PRONGHORN MANAGEMENT GUIDES

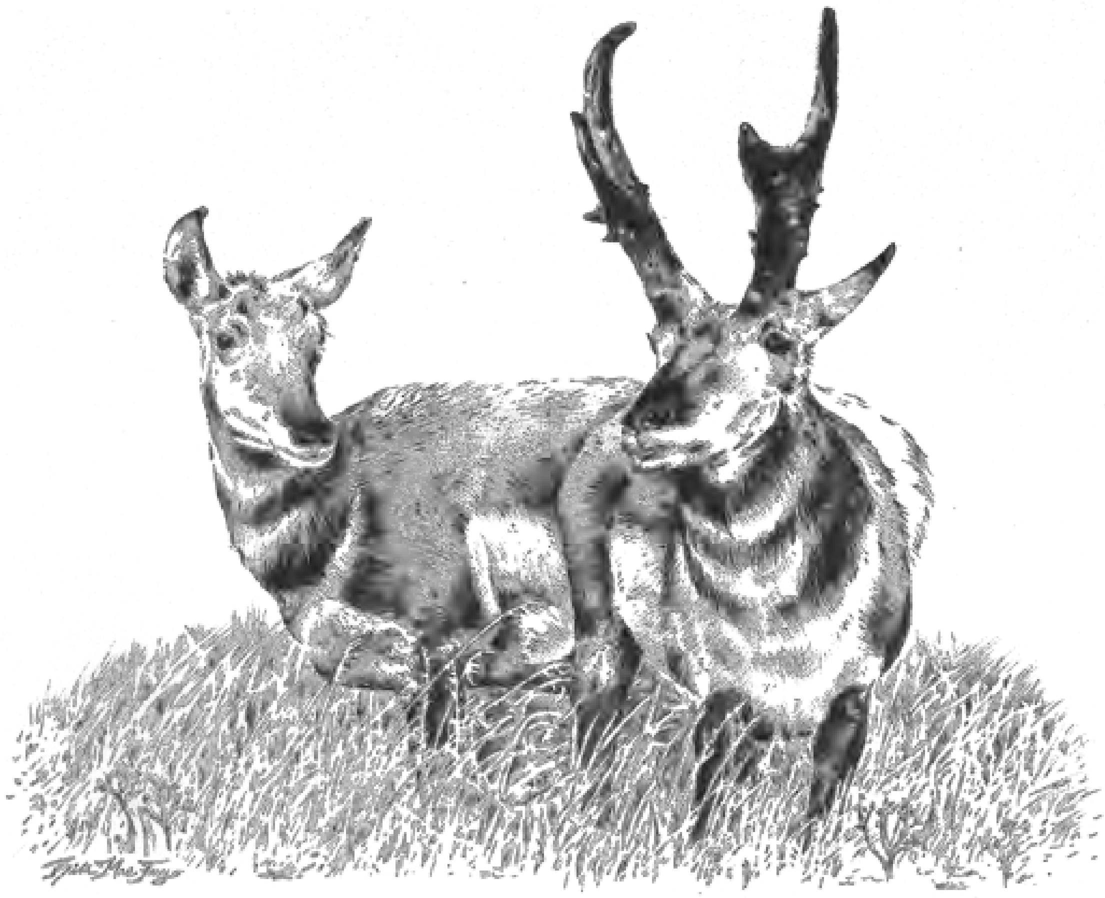
PRONGHORN MANAGEMENT GUIDES

Biological and management principles and practices designed to sustain pronghorn populations in the USA, México, and Canada.

BY:

J. D. YOAKUM,
P. F. JONES,
J. CANCINO,
R. J. GUENZEL,
R. SEIDLER,
A. MUNGUIA-VEGA,
I. CASSAIGNE,
M. CULVER

TWENTY-FIFTH BIENNIAL PRONGHORN WORKSHOP, SANTA ANA PUEBLO, NEW MEXICO.



Biological and management principles and practices designed to sustain pronghorn populations in the USA, México, and Canada.

Support Provided by:

Alberta Conservation Association
Conserving Alberta's Wild Side

CIB

WILDLIFE CONSERVATION SOCIETY

NEW MEXICO GAME & FISH

PRONGHORN MANAGEMENT GUIDES

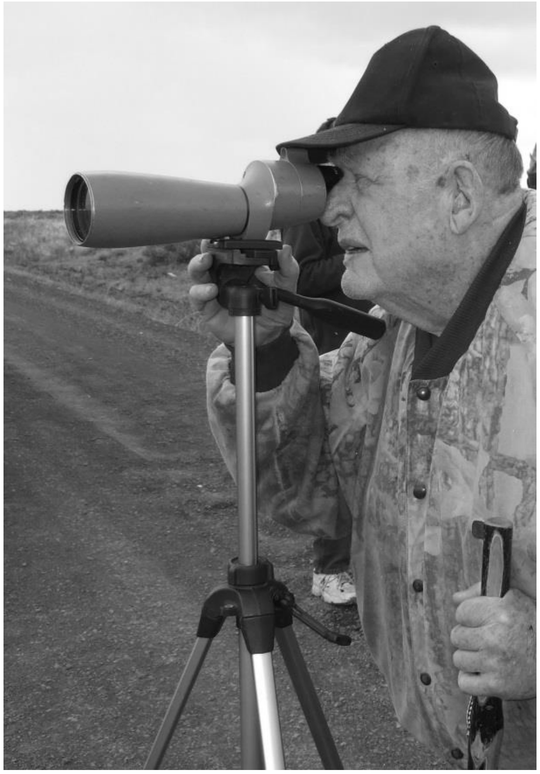
5th Edition

J. D. YOAKUM,
P. F. JONES,
J. CANCINO,
R. J. GUENZEL,
R. SEIDLER,
A. MUNGUIA-VEGA,
I. CASSAIGNE,
M. CULVER

Twenty-Fifth Biennial Pronghorn Workshop,
Santa Ana Pueblo,
New Mexico

Produced by:

Western Association of Fish and Wildlife Agencies' Pronghorn Workshop
and
New Mexico Department of Game and Fish



IN MEMORY

James “Jim” Donovan Yoakum

June 14,1926 - November 20, 2012

James “Jim” D. Yoakum was born in Templeton, California on June 14, 1926. At the young age of 17, Jim enlisted in the U.S. Navy, serving from 1944-1947. Though his military service was a short part of his life, Jim stated that it was the most important thing he did as it allowed him to gain an education, a career, and a place to call home.

Following his military service, Jim attended Humboldt State College where he studied Roosevelt Elk and received his Bachelor of Science in 1953. Jim then went on to Oregon State University where he studied pronghorn and received his Master of Science in 1957. Following graduation from Oregon State University, Jim was hired as the first wildlife biologist by the U.S. Bureau of Land Management, where he worked with the agency, first in Ely then Reno, Nevada from 1958 to 1986.

Jim was an advocate for wildlife and in particular pronghorn. He dedicated his life to their conservation, and the protection and enhancement of their habitat. Over the course of his career, Jim published numerous papers on pronghorn, but will be best known for co-authoring the book “Pronghorn: Ecology and Management”, a 903 page comprehensive book that serves as the guide for all things pronghorn.

Up until his passing on November 20, 2012, Jim continued to work on pronghorn, chairing the committee for the production of this edition of the Pronghorn Management Guides and a comprehensive pronghorn bibliography. This edition of the guides and the bibliography are dedicated to his memory. His enthusiasm, passion, and willingness to share his knowledge and point of view on pronghorn and their conservation will be missed.

TABLE OF CONTENTS

ABOUT THE PRONGHORN WORKSHOP

The Pronghorn Workshop began in 1965 as the Antelope States Workshop and currently meets every even year. Attendees represent western state and provincial wildlife agencies, federal land and wildlife agencies, universities and colleges, wildlife consultants, and private conservationists from southern Canada, northern Mexico, and the western United States. The Workshop's goals are to exchange information and encourage the perpetuation of sustainable wild herds of pronghorn.

Workshops are held in different locations to present technical and scientific data, and conduct field trips. This information is assembled into proceedings, which provide "state of the art" knowledge on pronghorn and their habitats. In addition, the workshop periodically publishes "Pronghorn Management Guides", providing a compendium of suggested practices and techniques for managing pronghorn and pronghorn habitat.

