. The special interest group samples should be randomly selected from organizational or comparable lists of relevant individuals.

List of Competent Investigators for Project 9

1. Dr. James Applegate, Rutgers University

2. Dr. Perry Brown, Oregon State University

3. Dr. Tommy Brown, Cornell University

4. Dr. William Burch, Yale University

5. Drs. Neil Cheek and Don Field, University of Washington

6. Drs. William Shaw and E. A. Carpenter, University of Arizona

7. Drs. George Stankey and Robert Lucas, University of Montana

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ADDENDUM TO INTERIM REPORT ON WILD HORSES & BURROS

EQUID CENSUS: POTENTIAL METHODS

Many animal population measurements fall into one of three basic categories: (1) indices, (2) complete counts, and (3) estimates based on various sampling approaches. With the exception of a few small-scale research studies, most current efforts to census wild horses and burros have involved some form of aerial counting. The choice has no doubt been made on the basis of cost effectiveness, topography, and limitations of manpower. There are almost no published data on the accuracy of aerial counts of wild horses and burros and very little data on the variability to be expected in repeated surveys of the same areas. It is thus essential to obtain such information before a final decision as to choice of methods is made. However, obtaining the necessary data calls for research on aerial surveys of wild horses and burros; thus in this review it will be assumed that the principal method to be considered is the aerial count. There will be only brief consideration of other methods.

Indices

Many wildlife problems have been approached by measuring relative abundance, i.e., by taking an index of abundance. Indices generally provide no estimates or counts of actual numbers of animals in an area, but instead provide relative measures of numbers. All indices depend on the universal assumption that the index values are some constant function of, or bear some constant relationship to, actual population size. Where this assumption holds, indices are valuable for estimating rates of population change over time and in comparing densities between areas.

The index methods that may have potential utility for wild horses and burros include visual counts, track counts, and fecal counts. Visual counts might be simple tallies kept in the course of travel on other business or made on selected routes at prescribed times. Counts at watering sites could also be particularly effective. Track counts, which might be combined with visual counts, are most likely to be effective if made on fresh snow or wet earth. Fecal counts have been extensively used for cervids (e.g., white-tailed deer and elk), but not for equids. Correction factors are available for cervids to convert their counts to estimates of absolute abundance; similar factors might be obtainable for equids. Development of an effective index method would require a designed study combined with censuses conducted by proven methods.

Since any management program that allocates forage to a specific number of equids requires an estimate of absolute numbers of horses and burros, an ordinary index would not be suitable. It would have to be "calibrated" somehow, so as to provide an estimate of absolute numbers. It actually may be appropriate to consider many of the present aerial-survey estimates as indices, as will be discussed below. It is for this reason, and because of the tentative inferences drawn earlier in this report on horse-population trends from aerial censuses, that the subject of indices has been mentioned briefly here.

Complete Counts

Present BLM surveys are almost exclusively attempts to conduct aerial counts of all animals on a given area. In fairly open regions with low vegetation, a skillful observer working with a cooperative pilot may be able to tally nearly all the animals present. Scientific proof of this ability depends on some sort of independent check, probably best obtained by a marking program. In areas of dissected topography and heavy cover, it is quite likely that some proportion of the animals present are missed. Data assembled from various surveys of different species (Caughley 1974) indicate that appreciable fractions of the animals present are not seen from the air. Extensive experience with African game animals has led workers there to use rather narrow strips for aerial counts, and to depend on sampling rather than attempting complete counts (see Sinclair 1972, Goddard 1967). Since the African environments involved are quite similar in topography and vegetative cover to many horse and burro ranges, careful consideration should be given to the techniques developed there.

Evidence also indicates that such factors as air speed, altitude, width of strip searched, type of aircraft, and observer experience have important effects on aerial counts. These factors are described by Erickson and Siniff (1963), Pennycuick and Western (1972), LeResche and Rausch (1974), Norton-Griffiths (1975, 1976), Caughley et al. (1976), and Frei et al. (1979).

When complete counts are attempted, their accuracy must be tested and correction factors devised. One such test is the "bounded-counts" method. It requires that a number of successive counts be made in a manner that provides some positive probability that at least one count will include all animals present in an area. The two highest counts are then used to estimate the actual population. The bounded-counts method is based on theory developed by Robson and Whitlock (1964), and was suggested by Regier and Robson (1967). Overton and Davis (1969) provide some further discussion.

