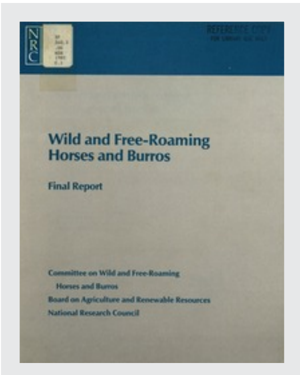

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Wild and Free-Roaming Horses and Burros

Final Report

Committee on Wild and Free-Roaming
Horses and Burros
Board on Agriculture and Renewable Resources
National Research Council

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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.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

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CONTENTS

EXECUTIVE SUMMARY

1. This report completes a "research study" assigned to a National Academy of Sciences (NAS) Committee by the Public Rangelands Improvement Act of 1978 (PRIA) and agreed to in a contract between NAS and the Bureau of Land Management (BLM) of the U.S. Department of the Interior. The contract specified that the Committee proceed in three phases: (I) review existing knowledge on wild horses and burros and design a research program, (II) evaluate horse and burro research contracted by BLM, and (III) submit a final report recommending management programs for wild horses and burros.

2. In December 1980 the Committee completed Phase I by issuing a 382-page report. During Phase II, the Committee evaluated five discrete research projects, a small fraction of the program recommended in Phase I. This report completes Phase III.

3. Ecological niches to which Pleistocene equids related do not exist today, and no other animals in the contemporary North American fauna would have the same niche relationships as the modern-day equids, with or without the latter's presence.

4. From annual agency censuses, reports from individual areas, and from the fractions of young in populations, statements have been made that horse and burro populations typically increase at rates ranging from 16 to 22 percent per year. However, the Phase I Report explored several biases in the census data, cited or calculated rates of increase based on a number of published values for reproductive and survival rates, as well as sex and age ratios, and concluded annual rates of increase of 10 percent or less. A recent study documented high increase rates in two Oregon herds. More data are needed to gain a better sense of the range and typical magnitude of the rates.

5. Although there is some evidence of density-dependent processes in feral (in this report "feral" is used interchangeably with "wild") equid populations, they do not appear effective enough to self-limit populations below levels at which they significantly impact the vegetation. Starvation has been observed in some horse herds and reported for some burro populations.

6. In response to congressional concern for the condition of public rangelands, as expressed in the PRIA and by the general sense in which the Act used the term "excess," the Committee has considered "excess" as that number of large herbivores exceeding the number that

(a) allows a range ecosystem to exist at some condition approaching its potential productivity, or prevents it from becoming as productive as feasible; and (b) permits a plurality of resources and uses.

7. The concept of excess also has a sociopolitical component. Different vegetation types and combinations of herbivorous animals, all meeting the above two criteria, are possible within the potential for a site. Decisions on which of these options to feature in a management plan are sociopolitical rather than biological ones, and deviations from an agreed-upon option can constitute excess.

8. Proper management plans for a given area require a strong information base on (a) biological potential for the area; (b) numbers and combinations of herbivorous animals that can safely be carried on it; (c) kinds and amounts of forage and habitat required by the animals; (d) effects of herbivores on vegetation and on each other; (e) effects on soil and hydrology; and (f) an understanding of economic and social values associated with the area.

9. Assessing site potential in western North America is beset by extreme spatial and temporal variations. Primary production on a given area may vary between years by a factor of 2 or more.

10. Given the extreme variability, range managers advocate a conservative grazing policy, in some cases setting stocking levels appropriate for average forage production, and, in the case of overused range, stocking in the range of 65 to 80 percent of average forage production. In practice, grazing capacities are not often determined, and stocking decisions are more often made on the basis of a range trend.

11. Horses have been found to be primarily grazing animals with considerable dietary overlap with cattle. The Phase II study in the Wyoming Red Desert showed that shrubs provided between 25 (in summer) and 35 (in winter) percent of the diets of horses. Cattle, too, were using appreciable amounts of shrubs.

12. The Phase II Colorado State University study indicated that mares consumed 14 percent more forage dry matter than did cows. The disparity was greater between lactating animals, less between nonlactating ones. This finding supports the BLM policy of assigning a higher animal unit month (AUM) rating to horses than to cattle. However the study found no relationship between horse body size (range 367 to 578 kilograms (kg) and forage consumption.

13. Except for protein, cows digested nutrients more thoroughly than did mares, possibly in part because food material passed through the cows more slowly. By moving the material through more quickly, the horse may be able to compensate for low-quality forage by consuming a greater total aggregate of scarce nutrients.

14. The Phase II habitat preference and use study in the Wyoming Red Desert showed horses occupying all areas used by cattle, but cattle were distributed over only a small fraction of the areas utilized by horses. Cattle remained close to water year round, horses only in spring and summer. During the seasons of coexistence, horses and cattle segregated to some degree among different vegetation types. If competition for forage occurs, it is most likely during spring and summer in the vicinity of watering areas. Prongnorn

antelope distribution closely followed that of horses.

15. Based on the Red Desert forage-impact study, winter stocking rates as high as 8 animal unit days (AUDs) per hectare (ha) are unlikely to produce undesirable changes in plant communities. But summer use of about 3 AUDs per ha is likely to be excessive. Such values are applicable only to other areas with similar vegetation, soils, and climate and need to be established for other areas with site-specific studies.

16. Recent range-management research shows the mutual benefit to grazing animals and vegetation of short, intensive grazing periods. This is obviously difficult to accomplish with feral equids, but should be explored.

17. Almost no formal research has been carried out on the impacts of feral equids on hydrology, and there is no alternative at this stage but to assume that their effects are similar to those of livestock. Abundant research shows that heavy, continuous grazing promotes soil erosion and accelerates runoff. However, measurements of soil and watershed parameters do not differ statistically between ungrazed pastures and those with light or moderate grazing. Riparian areas are especially attractive to grazing animals and are subject to alteration.

18. Soil loss constitutes irreversible change on a time scale measured in human lifetimes and undercuts the regenerative abilities of plant and animal resources. Populations of any herbivores--livestock, feral equids, or wildlife--must be considered in excess if they reach numbers that so alter the vegetation as to promote soil erosion.

19. The effects of feral equids on wild ungulates can be beneficial or harmful, depending on the similarity or complementarity of their food and habitat preferences and on their numbers and intensity of resource use. Since horses are primarily grazers, it is reasonable to expect them to have a beneficial effect on the primarily browsing and/or forb-feeding ungulates--deer, moose, pronghorn antelope, and elk--on ranges in reasonably good condition. However, on severely degraded ranges, diets of different species tend to converge, and competition is possible.

20. Competition between cattle and Rocky Mountain bighorn sheep, both grazers, has been inferred in several cases and between horses and bighorns in two. According to numerous investigators, the more precariously situated desert bighorn subspecies have been affected by cattle, domestic sheep, and goats; several have implicated competition with wild horses.

21. A 40-year publication history chronicles a wide range of research and investigators, some of whom conclude that wild burros compete with desert bighorns for water, vegetation, and/or space and have been one factor in sheep decline. Where such effects risk the survival of bighorn populations and public attitudes deem that the bighorn be saved, burros must be considered in biological excess in such areas.

22. Wild horse and burro census methodology will continue to rely on some form of aerial technique, but the present method misses animals, the percentage depending on the nature of the terrain and vegetation. Fixed-wing aircraft census in gentle topography with low

vegetation in the Phase II research located about 93 percent of horses present, but in a wooded mountainous area it counted only 40 percent. Helicopter census in the same area counted 48 percent. If accurate census is desired in such areas, and for burros, some form of capture-recapture or removal method will be necessary.

23. Census findings imply that there are more horses in the western United States today than estimated and that there were more in 1971 than the 17,000 sometimes claimed. However, those animals and their forage demands, whatever the correct values, still comprise a minor fraction of the domestic livestock and/or wild ungulates. The comparative numbers are more nearly similar in some grazing districts with few livestock and large norse populations.

24. Annual censuses do not appear necessary. It should be possible to manage herds adequately with one census every 2 or 3 years.

25. Herd growth rates would be reduced by removing mares of the more fecund age classes, but the effect would be short-lived and less effective than appears at first glance because of the interaction of herd growth, the periodic nature of round-ups, and the small fraction that these mares constitute of the total herd. The practice could also incur some logistic problems.

26. There is evidence that a small number of horse and burro foals are left behind and orphaned during round-ups.

27. A significant fraction of pregnant mares, perhaps approaching half in some cases, apparently abort their fetuses as a result of round-up, penning, transportation, and adoption.

28. If animals need to be chemically immobilized for administering antifertility drugs, combinations of etorphine and xylazine show promise. Succinylcholine is not recommended.

29. Despite positive results reported by one investigator, reducing horse reproductive rates by chemosterilizing dominant band stallions does not appear promising, because the two preconditions for success--a dominant stallion responsible for all breeding and the lack of movement of mares betweeen bands--have not held true in horse populations in Wyoming, Oregon, Montana, and New Mexico. Two observers object to this practice on the grounds that it blocks gene flow from the genetically superior animals. It also appears logistically unfeasible for herd reductions over a large geographic area.

30. Long-term fertility control in mares by injecting or implanting steroid compounds appears to have potential but has not received appreciable study. Such research should begin with captive or domestic animals.

31. A number of changes in public and government attitudes and policy regarding wild horses and burros have occurred since completion of Phase I. These include changes of opinion among the various interest groups, newly proposed policies in BLM, and pending legislation. The effects of new wild horse and burro management policies cannot yet be predicted.

32. Public opinion, along with biological factors, will continue to be a major force in shaping decisions on wild horse and burro management. A firm understanding of the nature and geographical

distribution of public attitudes, and their consideration in formulating management policies and procedures, are vital to the smooth facilitation of management programs. Also, the agencies involved need to be aware of the attitudes among their own personnel.

33. Land-use planning systems will continue to be controversial, because of data inadequacies and the difficulties of reconciling the mandates of single-purpose and multiple-use legislation.

34. In the present climate of economic austerity, adequate cost data are not available to ensure cost-effective management decisions. The uncertainty created by this lack of data affects the assurance and time frame of private decision making. Local and regional economics are likely to be affected, particularly in regions heavily dependent on the livestock industry.

35. Sound and effective equid management programs require a firm base of scientific information. The Phase I Report prescribed a long-term equid research program, 7 to 10 years at the very minimum. Such a program can best be administered in BLM by an expanded in-house scientific staff advisory to fairly high-level administrative positions.

INTRODUCTION

Basis for This Report

This report, along with the appended research documents, is the final step in the "research study" mandated by Congress in Sec. 14(a) of the Public Rangelands Improvement Act (PRIA) and agreed to in Contract No. AA551-CT9-16 between the National Academy of Sciences (NAS) and the U.S. Department of the Interior, Bureau of Land Management (BLM).

The 1971 Wild and Free-Roaming Horse and Burro Act directed that "The Secretary [of Interior and of Agriculture] . . . shall consider the recommendations of qualified scientists in the field of biology and ecology. . . ." The Act was the predecessor of that provision in PRIA calling for a study of wild horse and burro problems. Actually, an amendment to the Wild and Free-Roaming Horse and Burro Act, Sec. 14(a) of PRIA, directed the President of the National Academy of Sciences to impanel a committee to outline a research study that would further knowledge ". . . of wild horse and burro population dynamics and their interrelationship with wildlife, forage and water resources, and assisting him [the Secretary] in making his determination as to what constitutes excess animals."

The intent of Sec. 14(a) was actualized by a contract between NAS and BLM in May 1979, which specified that NAS would bring together a committee of scientists. Pursuant to the Act and the contract, the Committee's work was to be carried out in three phases:

Phase I, June 1979 (first meeting of Committee) to October 31, 1979:
  Review existing knowledge on wild horse and burro populations, forage requirements, impacts on other rangeland resources, and socioeconomic relationships of population control and management.

Phase II, November 1, 1979, to January 31, 1982:
  Evaluate horse and burro research under contract by BLM.

Phase III, February 1982 to October 31, 1982:
  Prepare and submit to BLM a final report that would contain recommendations and ". . . summarize scientific information upon which the Secretaries of Interior and Agriculture can make their recommendations to the Congress as to management of the wild horses and burros."

A Committee was duly appointed in 1979, and it proceeded with Phases I and II. This report constitutes the completion of Phase III.

Review of Committee Operations

Phase I

The Committee began Phase I in June 1979 with its first meeting in Salt Lake City. At that time members were assigned topics on which they were to review literature and available unpublished data and write sections for the Phase I Report. Members were also asked to specify and design research projects needed to fill in knowledge gaps that they detected in the course of reviews.

Toward completion of Phase I, the group also met in Reno, Nevada, in July 1979 (along with a day-long public hearing); in Laramie, Wyoming, in September 1979 (along with participation in an equid conference organized by the University of Wyoming); in Davis, California, in February 1980; and in Las Vegas, Nevada, in June 1980 (along with a BLM and National Park Service-sponsored field trip to burro problem areas in California, Arizona, and New Mexico).

The Committee completed a 382-page Phase I Final Report in December 1980. It contains an exhaustive review of what was known in 1979-1980 about wild horse and burro biology, management problems, and socioeconomic aspects of horse and burro issues and a proposed research program designed to provide a more complete basis for horse and burro management, as requested in PRIA.

The report was duly conveyed to BLM, and at that point Phase I of the BLM-NAS contract was completed. Because of its size, and the fact that it is self-contained, the Committee has elected not to incorporate the Phase I Report in this document, but its Executive Summary is attached hereto as the Appendix.

The Committee believed that this report could serve both as a useful reference volume for individuals concerned with feral (in this report "feral" is used interchangeably with "wild") equid management and as perspective for the recommended research program. The Committee recommends that the Phase I Report be more widely distributed to Bureau personnel than apparently has been the case and to others interested in feral equid management.

Phase II

Anticipating that the Phase I analysis would take considerable time, the Committee filed an interim report in November 1979 recommending several high-priority research projects that, the members concluded, should get under way as soon as possible. As stated in the BLM-NAS contract, House and Senate conferees on PRIA had concluded that the research program should span at least two horse/burro breeding seasons, and with spring 1980 approaching it was necessary to take the first steps toward getting the research under way.

Phase II was formally begun with a meeting in Logan, Utah, in early December 1979, between BLM officials and three members of the Committee. The purpose of the meeting was to begin drafting requests for proposals for four research projects designated high priority for early activation:

- comparative habitat selection by horses and cattle
- range impacts by horses and cattle
- comparative nutrition of range horses and cattle, and
- horse and burro census

Working on a very tight time frame, BLM announced Requests for Proposals (RFPs) in early 1980 and received proposals in ensuing weeks. Two meetings were held in Denver in the spring of 1980 between BLM officials and selected Committee members to review proposals. At Committee invitation, David R. Anderson, Leader of the Utah Cooperative Wildlife Research Unit, also participated in the Logan RFP meeting and one of the Denver proposal-review meetings. BLM awarded two contracts in May 1980--one to the University of Wyoming for the habitat-selection and range-impact studies, and one to Colorado State University for the nutrition study--and a third in July 1980 to the University of Minnesota for a census project to be carried out in Nevada and Oregon.

Both in a Discussion Paper presented by BLM and the Forest Service to NAS on March 6, 1978 (Anonymous, 1978) and in the BLM and the Forest Service to NAS contract, attention was given to socioeconomic considerations of wild horse and burro management. PRIA itself raises the question of whether excess animals should be removed, destroyed, sterilized, or left to "natural controls." The Committee concluded unanimously that cost and public preferences, as well as the agency's ability to implement the various strategies, must be considered in both defining excess and in selecting among these options. Furthermore, as we will discuss later in this report, the concept of excess, whioh appears repeatedly in PRIA and the BLM-NAS contract, has social and economic dimensions.

Hence the Committee gave considerable attention to socioeconomic issues in the Phase I study and prescribed several research projects in the areas, two of which were accorded top priority. In late 1980 and early 1981, material was provided for RFPs, and two Committee members traveled to Washington to confer with BLM officials on the matter. However, RFPs were never issued nor was any research initiated in the socioeconomic area.

In early 1981, RFPs were issued for a study of horse and burro pregnancy rates throughout the West in order to provide more insight into the magnitude of reproductive rates. Proposals were reviewed at a June Committee meeting in Rock Springs, Wyoming, and BLM awarded a contract on this study in July to Utah State University. This same meeting culminated a 1-week field trip that included site visits to research locations and problem horse areas in Oregon, Nevada, and Wyoming. And the meeting included a half day of project reviews by investigators involved in the BLM-sponsored equid research projects.

In October 1981, the University of Minnesota contract on census methods was amended to include investigations on horse survival rates in Oregon and Nevada.

The University of Wyoming and Colorado State University projects have been completed at the time this report is submitted. The reproductive study, originally scheduled for two years, is being terminated after one because of reductions in BLM round-ups. Thus, the six projects represent the total amount of research carried out in compliance with the mandate of PRIA and Phase II of the BLM-NAS contract.

Scope of the Phase III Report

As stated above, PRIA calls for research on ". . . wild horse and burro population dynamics and their interrelationship with wildlife, forage and water resources . . . ." The contract sets forth these same areas in more detail, as well as other topics.

In an effort to comply with the breadth of research intended in these two documents, the Committee proposed a research program divided into 21 separate titles and subtitles, several of which were to be replicated in three or four areas of the West, and many of which were to be conducted on both horses and burros. These are shown in Table 1. In the Committee's judgment, this array of projects was needed to provide the foundation of knowledge called for in the Act, and upon which its authors intended that a sound horse and burro management program would be based.

This is an extensive research program, considered the ideal by the Committee. A minimum program would perhaps include at least the two top priority levels shown in Table 1. Yet the five completed and one ongoing projects constitute less than a fourth of this minimum need for Phase II; a very limited research program on horses and, with the exception of the pregnancy study, none on burros. Furthermore, none was conducted on the socioeconomic questions.

This shortfall is mentioned here to make it clear at the beginning of this report that the full range of questions posed by the authors of PRIA cannot be answered at this time. The Committee will address those questions as best it can, drawing on the results from the limited research that has been undertaken, the findings of its Phase I study, both published and unpublished data, and its own professional experience. But many of those questions will remain unanswered until a commitment is made to an appropriate research program. Meanwhile, this report will be relatively limited in terms of the full scope of horse- and burro-management problems.