ACKNOWLEDGEMENTS

These Guides are the fifth edition and build upon the work of many collaborators that have graciously provided assistance and time to compile this and the previous four editions. For their effort we acknowledge the following; J. Ablegglen, E. Allen, A. Alexander, S. Amstrup, E. Anthonise, B. Autenrieth, M. Barrett, D. Beale, D. E. Brown, E. J. Brown, L. Colton, B. Compton, C. Eustace, E. Fichter, T. Funk, B. Glasgow, H. Harju, J. Herring, R. Hitchcock, R. M. Lee, F. Lindzey, D. Lockman, E. Loft, D. Lutz, B. McCarty, J. McKenzie, K. Menzel, B. Morrison, R. A. Ockenfels, B. W. O'Gara, T. M. Pojar, D. Pyrah, F. Ramírez, P. Riddle, V. Sánchez, S. Scott, B. Sherwood, D. Simpson, M. Smith, R. Streeter, E. Struzik, E. Taylor, T. Terrell, G. Tsukamoto, L. Upham, B. Watts, M. Wild, M. Willis, R. Wilson, C. Winkler, W. Van Dyke and S. Zalaznik.

We would like to thank the Alberta Conservation Association, Centro de Investigaciones Biológicas del Noroeste, S. C., Wildlife Conservation Society: North America Program for allowing us time to work on this project. R. Walker provided edits and comments on the complete draft; P. W. Hedrick provided insightful comments on the genetic section; J. Beckmann, J. Burrell, and A. Hardy edited the Industrial and Infrastructure Development section. Technical and editorial assistance with this version was provided by M. Jensen and M. Neufeld. G. Jimenez graphically designed the front cover of this edition. New Mexico Department of Game and Fish and Alberta Conservation Association provided funds for printing.

This edition of the Management Guides was a concerted effort of those listed below. Specifically, Ivonne Cassaigne revised and edited the Chemical Immobilization section, Rich Guenzel revised and edited the Population section, Adrian Munguia-Vega and Melanie Culver authored the Genetics section, Renee Seidler authored the Industrial and Infrastructure Development section, and Jorge Cancino, Paul Jones, and Jim Yoakum

updated and edited the remaining sections of the Guides. Jim Yoakum also served as the lead for the project and a source of inspiration.

These guides should be cited as:

Yoakum, J. D., P. F. Jones, J. Cancino, R. J. Guenzel, R. Seidler, A. Munguia-Vega, I. Cassaigne, and M. Culver. 2014. Pronghorn management guides. Fifth edition. Western Association of Fish and Wildlife Agencies' Pronghorn Workshop and New Mexico Department of Game and Fish, Santa Ana Pueblo, New Mexico. 159 pp.

Limited hard copies are available on a "first come" basis from: New Mexico Department of Game and Fish, Santa Fe, New Mexico. We give permission to make copies or reprints of this version without changes.

HISTORY OF PRONGHORN MANAGEMENT GUIDES

Participants at the 1976 Pronghorn Antelope Workshop identified a number of problems affecting the welfare of pronghorn (*Antilocapra americana)*. As a response, several committees were formed to prepare guidelines to identify problems and suggest management procedures and techniques. These recommendations were compiled into the *Guidelines for the Management of Pronghorn Antelope* (Autenrieth 1978) and published as part of the Proceedings of the 8th Pronghorn Antelope Workshop. The objective of that publication was to provide resource managers with information available for managing and perpetuating pronghorn and their habitats. Although these initial guidelines incorporated many of the suggested management methods identified and developed by Griffith (1962) for the Interstate Antelope Conference, the intent was to make the Guidelines applicable to pronghorn rangelands from Canada to Mexico. The need to periodically revise and incorporate new information was recognized at the outset.

The first supplement to the Guidelines*, Trapping and Translocation* (McKenzie 1984), was printed and distributed by the Texas Parks and Wildlife Department, and published as part of the Proceedings of the 11th Pronghorn Antelope Workshop. This supplement focused on the capture of pronghorn using corral-type drive traps and linear tangle nets and the subsequent handling of captured animals.

At the 13th Pronghorn Antelope Workshop in Oregon (1988), participants urged that the above section on trapping and translocation techniques be expanded with a special emphasis on how to evaluate suitable sites for translocations. O'Gara and Yoakum (1990) responded to this request with *Additional Capture Methods and Habitat Suitability Criteria for Pronghorn Translocations*, published in the Proceedings of the 14th Workshop. This supplementation contained information on some of the less-used capture methods as well as a survey of the literature on methodologies for evaluating translocations and relocation sites. Later, O'Gara and Yoakum (1992) produced the second edition of the Guides that consolidated various management supplements, along with updating and adding new biological and habitat findings. This edition was the first time that the Guides were a stand-alone document and separate from the proceedings.

At the 17th Workshop in California, it was decided to update the Guides, particularly the sections on habitat evaluations and modifications. Portions of the second edition, along with other new information, were published in the third edition (Lee et al. 1998). In 2000 the third edition by Lee et al. (1998) was translated into Spanish and only available electronically. Autenrieth et al. (2006) revised the 1998 edition, adding in new pertinent information and making it available for the first time electronically in English. This edition was again translated into Spanish in 2009 and printed. These guides are similar to previous editions in that they include new techniques, remove redundancies, include updates to relevant section(s) where new information is available, and address problems not heretofore considered. This current edition strives to achieve the goal of updating the Guides with new and pertinent information as well as maintaining the high standard set by previous editions.

INTENDED PURPOSE OF THE PRONGHORN MANAGEMENT GUIDES

Extensive management guides for wildlife should be general in nature. Their values are found in the discussions of basic requirements and problems. The purpose of the Pronghorn Management Guides is to document our collective knowledge of pronghorn, while implementing methodologies compatible with a holistic approach to the ecosystems, and not the fragmented, single-species approach (Talbot 1976). Because information from regional reports and past publications has been used to draw conclusions for management recommendations, care should be exercised in applying techniques successfully used in one area to another having different ecological conditions. It should also be remembered that these Guides reflect actual field management experiences as well as research investigations.

These Guides, when properly implemented, should assist land managers, biologists, and researchers in making decisions. The Guides should not be regarded as a "cookbook" of management practices to be used indiscriminately. Included are basic biological data plus recommended management procedures. Each technique needs to be evaluated for site suitability where the information will be used. Below are three examples of variations that can be expected based on local site conditions and are provided to highlight the need to evaluate the information contained within the Guides based on local conditions.

First, pronghorn males may employ different breeding strategies from one location to another, or from one year to the next within the same area. Pronghorn males may be either territorial during the breeding season, or males may have harems and/or territories. Given different years, even in the same general location, one cannot assume that males are naturally territorial at all times or for all habitats. This biological characteristic must be determined through field observations on site, and the resulting information corrected for different periods of time.

Second, there is considerable variation in parturition dates for pronghorn across their range. Intensive studies in Oregon by Einarsen (1948), Hansen (1955), Yoakum (1957) and Trainer et al. (1983) showed most parturition occurred between 14 May and 2 June. This period is probably appropriate for other northern populations (Idaho, Wyoming, Colorado, etc.). However, for southern herds, Lehman and Davis (1942) and Büechner (1950) reported fawns were born from February through April, and pronghorn in the Sonoran Desert typically give birth in February and early March (Murphey 1917).

Last, habitat suitability criteria have been established for some, but not all habitats. At times, a system for evaluating habitat suitability may be appropriate to use in different biotic communities, but care must be taken to use the appropriate regional ecological characteristics. An example would be that a ground cover of 5% grasses, 5% forbs, and 40% shrubs would be characteristic for vegetative composition in the Great Basin shrubsteppe; however, percentages for grasslands would more likely be 35% grasses, 10% forbs, and < 5% shrubs. Pronghorn prefer certain forage species over others, but diets vary locally due to availability as well as preference; therefore, consumption should be determined through local food habit studies conducted for all seasons of the year.

The Guides contain many citations for the management practices presently used to manage pronghorn and pronghorn habitat. Although attempts were made to summarize or review these practices, the reader is encouraged to consult the original reports for greater details regarding particular results. In addition, we have standardize the term male(s) for bucks and female(s) for does throughout the document. Exceptions would be in section titles where it made sense to use buck(s) and doe(s) when referring to ratios.

These Guides are the work product of dozens of biologists and resource managers. Most management practices are tried, tested, and proven; however, you may note items in need of correction or more information. Wanting to correct such errors, we strongly encourage suggested revisions be presented at future Pronghorn Workshops for consideration in the next edition. The Guides will continue to be valuable only if the publication is dynamic, and in keeping with current knowledge and experiences gained. Regular updates are required to ensure the Guides continue to serve their intended purpose.