The bounded-counts method depends on the ability to conduct repeated independent counts of the same population without counting any animal twice in a given count. It also requires conditions that permit a definite (although possibly very small) probability that all animals in a population are counted. Undoubtedly this latter assumption is the critical one, and no method for checking it has yet been suggested. To illustrate the kind of situation in which the method may fail, the Committee used data on 18 successive aerial counts of black rhinoceros (Goddard 1967) to compute population estimates from the bounded-counts method on 6 successive sets of 3 surveys. The results were 24, 26, 40, 47, 28, and 34 rhinos estimated to be in the population. However, Goddard had independent data showing that 69 animals were actually present. A number of the animals were under heavy cover or otherwise concealed so that they could not be seen from the air.

Another alternative exists for areas from which known numbers of animals are removed, as long as counts are made before and after removal. If the degree of undercounting is the same on each count, some simple algebra using the counts and the known removal yields an estimate of the degree of undercounting, and thus an estimate of the true total.

One prospect for checking coverage has been described as "ground truthing." Ground observers maintain intensive coverage of some sample areas in such a fashion that they can determine whether given bands are missed from the air. This scheme has not been attempted with wild horses or burros, but has been applied elsewhere. An account of the essential aspects of one application may be found in Eberhardt et al. (1979). Some trials would be necessary to determine the method's applicability to wild horses or burros. Ground observers could be positioned so as to allow them to keep one or more bands of horses under continuous observation, and thus to determine whether those bands are spotted by the aerial observers. An obvious difficulty is that of determining just which bands are sighted by the aerial observers, but careful mapping of locations from both the air and the ground can alleviate this problem. The size of wild horse bands and the coloration of particular individuals could serve as cues to the identity of given bands.

Radiotelemetry can also be used to check the aerial observer's record. Floyd et al. (1979) conducted quadrat searches for white-tailed deer, using telemetered deer and arranging flight plans (without the observer's knowledge) so that the aircraft passed over the area in which the deer were located. Individuals in the deer population that were telemetered were also equipped with "collars" for visual identification. The fraction of marked deer actually seen was used to correct the total counts on the survey quadrats. As the authors note, these checks should be done on quadrats that are part of the actual survey area, and should be conducted within the framework of the actual survey. If complete counts are attempted, there should be no need to conduct a special survey of this type. It is only necessary to assure that observers do tally any marked animals.

The accuracy of absolute counts can also be checked by marking specified numbers of animals in areas to be censused, and then determining the proportion of these seen during the census. It is then assumed that the same proportion of unmarked animals is seen. As an implicit assumption, the probability of seeing a marked animal is the same as that of seeing an unmarked animal, and it must then be true that the mark is not so conspicuous as to make the marked animal more readily seen. It must also be true that the act of marking does not make the marked animals shy and more prone to flee at the sound of an approaching aircraft.

Marking has been done either with paint-filled frangible bullets fired from a carbon-dioxide powered gun, or with specially made darts that contain the marking agent and are shot from an explosive propelled gun. The latter device is said to have much better accuracy and range.

The use of natural marks undoubtedly has potential. Several investigators have used natural marks, particularly when performing behavioral studies, the results of which might be influenced by the handling or harassment involved in applying an artificial mark or tag. However, natural marks sometimes lead to problems of misidentification or failure to identify a "known" individual in subsequent samples. Thus, it might be advisable to use natural marks only when a few thoroughly experienced observers are working together in a circumscribed area and where photographs can be used to record (and recheck) markings. The technique thus does not seem useful for large-scale surveys.

One variant of the use of natural markings may be worth further consideration for use on wild horses. This is an adaptation of the technique developed by Hewitt (1967), who censused male red-winged blackbirds by the Petersen (Lincoln index) method. Locations of birds seen were described into a tape recorder, using landmarks and a car odometer during the first trip through a census area. On a second trip, the observer listened to the tape and checked distances to determine which of the birds seen were also observed on the first trip. For wild horses, a combination of distinctive coloration, band size, and location could be used to identify previously sighted bands. Such a census might be practicable only on rather open and accessible ranges. Otherwise the tendency for bands of animals to occupy particular areas might well bias the results by making "marked" bands more likely to be reobserved on the second trip than unmarked bands. Because counts would be required over successive days to reduce the effects of movements from area to area, several observers might be needed to cover a given management unit.