TABLE 1 Research Projects Prescribed in Phase I

	Projects	
Initiated (x) Project Title	Horses	Burros
Priority 1		
1a. Habitat Preference and Use		x
b.[1]		
c.		
2. Food Consumption Rates and Nutrition	x	
8a. Grazing Impacts on Plant Communities	x	
b.[1]		
c.		
17. Census Methods		x
5a. Demography--Natality		x
x		
4. Blood Assays		
9a. Hydrologic Values		
b.[1]		
c.		
11b. Public Preferences for Alternative Management Strategies		
13 Nonmarket Values		
Priority 2		
7. Genetic Polymorphism		
14. Economic Considerations for Management Alternatives		
Priority 3		
5b. Demography--Survival		x
10a. Riparaian Zone Impact		
b.[1]		
c.		
11a. Taxonomy of Values and Benefits		
Priority 4		
3. Nutritional Plane, Condition Management and Reproduction		
6. Social Structure, Feeding Ecology, Population Dynamics		
11c Public Attitudes, Preferences, and Knowledge		
12. Analysis and Evaluation of Demand for Excess Equids		
15. Nonmarket Values		
16. Conceptual Development of Public Rangeland Management Models		
18. Contraception Studies		
Unprioritized		
Age Criteria[2]		

[1]The Phase I research design recommended that Projects 1, 8, 9, and 10 be replicated in three or four different areas of the western United States.

[2]A project on age criteria was not originally advocated in the Phase I Report. But since then, the need for such a study has become apparent and is therefore included here.

SOME MANAGEMENT-RELATED QUESTIONS ABOUT EQUID BIOLOGY

Among the contentious issues in wild horse and burro biology and management, some questions will not be resolved until enough research has been conducted to provide convincing evidence. Some, however, turn at least in part on semantic or conceptual problems, and some light can be shed on these aspects from existing biological knowledge or theory. It appears to the Committee that clarification of some of these problems will contribute to a common understanding by those concerned with the subject. In this section, we explore several of these.

Questions About Niche

The question is periodically raised as to whether contemporary North American wild horses and burros are merely "reoccupying" niches in the North American ecosystems previously "occupied" by the now extinct Pleistocene equids. It is well documented in the paleontological literature that the mainstream of equid evolution occurred in North America. Eurasian and African species originated from closely related forms that spread from North America prior to the Pleistocene extinction of *Equus* on this continent 8,000 to 12,000 years ago. The North American fossil record contains close relatives of every living African and Eurasian species of *Equus* except the unique African quagga. In one case, the wild horse (*E. caballus*) in Eurasia is thought to be the same species as its fossil counterpart in North America (Bennett, 1980).

Contemporary North American wild horses are variously claimed, depending on the claimant and the locale, to be the wild-mustang descendants of domestic horses introduced by the Spaniards in the sixteenth century, or of miscellaneous cavalry mounts, work horses, and saddle animals escaped or abandoned more recently. Contemporary wild burros are generally acknowledged to be the descendants of beasts of burden released or escaped within the past century or two.

The whole subject of niche in ecology has become increasingly mathematical and complex, and an extensive literature discusses niche measurement, niche breadth, and niche overlap between species. The concept has become a highly abstract one involving the aggregate of all relationships between a species and its environment in contrast to some space within that environment which the species physically occupies. In this sense, the question of whether the Pleistocene equid niches still exist is really a question of whether the contemporary environments and biota are similar to those of Pleistocene North America.

Aside from the question of climatic changes over the past 10,000 years, the western North American biota has changed profoundly in that period. As discussed in the Phase I Report, there is no evidence pointing to the evolutionary loss of plant defenses to grazing and browsing since the Pleistocene large mammals disappeared. But several authors (Young et al. 1976, 1979; Mack and Thompson, 1982) have emphasized the lack of such defenses in Great Basin plant species and the consequent vegetation changes following livestock introduction. Those changes have not only involved alterations in perennial plant composition, but also the introduction of exotic, annual plant species which may have displaced the natives (Mack, 1981).

Hence the Intermountain vegetation today is changed from that which prevailed during the Pleistocene and at the time of European settlement. That vegetation was evidently vulnerable to heavy use by herbivorous mammals, possibly because it had existed for centuries or millenia in the absence of heavy browsing and grazing pressures. Changes have also occurred in other parts of western North America.

In addition to post-Pleistocene vegetation changes, there obviously have been marked changes in the North American fauna. Many of the other large herbivorous species, with which Pleistocene equids may have competed, are no longer present as competitors with the new equids, while contemporary animal life--domestic, feral, and wild--introduced new relationships. Further, most of the large carnivores present in the Pleistocene, which presumably preyed on the equids, are no longer present.

In short, the environmental gradients to which contemporary North American feral equids relate are different from those of Pleistocene times. Consequently the niches of the Pleistocene equids no longer exist, and the answer to the original question must be in the negative.

A corollary of the Pleistocene niche question that is asked periodically is whether wild horses and burros today are "occupying unfilled niches," irrespective of whether they are similar to the ones occupied by Pleistocene equids. This question proves to be somewhat circular. In the above sense, the animal in part defines its own niche. Its presence implies the presence of its niche and its occupation of it. Since there are no other species in the North American ecosystems very similar to feral horses and burros, other than their domestic counterparts, the precise niches of the contemporary equids would not exist if they were not present.

These points are raised here because both proponents and opponents of feral equids on the western ranges use the issue to support their positions. Proponents suggest the availability of Pleistocene niches as justification for the presence of the contemporary equids and imply that their presence is ecologically desirable in somehow restoring previously greater biotic diversity. But, as we have suggested, the western North American biota has changed, both through evolution and human influence, and contemporary feral equids are not precisely the same as their Pleistocene counterparts. It cannot be argued that ecological voids dating back 10 millenia exist and that the introduced forms are restoring some kind of earlier integrity.

Opponents view contemporary equids as exotics (in the ecological sense of an introduced species) and therefore more likely to damage western ecosystems severely than native herbivores that have coevolved with the vegetation. But there does not appear to be any reason to assume that wild horses and burros would cause any more disturbance than comparable numbers of domestic livestock, except for the fact that the equid caecal digestive system requires somewhat more forage than a ruminant system in an animal of similar weight. Furthermore, uncontrolled numbers of native herbivores can also cause vegetation damage. In the final analysis, severe damage to vegetation, whether by native or exotic herbivores, can be prevented by limiting population density of all species involved.

What Are the Increase Rates?

One of the disputed questions regarding wild horses and burros is the rate at which their populations increase. The authors of PRIA and the BLM-NAS contract undoubtedly intended that the research recommended on population dynamics and census methods would serve to resolve this question. However, available funds permitted only two studies, one of horse and burro pregnancy rates across the West and one of horse survivorship in Nevada added to the ongoing census research. The problems were discussed at length in the Phase I Report and will only be briefly reviewed and updated here.

BLM and the Forest Service began systematic attempts to tally horse and burro populations around 1969-1971 and reported the overall 1971 horse population at around 17,000 animals. Recently, the herds were reported to number in excess of 50,000. These numbers suggest an annual increase rate of 16 to 17 percent. Reports from some individual areas and rough calculations, often based on fractions of young observed, have resulted in estimates of 18 to 22 percent rates of increase for both horses and burros. The Committee has been concerned about these high rates of increase, since most experience with large mammals and with domestic horses does not support such growth rates. In the Phase I Report, several lines of evidence pertaining to horse and burro censuses were reviewed. These included such factors as shifts from fixed-wing to helicopter censuses, increasing experience of observers, and various other factors, including season, herd sizes, vegetation cover, and topography. Census data from BLM files were analyzed and showed a substantial increase with shifts in mid 1970s from fixed-wing aircraft to helicopters. This difference has been borne out in part by the census research project carried out in Phase II (Siniff et al., 1982) Where horses were censused in two Nevada areas with both fixed-wing aircraft and helicopters, the latter disclosed statistically more animals than did censuses with the relatively fast Cessna 180. Results with the Piper Super Cub were slightly lower than with the B-2 helicopter, although the difference was not statistically significant.

An important unknown in the early data is simply whether or not the "estimates" were anything other than educated guesses in many situations. Discussions with BLM field staff indicate that the first requests for estimates caught them with virtually no direct counts. Many area managers and wild horse and burro specialists feel that only a few of their areas have been censused accurately over the years and that data on the other sites are of uncertain accuracy. We thus believe that estimates of totals and rates from the early years will remain in question and that various improvements are needed if accurate data are to be available for future management.

Approaching the question of population increase rates from the point of view of population dynamics, several biologists have calculated rates of increase on the basis of various assumptions and data on population parameters. Again, much of the detail on such rates and the sources appear in the Phase I Report.

Three investigators (Conley, 1979; Wolfe, 1980; Wagner, in the Phase I Report) performed these kinds of calculations and concluded that the annual increase rates for horse populations implied by published information from several studies on reproductive and survival rates must be considerably lower than the 16 to 18 percent commonly inferred from censuses and might conceivably be below 10 percent. Eberhardt et al. (1982) have since reported apparent high rates of increase shown by population censuses of two Oregon areas, and suggest some of the demographic conditions that need to prevail if populations are actually to increase at these rates. One of these conditions is very low adult mortality. A research project is under way in two Nevada areas using radiotelemetry to provide estimates of mortality, and the preliminary findings suggest that it may indeed be quite small in these two areas.

In the final analysis, increase rates are undoubtedly subject to a variety of environmental pressures: (1) year-to-year variations in forage conditions associated with annual weather variations within individual areas; (2) variations between areas in the average climatic and forage conditions; (3) variations in forage conditions associated with different equid population densities; and (4) variations in forage conditions associated with use by other herbivores, both wild and domestic. The rates are likely, therefore, to vary in both space and time. It will require considerably more research before the relationships between these variables and herd-increase rates can be quantified, and models developed that will predict increase rates for any given set of values of those variables.

Will They Self-Limit?

The question of how and whether wild horse and burro populations will limit their own population increase, or should be limited by human intervention, has been raised repeatedly by different persons concerned about the issue, and from differing points of view. The problem is really part of the more general animal ecological question of how animal populations are prevented from indefinite increase, and where wild equids fit in this scheme.

In general, populations of different animal species are limited by one or more of three classes of factors: (1) factors such as predation, inclement weather, and competition with other species that are external (or extrinsic) to the population and that kill animals and/or reduce reproductive rates, (2) exhaustion of a food or habitat resource by the animals of a population itself, and (3) limitation of a population by its own behavioral mechanisms at levels below which a resource is exhausted (i.e., "self-limitation"). Every animal species is limited by one or some combination of these.

If the effects of these factors on a population vary from year to year, as most factors do, and the variations are unrelated to the population's density, they are said to be "density-independent." In essence, they operate at random with respect to the population size, and by implication their relative effects do not vary regardless of how numerous or scarce the population becomes. A population existing through time solely under the influence of such factors will fluctuate at random and sooner or later vary to extremely high or extremely low numbers.

In fact, in animal populations that have been studied, one or more environmental factors has/have been shown to operate more stringently when a population reaches high density and to ease its/their effect when a population declines to low numbers. Such factors are said to be "density-dependent." They are most commonly held to be among the factors of classes (2) and (3) above.

Population ecologists have distinguished two patterns of population behavior: (1) absence of net increase or decrease for specified periods of time (termed "equilibrium") irrespective of the density at which this is achieved and (2) the mean density at which equilibrium is attained (F. H. Wagner, 1969, 1981, for amplification). A substantial school of thought, though not all population students, holds with the equilibrium concept. Advocates reason that a population existing through time solely under the influence of density-independent factors would fluctuate at random and sooner or later vary to extremely high or low numbers. According to this view, density-dependent factors provide a buffering effect, or "regulate" a population, preventing it from fluctuating to extremes.

The more relevant pattern for our discussion here is the question of what factors determine mean density or "limit" a population. Both density-dependent and density-independent influences serve this role. Some populations appear to be limited largely by one or the other of these classes of factors, others by combinations of the two.

The relative importance of these in equid populations is central to any herd-management philosophy. If wild horse and burro populations limited their numbers primarily with density-dependent mechanisms to levels below which there was any serious impact on their resources, it could obviate any need for herd reductions. Alternatively, if herds by nature increased to the point of serious impact on the vegetation, or other components of the ecosystem, and on themselves, this would present a different set of decision options in terms of what is best for the resource and the animals and how such management decisions would be implemented.

As an example of the diversity of views on this topic, Downer (1977) has argued that equid populations would limit their numbers at densities below which they would significantly damage the resources if allowed to assume those levels undisturbed.

Ryden (1978:295-296) inferred a similar capability in the Pryor Mountain wild horse herd and has frequently commented on the density-dependent tendencies in horse populations. But she has also agreed that horse populations have increased since passage of the Wild and Free-Roaming Horse and Burro Act of 1971; that their populations might increase to levels at which they seriously impact the vegetation; and that, in some areas committed to horse populations, it might be appropriate to allow them to increase without human control, even if it meant heavy vegetation damage. Population limitation would be achieved by reduced reproductive rates resulting from malnutrition and starvation. (This in itself would be a density-dependent process, but at densities where considerable damage would be done both to other components of the ecosystem and to the horses themselves.)

The Bureau of Land Management's basic management philosophy has assumed that equid populations will, in the absence of human interventions, increase until range vegetation is irreparably damaged and the animals themselves suffer serious malnutrition and death. Since a major aspect of the Bureau's statutorily defined mission is to maintain range vegetation in satisfactory condition, horses must be removed periodically to achieve this goal.

There are few really effective data to indicate which of these population scenarios corresponds to the real world. There is some limited evidence of density dependence in feral equids. Pellegrini (1971) suspected self-limiting tendencies in the foaling patterns of the Nevada horse population he observed. Douglas and Norment (1977) presented circumstantial evidence, reviewed on pp. 85-86 of the Phase I Report, of density dependence in burro reproductive rates. On p. 66 of the same report, we observed some decline in the annual rates of horse population increase, as implied by BLM censuses, between the early and late 1970s.

But it seems unlikely to us that these tendencies are sufficiently effective to prevent populations from increasing to the point of significant vegetation impact. In the Phase I Report, we reviewed studies of two horse populations that had increased to the point of severe vegetation impact and starvation in some years. These were the Pryor Mountain herd in Montana studied by Hall (n.d.) in 1971 and the Sable Island herd off the coast of Nova Scotia described by Welsh (1975) where severe winter weather was the proximate cause of death. As reported in the Phase I Report, the reproductive rates of these herds compared favorably with those of several other studied herds.

Cases of populations increasing to densities where they incur severe vegetation impact and malnutrition are commonly alleged, but seldom have been adequately described and documented. Three such cases of horse populations have come to our attention. The first two are the ones mentioned above. Former BLM employee Ron Hall (personal communication) observed the Pryor Mountain herd during the winter of 1969-1970. In an arid, topographically dissected area of sparse range forage, the horse population had increased to about 250 animals, about double the number the area could support in good condition, according to Hall's judgment. By late winter, the animals were pawing the ground in order to get at the roots of already grazed-off winterfat (Ceratoides lanata) plants. As spring arrived, some 10 to 15 animals died, while others were in a weakened condition. The winter was not exceptionally severe. On Sable Island, the large population had not been subjected to any human control for some years prior to the time Welsh (1975) conducted his study. Following the severe winter of 1971-1972, there was a ". . . large die-off . . ." (p. 241) in March and April, which reduced the population by a third due to the effects of extreme weather and forage availability. This was apparently characteristic of the population that historically had gone through periods of population increase only to decline from a combination of malnutrition and severe winter weather. A third case reported to us by Hall (personal communication) involved a horse herd west of the town of Gerlach, Nevada, that had increased for some years during the 1970s, and had been prevented from free-ranging movements by BLM grazing-unit fences. By the winter of 1977-1978, a winter of average weather conditions, the vegetation was in extremely poor condition, and the animals were seriously malnourished. As spring arrived, some 400 to 500 horses died. In the time available to the Committee, one or two reports of burro starvation have come to us, but without details or formal description. However, BLM officials in Arizona reported vegetation changes caused by burro feeding and showed us examples of such changes in the field near Lake Havasu in June 1980.

In their view, the first signs of burro effect are the thinning or disappearance of big galleta grass (Hilaria rigida). Subsequent changes include, sequentially, the destruction of ocotillo (Fouquieria splendens), breaking down major branches of ironwood (Olneya tesota) and palo verde (Cercidium microphyllum), and finally heavy use of white bursage (Ambrosia deltoidea). Ironwood and palo verde trees can become high-lined, with deer and mountain sheep thereby denied browsable foliage. These effects tend to be noticeable within 10 miles of permanent water, becoming progressively more marked as the water source is approached. Committee members were shown deformed palo verde trees in 1980, which reportedly were signs of burro activity.

We do not cite these examples to imply in any way that these kinds of severe impact are widespread or common in the wild horse and burro ranges of western United States. In fact, we have seen very few areas with heavy vegetation impacts, although we have asked the BLM to show them to us.

Our purpose here is simply to convey our impression that, while there may be some density-dependent tendencies in the demography of these equids, they do not appear effective enough to prevent populations from increasing to the point of significant impact on other ecosystem components. What population control policy this dictates depends on the management goal for any given piece of land. If the goal is solely equid management that is experimental and "natural" as possible, a laissez-faire approach may be appropriate. The equids and other ecosystem components could be allowed to seek their own balance. But where the goal is a multiple-use one, as set forth in PRIA, and there is concern for the values of other ecosystem components, it seems likely to us that horse and burro populations will need to be limited artificially by human action to avoid undesirable effects on other ecosystem components.

IMPORTANT MANAGEMENT CONSIDERATIONS

What Is Excess?

Excess Defined

The Congress repeatedly used the term "excess" in the Public Rangelands Improvement Act in relation to wild horses and burros. In Sec. 14(a) of the Act, it authorized the research study reported herein which was intended to assist the Secretaries of Interior and Agriculture in determining what constitutes excess. Given only this charge, the Committee could have outlined an array of management options ranging from multiple-use programs designed to accommodate livestock, native wildlife, and wild equids, to single-use areas set aside for equids; and from the maintenance of low-equid densities which competed minimally with domestic and wild ruminants, to high-density equid populations developed for maximum viewing and with little consideration for the effects on other ecosystem components. What constitutes excess, then, could take a number of forms relative to these alternatives.

However, the Act proceeds in Sec. 14(b) itself to define "excess animals" and thereby focus the Committee's attention on a limited portion of the array: " . . . wild free-roaming horses or burros . . . which must be removed from an area in order to preserve and maintain a thriving natural ecological balance and multiple-use relationship in that area." These references are clearly part of the broader concern in PRIA for the condition and improvement of the public rangelands:

Sec. 2. (a) The Congress finds and declares that --

(1) vast segments of the public rangelands are producing less than their potential for livestock, wildlife habitat, recreation, forage, and water and soil conservation benefits and for that reason are in an unsatisfactory condition; . . .