INTRODUCTION

Pronghorn evolved in western North America during the last 20 million years (Frick 1937). During recent times, this North American endemic ranged from the south-central prairies of Canada through the Plains and Great Basin's grasslands and shrubsteppes of the United States, southwestward to the semidesert grasslands and deserts of northwestern Mexico. Although the total area of suitable habitat has now been greatly restricted by human settlement, pronghorn inhabit much of their historic range (Yoakum 2004*a*), possibly as much as 50%. Areas of highest density have always been open grasslands possessing short shrubs where the size of some pronghorn herds reached legendary proportions. Reports from the journals of the Lewis and Clark, and Bartlett expeditions indicated pronghorn were most abundant on the Great Plains and in the Central Valley of California (Newberry 1855, Thwaites 1904-05).

Millions of pioneers, immigrants, and new settlers moved into the western rangelands between 1550 and 1920. Most showed little regard for pronghorn or their habitat. During this period, pronghorn numbers declined due to fencing, habitat loss, competition with livestock, and year-round hunting (O'Gara and McCabe 2004). By 1920, it was thought that only about 30,000 pronghorn remained (Nelson 1925). But then the future for pronghorn became brighter. Conservation-minded organizations supported state, provincial, and federal programs that curtailed hunting by settlers and market hunters, and provided protection through refuges. A prolonged drought, extending from 1918 to 1934 (Pechanec et al. 1937), together with low prices and surpluses of farm products, made cultivated crops uneconomical on semiarid homesteads. Consequently, livestock numbers were greatly reduced, and many marginal agricultural enterprises were abandoned allowing sizable areas of cultivated land to revert to native vegetation. State, provincial, federal, and private organizations began regulating the harvests of pronghorn, while reestablishing them to unoccupied historic rangelands. Only in relatively few areas was damage to vegetation by drought and livestock foraging so severe that pronghorn were unable to survive (Nielson 1962).

More favorable weather, regulated hunting, reversion of farmland to rangeland, and translocations resulted in a great increase in pronghorn numbers to > 1 million in 1983 (Yoakum 1986). By 2000, cumulative legal harvests of > 3.5 million pronghorn were being realized (O'Gara and Morrison 2004). Population expansions are currently limited by agricultural, urban, and mining expansions onto historic rangelands; restrictions of movement by fencing; the resistance of agricultural interests to population increases; the alteration of native vegetation by certain rangeland rehabilitation programs; and range overuse. In certain locales, these and other debilitating factors are such that managers are hard pressed to even maintain existing populations.

PRONGHORN HABITATS AND LIFE HISTORY

Habitat Requirements

Habitat requirements for pronghorn in shrublands, grasslands, and deserts have been investigated and summarized by Sundstrom et al. (1973), Yoakum (2004*a*, *b*), and Brown and Ockenfels (2007). Photographs 1 through 8 depict the various habitats occupied by pronghorn. Similar criteria for desert-dwelling pronghorn have not been documented and have limited information (Photographs 5-6).

1. Abiotic

a. Landscape Physiography

Although pronghorn typically use sites having slopes < 10%, they can occupy steeper terrain; however slopes > 20% are generally avoided. Rugged landscapes affect survival because mountain lions (*Puma concolor*) and other predators are often found in such sites (Ockenfels 1994a). Pronghorn typically use low rolling, expansive terrain. The area required depends on both habitat quality, quantity, and, in some areas, the provision of seasonal movement and/or migration corridors to avoid deep snow. Summer and winter rangelands are usually differentiated on the basis of snow accumulation, the availability of seasonal forage, and sources of drinking water.

Photograph 1. One of the largest ecosystems with the highest densities of historic and extant numbers of pronghorn is the short-grass prairie. Here, is a small herd of pronghorn in southern Alberta, Canada. Photograph by Paul Jones.

Photograph 2. Pronghorn occupy portions of the tall-grass prairie. When tall grasses are heavily grazed by bison (*Bison bison*) or cattle, or burned by wild fires, preferred grasses and forbs grow profusely and are readily consumed by pronghorn. The small herd pictured here lives on the Wind Cave National Park in South Dakota. Photograph by Jim D. Yoakum.

Photograph 3. Pronghorn in the sagebrush/bunch grass community near Laramie, Albany County, Wyoming. Photograph by Rich Guenzel.

Photograph 4. Pronghorn in the mesquite/grama vegetation community in the Trans Pecos ecoregion of Texas. Photograph by Shawn Gray.

Photograph 5. Semidesert grasslands in the state of Chihuahua sustained the highest number of pronghorn in Mexico. Photograph by Patricio Robles-Gil.

Photograph 6. Cold desert habitat located near the border of the cold and hot desert in Nevada. Photograph by Diego Johnson.

Photograph 7. Semidesert grassland communities formerly hosted moderate to large numbers of pronghorn. Fire prevention and the invasion of woody shrubs (as depicted above) reduced grass cover and led to a loss of nutritious forbs, many of these areas now support few, if any, pronghorn. The trees are *Juniperus monosperma,* a grassland invading juniper. Photograph by Richard Ockenfels.

Photograph 8 . Two pronghorn in the Choya forest in the Tule Desert, Arizona. Photograph by John Hervert.

b. Topography and Elevations

Pronghorn inhabit open, gentle landscapes, characterized by hills, ridges and draws. Substrates may be clay, gravel, or sand with dunes up to 6 feet (2m) in height. Elevations range from near sea level to an altitude of 11,000 feet (3,353 m). Animals in Mexico occur close to the seacoast while small herds in Oregon and Wyoming use alpine meadows. Greatest pronghorn densities, however, occur between altitudes of 4,000 and 6,000 feet (1,219 and 1,829 m) (Yoakum 2004*b*).

c. Natural Barriers

Natural obstacles can curtail movements and exclude the occupancy of suitable habitats. Natural barriers include abrupt escarpments or mountain ranges, deep canyons, thick copses of shrubs or trees, and densely wooded areas. For example, steep-walled canyons effectively separate pronghorn populations into distinct herds in central and northern Arizona (Ockenfels et al. 1994, Ockenfels et al.1997). Einarsen (1948) cited two examples of such barriers in Oregon, the Columbia River and a forested region, where pronghorn did not move into suitable but isolated habitats nearby.

d. Precipitation

Highest pronghorn densities occur in ecosystems whit mean annual precipitation of 8 to 15 in. (20 - 38 cm). Populations in precipitation belts above or below these parameters generally have lower survival rates and densities (Sundstrom et al. 1973, Yoakum 2004*b*).

Winter precipitation appears to be more important to pronghorn recruitment and survival than summer precipitation. Southwestern U.S. pronghorn populations require a minimum of 2 in. (5 cm) of precipitation between October through March for herd maintenance (Brown et al. 2002). No mean maximum precipitation amount has been documented, but probably ranges between 20 and 30 in. (51 - 76 cm) (Büechner 1950).

Dew and the water content of forage plants may be sufficient to provide necessary water requirements for adult survival, but may not meet lactation needs (Fox 1997). Sundstrom et al. (1973) and Yoakum (2004*b*) indicate that herds occupying rangelands with abundant drinking water every 1-3 miles (1.61 - 4.83 km) had higher densities compared to areas with limited drinking water (Hervert et al. 1997, Cancino et al. 1998).

In Texas, droughts were associated with decreased pronghorn vitality and fertility (Hailey 1979). Baker (1953*a*) found that pronghorn in Wyoming sometimes died while trying to get through fences to reach water. Pronghorn will drink from most facilities designed to water livestock, but these facilities should remain functional and usable by pronghorn throughout the spring, summer and autumn on northern rangelands, and year round in southern habitats.

e. Water

The quantity of water consumed by pronghorn varies with body size, sex, health, lactation demands, physical activity, the succulence of the forage, humidity, and ambient temperatures. Water use decreases with lower temperatures and the availability of snow, succulent forage, and the amount of dew or rain. Conversely, water use increases with drier atmospheric conditions, lack of snow, dry forage, and higher temperatures. In Wyoming, pronghorn were stressed when snow or free water was not available during winter (Guenzel et al. 1982, Cook 1984).

Based on studies of laboratory animals, the summer water requirements for an adult pronghorn in Wyoming was 0.95 gal/day/100 lb animal (3.60 L/day/45 kg) (Whisler 1984). However, the water needs for free-roaming pronghorn accustomed to drinking water may be greater. Measurements of pronghorn water consumption were conducted in a Wyoming field study (Sundstrom 1968).