Estimates Based on Sampling

While most of the current work on equid census attempts complete counts, there may be situations in which accurate, complete counts are not practical or feasible. Far more wildlife census work depends on sampling procedures than on complete counts. Several of the currently used principles of sampling estimation may be useful for equid census under given conditions.

Mark and Resight Methods

In this method--a modification of the more traditional capture-recapture method for aerial use--a first sample of animals in an area is marked, either after being captured or from the air, and then released into the population. Further, visual samples are then used to determine the fraction marked and thus to estimate the population size. Use of this method on equids has apparently been restricted to the Petersen method applied to a single resighting survey (unpublished BLM studies in Arizona).

A more effective approach would be to use repeated resighting surveys to improve the precision of the result (narrow the confidence limits). This has been done for deer by Rice and Harder (1977). An important aspect of the use of repeated resighting surveys lies in determining the relative efforts that should be devoted to marking and resighting. Relative cost or effort data must be obtained and used--along with variance estimates from the appropriate population estimation model--to determine an optimum allocation of effort. Robson and Regier (1964) have done this for the Petersen model with a single marking and single recapture. Their analysis can possibly be extended to multiple recaptures.

As was discussed in the section on "Complete Counts," this method requires the assumption that the probability of resighting is the same for marked animals as it is for unmarked animals. However, the trauma of being tranquilized by darts fired from a helicopter may cause marked animals to flee when they hear a helicopter approaching, thus changing the probability that they will be sighted. A behavioral study should be designed to compare the response of animals that have been marked with those that have not been handled. A companion study might also be done in which radio-telemetry-equipped animals are observed during the approach of aircraft at various distances and altitudes. The probability of capture also depends on sighting, so that large bands and bands frequenting open areas are more likely to be marked and to be resighted.

Plot Sampling

Where complete counting cannot be accomplished because areas are too large or the terrain and cover is not suitable, total populations can sometimes be extrapolated from complete counts on sample areas. Compactly shaped areas, or quadrats, are commonly searched by repeatedly circling the aircraft. Other areas, called strip transects, are strips of prescribed width on each side--or on one side--of the aircraft. Circling a quadrat again and again has the advantage of giving the observers a thorough look at an area from several perspectives. It may also startle resting or concealed animals, making them easier to see. Quadrat searches are thus of special value in rough country, or areas with substantial vegetative cover. However, because horses are highly mobile, repeated searches of a particular sample unit may drive the animals present out of the unit. This possibility must be taken into account in designing a sampling survey. An alternative to repeated circling is to use photography of the quadrat, as has been done by Norton-Griffiths (1973, 1974) and Mathisen and Lopp (1963). Some of the extensive experience in using quadrats is available in papers by Siniff and Skoog (1964), Evans et al. (1966), Goddard (1969), and Bergerud and Manuel (1969).

Plot sampling suffers from the same uncertainty as do complete counts: what fraction of the animals has actually been enumerated? Where possible, sample counts must be "calibrated" or adjusted for the fraction missed. The same approaches discussed in the section on "Complete Counts" apply to plot-sampling methods.

Strip transects can be spaced far enough apart that there is little prospect of given bands moving from one strip to another between successive passes by the aircraft, a definite advantage. On the negative side, perspective and area coverage are often limited thus presenting problems that may result in substantial variability of the estimates.

Field studies must be performed to determine the importance of these potential difficulties.

Flying strip transects is a method widely applied in Africa, and a great deal of practical experience has been accumulated. A review and description of the techniques used there can be found in Norton-Griffiths (1975). An appreciable amount of experience with strip transects has also been amassed in Australia (see Frith 1964, Caughley 1974, and Caughley et al. 1976) in arid and semiarid areas. It indicates that only a rather narrow strip can be searched effectively, and that low altitudes and air speeds are required. Even so, an unknown fraction of the animals present is missed (Caughley et al. 1976). A particularly impressive demonstration of the effect of strip width has been presented by Caughley (1974) and Caughley and Goddard (1975). These investigators report a dramatic change in the numbers of elephants counted from the air when strip width was changed from 100 to 600 meters.