(b) The Congress therefore hereby establishes and reaffirms a national policy and commitment to: . . .

(2) manage, maintain and improve the condition of the public rangelands so that they become as productive as feasible for all rangeland values in accordance with management objectives and the land use planning process established pursuant to section 202 of the Federal Land Policy and Management Act (43 U.S.C. 1712). . .

For these reasons, the Committee has taken the intent of PRIA as its basis for considering the concept of excess, and this appears to contain two basic elements:

1. A concern for the condition of range resources approaching maximum or potential productivity
2. A concern for multiple-use management and a plurality of resources (livestock forage, wildlife, water, soils, and recreation, as well as wild equids)

Consequently, it has tried to focus the concept of excess within the context of these two tenets. But before considering some of the specific criteria for management programs that avoid excess, it seems desirable to analyze the concept in the abstract.

For each site, or tract of land, there is some vegetation potential in terms of the kinds and amounts of plant species. In theory, one could perhaps think of such a potential uninfluenced by herbivorous animals, and determined by climate, soil, and topography, and by competition between the plant species themselves. Of course, in reality no site is free of all herbivores, whether they are insects, small mammals, large grazers, or others.

The effects of these animals on the vegetation vary in kind and degree. Some actually enhance the performance of individual plants by grazing if it is not excessive. Thus McNaughton (1976) has emphasized the enhancement of vegetative production by moderate, large-ungulate grazing in African grasslands, an effect that has been observed in North America in relatively mesic grassland situations.

Consequently, herbivores in a sense can enhance the potential of some areas. But some grazing reduces plant production. Such is the case with excessive grazing, even in productive grasslands, and appears to be the case with virtually any level of defoliation in semiarid and arid regions (Cook, 1971; Sims and Singh, 1978; Hilbert et al., 1981; Lacey and Van Poolen, 1981).

These effects on individual plants ultimately affect the composition of plant communities, and in various ways. Plants of the different species in a community compete among themselves for space, water, light, and mineral nutrients. In free competition, without interference from other organisms, a community will gradually shift to a predominance of those plant species that are the most effective competitors.

In those cases where herbivory is detrimental to individual plants, the competitive balance between plant species can be altered. Grazing on the less competitive species will tend to hasten the dominance of the superior competitors and reduce community diversity. But grazing on the more effective competitors can impair their competitive ability, reduce their abundance, and facilitate the coexistence of the less aggressive species. The result is to increase the species diversity of the community.

Because herbivores produce these effects on the vegetation on which they depend, they ultimately affect themselves and each other in various ways. An herbivorous species that increases grassland production through moderate grazing can improve its own lot and that of other herbivorous species feeding on the vegetation. But if its grazing is excessive, it competes with other herbivorous species that consume the same plant species to the detriment of those species as well as itself. On the contrary, an herbivorous species that materially reduces an otherwise highly competitive plant species, and allows the increase of less aggressive ones, benefits those herbivorous forms that feed upon the now-increasing, uncompetitive plant species.

There are numerous examples of these animal interactions. Bison in pre-European North America were grazers with food preferences very similar to those of domestic cattle. Limited numbers of each could coexist today on the same area without detriment to each other as long as the common grass resource was not exhausted. But excessive numbers of each would undoubtedly lead to competition between them, and to the detriment of one or both. Similarly Rocky Mountain bighorn sheep are also primarily grazers. In some areas they appear to have suffered from competition with cattle and to have declined.

Some species are benefitted by the presence of others because of complementary feeding patterns. Pronghorn antelope are primarily shrub and forb feeders. Bison grazing in presettlement America applied pressure to grasses that allowed shrubs and forbs to coexist. Hence bison formerly, and probably cattle today, enhanced pronghorn numbers. Similarly, cattle grazing in the intermountain West promoted the increase of shrubby species in the mountains that were beneficial to deer. The latter increased in the twentieth century to densities unknown by the early settlers.

Clearly, each tract of land is capable of supporting a wide range of alternative vegetation types and combination of animal species, both wild and domestic. Many of these could be considered to be in "a thriving natural ecological balance" as alternative expressions of the potential of each tract. Of course, herbivorous pressures can be excessive, and vegetation production and abundance significantly reduced from their potential. This stage can lead to soil loss, alteration of the water budget, and reduced carrying capacity for the animals.

All of this may seem to be a circuitous route to assigning a meaning to the term excess. But it constitutes the background for saying that the term has both a biological and social aspect to it. Biological excess, in our judgment, exists when the number of herbivores present degrades the ecosystem to the point where it is producing goods and services well below its potential, and particularly where the long-term productivity and capacity for ecological recovery are impaired. Excessive water runoff and soil erosion might be indicators of this state of affairs.

Such excess can occur with only a single species of grazing animal, or with some combination of two or more. For an oversimplified example, if a given area can properly carry 1,000 grazing animals but has 1,500, then 500 are in excess. It makes no difference whether the 1,500 are horses, cattle, or a combination of both. An excess still exists, hypothetically assuming equal substitution. In effect, there is a carrying capacity for 1,000 mouths, and the 500 additional constitute the excess.

Which of these species of animals should be carried in a given area becomes one of human values or preference. Biologically, the area may be able to support 500 cattle and 500 horses, and may be carrying them. But if the weight of public opinion calls for 1,000 horses, the area can be said in this context to have an excess of 500 cattle.

For these reasons, the term excess has both biological and social components. In the above example, biological excess constitutes any number of animals, regardless of which class, above 1,000. Social excess depends on management policies, legal issues, and prevailing public preferences.

In summary, then, we consider excess of any large herbivores to be that number of animals which exceeds the number that allows a range ecosystem to exist at some condition approaching its potential (maximum productivity), or prevents it from becoming "as productive as feasible" and improve toward its potential.

Potential varies from locale to locale, depending on soil, climate, and other variables. Excess varies locally, depending on these variables and on the condition of the vegetation at the time of assessment. If the vegetation is in poor condition, excess may be a small number. If it is in good condition, an area may carry large numbers of animals, and excess may be a large margin above these. For these reasons, potential and excess must be judged independently for each locale.

Alternative expressions of potential, involving different vegetation types and combinations of herbivores, are possible for a given area. Decisions on which of these alternatives should be managed are sociopolitical decisions and need to be based on a knowledge of prevailing economic and social values. Such decisions, too, will vary from locale to locale and presumably would be made through the BLM and Forest Service planning procedures.

Properly, management plans designed to achieve appropriate stocking levels on specified areas require a strong information base, including:

1. an estimate of vegetation, soil, and water potential for the areas in question
2. numbers of herbivores of different feeding types, and their various combinations--in essence, alternative management options--that can be carried on an area without significantly changing it from its potential
3. kinds and amounts of forage required by the animal species in question, and their habitat preferences
4. both the positive and negative effects of the herbivores on the vegetation, and consequent secondary effects of the animals on each other
5. effects of the proposed plan on soil and water resources
6. an understanding of the various human values and desires associated with the alternative decision options

We prescribed a broad array of research projects in Phase I to provide this range of information. Since most of them were never initiated, we do not have sufficient data to prescribe this level of informed management. We can summarize the results of the few projects that were funded and add additional, relevant information from literature not reviewed in the Phase I Report. These provide a few bits of information toward a broad underpinning--in effect a few tiles in a largely incomplete mosaic.

The remainder of this section will discuss this biological information relevant to formulating sound management plans. A later section will address the sociopolitical and economic factors.

Biological Information Needed To Formulate Sound Management Plans

In view of the scanty information specifically pertinent to biological aspects of decision-making on horse and burro grazing, three Phase II research projects were commissioned. One by University of Wyoming researchers studied the distribution and habitat use by cattle, wild horses, and pronghorn antelope in the Rock Springs area of southwestern Wyoming. A complementary study by another group of Wyoming scientists, also in the Rock Springs area, examined specifics of diet selection and grazing impacts on individual forage plants under known levels of animal density, including both horses and cattle. The third, by Colorado State University researchers, was designed to quantify forage consumption rates of wild horses, compared to cows, and to relate this information to animal size and physiological status (lactating versus dry animals). The latter project also studied dietary habits of horses and cows.

Additionally, independent work not under the overview of this Committee has proceeded during the 2 years since the Phase I Report was issued. Noteworthy in this category are the studies in southeastern Oregon by Oregon State University scientists (Martin Vavra, personal communication, 1982) and one by Utah State University investigators in northern Utah (Reiner, 1982). The salient points of all of this research are highlighted below as they relate to updating findings published in the Phase I Report. The reader is urged to refer to the original reports for particular details not covered in this treatment.

Assessing Site Potential The amount of forage produced annually on rangelands of the West is extremely variable in both time and space. (Here forage is considered as plant material that is sufficiently palatable and available to be consumed by large herbivores.) Precipitation and temperature patterns are the major forces in this variation, but other important factors include botanical composition or successional status of the plant community (range condition in the range manager's lexicon), temperatures, and soil features (depth, texture, stoniness, chemical limitations).

Some examples give perspective to this inherent variation: On salt desert shrub ranges in southwestern Utah, yields ranged from less than

100 lb per 0.4 ha to almost 500 lb per 0.4 ha in a 5-year time span (Hutchings and Stewart, 1953). A general rule in arid and semiarid regions is that year-to-year variability in precipitation increases as the degree of aridity increases. Hence, in such areas, the range manager is not only working with a small average forage base, but also one that may change unpredictably by factors of 2 or more from one year to the next.

In another situation involving pinyon-juniper ranges in the southwestern United States, grazing capacities (a reflection of forage production) varied from as low as 12 ha per animal unit month (AUM) on "very poor" condition ranges to as high as 1.2 or 1.6 ha per AUM on "good" condition ranges (Springfield, 1976). This was mainly a reflection of the differences in species mix of plants found on these ranges, and to a large extent resulted from different management practices applied over past decades.

Margins for error are small when making decisions about forage and grazing under such circumstances. The problems with wild equids are greatly magnified, considering that control over animal numbers and animal distribution is severely limited in most areas presently or, in other areas, is available only after a considerable time lag required by legal and bureaucratic procedures.

Allowable Offtake Given this type of biological environment and given the relatively unsophisticated tools for assessing forage production and controlling animal numbers (of livestock as well as wild equids), range managers have often adopted, at least in principle, a conservative philosophy of grazing management on public lands. For example, Stoddart et al. (1975) recommended that for situations where ". . . livestock numbers cannot be varied (from year to year), the stocking level should not exceed average forage production." Further, if an imbalance should occur temporarily, it should be in favor of the plant rather than the grazing animals, hence their recommendation of using values in the range of 65 to 80 percent of average forage production as a safe base for calculating grazing capacity. Proper use coefficients and other calculations would then be applied to this reduced base, rather than to the raw mean.

In practice, few grazing capacities have been determined on the basis of forage inventories and allocations of this forage to one or more species of grazing animal. This is because of the profound variation discussed above, the expense of conducting forage assessments under such conditions and the low precision of techniques available to the range manager. In the case of wild horses and burros, this approach has been seriously hampered by the very limited information on animal consumption rates, forage selection patterns, grazing impacts on plants and soils, and possible competitive interactions with other herbivores sharing the range. Thus, an alternative has been to use the existing stocking rate as a starting point and to adjust numbers over time as measurements of range trend dictate. (Range trend is the change in plant community successional status over time and is measured as changes in plant community botanical makeup.)

Most range managers would find acceptable a grazing regime that, as a minimum, maintained a stable range trend. Ideally, they usually would like to see an upward trend (denoting community change to higher successional levels), particularly on ranges in low successional status. Rarely, they might wish to maintain or even create a particular low successional community to produce forage or habitat for a particular animal wildlife species (e.g., brushy ranges for mule deer).

There are problems in using trend measurements as a basis for managing horse and burro ranges. One is that the measurement span only be made over relatively extended periods of time. Changes occurring during spans of less than, say, 5 to 7 years are often more reflective of yearly variation in climatic conditions than of grazing effects. On horse and burro ranges, such delays may not be acceptable.

Another problem is that downward range trend may be indicative of problems other than excessive animal numbers per se. It may point to improper season of grazing (e.g., year-after-year congregation of animals on south-facing slopes with repeated consumption of newly emerging grasses after snowmelt) or to improper distribution of grazing as is often seen in riparian zones or around man-made watering points. Even major reductions in animal numbers do little to alleviate such problems; they simply tend to diminish the size of the impacted area.

All of these problems considered, the range manager is often forced to make decisions about grazing based on experience and professional judgment rather than on hard, reproducible and documentable data. Indeed, Stoddart et al. (1975) define range management as both a science and an art. Even with major improvements in our fundamental knowledge of rangelands and range animals, the "art" element of range management is sure to remain into the foreseeable future.

Animal Diets and Food Habits Information on the species and kinds of plants that grazing animals select in their daily diets provides insights into potential grazing impacts on the plant community, potential competition with sympatric herbivores, and nutritional sufficiency or insufficiency. While recent research on this topic has not changed the earlier contention that wild and free-roaming horses are basically grazers (see Table 2.22 of Phase I Report), the Wyoming study (Smith et al., 1982) has contributed an element of caution. These researchers found that during summer, grasses contributed over 65 percent to the diets of horses on both heavily and moderately stocked paddocks while shrubs accounted for approximately 25 percent of the dietary content.

Important shrubs included winterfat, four-wing saltbush (*Atriplex canescens*), spiny hopsage (*Grayia spinosa*), and nuttall saltbush (*Atriplex nuttallii*), with winterfat contributing up to 22 percent on occasion. Smith et al. (1982) attributed this high usage of winterfat to the relatively high biomass of this species available for consumption. Cattle in the Wyoming summer study consumed a broader array of species than did horses, with grasses constituting an average 45 percent of diets, forbs up to 12 percent on occasion, and shrubs the remainder.

During winter, horses in the Wyoming study also used shrubs to a substantial degree (average composition = 35 percent for both stocking densities), with grasses constituting the major proportion (Krysl et al., 1982). Winterfat was again the most important shrub species. Animals were observed pawing portions of winterfat plants that remained after earlier grazing and consuming subterranean portions.

During winter, cattle selected diets similar to those of horses. This is illustrated by similarity indices (percentage of the diet consisting of plant species common to both animal species) of 80 percent and 88 percent for moderate and heavy stocking densities, respectively. Comparable indices for the summer season were 73 percent and 71 percent for the two respective stocking densities.

While similarity indices are not sufficient information in themselves to document dietary competition, they do provide reason for concern where forage may become limited in total quantity (such as during severe winters), where animal mobility and habitat separation might be restricted, and where spatial overlap appears to occur naturally (such as during summer in the Red Desert area).

An interesting contrast on dietary shrub usage by horses is provided by the recent Utah study (Reiner, 1982). Although conducted on a different vegetation type (sagebrush-grass-forb) than the Wyoming study (salt-desert shrub), a palatable shrub (bitterbrush) was a major component of the vegetative mix. Yet, in this case, horses essentially neglected all shrubs as dietary components. Likewise, the recent Colorado research (Rittenhouse et al., 1982) found horses to use little shrubby plant material in their diets (0.8 percent compared to 4.9 percent for cows).

An earlier study by Hansen (1976), discussed in the Phase I Report, is the only other evidence in the literature that horses used shrubs as a major dietary item. In that study, conducted on desert grassland range in New Mexico, shrubs averaged about 22 percent on a yearlong basis, with the least use (about 9 percent) during spring months.

The reasons are not evident for these exceptions to the general rule that horses basically select diets containing 90 percent or more grass (see Table 2.22 of Phase I Report). The relative availability of shrubs and grasses in the vegetation mix must be considered, but the palatability of certain shrub species to horses must also be assessed. For example, during summer in the Wyoming study, fourwing saltbush had dietary preference ratings as high as any grass species (Smith et al., 1982). Winterfat, as previously mentioned, was also consumed readily by horses. Both of these species are generally considered to be highly palatable to cattle and sheep. On the other hand, this generalization of common palatability of certain shrubs to horses and livestock would certainly not hold for the case of bitterbrush as demonstrated by the Reiner (1982) study. Recent conversations with Vavra (personal communication, 1982) on his continued work with wild and free-roaming horses confirmed earlier reports (Vavra and Sneva, 1978) that horses in the sagebrush-grass vegetation type of southeastern Oregon are fundamentally grass eaters.

Forage Consumption Rates and Animal Unit Equivalents Knowledge of the daily quantity of forage dry matter consumed by an animal of given size and physiological status (i.e., lactating, nonlactating) is a fundamental starting point for calculations of grazing capacity and is a factor in decisions for allocating the common forage reserve among various sympatric animal species. By virtue of anatomical differences in the configuration of the gastrointestinal tracts of horses and cattle, numerous researchers have theorized that a horse of a given size or body weight can consume more forage than a comparable-sized cow. Therefore, suspicion has existed that the standard procedure for calculating animal unit equivalents may be inappropriate for horses. This is discussed at length in the Phase I Report.

The accepted definition of an animal unit (AU) is a 455 kg (1,000 lb) cow or her equivalent (Society for Range Management, 1974). To convert among animal species, one merely divides the body weight (kg) of the animal in question by a factor of 455. The sophistication of this approach may be enhanced by using metabolic body weights, i.e., body weight (kg) raised to the fractional exponent of 0.75, divided by 455 also raised to the 0.75 power. However, the additional accuracy achieved by this procedure is open to question, and the use of simple body weights (i.e., weight to the power of 1) is the usual convention.

Since there is virtually no available literature concerning forage intake rates by the wild horses, the Colorado work by Rittenhouse and his associates (1982) was initiated during Phase II. These studies were conducted on a 400-ha tract of rangeland located some 8 km southwest of Durango, Colorado. Plant communities on the area included sagebrush-grass associations, open grassland parks, ponderosa pine woodlands, mountain meadows, and dense stands of gambel oak. Although no populations of feral equids are known in the general area, vegetation and topographic features are similar to those found on some of the other areas of the West where wild horses occur. Thus, some of the vegetation-related findings should be directly applicable to such areas. The more important question is the differences or similarities between horses and cattle occupying a common range, and results relating to this should be broadly applicable.

Findings were based on total fecal output measurements from animals equipped with fecal collection devices. These indicated that mares, on the average, consumed about 14 percent more forage dry matter (12.5 kg per head per day) than did cows (11.0 kg per head per day). However, a substantial difference of about 20 percent was noted between lactating mares (14.6 kg per head per day) and lactating cows (12.2 kg per head per day). Nonlactating mares and cows consumed 10.4 and 9.7 kg per head per day, respectively.