Daily consumption rates per adult pronghorn varied from 0.09 gal/day (0.34 L/day) in May to 1.19 gal/day (4.50 L/day) in August. Water should be provided to pronghorn during winters, in quantities of approximately 1/4 of summer consumption rates, when free water (including snow) is unavailable to herds accustomed to drinking in Wyoming (Sundstrom 1968).

A close relationship was observed between pronghorn distribution and water locations in Wyoming's Red Desert; 95% of 12,465 pronghorn surveyed from the air were within 4 miles (6.4 km) of a water source (Sundstrom 1968). Most pronghorn observations in Arizona and New Mexico are usually within 2 miles (3.2 km) of water (Ockenfels et al. 1994, Clemente et al. 1995). Occasionally, adult males are seen farther from water, and pronghorn in the Sonoran Desert have been seen 40 miles (64 km) from water (J. Hervert, personal communication).

Benson (1956) considered the advent of water developments in Saskatchewan to be associated with the dispersion of pronghorn populations. In Oregon, it was speculated that although suitable forage was available for pronghorn, the limiting factor was adequate drinking water in late summer (Oregon State Game Commission 1961). Beale and Smith (1970) suggested that water developments might encourage a greater distribution of pronghorn where natural water sources were limited, particularly during dry seasons or drought years. Water developments may also increase competition with livestock and elk (*Cervus elaphus*) into formerly unused habitats.

Minimum distance to water may be as important as maximum distance. Pronghorn in Arizona avoided the first 400 yards (366 m) from water sources, possibly to reduce the threat of predation (Ockenfels et al. 1992, Ockenfels et al. 1994). If an area is well watered, distance to water may vary little with the season (Ockenfels et al. 1994). In southern New Mexico, pronghorn ranged farthest from developed water in summer, when precipitation was the highest, thereby reducing reliance on stock tanks and other artificial water sources (Clemente et al. 1995).

f. Snow

When snow depths exceed 10–12 in. (25 - 30 cm), pronghorn frequently have difficulty obtaining forage. Prolonged periods of deep snow are especially detrimental when combined with inadequate forage, low temperatures, and snow crusting due to alternate freezing and thawing temperatures. Although wind increases chill factor, a complete absence of wind precludes bare patches of ground and interferes with foraging. Fences and other obstacles to movement may be especially detrimental at such times (Sundstrom 1969, Riddle and Oakley 1973, Hailey 1979). The severe winters of 1964 - 65 and 1968–69 resulted in high losses of pronghorn in Montana, North Dakota, South Dakota, and Arizona, because the animals could not reach areas with adequate food (Compton 1970, McKenzie 1970, West 1970). Wishart (1970) reported that severe winter weather in Alberta, Canada caused prolonged emigration, starvation, and increased predation as well as depressed reproduction the following year. Even in southern regions, pronghorn are not immune to winter mortality. Many pronghorn trapped by drift fences froze to death during blizzards in the 1880s, and settlers killed 1,500 trapped by a drift fence in Texas in 1882 (Haley 1949).

g. Temperature

Low temperatures seldom are a major limitation unless combined with deep, crusted snow. Freezing temperatures and precipitation during fawning may cause mortality to newborns. The effects of high temperatures, while poorly documented (Yoakum 2002), nonetheless play a role in water loss, forage availability, and physiological functions (Brown et al. 2006). A few trees, especially in open areas subject to high temperatures may be desirable for shade.

2. Biotic

a. Vegetation

Ground cover in grasslands occupied by pronghorn ranges from 60-80% living vegetation (mostly grasses and forbs) with 20 - 40% being non-vegetated ground cover. In shrubsteppe and semidesert grassland habitats, the percentages are > 50% living vegetation and < 50% bare ground, rock, litter, etc. (Yoakum 2004*b*). Habitats used by desert pronghorn generally possess < 50% ground cover (Brown 1994).

b. Plant Composition

Generally, composition of vegetation is 5 - 15% grasses, 5 - 10% forbs, and 10 - 35% shrubs on shrubsteppes; and, the typical composition is 50 - 80% grasses, 10 - 20% forbs, and < 5% shrubs in grasslands (Yoakum 2004*b*). In semidesert grasslands in Arizona, grass cover averaged 15%, shrub cover averaged approximately 10%, and forbs cover was 2 - 10% (Ockenfels et al. 1994). Desertlands used by pronghorn may have < 10% shrub cover with annual grasses and forbs composing < 2% of the ground cover. The use of semidesert and desert habitats with tree cover is usually low, but increases during hot, dry periods when pronghorn use scattered trees or other structural cover for shade (Ockenfels et al. 1994).

c. Plant Height and Density

Low vegetative structure, ranging from 10 - 18 in. (25 - 46 cm) in height is preferred. Vegetation > 25 in. (64 cm) is typically avoided, and > 30 in. (76 cm) is infrequently used. Pronghorn may use areas having high shrubs while traveling to or from preferred habitats. However, reduced visibility or decreased mobility due to tall vegetation are important factors in pronghorn survival (Goldsmith 1990).

Pronghorn in Arizona use savannas if canopy cover averages < 20% and other vegetation is < 30 in. (76 cm) (Brown and Ockenfels 2007). Other special habitats include dunes in the Vizcaíno subdivision of the Sonoran Desert (Cancino et al. 1995) and "cholla forests" in northwestern Sonora and southwestern Arizona (Hervert et al. 1998).

Plant height and density are synergistic factors affecting pronghorn. Plants, including grasses, > 2.5 feet (0.76m) tall are detrimental to pronghorn and dense stands of such plants preclude the animal's presence. Conversely, shrubs and other plants < 18 in. (0.5m) tall are often advantageous to pronghorn, especially if the shrub cover is < 40%. Trees and tall shrubs > 2.5 feet (0.76m) tall should comprise < 5% of the cover, and a density of such plants > 15% may exclude the permanent presence of pronghorn. As a consequence, pronghorn are usually lacking from dense big sagebrush (*Artemisia tridentata*), greasewood (*Sarcobatus vermiculatus*), one-seed juniper (*Juniperus monosperma*), and other tall shrub communities, just as this animal has always shunned tall-grass prairies (Yoakum 2004*b*). Tree density in most pronghorn habitats in Arizona are typically < 2/acre (5/ha) (Alexander and Ockenfels 1994).

d. Plant Diversity

Within shrubsteppes occupied by pronghorn, the number of plant species averages 5 - 10 grasses, 10 - 70 forbs, and 5 - 10 shrubs (Yoakum 2004*b*). On grasslands the number of plant species averages are 10 - 20 grasses, 20 - 60 forbs, and 5 - 10 shrubs. Although semidesert grassland habitats exhibit similar diversity, most desert habitats < 5 species of grasses, 5 forbs, and 1 - 2 shrubs with some of the grasses and forbs being annuals. As a consequence, plant species richness may vary by month, with the greatest variety usually being in spring (Ockenfels et al. 1994).

Trees are often absent or scarce in grasslands and shrubsteppes. When present, species richness is usually ≤ 2 except in the Sonoran Desert where up to 5 species of trees may be present (Brown 1994).

Open landscapes consisting of a mixture of vegetative types are preferred in contrast to monotypic vegetation (Yoakum 1957, Sundstrom et al. 1973). Pronghorn also forage and often congregate in areas of recent wildfires as these burns typically produce regenerated grass growth and a flush of succulent forbs (Deming 1963, Yoakum 1980, Courtney 1989).

e. Key Vegetation

Key vegetative areas are those necessary to sustain a pronghorn population during critical periods (e.g., severe winters, droughts). The use of such areas may or may not be seasonal, and often depends on environmental conditions. Vegetative requirements for pronghorn vary widely in relation to land management practices, geographic location, climate, soils, and habitat types. Examples of key rangelands used by pronghorn include spring feeding areas (Becker 1972), winter range (Compton 1970, McKenzie 1970, West 1970, Taylor 1975), seasonal movement or migration routes (Berger 2004, Brown and Ockenfels 2007, Suitor 2011), areas having water (Sundstrom 1968, Beale and Holmgren 1975), and fawning areas (Einarsen 1948, Pyrah 1974, Autenrieth 1976).

Life History

1. Behavior

Due to the ease of observations, pronghorn behavior has been studied extensively. Northern pronghorn tend to winter in large herds, with animals of both sexes and all ages feeding and bedding in close association with minimal social conflicts. However, the sexes may remain segregated in areas experiencing mild winters (O'Gara 2004*a*).