Line Transects

In this method, estimates of the distances from the observer to the animals sighted are used to correct for the fact that visibility drops off with distance from the transect line. It is assumed that all of the animals directly on the transect line are detected. Some experience with other species (Eberhardt et al. 1979) suggests that this assumption is likely to be valid only when specially equipped aircraft are used (i.e., those with a "nose bubble" or similar arrangement). Since the BLM work must be done in many locales and usually with locally chartered aircraft, this may offer difficulties. On the other hand, many of the available helicopters also have good forward visibility. Experience with aerial census methods that have actually been applied to wild horses and burros or similar species must first be assessed, and if such an analysis suggests a limitation due to small numbers of animals observed, then it may be desirable to investigate line-transect methodology. A detailed review of the methods is available in Eberhardt (1978) and Eberhardt et al. (1979). Line transect methodology is not restricted to aerial surveys, and much work with the method has been done in ground-based surveys.

Sources and Corrections of Bias and Variability

Group Size

One source of bias not yet investigated in wild horse and burro censusing is the likely effect of group size on observability. This problem actually subdivides into two kinds of bias. The first is simply that group size will have a marked effect on the probability that a given group of animals will be seen. One existing model that incorporates these variables is that of Cook and Martin (1974), while a more general approach has been explored by Patil and Rao (1978). Jolly and Watson (1978) have suggested some quite simple corrections for missed groups; they can be derived from ratio data collected to adjust for members of groups that are incompletely observed.

It should also be noted that group sizes are likely to vary seasonally, a fact that must be taken into account in survey design. In general, larger groups have the advantage of being much easier to locate from the air, so working in the seasons when large groups are most prevalent has a potential advantage. However, other factors may also affect the choice of season. Those methods or procedures that involve repeated circling over a group may cause a large group to break up into its component bands, thus changing a group size in subsequent surveys.

The second source of group-size bias is the increasing difficulty of accurately counting all animals as the size of their group increases (Sinclair 1973, Bell et al. 1973). African workers recommend photographing groups larger than 10 animals and checking the visual results against photographs (procedures are given by Norton-Griffiths 1975).

Sampling Methodology

A number of sampling issues need consideration in further research on censusing horses and burros. Random sampling is generally recommended, but should be approached with caution because searching one sampling area might affect the number of animals on, or adjacent to, the next such unit. This is not a problem if the sampling is truly random, that is, if the units are searched in the order in which they are drawn. However, such a procedure is demanding in terms of travel between units, so many investigators will draw the entire sample and then traverse the units systematically across the study area. An alternative is to use a restricted randomization, i.e., to place one sampling unit at random in each of a number of blocks that are large enough to avoid much movement of animals between blocks. The process can then be repeated on successive days of searching. Perhaps a more practical scheme is to use systematic sampling with a new random start on each day of searching.

Stratification should be considered, but may have a similar drawback: movements from one stratum to another may occur. An additional problem with stratification is that strata may be chosen by cover type, which is likely to result in differences in visibility between strata. The need for making separate corrections for each stratum then arises. Unless the study units are very large or animal densities vary markedly, it may be best not to stratify.

If sample areas other than strips are to be searched, it may be most practicable to use units of differing sizes. This practice brings in the problem of combining data obtained from units of disparate size. Jolly (1969) has suggested sampling with probability proportional to size (PPS sampling) or a ratio method for this situation. PPS sampling requires that a sampling unit be included each time it is drawn. In many instances, this does not mean that the unit is searched each time, but simply that the result of the first search is used repeatedly if the sampling unit is drawn again. This approach may not be realistic for wild horses, however, since the disturbance of an aircraft working over the area will most likely rearrange the population repeatedly. Hence, in PPS sampling, the units should be searched each time they are drawn.

In most cases, the areas to be searched for wild horses and burros will be well-defined, with adequate landmarks for laying out and conducting census flights. If this is not true, then it will be worthwhile considering an approach that requires only demarcation of a baseline. This method is described by Bell et al. (1973) and Norton-Griffiths (1973).

Variability

The appraisal of variability is obviously a critical issue in the overall problem of censusing wild horses and burros. If an unbiased method turns out to give extremely variable results, then it may be preferable to use a somewhat more biased method. Unfortunately, most of the decisions about variability require actual data collected under field conditions, and this has not been available for wild horses and burros except in a fragmentary and limited way. Hence the issue of variability must become an important part of the needed field research program.