A surprising result of the Colorado research was that forage consumption by horses was not related to animal body size (weight), within the range of mature animal weights studied (367 kg to 578 kg per head). This led the researchers (Rittenhouse et al., 1982) to conclude ". . . when comparing intake for horses and cows of approximately the same body sizes, reporting intake on a per body size basis may be more confusing than helpful."

Utilization of nutrients (as measured by apparent digestion coefficients) was higher in cows than in mares, with the exception of protein that was digested more thoroughly by mares (44 percent versus 36 percent). Cows digested (cell wall constituents) much more extensively (65 percent) than did mares (53 percent). The rate of passage of food material through the alimentary tract of cows was considerably slower than through mares, hence the longer residence time of ingesta in cows partially accounted for the higher fiber digestion. Theoretical concepts relating to consumption rates in equids and ruminants are discussed in considerable detail in the Phase I Report.

Although some need further researcn, results from this study carry potentially important implications for wild horse management. Findings on consumption rates add support to the practice noted in the Phase I Report (see p. 97) of attributing an animal unit equivalent of 1.25 to mature horses. Although this value appears high in light of tne current Colorado results (i.e., an average 14 percent greater forage consumption by mares), unreported evidence suggested that the 14 percent difference was conservative (L. R. Rittenhouse, personal communication, 1982). The difference appeared to hold over a fairly wide range of forage quality conditions.

The findings also raise the temptation to speculate on relative adaptive strategies of horses and cows. Differences in passage rates of ingesta would appear to confer an advantage on horses over cattle under poor forage conditions. For example, horses would appear to be able to consume more forage per day to compensate for the low nutrient concentrations, whereas cows (and other ruminants) would not. Horses are well equipped to extract the scarce quantities of dietary protein that are usually nutritionally limiting under such conditions. Behavioral attributes, such as the greater mobility of horses would also appear advantageous; they could quickly move to alternate areas when forage became scarce. However, the appropriate data to test hypotheses relating to competition definitively are still insufficient. This statement is not intended to detract in any way from the major contribution made by the Colorado researchers to our knowledge of nutrition and grazing ecology of horses and cows. The reader is encouraged to refer to their original report (Rittenhouse et al., 1982) for details.

<u>Habitat Preference and Use</u> The problem of making decisions on forage allocations to combined populations of horses and livestock, and of assessing competition between the two, is a more complex one than can be solved with measurements of dietary overlap alone. For, in an oversimplified case, if horses and cattle chose very different habitats on the basis of topography or vegetation type, there would obviously be no chance for interspecific competition even though they fed on the same plant species. And all of the allowable forage offtake

in each habitat could be allocated to the respective occupants of the habitats without any trade-offs.

Of course the world is not that simple, but varying degrees of habitat segregation between horses and cattle have been reported. For this reason, we advocated studies of habitat preference and use during Phase II, and one such project was carried out in the Wyoming Red Desert by scientists of the University of Wyoming Department of Zoology and Physiology (Denniston et al., 1982). A major goal of this project was to contribute information toward the development of site-suitability criteria, a need reported to the Committee by Robert Springer of BLM (personal communication) and by Wright (1979).

The most extreme case of habitat segregation was shown to the Committee by Martin Vavra in the Three Fingers Herd Management Area, Shepherd Mountains of eastern Oregon. Here, horses largely occupied mountain-top terrain, while cattle occurred almost entirely on the lower elevations. Vavra (personal communication) commented that horse habitat in this area coincided more closely with that of bighorn sheep than of cattle.

Somewhat less complete segregation has been reported by Pellegrini (1971) and Salter and Hudson (1980). Pellegrini observed horses in western Nevada in an area used for both sheep and cattle grazing. In about December the horses moved up on ridge tops unoccupied by livestock. He surmised that the animals were attracted to these areas by the food available on ridges swept free of snow by wind. But he also suspected that part of the movement may have been hastened by introduction of sheep onto the lower elevations. Cattle were moved onto the lowlands in early April after the horses had moved out and sheep had been removed. Horses returned to the lowlands in late spring or early summer to use springs for watering. They coexisted with cattle at this elevation until the latter were removed in early June.

Similarly, in an Alberta study area, horses used nearly all vegetation types. But they moved out of those occupied by cattle during the latter's June to October occupancy period (Salter and Hudson, 1980).

Wright (1979), like Pellegrini, has observed a preference for the ridges by horses in winter. In summer, they are forced to move to the lowlands for water, where they overlap with cattle distribution. But the latter remain near the water sources, while horses return some distance to the ridges after drinking. He concludes that horse-cattle competition is less pronounced than widely believed.

The thorough Wyoming Phase II study by Denniston et al. (1982) describes less marked, and subtle, forms of habitat segregation. Cattle tended to remain relatively close to water sources, year-round, and ranged over a small fraction of the 540-mile^2 (1,399-km^2) study area. Horses (and pronghorn antelope) moved much farther from water in fall and winter, ranging over the entire study area. During spring and summer they remained as close to water as the cattle, but grazed to a considerable degree in winterfat (*Ceratoides lanata*) and nuttall saltbush (*Atriplex nuttallii*) vegetation, types used less by cattle.

By the same token, cattle grazed in certain types less often frequented by horses, namely greasewood (*Sarcobatus vermiculatus*) and rabbitbrush (*Chrysothamnus viscidiflorus*).

One can generalize all of these examples with the statement that horses are considerably more wide-ranging than cattle and less tied to water. In all of these cases, with the possible exception of Vavra's, horses ranged over nearly all the terrain occupied by cattle--though not necessarily at the same time of year--while cattle ranged over only a small portion of the area used by norses.

Clearly the problem of allocating forage to the two species is more complex than merely estimating the gross number of AUMs for an area, and assuming direct equivalence between tne two species in using that forage. As Wright (1979) put it: "I doubt that the agencies [sic] statement, 'ten thousand horses on, ten thousand cattle off', is all that accurate."

None of this is said in any way to imply that horses and cattle cannot or do not compete for forage. Denniston et al. (1982) concluded that they did not have evidence to prove the existence or absence of competition, but they acknowledged that there was a potential for it on their area. In their view, it was most likely to occur, if at all, in the areas close to water where year-round cattle use and spring-summer horse use were concentrated.

Competition may also occur for space. When two species seek different habitat, the possibility exists that they are avoiding each other for behavioral reasons. The possibility was suggested to us that horses may on occasion move out of an area occupied by cows, and testing this hypothesis was one of the objectives of tne Denniston et al. study. However there were not enough cattle on the study area, nor was the study conducted long enough to provide a definitive test.

One may argue that the cattle and norses coexisted during spring and summer. But this may have been forced by tne mutual water need. When water was no longer scarce, horses moved away from the areas occupied by cattle, and as Pellegrini (1971) suspected they may have moved away from areas occupied by sheep. In the Phase I Report we discussed two cases in which elk appear to have avoided areas occupied by cattle (p. 142), and Child and Wilson (1964) have discussed similar avoidances between roan and sable antelope in Africa.

In short, we do not assert that behavioral competition prompts habitat segregation between horses and cattle. We only suggest it as a possibility needing investigation. The main point here is that forage-allocation decisions will become more effective and sound when studies like that of Denniston and his coworkers have provided a thorough understanding of the complexities involved. In the Phase I Report we recommended that studies of this type be repeated in several areas of the West.

Forage-Plant Utilization Discussion in the Phase I Report recognized that short-term studies (less than about 5 years' duration) can offer little direct insight into grazing impacts on plant community composition and production (range trend). However, the Report indicated that useful management-related data could be obtained from studies in relatively small paddocks (as opposed to the open range) where numbers of animals and days of grazing use could be closely controlled. Insights into such questions as dietary botanical composition under different grazing intensities, dietary relations between horses and cattle, also under different grazing intensities, and relative levels of plant consumption under various grazing intensities and animal species combinations would be particularly important in this light.

Plant-utilization studies by the Wyoming researchers (Smith et al., 1982) showed relatively heavy utilization on grass and sedge species (range = 61 to 95 percent) during summer irrespective of the stocking density of animals. The two stocking densities used during the summer study were: "heavy" (about 12 animal unit days (AUDs) per hectare) and "moderate" (about 3 AUDs per hectare). They also observed utilization of about 75 percent on two shrub species, winterfat (Ceratoides lanata) and rabbitbrush (Chrysothamnus viscidiflorus), during the summer period.

This is in contrast to Utah studies (Reiner, 1982) conducted during early summer, where shrub utilization was negligible, even though stocking densities were six- to ninefold higher (moderate = 27 AUDs per hectare; "heavy" = 68 AUDs per hectare) than in the Wyoming study. Grass utilization in the Utah study averaged 44 percent and 76 percent for moderate and heavy stocking densities, respectively, while comparable values for forbs were 8 percent and 19 percent. These utilization patterns, coupled with observations of higher production in the desirable shrub bitterbrush (Purshia tridentata) on horse-grazed paddocks, led the researchers to the conclusion that intensive grazing by horses could be used effectively for improving the habitat value of their ranges for wintering deer and elk. Apparently, the selective utilization of herbaceous plants with no effective grazing on the shrubs reduced competition for scarce moisture by grasses and forbs in favor of shrubs.

The major differences in grazing treatment design between the Wyoming and Utah studies were stocking density, quantities of forage available, and length of the grazing period. The Utah paddocks were small (0.5 to 1.0 ha) and were grazed by a proportionately higher density of animals over a short (5- to 9-day) grazing period, whereas the Wyoming paddocks were larger (32 to 194 ha), were grazed by a lower density of animals, and for a 34-day period. Apparently much of the forage reported as utilized (i.e., that which disappeared over the course of the grazing period) in the Wyoming study was not actually consumed by horses (or cattle) but was lost to other factors, including natural weathering and consumption by other herbivorous vertebrate and invertebrate organisms. In contrast, a much higher proportion of the forage that disappeared in the Utah study was due to outright consumption by horses.

Observations from these two studies illustrate a feature of grazing management that is becoming more widely recognized in domestic livestock production systems and that may have implications to wild equid management. In situations where animals graze a particular pasture or range unit for long periods of time (i.e., season-long, or even yearlong in the case of some feral horse herds), often at relatively low animal densities, the efficiency of forage harvest by grazing is low. Considerably more forage must be allocated per animal unit than in situations where the graze time is short and animal density per unit of land is high. There seem to be at least three causes for this effect. First, under the low-intensity situation, a disproportionately large part of the forage biomass is lost to unaccountable "wastage" factors. (However, we do not overlook the fact that, from the standpoint of soil protection and watershed features, much of this "lost" forage may become litter, which has other nonforage values.) Secondly, the increased off-take possible from short-term intensive grazing periods interspersed with rest periods may result from increased plant vigor due to the rests. Third, if the animals are forced to graze quickly under high intensity, they may be less selective for preferred plants and grazing sites, thereby using forage that they might avoid if given time and leisure to select.

Wyoming researchers (Smith et al., 1982) also conducted winter grazing trials during November and December 1981. Until this study, there had been little work on horse-forage relationships during winter, even though the winter season is often suggested as the period that sets limits on survivability for certain segments of the population. As summarized in the Phase I Report, Salter and Hudson (1979) reported that horses were effective foragers during winter in the upper foothills of the boreal forest zone in western Canada.

Stocking densities used by Wyoming researchers were about 3.5 AUDs per hectare for "moderate" grazing and about 8.8 AUDs per hectare for "heavy" grazing. Under this regime, utilization levels for grass were about 15 percent for moderate and 49 percent for heavy stocking densities. A few differences were found in utilization of particular plant species by individual animal species (i.e., horses, cows, or horse-cow combinations), but no important departures from the means presented above were seen.

Winterfat was the only shrub to sustain noticeable utilization during winter, and the levels observed were appreciable: 59 percent under moderate and 80 percent under heavy stocking. No major differences were seen for either horses or cows in this regard.

Utilization Studies in Perspective The Wyoming and Utah studies discussed above were both conducted under confinement conditions, a necessary experimental constraint for accurately relating a particular level of forage use to a known stocking intensity, duration, and time of grazing. Critics may argue that wild horses and burros rarely, if ever, exist under such conditions. This may be a valid point, but not one that voids the applicability of such studies to wild and free-roaming populations.

Specific points applicable to wild horse range management are:

1. Winter stocking densities as high as 8 AUDs per hectare are unlikely to lead to undesirable successional changes in plant communities under conditions similar to the Wyoming Red Desert. The relatively heavy use on winterfat, a palatable and nutritious

suffrutescent shrub, merits some concern, but early studies (Hutchings and Stewart, 1953) showed steady improvement in winterfat yields under 60 percent winter utilization. Winter conditions may prompt animals to concentrate in particularly favorable sites, leading to increased risk of overuse, but the dormant condition of vegetation during winter also renders plants less subject to physiological stress from grazing.

2. Summer utilization levels similar to those applied in the Wyoming study would probably lead to undesirable changes in the plant community, whether by horses or cattle. Shrubs in particular seem vulnerable to heavy defoliation during periods of active growth (Cook, 1971). The number of animals that would produce such utilization on any particular area can only be determined by site-specific, periodic utilization studies. This proved to be about 3 AUDs per hectare in the Wyoming area.

3. Animal distribution over the range, and its relationship to animal numbers and length of the graze period on particular sites, is a key element in plant community impacts. The importance of short, but perhaps intensive, grazing periods (as contrasted to protracted or season-long grazing) is illustrated by the comparison of the Wyoming and Utah studies and resultant utilization levels. The longer animals remain on a particular site, the higher the likelihood of regrazing plants and the regrowth of vegetation produced after the initial defoliation. Recent research (e.g., Caldwell et al., 1981) indicates that certain Agropyron bunchgrasses may be placed at a competitive disadvantage by this kind of grazing during the growing season.

Finally, it goes without saying that grazing duration is more easily controlled with domestic animals than with wild herbivores. The high mobility of feral horses could perhaps be an advantage in this regard, and management activities should explore ways to capitalize on this behavior. Opening and closing water points could be one possible measure in certain areas.

Range Hydrology The existing knowledge about the impact of wild equids on range hydrology is scanty, at best. Virtually no information exists in scientific journals, nor was such research funded during Phase II of the NAS effort. However, numerous anecdotal comments have appeared from time to time, and some limited in-house reports have been issued by various federal agencies that purport to identify the hydrologic impacts of wild equids (Dixon and Sumner, 1939; Weaver, 1959; Buechner, 1960; Welles and Welles, 1960, 1961b; Koehler, 1974; Fisher, 1975; Stoddart et al., 1975; Woodward and Ohmart, 1976; Carothers et al., 1977; Norment and Douglas, 1977; Zarn et al., 1977; O'Farrell, 1978; Hansen, n.d.; Jones, 1980). Lacking an adequate and systematic knowledge base on which to judge the effects of feral equids, the Committee has no choice but to assume that wild equids impact range hydrology in a manner similar to that of livestock. Considerable information exists in scientific journals on the hydrologic impacts of livestock grazing (Skovlin, 1981; Blackburn et al., 1982) and this was reviewed in some detail in the Phase I Report.

Most wild equid range is arid to semiarid. The grazing potential is naturally low, very sensitive to overgrazing, and recovers very slowly from abuse. Moreover, water is a scarce commodity and therefore in particular need of proper management.

Grazing, whether by large mammals or other herbivores, has an impact on watershed parameters. It has been recognized for 70 years that heavy, continuous grazing accelerates erosion and runoff (Rich, 1911; Duce, 1918; Sampson and Weyl, 1918). The literature is filled with examples of the adverse impacts of overgrazing on watersheds (Blackburn et al., 1982). Love wrote in 1958 ". . . there is a large body of information leading to the conclusion that heavy grazing has had bad hydrologic consequences. It is doubtful that more investigations are needed to emphasize this conclusion." Recent research has supported Love's conclusions.

The available data strongly suggest that hydrologic differences between pastures continuously grazed lightly and those grazed moderately are not significant. There appears to be no hydrologic advantage to grazing a watershed lightly rather than moderately. Some studies have failed to show a difference in soil loss, infiltration capacity, or soil bulk density among light, moderate, and ungrazed pastures. Thus the existing information indicates that rangelands can be grazed at a light or moderate rate without adverse hydrologic impacts.

Riparian areas constitute only a fraction of the total western rangeland area, but they are as productive in terms of species diversity and biomass per unit area in both plants and animals as the remaining land base (Skovlin, 1981). Riparian zones are also an important component in the maintenance of healthy populations of fish and wildlife and a quality water supply (Platts and Raleigh, 1981). Sediment production within the riparian zone is often a serious matter, as problems with bank stability are frequently encountered. The bank-stability problem is often a combination of such things as destruction of vegetation, mass wasting, and bank cutting, all induced by excessive pressure from large herbivores. In general, natural, stable, well-vegetated stream banks help maintain stream-channel integrity.

The most basic resources of western rangelands, on which the living resources depend for their existence, are soils and water. Vegetation and animal life can be altered considerably, but short of extinction they have the regenerative power to recover to earlier states on a time scale measured in years or decades if afforded the appropriate protection. However, soil loss, usually associated with hydrologic changes, represents irreversible change on a time scale relevant to human lifetimes. And such changes undercut the regenerative abilities of plant and animal resources, and they too are subject to irreversible change as a consequence.

Hence, by the criterion of irreversibility, populations of any herbivores--whether domestic livestock, wild ungulates, or wild equids--must be considered in excess by the criteria set forth herein: if the vegetation is so altered as to move it significantly from its potential, and if that alteration promotes soil loss and hydrologic change to the point of irreversible change.

Similar wild equids and/or domestic livestock grazing can be managed short of excess if it permits sufficient streamside vegetation to hold soil in place, prevents unacceptably high water temperatures, and avoids bacterial pollution.

Effects on Wildlife Given the multiple-use criterion of excess feral equid numbers, interrelationships with wildlife also need to be considered. Wildlife constitutes a set of values that figure into decisions on management options for land units. Such decisions will be made most effectively with the same types of information on wildlife species as discussed above on horses and cattle: site potential, kinds and amounts of forage consumed, habitat preferences, impacts on vegetation and hydrology, and public preferences. Given these types of data, forage allocation decisions can be made for desirable mixes of livestock, feral equids, and wildlife.

While the research program we recommended in the Phase I Report largely considered horses, burros, and cattle, the same kinds of studies are needed for wildlife species that coexist with feral equids. If only a limited amount of research has been carried out on livestock-equid relationships, far less has been done on relationships between equids and wild ruminants, with the exception of feral burros and bighorn sheep. Hence, except for the burro-bighorn case, the relationships are largely matters of surmise, or of inference from interrelationships between cattle and wild ruminants on the grounds of a rough cattle-horse equivalence. Despite this shortage of information, it seems worth discussion here because of the multiple-use aspect, the concern of traditional wildlife groups with the wild equid issues, and the fact that we did not review the matter in any length in the Phase I Report.