Behavioral adaptations during winter to conserve energy include establishing hierarchies at feeding craters when pawing in the snow, selection of microhabitats with lower wind velocities and less or softer snow, reducing daily travel, traveling single file, and lying down during days having hard snow and low temperatures. During periods of high winds, pronghorn may lay down in compact groups with their heads curled back along their bodies (Bruns 1969).

Females typically isolate themselves prior to giving birth. By mid-summer, females are often found in female-fawn groups, with non-territorial males interacting with others in bachelor herds (Prenzlow et al. 1968, Kitchen 1974, Autenrieth and Fichter 1975). Dominant males are often territorial or strive to maintain a harem at this time.

The presence of territorial males (Photograph 9) ensures that bachelor males do not compete with females and fawns for forage on the best rangelands (Gilbert 1973). The most vigorous males do most of the breeding in either a territorial or harem breeding strategy (Byers 1997).

a. Movements and Migration

Pronghorn are an adaptable species that exhibit a wide range of movement strategies. Pronghorn change locations due to drought, blizzards, disturbance, and forage and/or water availability (O'Gara 2004*a*). Pronghorn migration is defined as traditional movement from one seasonal-use area to another, following approximately the same route year after year (Berger 2004, Sheldon 2005). According to Einarsen (1948) and Yoakum (1978), most pronghorn exhibit seasonal movements and relatively few populations now participate in traditional migrations. This assessment was made prior to the advent of global positioning system (GPS) and Argos technology, both of which have now allowed researchers to gain a deeper understanding of the processes, timing and frequency of pronghorn migrations across their range. Indeed it is now known that pronghorn can be either resident, or obligate or facultative migrations. Obligate migrations are movements made in anticipation of stressors (e.g., winter conditions), or migrations can be facultative, when animals move in response to actual weather conditions (e.g., winter storm) (White et al. 2007, Jacques et al. 2009, Suitor 2011).

The timing and length of seasonal movements are generally in response to changes in

Photograph 9. Territorial males' scent-mark vegetation to warn other males entering the area. Territoriality ensures that bachelors generally do not harass or compete for forage with pregnant or lactating females on rangelands in good ecological condition. Males may have territorial or harem breeding habits, or both, during different years in the same location. Photograph by Jim D. Yoakum.

climatic and vegetative conditions. In the northern parts of their range, pronghorn sometimes move up to 200 miles (320 km) in response to deep snow or to reach available winter forage (Riddle 1990). During dry seasons, southern pronghorn move in search of forage and/or water (Büechner 1950, Hailey 1979, Ockenfels et al. 1994).

b. Reproduction and Recruitment

Although pronghorn fawns occasionally breed (Wright and Dow 1962, Mitchell 1967, O'Gara 2004*b*), females usually breed the first time when 16 - 17 months of age. The gestation period, averages 252 days, and is long compared to similar-sized ruminants such as deer (*Odocoileus* spp.) (Hepworth and Blunt 1966). Most northern pronghorn breed during a short period from mid-September to early October (O'Gara 1968), while animals in more southern areas may breed from July through October (Lehman and Davis 1942, Büechner 1950). The mean number of fetuses per females in 6 studies involving 209 females was 1.94 (O'Gara 2004*b*).

Wildlife managers for pronghorn use "fawn recruitment rate" as an index for herd reproduction and survival of fawns to 4 months of age (Autenrieth et al. 2006). The rate is based on an estimated number of females and fawns during July or early August. Its major value is it gives an annual number of fawns surviving for a given site and time. The ratio is also used to guide the allocation of harvest permits. In Arizona, hunt management guidelines indicate permit decreases when fawn:doe (hereafter ff:dd) ratios fall below

30ff:100dd and increases when ff:dd ratios rise above 40ff:100dd (Arizona Game and Fish Commission 2011). When tabulated over a period of years, the rate indicates the trend in fawn numbers entering the breeding population. For example, for a summer estimate of 50 fawns and 100 females, the fawn recruitment ratio is expressed as 50ff:100dd. Ellis (1970) gathered information on ff:dd ratios and reported means ranging from 80 - 100ff:100dd in the Great Plains and 30 - 50ff:100dd in the Intermountain West. Fawn to doe ratios in the arid Southwest average less than other areas. Vriend and Barrett (1978) were the first to examine fawn recruitment rates across Canada and the continental United States from the 1948 - 1977. They concluded the geographic area comprised of southeastern Montana, southwestern North Dakota, western South Dakota, and Wyoming had the highest fawn recruitment rates, and fawn mortality during the first 3 months of life are naturally high (Vriend and Barrett 1978). Jones and Yoakum (2010) revisited the issue of low fawn recruitment rates by comparing 1953 - 1977 recruitment rates across Canada and the United States with those observed from 1978 - 2008. Higher fawn recruitment rates were observed during the first period than the second when the data was pooled. There was also higher fawn recruitment rates for 9 of 10 jurisdictions with sufficient data during the first than the second (Jones and Yoakum 2010). Jones and Yoakum (2010) also found fawn recruitment rates differed between jurisdictions and the 10 jurisdictions could be placed in 6 groups with similar means. Recruitment rates were different based on 4 vegetative communities with the highest recruitment rates observed in the tall-grass prairie. They concluded pronghorn naturally exhibit high mortality rates that are influenced by density-dependent (population size) and density-independent (precipitation) factors.

2. Diet Selection

Pronghorn food habits vary greatly as they occupy diverse vegetative communities in grasslands, shrubsteppes, and deserts. Pronghorn are selective opportunistic foragers, feeding on grasses, forbs, shrubs, and trees, depending on plant palatability and availability. More than 200 diet selection studies have been conducted during the past half-century (Yoakum 2004*c*) with 21 of these provided data on forage classes available as well as the percent composition taken each season. Preference ratings were calculated from these data for the grassland and shrubsteppe biomes (Figure 1). Thus, management decisions favoring an abundance of palatable forbs throughout the year are desirable (Yoakum 2004*c*).

Grasses are grazed most intensively during first green-up when shoots are 2 - 3 in. (5 - 8 cm) tall and highly nutritious. Pronghorn will consume dry grass, but not in large quantities. Short and fine-textured bunch grasses are preferred over large coarse bunch grasses. Annual and perennial forbs are grazed throughout the year when available. In the northern Great Basin shrubsteppes, Hansen et al. (2001) reported pronghorn consumed large quantities of perennial forbs during a mild winter with little snow covering small herbaceous plants.

There is another aspect related to the forage consumption, and additional interesting elements that need discussion. Zarn (1981) stated that "while many intake studies have been completed for domestic sheep and cattle, there remains virtually no data base for determining wild ungulates forage intake requirements, on a seasonal basis, for the widely