Double Sampling

One possible means of testing the completeness of counts--either total counts on an entire area, or counts on sample plots--is that of "double sampling." This approach involves the use of both an accurate, unbiased method on a series of test areas (when and if one is devised), and some other admittedly biased, but perhaps less expensive and more readily applied method (Cochran 1977) on the same area. Ratio or regression methods are then used to extend the results from this "calibration set" to a larger set of areas on which only the less expensive method is used. The practical difficulty is that present recommendations (Cochran 1977) call for about 30 pairs of samples for the calibration. It is very possible that this requirement can be reduced somewhat, but just how much has not been established. Such an approach does not seem feasible for the circumstances discussed here, with the possible exception of estimating the entire population of horses (or burros). For such a count, it may be feasible to use the most recent district estimates as the "auxiliary variable" in double sampling, and to survey a subsample with the accurate method to obtain an improved estimate of the total.

The double-sampling approach has other potential uses. For example, Jolly and Watson (1978) advocated that a subsample of the groups of animals sighted in a survey should be circled and observed until the observer is satisfied that all animals in the group have been sighted. These more accurate extimates are then used in a ratio correction to adjust the overall group size observed on the transect line (i.e., observed without circling). A problem with this approach is that some of the smaller groups will not be seen at all. Jolly and Watson suggest an approximate method for correcting for this problem, based on the ratio data. It is probably best to attempt this approach on strip transects, because of the likelihood that nearby groups will be disturbed while one band is being circled for accurate counting.

Preliminary Analysis of BLM and Forest Service Census Data

The accuracy and precision of the existing horse and burro census procedures need to be investigated with the proposed research project on this subject. It is only by means of the proposed research that firm assessment of the procedures can eventually be obtained. The extensive data on horse and burro censuses in the files of the BLM and the Forest Service should be analyzed thoroughly as part of the census research effort.

To gain some preliminary familiarity with the agencies' research efforts, and learn whether or not tentative inferences could be drawn from them about horse and burro population behavior, census data were obtained from the files of 10 BLM districts and one national forest. These data included censuses of 72 herds: 68 horse herds, 3 burro herds, and one area that contained both species. The districts involved are Susanville and Riverside, California; Burns, Vale, and Lakeview, Oregon; Salmon, Idaho; Billings, Montana; Rock Springs, Wyoming; Salt Lake, Utah; and Ely, Nevada. The national forest is the Humboldt in California.

BLM officials recommended these sites as being representative and among the ones with the more complete data series.

Accuracy, Variables, and Biases in the Counts

Upon first examination, several characteristics were evident in the results.

1. The number of years through which each herd was censused varied between 1 and 11 years, and between 1 and 18 counts. Most of the herds had been counted over 4 to 7 years.

2. The time of year at which a herd was counted often varied. Thus a herd might be censused in March of one year, and in August of another. The populations of all seasonally breeding animals vary during the year; they rise to a maximum at the end of the birth season, and then decline until the next as a result of mortality. Since foals are dropped seasonally in wild horses, counts in March and August of the same year could vary by 15 or 20 percent. It is a basic principle in censusing animal populations that year-to-year trends and comparisons must be based on censuses taken at the same season each year, or at the same stage in the annual life cycle.

While burro populations drop colts throughout the year, the drop is intensified in late spring and early summer; hence, the same principle should apply to burro census.

3. While most of the counts were made from the air, the manner in which the census was carried out varied. Sometimes it was conducted on the ground, sometimes from fixed-wing aircraft, and sometimes from helicopter. In many cases the method was not specified.

Casual inspection showed one seemingly obvious difference between census modes: it appeared that in most cases where fixed-wing aircraft were used one year and helicopters the next, the census count increased abruptly in the second year. An effort was made to explore this change further. Out of the 72 herds, there were 19 horse herds in which a change from fixed-wing to helicopter counts was made between years and recorded, and in which the census season was held reasonably constant. The unweighted mean difference between the 19 pairs of counts was 88 percent higher for the helicopter counts over the fixed-wing counts of the previous year. Even after discounting this percentage by 14 percent for population increase, the helicopter counts appear to be some three-fourths more efficient in finding animals than the fixed-wing counts. Since fixed-wing counts were used more commonly in the earlier years, and helicopter counts more generally in recent years, it is quite likely that earlier counts underestimated the actual numbers to a considerable degree.

The helicopter counts also appear to be less variable than the fixed-wing counts. The coefficient of variation about the mean count for the fixed-wing censuses was 170 percent; that about the mean helicopter count was 131 percent.