As discussed above, the interrelationships between large herbivores can be beneficial or harmful to each other, depending on the similarity or complementarity of their food and habitat preferences and on their numbers and intensity of resource use. One of the likely cases of complementarity is between horses and deer. Since horses tend to be grazers, while deer are more characteristically browsers, the two are not likely to compete in a reasonably diverse vegetation with forage species for both. Thus in three Colorado studies, horse and mule deer diets generally overlapped by less than 5 percent (Hubbard and Hansen, 1976; Hansen and Clark, 1977; Hansen et al., 1977). And we referred above to the Utah studies in which horse grazing is being used experimentally to see whether habitat can be improved for mule deer and elk.

Moose, too, are browsers. They feed on different plants and select different habitat than do horses (Storrar et al., 1977; Salter and Hudson, 1980)

The relationship between horses and pronghorn antelope may be another case of complementarity. We discussed above the complementarity between bison and pronghorn and between cattle and pronghorn. Given the similarity between horse and cattle diets, the horse-pronghorn case is a reasonable surmise. Indeed, Olson and Hansen (1977) found little dietary overlap between the two species on the Wyoming Red Desert, while Denniston et al. (1982) found close similarities in their distribution.

Given the complementarity between browsing ungulates and horses, there is little, if any, question of a forage trade-off between the two, at least in conditions of normal weather and range in reasonably good condition. In fact, the feeding activity of each might tend to push vegetation composition toward that favoring the other in areas where both species occur together. A reasonable balance between the two would tend to stabilize the vegetation and enhance long-term productivity.

But on degraded range, the plant species of each might be depleted to the point where the food habits of grazers and browsers converge. In this case competition could occur, a condition that Forrest Sneva (personal communication) observed between horses and mule deer in overutilized range in Oregon. Similarly, severe winter weather can reduce vegetation availability, and force together species that normally feed in different habitat and/or on different plant species. Thus, Miller (1980) observed the convergence of horses, cattle, elk, and pronghorn along ridges when deep snow buried much of the vegetation in more gentle terrain.

As with wild horses and cattle, the potential for competition and the problem of administrative trade-offs in allocating forage are most likely to occur between equids and wild ungulates with similar dietary preferences. The fact that two species live together and have similar diets does not necessarily imply competition. If they do not significantly deplete the vegetation, they do not compete for food in an ecological sense. And as discussed above, light-to-moderate grazing can, in some cases, increase vegetation production. Hence grazing by two species can increase their mutual food resources in these situations.

Ecologically, competition for food occurs when two species reduce their common food supply enough to create nutritional problems, affect each other's birth and/or survival rates, and ultimately influence each other's population levels. In a land management sense, if one species is reduced artificially to provide a maximum amount of forage for another, this could be considered a form of competition, bureaucratically imposed.

Several species of wild ungulates have sufficient dietary and habitat overlap with equids to run the risk of, or achieve, competition. Elk are broad-spectrum feeders and graze enough to overlap horse diets materially (Olsen and Hansen, 1977; Hansen and Clark, 1977; Salter and Hudson, 1980). And as mentioned above, Miller (1980) observed the convergence of horses and elk on wind-swept ridges during a severe winter. None of these authors actually demonstrated competition, however. Two cases of apparent cattle-elk competition were reported in the Phase I Report (p. 142).

Potential or actual competition between equids and bighorn sheep has received by far the most attention in the ecological literature of any North American equid-wild-ungulate interactions. Bighorn sheep appear demographically fragile. Nowhere in North America do they occur in large numbers, and Wagner (1978) suggested that their primeval numbers may be the most underestimated of any North American ungulate. Hence, their contemporary remnant status may imply one of the most extreme postsettlement reductions of any large herbivore.

Most of the attention on the Rocky Mountain subspecies has focused on livestock effects on bighorn numbers, there being little information on wild horse interactions. But these livestock effects may indicate susceptibility to horse competition. Strong inference of cattle-bighorn competition has been reported for Wyoming (Honess and Frost, 1942), Colorado (Packard, 1946), Montana (Berwick and Aderhold, 1968), and Idaho (Morgan, 1971). McCann (1956) suggested that cattle, competing with elk on valley bottoms and foothills, forced the elk higher and into competition with bighorns. Crump (1971) actually concluded that bighorn range in the Wind River Mountains of Wyoming was limited by horse competition, as did Stelfox (1976) for Alberta. Martin Vavra (personal communication) observed that wild horse habitat preferences in eastern Oregon coincided more closely with bighorn than cattle range.

It is the southwestern or desert bighorn subspecies that appear particularly fragile (McKnight, 1958; Lange et al., 1980), their populations being subject to precipitous declines (Lenarz, 1979; Lenarz and Conley, 1980; Watts and Conley 1981). That fragility may in part be a function of the inherently fragile, arid habitats that they occupy and their relict status occasioned by the post-Pleistocene warming, drying, and shrinkage of their habitat (McCutchen, 1981; Hansen, 1982). The state of New Mexico has placed the bighorn officially on its state "Threatened" list. They are apparently now extinct in several northern states of Mexico, and their status is of great concern throughout their range.

A 40-year research history chronicles the view that livestock competition has played an important role in the decline of the southwestern subspecies in all of the five states in which they occur--Texas (Davis and Taylor, 1939), New Mexico (Gordon, 1957; Sands, 1964), Arizona (Gallizioli, 1977), Utah (Dean and Spillett, 1976), Nevada (Reese and Baxter, 1973; McQuivey, 1976, 1978), and California (Weaver, 1973a)--and in the Mexican state of Sonora (Valverde, 1976). That literature is cited here to show the long history of concern for the fragility of the desert bighorn subspecies and their likely susceptibility to equid competition.

Some authors implicate competition with cattle (Russo, 1956; Gordon, 1957; Albrechtson and Reese, 1970; Ferrier and Bradley, 1970; Yoakum, 1971; Wilson, 1975; Jones, 1980), while others ascribe the decline to domestic sheep and/or goats (Davis and Taylor, 1939; Gordon, 1957; Jones et al., 1957; Buechner, 1960; Grass, 1960; Valverde, 1976). Several authors have implicated competition with feral horses (Halloran and Deming, 1958; Buechner, 1960; Albrechtson and Reese, 1970; McQuivey, 1978; Jones, 1980). Most of these cases rely to some degree on inference that the domestic animals have caused the sheep declines, but that inference is strengthened by cases in which wild sheep increased following the removal of livestock: in the San Andreas Mountains of New Mexico (Gordon, 1957) and in southeastern Utah (Wilson, 1975).

It is the interaction between desert bighorns and feral burros that has stimulated the greatest range of investigations and a lengthy, sometimes contentious, literature. This subject was reviewed in the Phase I Report, but bears further treatment here as it relates to the question of excess.

Most inferences about burro and desert bighorn competition involve water and vegetation. While several authors (Welles and Welles, 1961a, b; Moehlman, 1974; Golden and Ohmart, 1976) have failed to observe the problem, a lengthy list of investigators contend that, in areas where burros are numerous and water scarce, the equids foul or completely use up water sources so that sheep cannot drink (Dixon and Sumner, 1939; Halloran, 1949; Sumner, 1952, 1959; Ferry, 1955; Russo, 1956; Bendt, 1957; Weaver, 1959, 1973b; St. John, 1965; Thomas, 1979; Jones, 1980). The claims involve a number of areas in Arizona, Nevada, and California. The problem may revolve around the abundance of water. Obviously, it should not arise where the water source is a flowing stream, as in the case of some bighorn range in Arizona, Nevada, and California along the Colorado River, its impoundments, and its tributaries. But where the source consists of small, isolated desert springs, the problem may be real.

A more extensive array of observations implicate competition for forage in numerous southwestern areas (Ferry, 1955; Bendt, 1957; Sumner, 1959; Sleznick, 1963; Weaver, 1973a,b; Wishart, 1975; Douglas, 1977; Walters, 1977; Hinks, 1978). Clearly, many forage species are fed upon by both wild burros and bighorns (McMichael, 1964; St. John, 1965; Seegmiller and Ohmart, 1975, 1976; Seegmiller, 1977; McQuivey, 1978; Walters and Hansen, 1978). In the most recent and detailed analysis, Seegmiller and Ohmart (1981) found burros taking a larger percentage of grasses and sheep taking more browse, with the percentage of dietary overlap at around 50 percent. But of the 10 plant species most abundantly consumed by each herbivore, 6 were common to both. These were assumed to be the most nutritious and therefore important for both bighorns and burros.

As stated above, however, common use of a resource by two animal species does not necessarily constitute competition. They compete only when (1) the resource is depleted to the point of detriment to one or both species, and (2) the detrimental effect results in lower populations of one or both. The evidence on both of these criteria is limited and circumstantial, but suggestive nevertheless.

Most authors agree that forage depletion is most likely to be severe in areas close to water. Both burros and bighorns range closer to water during the summer, and pressures on vegetation concentrate as the water source is approached. Burros are more mobile than sheep and range farther from the water source (Seegmiller and Ohmart, 1981). Sheep are less mobile, especially when they are accompanied by lambs. Hence they are forced to remain closer to the water at this time of year (McMichael, 1964; Thomas, 1979) and in the area where vegetation is more heavily impacted. The result may be food shortage at a critical time when ewes are lactating and lambs are gradually being forced to feed on their own.

Several authors (e.g., Sleznik, 1963; Jones, 1980) have pointed to the differing habitat selection between burros and sheep that might reduce the probability of competition, as discussed above under horse-cattle habitat preference and use. Seegmiller and Ohmart (1981) depicted a pattern somewhat similar to that described for horse and cattle overlap. During summer, both sheep and burros tend to converge on the lower elevations near water. But in the cooler months, sheep move onto the talus terrain and long steep slopes, while burros favor the foothills.

Nevertheless, we can question, as we did in discussing horse and cattle habitat segregation, whether a spatial separation reflects some kind of behavioral avoidance. Several observers have reported burros and sheep grazing in close proximity without overt interaction. But as with cattle and horses, they are forced together in summer by their mutual water need. The possibility must be acknowledged that the sheep simply prefer areas not occupied by burros, and their range is reduced thereby when burros are present on a portion of an area they would otherwise occupy. This suggestion has already been made by Jones et al. (1957), Buechner (1960) and McQuivey (1976).

Several circumstantial population comparisons have been made. A number of cases, reviewed in the Phase I Report, have been reported of thriving sheep populations in areas without burros and a lack of sheep in areas occupied by the equids (McKnight, 1958; Thomas, 1979). Dixon and Sumner (1939) and Brandt (as cited in McKnight, 1958) reported a sequence of changes at Willow Spring in Death Valley that constituted an inadvertant experiment. In 1935, the spring was being used by a local sheep population and was clean; apparently there were no burros. In 1938, the spring was trampled and muddied by burros, and no sheep could be found in the vicinity. By 1957, wild burros had been trapped out of the area, and it once again supported a thriving sheep population. Jones et al. (1957) and Buechner (1960) have also discussed cases where burros appear to have restricted bighorn range or displaced them.

In sum, much if not most of these results are circumstantial, or are derived from research that can be criticized on methodological or conceptual ground. But so many investigators over a four-decade period have converged on the same view that the results and their conclusions cannot be dismissed lightly. Some Committee members, therefore, consider it a strong probability that burros have been detrimental to desert bighorn populations over much of the latter's range. In their view, where such detrimental effects risk the survival of bighorn populations, they must be considered in excess on the basis of the irreversibility criterion set forth above, a view shared by several recent authors (McCutchen, 1981; Seegmiller and Ohmart, 1981; Hansen, 1982). However, the Committee is not unanimous in these views. The reader is referred to the Phase I Report for a better indication of the ambiguities in the available literature concerning the burro-bighorn issue.

Because of the continuing concern over this issue, there is a strong need for conclusive experimental research to answer once and for all the question of whether burros are competitors with desert bighorns. Since the definitive criterion of competition is a population effect, and burros compete with sheep only where they reduce the latter's population, this effect must be investigated by reducing or removing burros in some areas, not in others, and observing sheep-population responses. If vegetation is the resource under competition, such research would be strengthened by vegetation analyses that showed the existence or lack of a plant response to burro removal.

With research funds tight as this is written, and desert bighorns having little or no game importance, it is highly problematical that the needed funds for such research, carefully designed, will be available in the foreseeable future. However, de facto experiments are underway. The BLM in Arizona is systematically removing burros from areas where there is a potential sheep conflict. The Park Service is also removing burros from national parks and monuments pursuant to their policy of removing exotics, and the Department of Defense is removing them from the China Lake Naval Weapons Center for safety reasons. If these agencies and/or the state departments of fish and game would, over the next few years (perhaps 6 to 10), systematically census bighorns in areas where wild burros were and were not removed, it could supply more information toward resolving the problem.

How Many Horses/Burros Are There in the West?

Census Methodology

Census methodology was discussed in some detail in the Phase I Report. Since then, a census research project has been carried out during Phase II by University of Minnesota investigators (Siniff et al., 1982), and various other kinds of information have become available. The final report on the census research project suggests a number of improvements in census methodology. Here we will only attempt to update some of the Phase I material, refer briefly to the Phase II research, and suggest some further research needs.

It seems clear that most wild horse and burro censuses will need to depend on aerial counts of some kinds. The very large areas, topography, and access problems generally combine to make aerial counts the only cost-effective methodology. One of the major drawbacks to the aerial counts used in the past is that some horses were undoubtedly not counted (missed by the observers). While many BLM employees have considerable confidence in the accuracy of the censuses, the Phase II research has shown that they may miss anywhere from 7 percent of the horses in very open areas to as many as 60 percent of the ones present in areas of dissected topography and tree cover, even when carried out by experienced and careful observers.

These discrepancies were detected in two ways by the researchers. One was by marking (with tags or paint-filled capsules fired from a helicopter) a sample of animals in Nevada populations. The populations were then surveyed from the air, including a count of marked animals. The proportion of the entire population not seen could be judged from the proportion of marked animals not seen, or on the basis of separate population estimates made with capture-recapture procedures.

In this way, it was concluded that fixed-wing aircraft census in the Beatys Butte Herd Management Area in Oregon and the Chain Lakes Herd Area in Wyoming, both open areas with moderate terrain, was finding about 93 percent of the wild horses present. But in the more dissected Pah Rah Mustang Area of Nevada, helicopter census was missing about 35 percent of the animals. In the wooded Pine Nut Mountains of Nevada, helicopter census was missing 52 percent, and fixed-wing census was missing up to 60 percent.

We have no data on the proportion of horse range in the western United States that has relatively open terrain promoting near-complete counts, and the proportion that is wooded and mountainous and likely to be significantly undercounted. Hence we have no way of knowing whether the West-wide estimates of horse numbers are closer to 93 percent accurate or 48 percent, and we caution against the use of any blanket correction factor that attempts to expand census figures to allow for unseen animals.

Capturing and tagging wild horses or burros is expensive and time-consuming and involves some further complications, as does paint-marking. Both methods were tested in the research program. Horses were tagged after being rounded up, which means that many members of a given band were marked. Since the bands largely stay together, this was not a very efficient approach. Paint-marking from a helicopter allows more flexibility, but there are uncertainties about persistence of the marks (and some fresh paint spots were transferred to other horses by bodily contacts, thus giving a false mark). These problems were taken into account in forming the above conclusions about completeness of the censuses.

The second way of detecting incomplete counts utilizes the periodic removals of surplus horses and burros made by the management agencies. If aerial counts are made both before and after the removals, then the reduction in abundance caused by the removal should be reflected in the second count. Some simple algebra then permits estimating the proportion of the horses present that are actually seen. An important assumption is that this proportion does not change from the preremoval aerial count to the postremoval count. This means that these counts should be taken immediately before and immediately after the removals take place and should be made by the same observers under comparable conditions. The basic methodology and some examples appear in Eberhardt (1982).

Perhaps the chief advantage of this method is that it uses data normally gathered in management, i.e., a preliminary count and the removal data. In actual management practice, a postremoval count is not usually made, but is needed for the census application. So far, one such experiment has been conducted in the census research on an Oregon area. In this case, five preremoval and five postremoval counts were made. A number of further tests are needed, along with some further work on the problems of estimation (the Oregon experiment showed that the estimation scheme needs improvement). Very likely this method will be best suited to BLM needs, but a good deal of testing and checking is needed. Also, the method is not effective unless a substantial proportion of the animals present are removed (roughly 30 percent or more).

Other aspects of the census problem that require more research include the questions of censusing large areas with definite boundaries. So far most of the research and much of the other experience has been on areas that are either fenced or otherwise subdivided into manageable units. A little work with sampling and subsampling has been done in the census research project, but much more is needed. Also, it will be especially important that the research results be subjected to a process of field-testing and demonstration before they become a part of routine BLM operations. A census manual was required in the Minnesota contract, and the Minnesota investigators are working on such a manual. But with only 1 year's research, it must be considered preliminary. It will require considerably more research and testing to become a refined and generally usable document.

The Phase II investigators participated in one BLM burro census in Arizona in which paint-marking was used. Some data are available from other attempts at burro censusing. In one Arizona study by Ohmart et al. (1978), the investigators saw only about a third of marked animals during 7 hours (h) of helicopter census. We suspect that marking will be required for virtually all burro censuses, due to the difficulty of spotting these animals, but the removal method has not yet been tested on this species.

The implications of all of this work are that the standard aerial censuses now being carried out must be viewed with some reserve. And in many areas, if accurate censuses are desired, it will be necessary to use capture-recapture or removal procedures.

Management Implications

There are several additional management implications of the Phase II research findings on census that bear mention here. The first relates to the accuracy of published figures on horse and burro numbers in western United States. In their periodic Wild Horse and Burro Report, BLM publishes estimated numbers of wild horses and burros on the public lands. These numbers were 52,400 and 12,200, respectively in 1980; 44,930 and 11,870 in 1981.

While the Phase II census project had nowhere near the time and resources to make independent estimates of West-wide populations, it was able to develop some idea of the completeness of the BLM counts, as discussed above. On the basis of this research, it appears that the above population estimates of horse numbers are conservative.

It is our understanding that Bureau personnel are well aware of the incompleteness of wild burro censuses, based on earlier research described in the Phase I Report, and appropriately correct the census values upward. Hence the burro figures may approximate reality. But we have found a general tendency in the Bureau to assume that wild horse censuses are accurate, and little or no awareness of their conservatism.