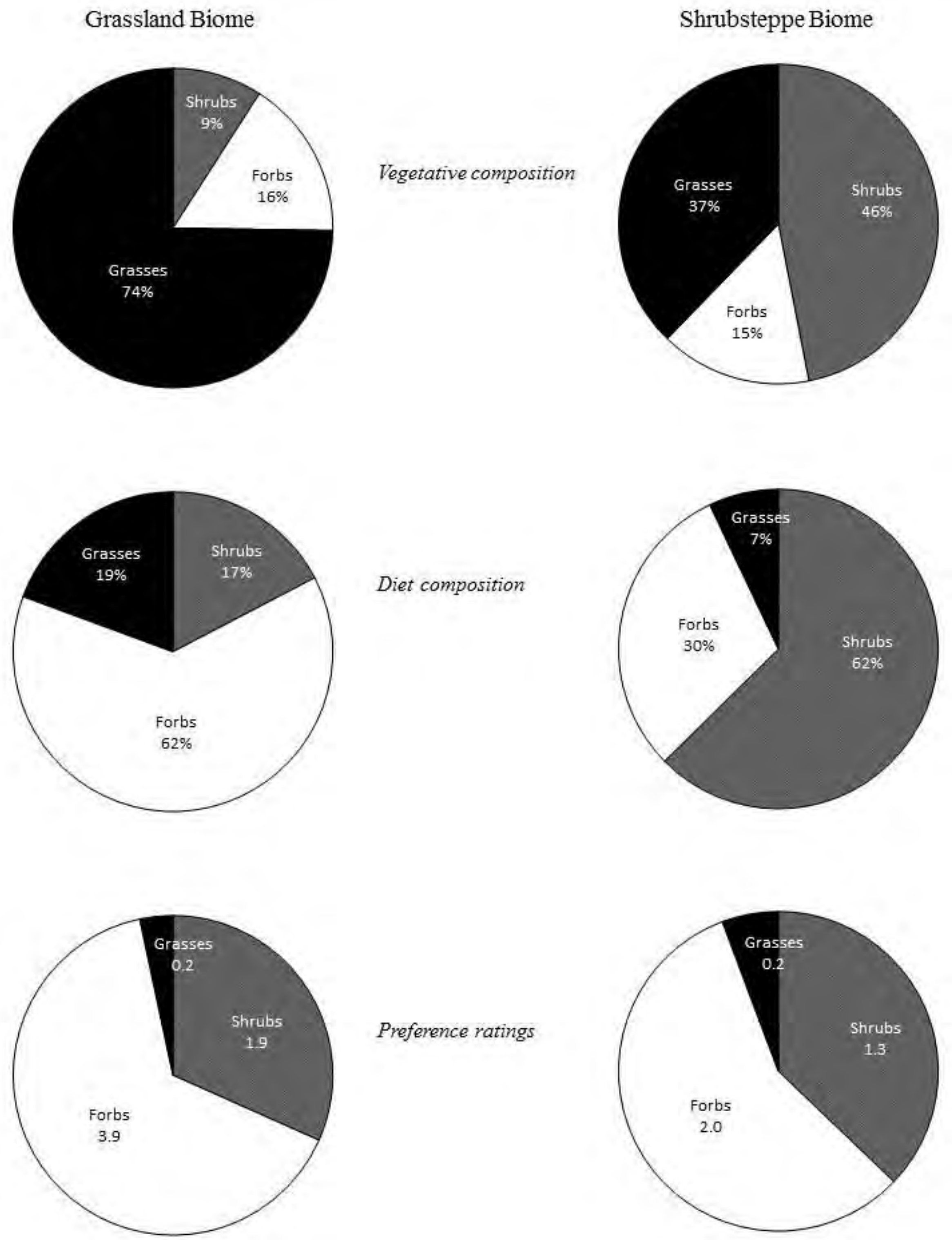


Figure 1. Vegetative and diet composition, and preference ratings for pronghorn year-long food habits in grassland and shrubsteppe (modified from Yoakum 2004*c*).

varying range conditions". This fact is still valid more than 30 years later. Quality of forage changes not just with the plant phenology, but also nutrient content, and should be evaluated locally. For instance, Barrett (1974) assessed different aspects of *Artemisia cana* consumption by pronghorn in winter. Drake (2009) studied the relationship between the food habits and diet quality at Anderson Mesa, Arizona. Hansen and Anthony (1999) included the evaluation of forages consumed for different ungulate species including pronghorn. Cancino (2001) reported proximate analysis for pronghorn, among other species, consuming mourning dove (*Zenaida macroura*) feces due to its salt content. The abundance and consumption of dove feces by pronghorn was under local and temporal conditions (i.e., there was an irrigation system in the Vizcaino Desert to promote the native vegetation growth) and the concluded dove feces salt content was similar to the content of salt blocks. Other local studies with different focuses are: Smith and Malechek (1974) in Utah, Jeffers (1985) in New Mexico, and Mix and Miller (2010) in Arizona.

Forbs may well be the most important forage class to pronghorn, for they provide greater amounts of nutrients than grasses or shrubs during late winter and early spring (Ellis 1970, Smith and Beale 1980, Hervert et al. 2000). This is the time of year that most parturient females are carrying two fetuses that grow rapidly during the third trimester of gestation. Pyrah (1987) referred to herbaceous plants as "production plants". Early summer is by far the most important season for consumption of forbs, as the female must obtain sufficient quality forage for her to nurse two fawns and, at the same time, maintain her health.

Shrubs, like forbs, are often consumed each month of the year, however, they are browsed in greater quantities during autumn and winter. Shrubs are "survival food" because they often are available during deep snow depths and during years of droughts. Shrubs often have greater concentrations of nutrients during the autumn-winter than spring-summer. Some of the lesser preferred shrubs are consumed in greater quantities during severe winters and droughts because nutritional forage is scarce.

While conducting studies of pronghorn for > 20 years on the grasslands of the National Bison Range in Montana, Byers (2003) concluded that rangelands with an abundance of succulent, nutritious forbs in the autumn-winter sustained heavier, larger fawns and had high survival rates during summer following parturition than those rangelands without.

Pronghorn mortality due to inadequate quality and quantity of nutritious forage is often not detected in the field. Then too, malnutrition may be a secondary mortality factor that is credited as an agent for killing animals (e.g., severe winters, droughts, entrapment in fenced pastures, predation) (Martinka 1967, Compton 1970, Ellis 1970, Riddle and Oakley 1973, Barrett 1974, Pyrah 1978).

Adult pronghorns require an average of 2.5 - 3.0 pounds (1.1-1.4 kg) of air-dry forage per day, and these animals consume < 1% of the forage produced on western rangelands (Wagner 1978). The amount of forage required by young animals is unknown. Pronghorn seldom suffer ill effect from eating normally toxic plants for domestic livestock and, at times, apparently relish them (Yoakum and O'Gara 1990).

Pronghorn often visit salt and mineral blocks used by domestic livestock. Their mineral requirements, however, remains to be quantified and requires further study (Yoakum 2004*b*). Pronghorn sometimes eat sand, soil, and even dove feces (Cancino 2001).

3. Parasites and Diseases

Extensive epizootics controlling pronghorn populations are uncommon. However, 33 species of roundworms, 21 genera of bacteria, 14 viral diseases, 8 species of protozoa, 5 species of tapeworms, and 4 species of ticks, one fluke, and a louse fly have been reported in or on pronghorn (Lance and Pojar 1984, O'Gara 2004*c*). The impact of most of these agents on free-ranging populations is unknown. Bluetongue is the most serious disease affecting pronghorn with approximately 3,200 pronghorn found dead from this disease in eastern Wyoming during 1976, and another 300 found dead in northeastern Wyoming during 1984 (Thorne et al. 1988). Bever (1950) reported the loss of 30 - 60% of pronghorn fawns in South Dakota, primarily due to parasitic worms. Bever (1957) found, with proper management of domestic livestock, no parasite-caused mortality occurred, but that rangelands overgrazed by domestic sheep resulted in high parasite loads in pronghorn in South Dakota. Tarrant et al. (2010) believed that parasite loads of *Haemonchus*spp. were an additional factor to fluctuating precipitation levels limiting pronghorn populations in the Trans-Pecos ecoregion of Texas.

4. Longevity

Pronghorn seldom live > 9 years under natural conditions (Einarsen 1948, Hepworth 1965), but Trainer et al. (1983) reported collected females living as long as 16 years as determined by tooth sectioning. In their northern range, pronghorn are susceptible to frequent winter-kill (Einarsen 1948). Winter-kill is rare in more southern ranges, but can be catastrophic when it does occur (White 1969). Advancing age and disease also reduces survival. Hunting is generally strictly regulated and most of the harvest is males (O'Gara and Morrison 2004). As a result, male survival is often less than that of females. Predation is not considered a primary factor in adult survival. Four major fawn predators are common throughout most of the pronghorn range: coyotes, bobcats, golden eagles, and domestic dogs. Mountain lions are a concern in rugged terrain in the Southwest (Ockenfels 1994*a*, *b*). Other mortality factors include poaching, crippling, road kills, toxic poisoning (Hailey et al. 1966), fence entanglement, parturition complications (Canon and Bryant 1992), starvation, drought, and natural accidents (Einarsen 1948).

Adult survival rates vary by gender and by area. Hunting management strategies, weather, density of vegetation cover, and ruggedness of terrain are significant factors affecting survival rates. Annual survival rates may be as low as 0.55 (Mitchell 1980) or approach 1.00 (Canon and Bryant 1992, Ockenfels 1994*a*, O'Gara 2004*a*, *c*).

MANAGEMENT RECOMMENDATIONS

Population Surveys

Survey methodology depends upon the survey objectives and the local habitat characteristics, population density, and distributions. One technique may be better suited for certain conditions than others, such as with low density herds, populations with very clumped distributions, etc. Animal disturbance is an important consideration with ground and aerial surveys. High flying (> 300 ft (90m)) fixed wing aircraft causes the least disruption, with low flying helicopters causing a greater disturbance. The best methodology is usually conducted with aerial surveys using either fixed-wing aircraft or helicopters, with a skilled pilot and observer(s) allowing for more representative coverage.