Rationale

Public Law 95-514 states that the Secretary of the Department of the Interior shall "maintain a current inventory of wild free-roaming horses and burros ..." (Section 14 (b) (1)). Both effective management in terms of resource use and communication with the interested public require that such inventory data be both accurate and reliable. Little is known about the accuracy of the existing estimates. There is thus an urgent need for research to evaluate the existing methods, and to develop satisfactory alternative methods where needed.

This section outlines a research project that would investigate three approaches to horse and burro censusing: "complete" counts (the approach currently used by the management agency), mark-resight estimates, and strip-transect estimates. The three approaches would be used together in each study area to serve as checks against one another, to determine which provides greatest accuracy and precision in a given set of environmental conditions (terrain, vegetation, etc.), and to ascertain which is most suitable for horses or for burros. For the present, quadrat and line-transect estimates are not being suggested for inclusion in the initial study. When a first set of data has been collected and analyzed, it may be found desirable to test other methods.

The project could be directed by two people: one with expertise in statistical methodology and special interest and experience in animal-population measurement; the other a wildlife biologist with experience in aerial census. The possibility should not be precluded, however, of direction by one person with adequate training and experience in both areas.

For the first project or two, attention will be directed only to wild horses, and subsequent efforts will investigate burro census and alternative census methodology.

Objectives

1. Test the accuracy and precision of three approaches to wild horse census:

   a. Complete counts

   b. Mark-resight estimation

   c. Strip-transect estimation

2. Develop a set of criteria by which to choose the appropriate approach for a given area with particular habitat characteristics.

3. Investigate the effect of such variables as weather, vegetation, terrain, herd size, and horse distribution on probability of observation.

4. Prepare a report that would outline procedural details for carrying out the three approaches. The report should pay special attention to any further work needed to establish methodology--including a reference manual--for future BLM censuses.

Procedures

1. Select, with help of BLM officials, three to four western U.S. regions in which to evaluate the three approaches. It is desirable that these areas contain geographically discrete populations, physiographically isolated or fenced if possible, to minimize or prevent ingress and egress. Modifications of the procedures suggested here may be required for individual sites.

2. Conduct a typical "complete-count" census of each area with helicopters in late summer or early fall.

3. As soon as possible after censusing, mark approximately half (if possible) of the horses on each area from helicopters by using paint capsules. Flying costs may impose a limitation on the proportion marked.

4. After marking, conduct a series of overflights at 3 to 7 day intervals, counting the number of marked and unmarked animals seen and tallying group sizes. Each overflight should consist of parallel, straight-line flights across the entire area, spaced at 1- or 2-mile intervals. Each such set should be oriented toward a different compass direction, and its path selected a priori without relation to the area's terrain or vegetation characteristics, or the locations of marked horses. The second alternative is to use random starting intervals rather than equidistant ones oriented to random compass directions. Terrain or visibility factors may dictate this option.

5. Additional overflights should be used for strip-transect counts of horses in the line of flight. First priority should go to the mark-and-resight effort as a check on the complete counts. However, strip-transects may be deemed especially suitable for some sites.

6. As soon as possible after the overflights, two or three additional helicopter complete counts should be

conducted to provide an array of values for the bounded-count method, which will be used to check the accuracy of the complete counts. This is regarded as having lowest priority.

7. In support of Objective 3, conduct intensive interviews with personnel experienced in large-scale censusing to gain information on the effects of vegetative, climatic, and equid behavorial variables on observability.

8. Opportunities to conduct censuses over ground-truthed research projects should be taken wherever possible and convenient.

9. Potential contractors should be encouraged to suggest improvements in these procedures. Tests of "complete" count methodology are, however, essential.

Partial List of Competent Investigators

1. Dr. David Bowden (Colorado Utah University) and Dr. Gary White (Los Alamos Scientific Laboratory)

2. Dr. K. H. Pollock (University of California, Davis) and Dr. Dale McCullough (University of California, Berkeley)

3. Dr. Morris Southward (New Mexico State University) and Dr. Steve Carouthers (Northern Arizona Museum, Flagstaff)

4. Dr. D. B. Siniff and Dr. R. D. Cook (University of Minnesota)

5. Dr. Lyman McDonald and Dr. Rick Miller (University of Wyoming)

6. Dr. Fred Ramsey and Dr. W. R. Rice (Cregon State University)

7. Dr. James Peek and Dr. K. Steinhorst (University of Idaho) or Dr. V. Schultz (Washington State University)

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