Significance of the disparity between current horse numbers and the censuses is not clear to us at this time. One obvious implication is that there are more wild horses on western public lands than is generally assumed to be the case. And hence, more range forage is being consumed by them than is generally believed.

This statement is not made in any way to suggest that the situation is desirable or undesirable. Forage use by wild equids remains a small fraction of the total forage use by domestic animals on western public ranges, regardless of whether the actual number of equids is in accord with the censuses or somewhat higher.

Comparison of feral equid numbers and forage demand with those of domestic animals on public range may provide some perspective on the matter. BLM Public Land Statistics/1980 (USDI-BLM, 1981) and Forest Service Annual Grazing Statistical Report for the same year (USDA Forest Service, 1981) provide combined estimates of 67,296 wild horses and burros in 1980. During this same year, these reports list 3,209,050 cattle, domestic horses, sheep, and goats authorized for use on BLM land and 3,369,188 on the national forest system.

Converted to forage demand, a better basis for comparison, the domestic animals were allocated 18,631,934 AUMs of authorized use. Forest Service converts its wild equid numbers to 20,200 AUMs of forage demand. If the 64,545 equids on BLM lands are assigned (by us) 12 AUMs each, the total for feral equids on both kinds of public lands is 794,740 AUMs. Hence the ratio of forage use by livestock to that of feral equids is about 23:1. Since the number of domestic animals and AUMs on BLM and Forest Service land are similar, but most of the feral equids are on BLM lands, this ratio is about halved for BLM lands. Depending on how conservative the horse populations are, the ratios are somewhat lower yet on BLM lands.

It may also be of interest to point out that the public lands carry sizable populations of big game animals. The above BLM statistical report cites a total of 1,559,887 on BLM lands of all states except Alaska. Since most of these are deer and pronghorn antelope which, by virtue of their smaller size, receive only one-fifth to one-sixth the AU ratings of wild horses, the AUM comparison is quite different. The Forest Service report does not cite the numbers of big game animals on national forests.

Some readers may argue that these total, West-wide figures do not make for meaningful comparisons because decisions on how much forage to allocate to livestock, feral equids, and wildlife are made on a locale-by-locale basis rather than on their contributions to regional numbers. But for some years de facto regional goals have emerged periodically in various forms, and approach policy status. Stockmen and BLM officials have been quoted as advocating a reduction of equid numbers to the 1971 levels existing at the time the Wild and Free-Roaming Horse and Burro Act was passed (Ryden, 1978:295; Thomas, 1979:139). The magnitude of those numbers has varied considerably between different reports. In the latter 1960s, the BLM distributed an undated document entitled "Fact Sheet: Wild Horses" that reported horse numbers at 17,300. During the April 1971 hearings of the Senate Subcommittee on Public Lands (Committee on Interior and Insular Affairs), Assistant Secretary of the Interior Harrison Loesch reported 17,000 "nonpermitted" horses of which 7,500 were branded and 9,500 were unclaimed. In those same hearings, Hope Ryden pointed out the array of estimates cited by BLM that ranged from 10,000 to 25,000.

In January 1982 BLM included a sheet entitled "Bureau of Land Management Wild Horse and Burro Population Estimates" in a packet of material submitted to the Senate Committee on Energy and Natural Resources. The sheet included a table with columns for "Estimated Current Populations," one for "Estimated Management Levels" that totaled 21,215 horses, and one for "Estimated Removals" as the difference between the first two and totaling 23,715. Similar totals for burros were an "Estimated Management Level" of 3,810 and "Estimated Removals" of 8,060.

Nevertheless, it is fair also to point out that local cattle-horse ratios vary over a range of values quite different from tne gross, regional ones. Thus, on BLM lands in Nevada, the Bureau's records show the overall ratio of cattle to horses is 11:1 on an animal number basis, 4.8:1 on an AUM basis. Within the state, this varies from 66:1 (number) or 23:1 (AUMs) on the Elko BLM District (which has 38 percent of state cattle numbers and 6 percent of horses), to 2.7:1 and 2:1 on the Las Vegas District (which has 5 percent of the state's cattle and 21 percent of wild horses).

A second implication of the conservative horse population estimates bears on BLM's herd management plans. As discussed above, some consideration has been given to reducing horse populations to the level prevailing when the Wild and Free-Roaming Horse and Burro Act was passed. One value that has been cited at various times is roughly 17,000, a value derived only the second year of BLM's formal census efforts.

The census research now suggests that the 17,000 estimate was probably conservative. Even if herds were censused with the same skill and effort in 1971 as today, the 17,000 figure would have to be suspected of being conservative because of the Phase II census research findings. Since the 1971 census was conducted largely with fixed-wing aircraft, and only in the second year of census, one has to suspect that this led further to underestimation. The 17,000 figure is undoubtedly low to an unknown, but perhaps substantial, degree.

One final aspect of census bears mention. It does not appear to the Committee that annual censuses are necessary. That necessity would depend on the management objective for which the censuses are conducted, and perhaps there are administrative or public-information reasons with which we are not familiar. But if the purpose is to maintain annual appraisals of herd size in order to know when to carry out herd reduction and to make annual forage allocations, this could in our judgment be done with less frequent census.

Equid populations are demographically conservative by comparison with most species in the animal kingdom. Regardless of whether their herds increase at the often-claimed 16 to 20 percent rates, or at rates lower than 10 percent as speculatively calculated in the Phase 1 Report analyses, it is clear that annual increase rates generally fall somewhere in the limited range of 3 to 20 percent per year.

It seems likely that the Bureau and Forest Service will set as management objectives the maintenance of individual populations within a prescribed range of densities. It seems unlikely that herd management plans will be so rigid as to require that herds be reduced each year in order to maintain them at precisely the same levels annually. Rather, the likely scenario (and this appears to be the practice) would appear to be one of reducing populations to some prescribed level in a given year, allowing them gradually to increase for a few years, and then reducing them again to the earlier numbers.

The point here is simply that it does not appear necessary to census such populations each year to follow the pattern of recovery. If a herd is reduced in a given year and its numbers known, then a district manager can be confident that the herd will increase in following years by somewhere between 3 and 20 percent. This range does introduce a measure of uncertainty, but a census each second or third year would dispel that uncertainty and sharpen the manager's knowledge of the herd's size. In the process, one census every 2 or 3 years should allow considerable savings in funds over the present pattern of annual censuses.

Considerations on Herd Reduction

Given a policy of maintaining wild equid populations on BLM and Forest Service lands in a geographically flexible, multiple-use mode, as appears mandated by the Public Rangelands Improvement Act--and given the probability that their populations will not self-limit below densities that would be considered excess by the intent of the Act and our criteria discussed above--it seems clear that continuing effort will be exerted to limit most equid populations by human intervention.

The round-up procedures are now well established and could continue to be an important herd-reduction method. However, if the adoption demand for wild horses and burros were to decline, and no other policy allowed for the disposal of excess animals, the feasibility of round-ups might change, since to continue them would accumulate a large number of unwanted animals. Hence, some other mode of population limitation might be found useful as an adjunct to, if not an alternative for, round-ups. Two forms of chemosterilization have been proposed and bear some discussion here. In addition, limited information on several aspects of round-ups has come to our attention that seem worth mentioning.

Round-Ups

<u>Purposeful and Inadvertent Manipulation of Population Composition</u> It is periodically suggested that herd reductions focus on the disproportionate removal of animals in the prime breeding ages, particularly the females. This practice would skew the age composition of the remaining animals toward the younger, prebreeding, and less fecund age classes and toward a higher proportion of males, with the result that herd growth would be slowed. In particular, Hope Ryden (personal communication) has advocated selective removal of

mares in the 7- to 12-year age classes, those of maximum fertility (see Table 2.3 of Phase I Report).

Ron Hall (personal communication), a former BLM employee, has suggested to us that the standard horse round-up techniques tend to work in this direction already. The round-ups attempt to bring in whole bands of animals as encountered in the field by the helicopter drives. The family bands comprised of mares, foals, yearlings, a few younger stallions, and a dominant stallion tend to be cohesive and remain intact as they are driven toward traps during the drives. But the bachelor stud bands do not hold together as well, and these stallions may disperse during the drives. Hence, according to Hall, a higher proportion of the mares and young animals are caught than of the stallions. This presumably would leave a population residue with a higher proportion of males.

In the Phase I Report, we analyzed records in the BLM files to determine the sex and age composition of 8,764 wild horses taken during round-ups (Table 2.7). While the proportion of males among the foals and yearlings was 51 percent, that percentage dropped to 42.8 among the 2-year-olds and older animals. While we speculated in the Phase I Report that this might be due to differential mortality of males, as commonly occurs in mammals, and correctly reflects the age composition of wild horse populations, it could as well result from Hall's selective round-up effect. The fact that this age-specific differential in sex ratios occurs in studied populations in which the sex and age of all animals is determined (Phase I Report, Table 2.10) tends to support our Phase I inference rather than Hall's. Like so many of the equid questions we have addressed, this one can only be resolved with field research.

However, before any commitment is made to examining the effects of round-ups on herd sex ratios, or to engaging in selective herd reduction, some preliminary indications could be gained through computer simulation of the effectiveness of such practices. Conley (1979), Wolfe (1980), Eberhardt et al. (1982), and this Committee in the Phase I Report have calculated rates of herd increase, given various assumptions about reproductive and survival rates and sex and age composition. The same could be done to predict the effect on herd increase rates if different fractions of mares were removed, or if certain age classes of the populations were selectively culled.

The Committee has not had the time or resources to conduct such a study, but one small test was carried out for the purpose of this report. In one simulation of a hypothetical herd that increased at 10 percent per year, removing half of the mares in the 7- to 14-year classes in a single year reduced the increase rate in the following year to 6 percent. In the next year the rate increased to 7 percent, and then to 8 in the year after that.

The net result of this procedure on an actual population would be a material reduction in the increase rate in the year following mare removal. But in each subsequent year the younger age classes would advance a year and enter the highly fecund 7- to 14-year classes. Meanwhile, the age classes originally halved would advance into the older and less fecund ages and decline in numbers due to mortality.

The effect would be gradually to return to the original increase rate, and nence the effects of the removal would be short lived. Furthermore, the difference between a herd growing for a few years at rates increasing from 6 to 10 percent and one growing over the same period at 10 percent per annum turns out to be slight, the former lagging behind the latter in numbers by only 1 year.

Of course, reducing the number of 7- to 14-year-old mares by half is only one of many possible manipulations. Another would be to remove all of the mares in these year classes, plus others. This would obviously reduce the increase rate further, but now the numbers removed begin to affect population, and perhaps social structure materially. Data on the 8,764 horses rounded up by BLM, and discussed above, indicated that females in the 7 to 14 age classes make up about one-fourth the mares in western horse populations (Phase I Report, Table 2.7).

Furthermore, because the 7- to 14-year-old mares make up a minor fraction of the entire population--12 percent of the animals of both sexes analyzed in Table 2.7 of the Phase I Report--their one-time removal would not keep up with annual herd increases, and could in practice work against the goal of reducing the round-up burden. For example, BLM's current herd-reduction practice is to remove a sizeable fraction of a population considered by them to have risen to excess levels. Such a herd might not be rounded up again for, say, 4 years. In this time, a herd increasing at 10 percent per annum would increase by nearly half and would need to be cut back by a third to return it to the level of 4 years previous.

But the 7- to 14-year-old mares would make up only a small fraction--no more than 12 percent--of the population. Consequently other sex and/or age classes would need to be removed. If something approaching the entire third were taken from the mare sex class, this would seriously distort herd composition, since they make up only half of the herds. But if males were removed, this would work against the goal of reducing increase rates, because any reduction in the male component of the herds would tend to raise the net, total-herd increase rates.

Selecting certain sex-age classes for removal and returning the remainder of captured animals to the range would also appear to pose some logistic problems. Since round-ups may gather horses over considerable distance, returning the ones not held out to their original locales would necessitate a "reverse round-up" and considerable increase in cost.

In conclusion, the idea of sex-discriminate removal to reduce nerd increase rates has some potential in theory. But closer inspection indicates some problems with the approach that are not intuitively obvious. It should, however, be given more detailed analysis than the cursory one posed here.

Biological Effects on Herds

1. Foal orphaning. Some evidence has come to our attention regarding the effects of round-ups on herds that may not be generally known.

One is the possibility of foal orphaning. In the above-cited BLM data on sex-age composition of 8,764 rounded-up horses summarized in the Phase I Report, the number of foals captured was below what would be expected of a natural, population age distribution. We surmised in that report that the round-ups were missing or leaving behind a portion of the foals. Elsewhere in the report (Table 2.16), we similarly analyzed the age composition of 666 burros rounded-up in Arizona. Here again, the age distribution suggested a deficiency of foals.

Since then, Seal and Plotka (1982) examined the reproductive status of 86 mares rounded-up in the Challis region of Idaho in October 1980. They found 62 of the mares lactating, but there were only 56 foals brought in by the round-up.

Whether foals orphaned by round-ups would fail to survive is not known. William Swan (personal communication) reports that domestic foals born in the summer are self-sufficient by September. Presumably feral animals would be no less vigorous.

2. Abortion. Another apparent effect of round-ups is abortion by rounded-up mares. Lee Boyd sent questionnaires in 1980 to people who had adopted 394 mares from the Rock Springs, Wyoming, corrals in 1977 and 1978 (Boyd, 1980). The purpose was to obtain follow-up information on the history of the adopted animals. Boyd found that a high percentage--perhaps approaching half--of the pregnant mares rounded up in the fall aborted their fetuses, presumably from the stress of the round-ups, penning, transportation, and adjustment to the new, adopted environment. Boyd's evidence (personal communication) further indicated mares rounded up in late winter or spring, when they were near term, were considerably less likely to abort. Hence, she advocated further investigation of the possibility that spring roundups might be preferable to fall.

Chemosterilization

A frequently suggested alternative or adjunct to round-ups is some form of sterilization to reduce the reproductive and growth rates of equid herds. In fact, this approach would not completely remove the need for round-ups since it would not be a primary means of cutting down an excessively large herd in the first place, but could prevent or slow increase in a herd that had been reduced to, or originally existed at, a desirable level. Both stud and mare sterilization have been proposed, and 1-year and longer sterility have been advocated.

Recent research and available information permit brief comment here on sterilization by chemical means.

Immobilization Although some research has been done recently on administering chemosterilants without immobilizing the target animals, as will be discussed below, some require administration to animals that have been immobilized. Seal et al. (1982) have experimented with chemical immobilization of horses in the course of the Phase II census research. The findings of that work are summarized here, along with a review of previous work on chemically immobilizing equids.

There are no published reports on the use of chemical immobilization for capture of wild horses in North America. Burros were captured in Death Valley with etorphine (Blake et al., 1981) but details of immobilization were not presented. A report to the BLM (Moore, 1979) described the use of etorphine in combination with tranquilizers to capture 34 horses. There were 8 deaths. No drug dosage or physiological data were included. Another report (Borchard, 1980) describes the use of succinylcholine from helicopters for the capture of 23 stallions and 1 mare in Idaho. There were 9 deaths. This investigator tested etorphine in 6 animals in corral trials and rejected its use because of tremors in the animals after immobilization and expense of the drugs. The report includes data on serum enzymes and cortisol in domestic horses immobilized with succinylcholine. High death rates have been common with succinylcholine in horses and other wild species (Tavernor, 1960; Jones, 1972) and we do not consider it advisable to use this drug.

Etorphine in combination with various tranquilizers is commonly used for the immobilization of equids in zoos (Jones, 1972; Seal et al., 1978; Wright, 1982) and in the wild (Harthoorn, 1976). Etorphine, in combination with acepromazine, has been used in thousands of domestic horses particularly in the United Kingdom (Jenkins et al., 1972; Dobbs and Long, 1972; Evans, 1974). Tranquilizers are used in combination with etorphine to reduce the intensity and duration of the excitement phase during immobilization and to provide better relaxation in the anesthetized animal. Acepromazine and xylazine are most commonly used for this purpose in equids (Kerr et al., 1972; Hillidge and Lees, 1977; Muir et al., 1979). Fatalities have been recorded for xylazine and etorphine in horses, but the incidence appears to be less than 0.1 percent (Hillidge and Lees, 1974; Fuentes, 1978).

Seal et al. (1982) administered combinations of etorphine and xylazine in dosages to test their value as immobilizing agents on 16 recently captured wild mares in the Palomino Corrals near Reno. The results of these trials led to the development of a standard combination of 5.5 milligrams (mg) of etorphine, 150 mg of xylazine, and 3 mg of atropine in a 7-milliliter (ml) dart syringe for field capture. This combination was used, with a dart gun from helicopters, to capture 87 wild horses from about 80 bands. Five animals died at the time of capture, and the remains of 3 were found near the site of capture 4 months later. Approximately 48 minutes of helicopter time were required per horse captured. The cost per animal captured was $159 for helicopter time and $66.7 for drugs and darts.

The investigators found that the induction time and relaxation effects of xylazine were dependent upon dose. It would be useful to do further corral studies to develop a combination of dosages that would further reduce the induction time. This would reduce the losses of animals in difficult terrain and helicopter time.

The calculated material and helicopter-time costs for capturing the animals could be reduced by perhaps 30 percent with experience. This cost figure did not include the time and other expenses of the biologists. The method of capture appears to have particular value for selective capture of animals from individual bands on site. The investigators repeatedly observed that the mares rejoined their bands shortly after recovery. An experienced crew could capture and process 8 to 10 animals in a working day.

Stud Sterilization Kirkpatrick et al. (1981) have conducted research on stud sterilization by administering the steroid hormone testosterone propionate to dominant band stallions. The dosages were delivered in microcapsules with a dart gun from helicopters. Seven band stallions were dosed in 1980 in the Challis Wild Horse Range of Idaho. Their behavior and band reproductive performance, along with those in eight control bands, were observed in 1981. The basic premises of the research were that all breeding is carried out by the dominant band stallion and that band integrity is so tight that mares do not move to other bands where the stallions had not been given the antifertility drug. If the harem stallion's fertility could be reduced without loss of libido, sexual behavior, and social dominance, the mares mounted by him would not be fertilized, and foaling in the band would be reduced or prevented.

Kirkpatrick's results in this one experiment were positive. The number of foals born in 1981 in the seven experimental bands, with their total of 30 mature mares, was 2. The number of foals born in the eight control bands with 35 mature mares was 13. The frequency of sexual and dominance displays by the harem stallions in the experimental bands was not statistically different from that in the controls.