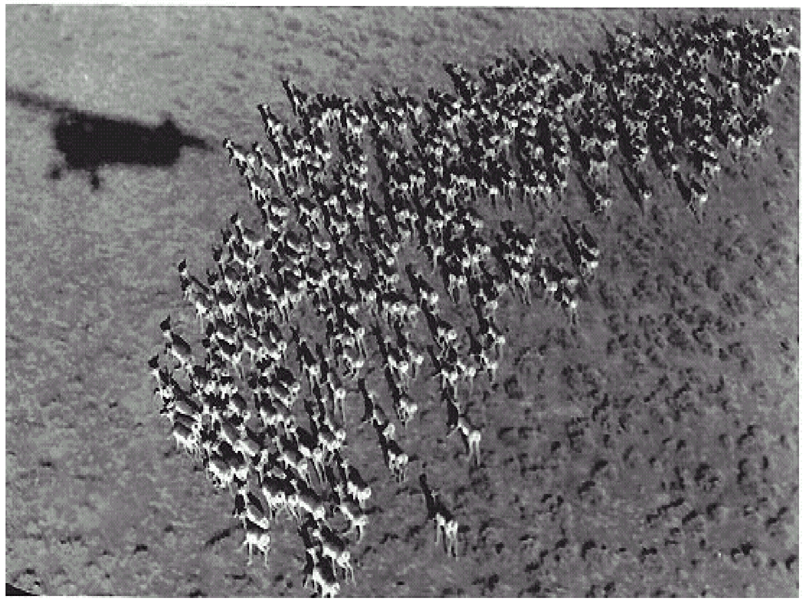
Skill level and alertness are important to rapidly classify and count pronghorn, thus avoiding the need to remain close to the animals or having to make multiple passes. If multiple passes must be made, it is important to refrain from running the animals for long distances or for any length of time in order to reduce the amount of stress that accompanies any survey. The survey team needs to be careful not to run animals into sample areas where they might be counted again.

1. Population and Composition Counts

Pronghorn inhabit open terrain making the animals relatively easy to observe (Photograph 10). Observers can therefore get a false sense of security when conducting an aerial survey designed to estimate population density and herd structure. Although easily visible under most conditions, pronghorn can also be very cryptic in some situations, which leads to significant biases in making population estimates. However, obtaining useful and reliable population data is possible by following statistically sound sampling methods and by maximizing the search intensity of the area to be sampled.

Unfortunately, the ideal is not always possible and pronghorn managers have relied on trend counts, wherein those animals seen serve as indices of population size. Detection of changes in population size therefore depends on the precarious assumption that counting conditions have been standardized, and that the percentage of animals counted is similar from one survey to the next (Nichols 1992). In Wyoming, extensive line-transect samples indicate that traditional methods have consistently underestimated pronghorn numbers. Therefore, Wyoming is continuing to explore refinements in the line-transect method to further improve the reliability of their annual abundance estimates. Lee (2000) and Pojar (2004) discussed various wildlife survey techniques and factors that affect survey results.

The time of the survey has a profound effect on survey results and reliability as pronghorn group size and distribution vary throughout the year (Kitchen 1974, Mitchell 1980). Group size and distribution become important when choosing an effective sampling



Photograph 10. While conducting a winter survey, the photographer took this scene of the shadow of his fixed-wing aircraft and a herd of > 270 running pronghorn on the shrubsteppes of southcentral Oregon. Although easily visible under most conditions, pronghorn can also be very cryptic in some situations. Photograph by Eastman Studio, Susanville, California.

unit for a sample-based survey. Surveying dispersed subjects is an advantage in reducing the variance (i.e., increasing the precision) of sample-based statistics (Allen and Samuelson 1987, Johnson et al. 1991). Pronghorn are most dispersed during the May - June fawning period, and remain in relatively small groups through late summer (Mitchell 1980). Therefore, sample-based surveys generally have relatively lower variance if done during the May - August period. After mid-July, young of the year join adult groups, making it possible to include them in the survey results and thus obtain fawn to female ratios.

a. Estimating Population Size

Sample-based aerial surveys which account for detection probability are a means of estimating total population size and, in addition, offer a significant savings in flight time over attempts at total coverage (Johnson et al. 1991). Normally, density (number/unit area) is estimated using a sampling technique and then that estimate is applied to a known region to estimate the total population. Some sampling techniques applicable to pronghorn surveys are: (1) strip transects, (2) line transects (distance sampling) (Photograph 11), and (3) quadrants. However, use of a sound sampling design does not ensure an unbiased total population estimate; search efficiency and the observability of the subjects influence the accuracy of the estimate. The assumption, common to all sample-based systems, is that all subjects in the sample unit (e.g., strip transects, quadrants) are counted in order to obtain an unbiased estimate. There are a number of approaches to correct estimates for the probability of detection when detection is imperfect within the sample unit, which require additional

Photograph 11. The line-transect method can also be done with fixed-wing aircraft, which cost about 25% as much to rent as helicopters; no on-the-ground markers are needed if a navigation system such as GPS or Loran C is used; and confidence limits can be calculated by double sampling and then calculating a population estimate. Photograph by P. Wertz, courtesy of California Department of Fish and Game.

data be collected and used in the analyses. In line-transect sampling there is also the assumption that no animals are missed on the transect line (e.g., center line or one side of the aircraft) or in the first distance interval from the center line (Burnham et al. 1980). Animals can be missed in other distance intervals and not invalidate the method. Ideally, some means of estimating search efficiency should be employed on a portion of the sample units so that adjustments can be made for biases. For line transects, double sampling is always prudent, or results should be compared to known density areas (White et al. 1989). Unless strip transect data are corrected for bias by double sampling, distance interval data (line transects) should be collected to provide a correction for missed animals (Burnham and Anderson 1984, Graham and Bell 1989). A more appropriate approach would be to conduct the survey as a true line-transect survey, maximizing the probability of seeing all the pronghorn groups on the line. Distance intervals alone can help detect problems but the observer may be looking farther out, resulting in an increasing function with distance that can be confounded by group size bias (larger groups easier to see than small ones or singles), movement away from the aircraft, or observers scanning too far out where detection is poorer. Otherwise, only an unknown fraction of the population is counted and the nagging question, ubiquitous in wildlife inventories, persists - "How good are the survey data"?

The demand for more precise management necessitates better population estimates, which allow managers to base decisions on better data rather than only indices or trends. However, no technique will be perfect. Procedures are available to correct for biases in surveys and should always be employed at some level depending on management needs.

Eberhardt (1987) demonstrated a double sampling technique to calibrate indices with estimates of population size. Observability models based on radio collared animals also provide reasonable corrections for survey bias where group size and vegetative cover are factors (Samuel et al. 1987). Smyser (2005) developed a sightability model for pronghorn using double observers in a fixed-wing aircraft. Capture-recapture models offer other correction possibilities (Nichols 1992, White 1996, White and Burnham 1999). The intense search of quadrants using a helicopter resulted in an upward population correction of only 2.1% (Pojar et al.1995). This study suggests that intensive helicopter searches of relatively small sample units can be used in a double sampling scheme to correct survey information that, while less expensive to execute, produces less trustworthy population estimates.

The line-transect method (Burnham et al. 1980, Buckland et al. 2001) has been used successfully in Wyoming mid-May - June, when pronghorn are widely dispersed and highly conspicuous against the green background (Johnson et al.1991, Guenzel 1997). This technique uses distance from the transect and group size to estimate the detection probability. The line-transect estimates tend to be higher, as would be expected when you account for not seeing all the animals that were in the strip, and although not tested against known density or double-sampling surveys, this survey method produced population estimates that were consistent with population modeling trends and is used to calibrate simulations.

The line-transect method offers several attractive features: 1) it can be done with fixed-wing aircraft, which cost about 25% as much to rent as helicopters; 2) no on-the-ground markers are necessary if a navigation system such as GPS is employed; and, 3) confidence limits can be calculated for the population estimate. This method is far superior to total coverage by strip transects because it is more efficient and the "accuracy" of any estimates are subject to tests of variance. Procedures for line-transect data analysis have been provided by Guenzel (1997) and Burnham and Anderson (2002), while software for completing the analysis (called DISTANCE) is available to be downloaded from: http://www.ruwpa.st-and.ac.uk/distance/.

Fixed-wing line-transects and helicopter quadrant surveys were compared for accuracy by Pojar and Guenzel (1999) on northern pronghorn range (Colorado/Wyoming) where pronghorn densities are approximately one animal per 0.37 – 0.58/mile^2 (one animal per 1-1.5/km^2). Helicopter survey results were used as the standard to compare with the more economical fixed-wing line-transect method. Helicopter quadrant surveys are believed to provide the least biased estimate of pronghorn density of practical survey methods available (Pojar et al. 1995). Line-transect survey estimates averaged 0.735 of quadrant estimates (Pojar and Guenzel 1999). Based on these line-transects, managers should adjust estimates by either dividing by 0.73 or multiplying by the inverse of 1.37 to get a more accurate estimate of total population size. Given the sampling intensity of this study, the precision was similar for both methods; 90% confidence intervals were + 24 - 29%. In other areas or during different times, corrections could vary among surveys based upon detection probability and conditions.