Despite the apparent success of this experiment, there has been considerable skepticism among a number of individuals over the potential of stud sterilization. As mentioned above, its success requires both that the dominant harem stallion do all the breeding and that there is no exchange of mares between bands in which the stallion has and has not been treated.

While Kirkpatrick's observations found these conditions to hold in the Idaho bands he observed, no other observers have found it. Band exchange has been reported by Miller (1980) and others in Wyoming horses, by Martin Vavra (personal communication) and coworkers in Oregon horses, and by Nelson (1980) in New Mexico horses. And it has been observed by Hope Ryden (personal communication) in the Pryor Mountain horses of Montana, despite Kirkpatrick's observation that it does not occur in this area where he conducted earlier research.

Furthermore, both Ryden and Nelson observed breeding by subdominant stallions. And one quote from Miller (1979) seems especially appropos here:

> We have since found that more than one male is breeding in most of these multimale bands. In fact, I have seen one female bred by

three different males from her band within five minutes without any apparent aggression between males. We know females are being bred from other bands, and by bachelor males. Except in the usually relatively small single male bands, it seems to be unusual for a female to be bred by only one male.

Nelson (1980) and Ryden (personal communication) have further objected to sterilizing harem stallions on the grounds that it blocks gene flow from the genetically superior animals.

Kirkpatrick also advocates dosages that only block fertility in stallions for a single year. This would require that they be dosed annually to prevent herd growth over any period of years, thereby increasing the cost.

The approach, even if behaviorally successful, would not appear to be applicable to the West-wide problem of wild equid population control. In order to be applied to a major fraction of western horses, it would be necessary to observe individual bands for a period of time to determine which animals were the dominant stallions. Then these animals would need to be pursued and dosed individually by helicopter. To carry out this protocol, especially if annually, with a major fraction of the 40 to 50,000 horses in western United States would appear to be prohibitively costly in terms of time, manpower, and flight costs.

On the whole, there appear to be too many problems and uncertainties with the method as a general technique for West-wide population control. It might have potential for individual, intensively managed areas.

Mare Sterilization The Phase I Report suggested that fertility control of mares was feasible but that further research was needed to test the efficacy of alternative methods. This conclusion remains unchanged.

Fertility control of mares has been suggested as a means of controlling population growth that might (1) reduce management costs by limiting the rate of increase, (2) allow each animal at some future date to serve as a parent and make a genetic contribution to the next generation, (3) minimally disrupt the social structure of the band and herd, and (4) possibly be reversible if increased production became desirable.

Recent data on wild horse pregnancy rates indicate that the age of first pregnancies can occur as early as 1 year, although numerous field studies involving several hundred mares have shown, with the exception of a single animal, first production of foals at 3 years (Phase I Report, pp. 33-34). Mares also can become pregnant while lactating and thus breed successfully in the foal heat or shortly thereafter. Factors limiting successful breeding by 2-year-olds and by lactating mares presumably include the nutritional status of the mare and range condition. Maintenance of satisfactory range quality is one of the objectives of fertility control in wild horses. However, early and yearly reproduction may be enhanced on ranges in satisfactory condition and more extensive fertility control may be required.

Genetic, behavioral, and reproductive considerations suggest boundary conditions for the application of reversible fertility control in wild horses. First, the method might be applied depending on the desired results from demographic analysis to all mares (foals and older) captured in a given area. Second, fertility control would need to be 95 percent effective in treated animals. Third, the treatment would need to be effective for a defined period of time--perhaps 3 to 6 years--and be spontaneously reversible. Fourth, it would need to produce minimal physical morbidity or disruptive behavioral effects. Finally, application of the treatment by local personnel to horses captured on site and released would appear desirable. This would reduce costs of application.

This approach to fertility control appears to preclude application of permanent techniques such as surgical or chemical sterilization, immunization against endogenous gonadotrophins, and the use of intrauterine devices that are difficult to fit and install and that require later removal.

Endocrine suppression of fertility is the other currently available methodology. Target organs for action of endocrine suppression of reproduction include the hypothalamus, pituitary, ovary, fallopian tubes, and uterus. The duration of action of an agent's single dose may range from 1 day to a year. The modes of delivery range from daily intake or monthly injections to implants lasting years. The useable delivery modes appear restricted to the minimum possible for horses. Thus, daily intake of a treated feed would appear impossible to deliver effectively to wild and free-ranging horses. Monthly injections or even seasonal injections also would be of limited application. Such approaches would have to contend with the return to estrus, which would occur with missed treatments and the costs of continuing delivery.

Long-term treatments, effective for more than 1 year, but reversible, are limited to injectable or implantable preparations. Both techniques act by sustained continuous delivery of a compound at an effective dose rate. Injectable, microsuspensions appear to be effective for 6 to 18 months at a maximum. Implants effective for 1 to 3 years have been tested. It may be possible to extend these for longer periods. There have not been suitable studies done in horses to establish effective compounds and doses to allow application of this technique. Such studies need to be carried out first on domestic (or captured) horses if this approach is to be seriously considered.

SOCIOPOLITICAL AND ECONOMIC CONSIDERATIONS

Introduction

Sociopolitical and economic factors, as well as biophysical factors, will control the determination of what constitutes excess horse and burro numbers and appropriate control strategies. In the absence of new data or studies since the Phase I Report, the Committee chooses to comment on factors that ought to be weighed in the decision-making process. There have, in addition, been a number of important changes, in attitude as well as in policy, which were detectable as nascent trends during Phase I of our inquiry and which now appear to us to be important aspects of the socioeconomic, political, and legal climate of wild horse and burro management.

Changed Conditions

In the Phase I Report, several sociopolitical and economic issues were identified, research projects proposed, and several recommended for funding, although none were in fact funded. Therefore, due to budgetary and other constraints, this report does not address some of the topics that were envisioned for inclusion when the Phase I Report was prepared.

Certain conditions, important to any consideration of wild horse and burro management, have changed since the Phase I Report was completed. Public concern about wild horse and burro management appears to have diminished, and interest-group alliances and attitudes have become more clearly focused. Traditional environmental organizations such as the Sierra Club and Audubon Society, and wildlife organizations like the National Wildlife Federation, support the removal of wild horses and burros from public lands. Wild horse and burro advocacy organizations do not present a united front, some groups favoring natural control while others support adoption policies.

These shifting alliances and attitudes may explain new legal developments. In several recent cases, the courts have ordered the BLM to remove wild horses and burros from certain public lands, especially unfenced checkerboard lands. Moreover, in an era of reduced government budgets and program cutbacks, the public and public managers have demanded more cost-effective management methods. For example, the BLM has proposed a $200 adoption fee for wild horses, at least in part to recover the cost of carrying out the wild horse and burro management program. Congress is presently considering legislation that would permit commercial sale of excess horses (S.2183, H.R.5825). This cost consciousness is expected to continue.

Partially related to the demand for reduced cost management, major changes are being considered in both the BLM land-use planning system and the grazing management program. These evolving programs are designed to streamline the planning process, in part by gathering resource inventory and vegetation survey data only in areas where they are necessary for land-use planning. The effect of this change on forage allocation decisions is, as yet, unclear.

All of these changed and changing conditions will influence decision making about wild horse and burro management. Yet to date it is impossible to predict precisely what the influences will be.

Sociopolitical and Economic Factors To Be Weighed in Choosing Management Options

The Committee and Congress have identified two major management issues facing the BLM and the Forest Service: (1) determining what constitutes "excess" animals, and (2) determining how herd size can be reduced if excess animals exist. In addition to the biological factors that must be considered in making such determinations, certain sociopolitical and economic factors come into play. These are much the same for both "excess" determinations and herd-reduction decisions.

Social Factors

It continues to be obvious that the major motivation behind the wild horse and burro protection program and a primary criterion of management success is public opinion. Attitudes and values that influence and direct public priorities regarding the size, distribution, and condition of horse herds, as well as their accessibility to public viewing and study, must be an important factor in the determination of what constitutes excess numbers of animals in any area. The choice of control strategies, when and if they become necessary, must also be responsive to public attitudes and preferences and cannot be based solely on biological or cost considerations. The issue of excess numbers is conceptually severable from the strategies question. However, an otherwise satisfactory population level may be controversial or unacceptable if the strategy for achieving it is not appropriately responsive to public attitudes and values.

Limited data on public attitudes toward horse and burro management suggest that three major factors be considered in designing socially acceptable equid removal programs: humaneness of the control procedure, specificity of its impact, and cost-effectiveness. The public is especially concerned about the presumed pain and cruelty of wild horse and burro removals. Criteria for establishing tolerable levels of pain should be considered--e.g., length of time until consciousness is lost, degree of pain evidenced, and percentage of harmed and wounded among the animals removed. Additionally, removal should minimize stress or other risks inflicted on those animals not identified for control. Finally, reasonable costs appear to be a necessary component of any successful management program.

Public perception of excess animals depends considerably on priority uses of the public lands. Serious consideration should be given to the desirability of emphasizing recreational and nonconsumptive enjoyment of horses and burros in areas characterized by frequent recreational use. Conversely, prime agricultural and livestock lands, relatively unimportant for recreational reasons, could emphasize commodity considerations. Finally, limited survey data suggest that both livestock producers and the general public prefer that wildlife be given priority consideration over livestock and wild equids in situations where competitive interaction is significantly present (Kellert, 1981).

In making these determinations through the land-use planning process, the Bureau must be aware of the geographic distribution of the wild horse and burro constituency. Although there are strong biophysical, managerial, and political reasons for local-level resource inventory, analysis, and decision making, such an orientation may severely and uniquely disadvantage horse and burro advocacy organizations.

Personnel attitudes must also be accounted for in the decision-making process. We have, in the process of our inquiries, encountered a broad range of attitudes toward the wild horse and burro management program among BLM employees. We are not, however, confident that attitudes are evenly distributed throughout the Bureau. Indeed, we have met many employees who are sincerely committed to wild horse and burro management in the spirit of the 1971 Act. But our experience also suggests that the Bureau must be sensitive to considerable pockets of resistance to the program within its own ranks and to the pressures which many district and area personnel feel to depict range, population, and other conditions in an antihorse and antiburro context.

Political Factors

<u>Data</u> As discussed in earlier sections of this report, sufficient research has not been done on equid biology to provide a firm consensus on data regarding equid demography, interspecific relationships, and other critical variables. Reliable data on range condition and trend are also lacking in many instances. Under these circumstances, whatever decision land managers make in allocating forage resources among wild horses and burros, wildlife, and domestic livestock will be disputed on the basis that insufficient data are available to support the decision. Public controversy and debate are inevitable given these data deficiencies.

Land-Use Planning System Whatever land-use planning system is utilized by the BLM, it must confront the difficulty of simultaneously meeting single-purpose and multiple-use management mandates. The Federal Land Policy and Management Act (FLPMA) directs the BLM to manage public lands for a wide variety of uses and does not set priorities among them. The BLM planning system is designed in accordance with FLPMA to achieve this goal, attempting to identify an optimal mix of uses based upon resource values within the planning unit. Other statutes, such as the Wild and Free-Roaming Horse and Burro Act, focus on a single resource and give little direction on how that resource should be balanced with other resource values. Due to the tension between the single- and multiple-use statutes, allocation of forage resources in the planning process will inevitably involve controversial trade-offs.

Economic Factors

The Phase I literature review led to the conclusion that economic studies of local impact by excess animals, of reductions, or of changed allocations could be accomplished with the application of existing economic methodologies. Research on these topics would importantly quantify alternative management scenarios on local/regional economics.

In the current public management setting, options are affected by budget reductions that will affect funding for many kinds of programs, including those for wild and free-roaming horses and burros; these give heightened attention to cost-effectiveness. The economic outcome may manifest itself in several forms--e.g., reduced budgetary support, increased fee levels, reduced adoption numbers. Management and regulatory cost data for horse and burro programs within the Bureau and the Forest Service are unfortunately not available in the form that will ensure the clear defense of public-sector decisions on cost-effective management options.

Public decisions directly impact the private sector through excess animals, herd reduction, and other allocative decisions. Changing political decisions bear economic costs as well. Uncertainty about possible public management decisions incurs costs on private decision makers, skewing decisions toward short-term strategies, and reducing the attractiveness of long-term investment and management decisions by the private sector. For example, long-term investments in range improvements are not as likely to occur under uncertain and indefinite property or leasehold privileges. Private decision makers must subjectively assess uncertainty about programs, the manner of their implementation, and their permanence as they consider possible management and conservation decisions. Local and regional economies will also be differentially affected by management policies that attempt to deal with allocative decisions brought about by excess horse and burro numbers. These indirect costs are likely to be of more consequence to communities and regions largely dependent on the range-livestock industry, as opposed to areas with more broadly diversified economic bases.

In summary, excess animal and herd reduction decisions cannot disregard the considerable impact of sociopolitical and economic factors. While they may be expressed in noncommensurate values, the marginal benefits and costs of alternative management strategies must be considered nevertheless. Efforts to measure and otherwise obtain widely based information about sound political and economic changes will enhance decision making, as well as the ability to offer defense of public-sector decisions to members of the public, including those in various concerned interest groups.

LONG-TERM RESEARCH NEEDS

It is obvious by now that the Committee holds the basic conviction that sound and effective management programs require a firm base of scientific information. Without such a base, management decisions tend to be made on tradition, best guesses, and the pressures and opinions of different interest groups, which are seldom objective. And the misconceptions or uncertainties discussed above about niche, rates of population increase, accuracy of the censuses, degree of food and habitat partitioning between feral equids and other species, economics, and public attitudes bear witness to the problems with which decision making in that climate is beset. In the long run, management programs based on a sound information base will be in the best interests of the range resource, the various classes of animals using that resource, and the American public.

We prescribed a lengthy list of research projects in the Phase I Report, including a rationale, objectives statement, and brief resume of suggested methodology for each. These are listed in Table 1 of this report.

We do at this point recommend one additional study to investigate the validity of the tooth-aging technique in equids. A precise understanding of herd age structure is important to a thorough assessment of population dynamics and there are some uncertainties about the validity of the tooth-eruption and -wear criteria for wild horse and burro age determination. Hence, the criteria need to be investigated and either verified or changed.

Beyond the addition of this project, we have not changed our views on the need for the studies outlined in Phase I. Hence, our position on research needs is essentially the same as that set forth in the Phase I Report and we see no point in duplicating them here.

However, a few comments can be made in closing. The recommended projects are shown in Table 1 of this report in order of priority judged by the Committee. We do not suggest that all of the projects have equal importance. But we do suggest that at least the top two or three priorities should be considered a minimum program.

Some mention needs to be made about time scale. PRIA allowed roughly 2 years for completion of the research. A number of the projects could have been completed in that time if the funds had been available at the beginning of Phase II. But the more heavily ecological studies require far more time, as was pointed out forcefully on page 108 of the Phase I Report. Given the great year-to-year climatic and biological variation in the semiarid and arid regions occupied by feral equids, at least 7 to 10 years are required to begin to gain an insight into the effects of grazing on vegetation, hydrology, and other animals. Indeed, the excellent understanding of cattle- and sheep-grazing effects developed on the Experimental Ranges of the Forest Service and Agricultural Research Service in New Mexico, Colorado, Idaho, Utah, and Arizona has only come after decades of research.

A final word needs to be said about the need for improved research administration in the BLM. The agency now has a science staff, but it is small and, as pointed out by Mankin et al. (1979), heavily burdened with management and administrative assignments. We believe that BLM ought to explore options for strengthening that staff.

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APPENDIX

EXECUTIVE SUMMARY OF PHASE I REPORT

BACKGROUND OF THE REPORT

The Public Rangelands Improvement Act of 1978 (PL 95-514) and contract AA 551-CT9-16 between the Bureau of Land Management (BLM) and the National Academy of Sciences (NAS) direct NAS to impanel a committee to assess the state of knowledge on wild horses and burros, to recommend research to fill gaps in knowledge, to oversee the research during its conduct, and to compile all relevant information at the end of a 2-year research effort. The state-of-knowledge assessment and the research design were designated Phase I of the total undertaking, and this document is the final report of Phase I. It reviews knowledge about a wide array of topics, recommends 18 research projects, and discusses information relative to policy questions without, itself, advocating policy.

The Committee on Wild and Free-Roaming Horses and Burros was impaneled in June 1979. It divided its task among three subcommittees with responsibility for horse and burro biology, effects on other ecosystem components, and sociopolitical and economic considerations. Following the introductory statement in Chapter 1, the main body of this report is divided into four major sections. Chapters 2, 3, and 4 correspond to the subject matter investigated by the three subcommittees, and Chapter 5 is concerned with research and management methodology. There are also three appendixes.

BIOLOGY OF HORSES AND BURROS

History and Paleontology of Equids in North America

The mainstream of equid evolution occurred in North America. Fossil evidence shows the presence of a large horse and an ass, structurally indistinguishable from the modern horse and donkey, as recently as 11,000 years ago. Their extinction occurred at that time along with the demise of a number of other species of large mammals. Modern wild horses and asses were reintroduced into North America by the Spaniards in the late fifteenth century. Some observers believe that the vegetation in the West was vulnerable to the introduction of domestic herbivores because it had experienced little grazing pressure since the late Pleistocene period. These observers consider equids to be particularly disruptive to the ecosystem because they are alien to the region. However, the view may need to be tempered by a knowledge of the paleohistory of equids in North America. The possibility exists that there are vacant niches into which these animals could fit.

Social Organization

Two types of social organization have been reported in wild equids: (1) the harem or stable family group, with a dominant male; and (2) the territorial form, in which stable bonds occur only between mother and offspring. These may constitute the extremes of a continuum along which different species--and different populations within a species--occur, depending on environmental, social, and population factors. For example, feral asses (burros) in the arid southwestern United States have little social structure except for the mother-young relationship, exist at low densities, and display considerable aggressive behavior. In contrast, asses on humid Ossabaw Island, Georgia, form stable groups and display little aggressive behavior.

Under conditions of dry-season water stress in arid areas, asses concentrate within 3 km of water sources, and lactating females commonly threaten and reject their own young when they attempt to nurse. Concentration of the animals around watering areas has a heavy impact on local vegetation. Arid-land burros are browsers and may spend up to half their time feeding. On Ossabaw Island, however, burros are grazers and spend only about a third of their time feeding. Male asses in the Southwest display greeting behavior among themselves, but rarely are social grooming or social play seen among the young. Ossabaw Island animals exhibit the reverse of these patterns.

The basic social organization among wild horses is that of a family group with a dominant male, subdominant males, and females and their young, but some variations on this pattern occur, as do exchanges between groups. In arid areas, distribution of horses is oriented around water during the dry season, but in areas more to the north, distribution seems to be oriented around availability of forage.

Equid Demography

Horses

Although confined domestic fillies begin ovulating and breeding at 1 year of age, only one 2-year-old mare has been observed to bear a foal in seven wild horse studies spanning 1 to 5 years' duration. A small percentage (mean of 13 in the studied herds) breed at 2 and foal at 3 each year (gestation period is about 11 months). Evidence suggests an increasing percentage of mares foaling in each older age class, as occurs in domestic horses, with around two-thirds of 5-year-old and older animals bearing young. Whether the percentage declines after ages 10 to 12, as in domestics, is not known. Wild horse breeding is highly seasonal, with most foals born from April to June.

Only crude approximations exist of first-year survival rates in wild horses: the available values range from 50 to 86 percent. Mean annual adult survival rates are also poorly known, but most estimates fall between 75 to 95 percent. Age compositions of 8,764 animals rounded up during herd reductions show that the greatest numbers are in the youngest age classes (40 to 45 percent of all animals are in the foal through 2-year-old classes), with progressively fewer in each older age-group. Males slightly outnumber females at birth, decline to 39 percent of animals at 4 to 6 years of age, and then may increase again slightly in the older age classes. Total herd sex ratios approximate 55 percent female.

Population increase rates calculated from BLM and U.S. Forest Service (USFS) census data average 15 to 20 percent annually for western U.S. horse herds, rates similar to those quoted by these agencies and cited in a number of earlier publications. In some cases, these may be magnified by (a) increasing commitment to and proficiency at censusing, (b) increasing visibility as herd sizes increase, and (c) change from fixed-wing to helicopter censuses in the 1970s. But in others, the experience of observers, low-stature vegetation and moderate topography, and fencing that prevents ingress or egress would seem to preclude these biases.

In contrast, two authors have projected increase rates with population models that incorporate birth and death rates similar to those published for several herds and concluded that annual herd increase rates well below 10 percent are probable. Similar calculations with life tables in this report indicate that 15 to 20 percent increase rates can only occur in populations with geometric age distributions with (a) very high reproductive rates, and (b) virtually no mortality. Such demographic conservatism is produced in populations with half their numbers in prebreeding or low-breeding (3-year) age classes, only about two-thirds of older mares foaling each year on the average, and some mortality. The question of increase rates is central to horse management, and the disagreement cannot be resolved with presently available information. Research is needed to settle the question.

Burros

A small percentage of 2-year-old burros foal 1 year earlier than horses. The percentage of 2-year-old and older jennies foaling exceeds 60 percent per year, on average, with the 2-, 3-, and 4-year-old percentages probably exceeding those for horses of the same ages.

Some populations breed year-round, albeit with spring-summer emphasis in some. Survival rates are less well known in burros than in horses, but some evidence suggests high first-year loss in some areas and years, low in others. Age compositions are roughly similar in the two species, but some burro populations have higher percentages of foals. The earlier breeding and higher fertility rates potentially enable burro populations to increase faster than horses, but reported rates of 20 percent per year and higher press the biotic potential of the species, given geometric age distributions. Some populations have been reported to increase very slowly or not at all, as in the case of several Death Valley populations. In general, burro demography appears more variable than that of horses, suggesting some sensitivity to density and the plasticity of a species adapted to the desert.

Fecundity rates of females rounded up during herd reduction could be determined readily through rectal palpation.

Genetic Polymorphism

A knowledge of genetic polymorphism in horses and burros could give some idea of the minimum herd size needed to survive through periods of environmental change and could delineate the racial lineage of wild horses, including their relationship to Spanish mustangs. While some work has been done on the genetics of domestic horses, none has been done on wild animals. Modern techniques of blood-group genetics provide a powerful tool for addressing these two biological questions.

Nutrition

While burros apparently prefer green grasses and forbs, they are highly opportunistic, broad-spectrum feeders, and are capable of surviving on high-fiber, low-nitrogen diets, including coarse shrub branches, yucca, and cholla cacti. Studies conducted so far show grasses ranging from 0 to 79.6 percent, forbs from 8.0 to 77.4 percent, and browse from 5.7 to 83.8 percent of burro diets at different seasons and in different areas. Horses are much more selective feeders. Some use of forbs and browse has been reported, but in 29 published diet analyses, consumption of grasses ranged from 36 to 100 percent of total diet, averaged 89.4, and made up 85 percent or more in 24 of the studies. This dietary preference coincides closely with that of cattle and overlaps to some degree and in some seasons with those of elk, bighorn sheep, bison, and pronghorn antelope. Most dietary studies have not related animal data to vegetation composition, nor have they described spatial and habitat overlap with sympatric ungulates or lack thereof.

There is some reason to believe that equids have higher forage intake rates per unit of body weight than ruminants because food can pass more rapidly through the equid's cecal digestive system. The ruminant is limited in its throughput rate by the capacity of the rumen and the fermentation rate that occurs there. As a result, the equid may have an advantage when only high-fiber forages are available, since it can compensate for the low nutrient content by increasing its intake.

Essentially no data exist on the nutritional responses of free-ranging equids in western North America to the well-studied and well-documented seasonal changes in nutritional content of vegetation. In the Southwest, forage quality is highest in late winter and early spring in the Mojave Desert, with its winter rainfall season; in late summer and fall in the Chihuahuan Desert, with its late-summer season; and at both times in the Sonoran Desert, with its bimodal rainfall pattern. In the Great Basin-Intermountain region forage quality is highest in spring and early summer. If equids can compensate for low-quality forage by increasing intake, then quantity rather than quality may be the factor that limits food; thus equids may be less subject to seasonal nutritional stress than are ruminants.

Habitat Preferences

Understanding habitat preferences and uses is important to detecting competition between equids and other herbivores, wild or domestic: to making forage-allocation decisions: and to establishing site-suitability criteria for equids, domestic animals, and wildlife. Competition occurs when two species use a common resource and reduce it to the point where the numbers of one or both species are limited. If the resource is not reduced to this point, the two species can both use it without competing. It is conceivable that two or more species of herbivores (a) may choose and occupy different habitats and thus not compete; (b) may have overlapping habitat preferences but segregate through behavioral interaction, thus competing only if food becomes limiting; (c) may occur in the same habitat but eat different foods, in which case they will not compete; and (d) may co-occur and eat similar foods, competing only when food becomes limiting.

Recommended Research

Seven research projects on the biology of horses and burros are recommended:

- Project 1: Habitat Preference and Use
- Project 2: Food Consumption Rates and Nutrition
- Project 3: Nutritional Plane, Condition Measures, and Reproductive Performance
- Project 4: Blood Assays
- Project 5: Demography
- Project 6: Social Structure, Feeding Ecology, and Population Dynamics
- Project 7: Genetic Polymorphism.

The projected 2-year span for the research is unrealistic. Because of the extreme year-to-year variability of environmental conditions and equid performance, no comprehensive picture can be developed in less then 6 to 10 years. Project 1 should be conducted in areas not less than 5 to 6 square miles per experimental treatment. Projects 2--and 8 and 9 to be listed later--can be carried out in paddocks of 100 to 300 acres. All experiments should be conducted in treatments involving horses only, cattle only, and horses and cattle, each at moderate and heavy grazing intensities. Horses and cattle are emphasized here because the possibility of their competition, both for space and for food, seems to be greatest. If funds permit, the research could be repeated with burros and with domestic sheep. Projects 2 and 9 should contain control areas without grazing.

EFFECTS OF EQUIDS ON OTHER ECOSYSTEM COMPONENTS

Impacts on Rangeland

Although it is widely alleged that horses and burros have severe grazing impacts on western rangelands, there are few published studies about the nature and extent of these impacts. Most of the existing studies are on grazing effects of burros. Studies along the lower Colorado River and in Death Valley National Monument showed heavy impacts on vegetation from grazing burros within a radius of 2 to 2.5 km from water areas. Studies in the Grand Canyon National Park showed heavy impacts at the Colorado River elevation and moderate-to-light effects at progressively higher elevations. Range in Bandelier National Monument was degraded over 4,000 ha by 107 to 120 burros. A study in the Lake Mead National Recreation Area, however, revealed no major impacts. Little controlled research has been done on impacts of grazing horses; the extensive management of horse range apparently proceeds largely from management-level inventories, experience, and judgment.

The range-ecology conceptual framework used in livestock management can at least be used as a starting hypothesis for, if it cannot be applied directly to, equid management. In this scheme, plant-community successional trends are roughly proportional to grazing intensity. Properly managed grazing--which takes into account the species, number of animals, season, and distribution of grazing--can be harmonious with most resource needs and values. The specifics of managing range vegetation vary geographically and seasonally with climate and vegetational type. Year-to-year variation in precipitation can be a more influential factor in altering plant-community composition than season and intensity of grazing. Annual forage production is strongly correlated with that same variation, and herbivore numbers properly should be adjusted to the changes.

Interspecific Competition

Because competition only exists where a population is limited to some degree, it is best demonstrated experimentally by manipulating the numbers of one suspected competitor and observing whether or not the other responds. If the population cannot be manipulated, a preliminary indication can be gained by calculating the resource need of each species, measuring the amount of resource available, and determining whether the need exceeds that available. Ideally, such calculations should be combined with population-limitation experiments.

Burros are widely claimed to compete with desert bighorn sheep for water, forage, and space. Reports on water are conflicting and may depend on abundance. Competition for forage could occur near water holes. Two authors indicate that sheep avoid areas occupied by burros. While all of this evidence is equivocal, several authors point to negative correlations between burro and bighorn distribution in space and time. The possibility of burro competition with mule deer has been reported for Bandelier National Monument, and there is evidence of competition with small mammals in Grand Canyon, Death Valley, and Bandelier. Less work has been done on horse competition. Dietary overlap has been reported for some seasons and some areas between horses, cattle, elk, mule deer, pronghorn antelope, and bighorn sheep, with joint occupation of the same habitat in some cases.

Effects of Equids on Soils

There are numerous anecdotal or localized reports of equids, mostly burros, compacting soil surface, forming trails in steep terrain that accelerate erosion, and polluting water holes. Equids are potentially capable of the same types of impacts as are created by livestock. The latter have been thoroughly studied.

Overgrazing (a) reduces protective cover and increases the impact of raindrops, (b) reduces soil organic matter and soil aggregates, (c) increases surface vesicular crusts, (d) reduces infiltration rates, and (e) increases erosion. Overgrazing reduces vegetation mulch, increases the proportion of bare ground and rock cover, increases soil bulk density, and reduces moisture infiltration rates.

Heavy grazing increases the sediment load of watershed runoff, an effect caused mostly by vegetative reduction, but also partly by trampling. Serious problems of sediment production in the riparian zone are often associated with bank instability. Total and fecal coliform counts generally increase with the presence of livestock, especially during runoffs. In some cases, bacteria are stored in the bottoms and banks of streams.

Recommended Research

The following research projects are recommended:

- Project 8: Grazing Impacts on Range-Plant Communities
- Project 9: Hydrologic Impacts
- Project 10: Riparian-Zone Impacts

Horse-cattle studies are again accorded priority because horses are more widespread than burros, potentially more serious competitors with livestock, and more likely to compete with cattle than with sheep. Horse-sheep studies should be initiated if resources permit.

Studies of equids in relation to wildlife are not recommended at this time because the possible combinations (horse-elk, horse-deer, horse-antelope, horse-bighorn, burro-desert bighorn) are so numerous, and because controlled experiments with wild ungulates are so difficult. But we urge that federal and state agencies watch for opportunities to take before-and-after censuses of wildlife populations in areas slated for horse or burro herd reductions. Censusing 1 or 2 years before and several years after herd reductions could give clues to the existence of competition, especially if censusing were replicated in several areas. If nearby populations in areas with no equid reductions could also be censused in the same years, the results could be compared to create a roughly controlled experiment.

SOCIOECONOMIC AND POLITICAL ISSUES

In the Committee's opinion, several kinds of socioeconomic and political information are needed to facilitate decision making in horse and burro management. While there is abundant information on range and ranch economics in the western United States, there is little economic literature specific to wild, free-roaming horses and burros, and development of market and nonmarket valuation techniques is limited. Areas in which inquiry is needed include: (a) the value of and demand for wild horses and burros; (b) evaluation of adoption procedures; (c) evaluation of control and managment techniques; (d) analysis of optimal numbers for wild equids and management alternatives; and (e) evaluation of the costs of existing legal regulations and restrictions.

The legal-political literature on wild horse and burro matters is extensive, particularly in terms of providing a perspective on the public agencies' overall land-management responsibilities--the context in which policies concerning wild horses and burros should be considered. Review of civil cases under the Wild and Free-Roaming Horse and Burro Act of 1971 shows that most lawsuits fall into two categories: (1) those challenging the need for round-ups, and (2) those questioning the adequacy of the environmental impact statements relied upon both by the government and by those challenging federal--as opposed to state--government authority over the animals. Concern has been expressed over protection of the animals, preservation of state control, impacts on rangeland, and the validity of information and views on population characteristics and impacts on other wildlife as well as the range resources.

There are almost no data on sociological aspects of the wild horse and burro issue.

Recommended Research

Six research projects, one of which is designed at three levels of intensity, are recommended. They will provide a base of socioeconomic and political data that will facilitate decision making in equid management. The projects are organized into three groups in descending priority in terms of importance of information and urgency of funding:

Group 1 includes:

- Project 11A: Taxonomy of Values and Benefits
- Project 13: Management Costs of Alternatives
- Project 14: Economic Considerations for Management Alternatives Drawn from Proposed Research Programs

Group 2 includes:

- Project 11B: Public Preferences for Alternative Management and Control Strategies
- Project 12: Analysis and Evaluation of Demands for Excess Wild Equids
- Project 15: Nonmarket Values

Group 3 includes Groups 1 and 2 and adds the following investigations to provide socioeconomic data necessary to a systems-level understanding of wild-equid management:

- Project 11C: Public Attitudes, Preferences, and Knowledge
- Project 16: Conceptual Development of Public Rangeland Management Models

RESEARCH AND MANAGEMENT METHODOLOGY

Methodology for censusing animal populations falls into three basic categories: (1) indices, (2) complete counts, and (3) various kinds of estimates based on sampling. Indices do not appear to have much potential in equid census, because they do not provide the estimates of actual numbers needed for forage allocation unless calibrated to total numbers. Current agency census efforts attempt complete counts from the air. The completeness of these--as well as the effects of such factors as vegetation type, topography, airspeed, altitude, type of aircraft, and observer experience--remain largely unstudied. One study showed experienced observers to be more efficient at spotting horses than inexperienced ones.

The accuracy of existing censuses must be tested and correction factors devised for deviations from total accuracy. Several approaches can be taken. Complete counts are most likely to err on the conservative side, but the Committee's impression is that current horse censuses, especially in open terrain, are reasonably accurate. On the other hand, one test of accuracy of a burro census in Arizona showed that only about a third of the burros had been counted. Some estimation techniques--especially mark-resight methods--may be useful with burros, and plot sampling may be possible for horses. These methods should be coupled with others, preferably complete counts, so that accuracy can be checked. Accuracy of an equid census can be affected by relative visibility, which may increase as group size increases; by observers' experience, as mentioned above; and by certain approaches to random sampling.

Preliminary analysis of BLM and USFS census data showed: (a) a failure to standardize the season of census, which raised the problem of a seasonal change in numbers due to foaling; (b) an abrupt 88 percent mean increase in horse numbers in the years when helicopter census replaced fixed-wing-aircraft census; and (c) less variability in the helicopter counts.

The "Soil-Vegetation Inventory Method" is commonly used in contemporary range-survey work and for a number of other purposes, including compliance with the wild horse and burro mandates of recent legislation. The Committee reviewed 10 BLM and joint BLM/USFS wild horse capture plans with their accompanying environmental analysis reports (EARs). Eight reductions were proposed because of problems perceived in range conditions. However, few provided much information on range condition and the techniques used to determine it, or on which herbivores (horses, cattle, wildlife) caused the problem. The most recent EAR provided detailed supporting data. The Committee concluded that, while range studies have not always been properly used to support adjustments in numbers of wild equids, the technology exists and appears adequate.

Fecal analysis, the most widely used technique for analyzing diets, is currently subject to question in ungulate studies. Not only do some consumed plant species fail to appear in feces, but the proportions of food items consumed and those showing up in fecal remains differ. The equid digestive tract may be less subject to these problems, a possibility that is supported by studies on zebra diets. However, conclusions based on equid fecal analysis should be drawn with caution until the method has undergone further study, preferably with the use of fistulation.

A more intractable problem is that of the time lag between consumption of forage and fecal deposition in highly mobile species such as equids. Defecation may not occur until 37 hours after ingestion, making it difficult to relate diets to the vegetation and habitat from which they were taken. Statistical problems and lack of microhistological reference material may pose other difficulties.

The in vitro techniques widely used for studying ruminant nutrition should not be relied upon until they have been proven for equids. In vivo comparisons, the use of indicators, and regression procedures should all be tried.

Assays of a number of chemical constituents in the blood may have potential for (a) evaluating nutritional condition of individual animals, and (b) using an animal's condition to indicate the nutritional adequacy of the range it occupies. Blood samples could be taken easily from horses and burros brought in from herd round-ups, and from animals used in the research projects.

A number of the research projects outlined in this report can use confined animals, domestic ones, or both. Questions will arise as to the degree to which the results from the two categories can be extrapolated to wild and free-roaming animals. Observations of the behavior of the two former groups and of wild and free-roaming animals can be used to assess the comparability of results and to facilitate extrapolation from one group to another.

A set of observations of behavior is set forth to assist in cross-comparisons. The set includes considerations in selecting the animals to be observed, statistical aspects, behaviors to be recorded, and schedules of observation. In addition, recommendations are set forth for observations of behavior to be made within the specific research projects outlined in this report, including an extensive repertoire of social and maintenance behavior. The rationale for each recommendation is included.

If fertility control is deemed a desirable method for limiting population, a range of contraceptive agents is available that could be implanted and might be effective for up to 5 years. Considerations of population and behavior point to attempts at reducing fertility in mares rather than stallions. The technique needs to be researched, however, initially in captive animals.

Chemical immobilization is not deemed an efficient primary capture technique for wild horses, but it can be used to quiet captured animals for purposes of research and handling. The preferred drug for this use is etorphine (also known as M99 or Immobilon).

Two methodological research projects are recommended:

- Project 17: Census Methods
- Project 18: Contraception Studies

Project 17 should investigate the validity of two or three alternative census techniques, including "complete" counts. The project should begin with a pilot effort on horses, later extended to burros. Project 18 should evaluate contraceptive methods.