There is good evidence that the major assumption of the line-transect method (i.e. that all subjects in the innermost distance band are seen) is not being met. The severity of assumption violation depends upon several factors including observer experience, groundspeed, light conditions, and background. Guenzel (1997) stresses the importance of training and close adherence to line-transect protocol as a means of minimizing biases. Double sampling, in which two observers independently record their observations is also highly recommended (Pojar and Guenzel 1999). Other approaches to correcting line-transect estimates for imperfect detection of pronghorn on and near the line exist. Program DISTANCE includes options to incorporate other data (e.g., covariates) and corrections (e.g., multipliers) in the analysis. Smyser (2005) developed a pronghorn sightability approach that could be incorporated with line-transect sampling. Laake et al. (2008) showed how estimates from aerial pronghorn line-transects could be corrected for biases due to variation in height above ground and airspeed.

When money or expertise is unavailable for an aerial survey, and field conditions permit, a ground or spotlight survey may be the best alternative to an aerial survey. Clemente (1992) experimented with walking and driving spotlight censuses of pronghorn and recommended driving road transects where roads are distributed in most of the survey area and vehicle traffic does not affect the presence of pronghorn. If such surveys are to be useful, the animals must be visible from a vehicle and not obstructed by vegetation and have eyes that reflect light. As with most surveys it is highly desirable to be able to do a series of transects in a minimum amount of time. Double observer approaches similar to those suggested for aerial surveys have been applied to road-based surveys. A drawback to road-based surveys is that they usually are non-random with respect to the pronghorn distribution and animals' avoidance of roads.

Significant time and resources will be saved if a competent statistician is consulted during the design phase of a survey. A major reference on the methodologies of estimating animal populations is Seber (1982) or Krebs (1999). Data from previous surveys can be very helpful in designing future surveys and evaluating whether or not the planned effort will provide the reliability desired for the survey.

b. Fawn to Doe Ratio Surveys

The best time of year for conducting surveys in most of the pronghorn's range is during late summer. By this time, the initial surge of postnatal fawn mortality has subsided and fawns are still distinguishable from females.

There are three important factors for a reliable estimate of ff:dd ratios: an adequate sample of the population must be observed, an accurate classification must be made, and a representative sample of the population must be obtained.

The first requirement of accurately classifying males, females, and fawns is relatively easy if the survey is done during late summer. Obtaining a random sample of the population to be surveyed is an important factor that is sometimes overlooked. If the sample is not representative of the population, the ff:dd ratio may be biased. Pronghorn distribution is determined by the location of food, water, and cover, and cannot be assumed to be a random distribution. Also, groups are not a random collection of individuals but a function of social structure in which different groups may be using different habitats. To circumvent potential bias in areas where the entire pronghorn habitat is not being surveyed, surveys should be conducted in randomly selected sample units, either strips or quadrants.

Another important factor for obtaining reliable ff:dd ratio estimates is determining the number of animals to classify. The Arizona Game and Fish Department (1993) analyzed historic survey records to determine adequate sample sizes to produce acceptable survey confidence intervals. These data showed it would be necessary to survey approximately 88% of the total population if the estimated number of animals is between 200 - 300, 57% if the number is 500 - 700, and 50% if the population is > 1000 to get reasonable confidence limits for management purposes. Czaplewski et al. (1983) looked at proportions assuming a binomial distribution based upon two populations: males and females and females and fawns. The closer the proportion of males or fawns to 0.5, the larger the required sample size. They developed a chart of sample sizes required to obtain prescribed confidence intervals for ratio estimates. They assumed pronghorn are randomly distributed and that groups are formed of random individuals; seldom, if ever, is either assumption valid. However, their chart may be useful as a general guide for the number of animals to be classified and used in conjunction with a randomized sampling system. The randomized sampling system can be the same as, or a modification of, the system used to estimate population size. If possible, the surveys should be conducted from a helicopter as these maneuverable aircraft can fly low and slow, thereby minimizing classification errors. Classification surveys from fixed-wing aircraft often require flying lower than for abundance estimates, so safety is of greater concern.

If it is not possible to use an aircraft, either fixed-wing or helicopter, to do ff:dd ratio surveys, a ground survey can also obtain acceptable results. The sampling system described by Bowden et al. (1984) was modified to survey a 4,500 mile^2 (11,655 km^2) area of short-grass prairie in northeastern Colorado. Random ground routes, following established roads, were driven or walked by 2-person crews and all observed pronghorn were classified. The ground-route ratios were comparable to those obtained on fixed-wing surveys taken a few days later in the same area.

c. Buck to Doe Ratio Surveys

Late summer is also an optimal time to conduct male to female (hereafter bb:dd) ratio surveys. Later surveys are less desirable as it is important that fawns can be distinguished from females to get accurate bb:dd ratios. After October 1, early fawns can be mistaken for adult females, which inflates the female count and widens the bb:dd ratio.

Because males do not associate as consistently with females as do fawns, the estimated ratio of males to females is more variable than the ff:dd ratio. Males frequently are seen in all-male groups or as singles; fawns are almost always seen with females. This behavior is responsible for a higher variance in bb:dd ratios than ff:dd ratios. Given the same sampling intensity, the bb:dd ratio will be less precise than the ff:dd ratio. For example, if the ff:dd confidence interval (90%) is ± 10 percent, the same sampling intensity might yield a bb:dd ratio confidence interval (90%) of ± 30 or more percent.

The potential for serious bias in estimates of bb:dd ratios is real. Buechner (1950) noted that isolated males did not flush from helicopter noise as readily as groups, and Firchow et al. (1990) observed that females moved sooner than males from quadrants that were repeatedly surveyed by helicopter. Therefore, an intensive search of a sample unit may be needed to detect all males present. Using a helicopter to search strip transects and mile square (2.59 km^2) quadrants, Pojar et al. (1995) obtained significantly lower ($P<0.10$) bb:dd ratios from strip transect estimates than from quadrant estimates. They attributed this difference to the more intense search of quadrants, which flushed single and small groups of males not flushed during the transect search. Since most herd structure estimates are made from fixed-wing aircraft that are flown at 80-120 mph (130-190 kmph) and 300 feet (90 m) altitude, there is considerable potential for misclassifying animals and for missing animals that do not flush. Ideally 300 feet (90 m) above ground level is acceptable for searching for groups, but to classify animals it is recommended they drop down below 200 feet (61 m). Woolley and Lindzey (1997) found bb:dd ratios from the air were lower than for ground surveys of the same areas. Some yearling males may be misidentified as females from aerial surveys.

As with ff:dd ratio estimates, it is important to accurately identify observed animals, obtain a random sample of the population of interest, and classify an adequate number of animals to obtain reasonable precision. In addition, the search of sample areas must be intense enough to flush small groups or single males to get an unbiased estimate of the bb:dd ratio. The interpretation of adult sex ratios can be confounded by several factors including harvest rates and density (Hoffman and Genoways 2012). Additional demographic data are required to interpret age and sex ratios (Caughley 1974).

Population Models and Estimates

Efforts should be made to develop valid simulation models to better manage pronghorn populations (Salwasser 1980, Gasson and Wollrab 1986). A review of the various population models used to manage pronghorn is provided by Kohlman (2004). Simulation models also assist in collating available survey and hunt data, and making reasonable population projections (Pojar 2004). As demand for pronghorn resources increase, it will become increasingly important to refine harvest strategies to maximize recreation, while ensuring that the resource is protected. Population simulations can provide better definition of herd units, help organize data collection, and stimulate better methods of data collection. Building a simulation model also serves as a learning experience because managers cannot replicate the structure of a population, manipulate that population, and judge the validity of their data without becoming increasingly aware of the complex interactions occurring. A better understanding of population dynamics and the ability to generate and explore management options before implementation can only lead to more enlightened management.

Several computer programs such as “Vortex” have been developed to model populations. “Vortex” has been used to model endangered pronghorn populations in Sonora and Baja California Sur (Cancino et al. 1995, DeVos and Thompson-Olais 2000, Hosack et al. 2002). This model is specifically designed for population viability analysis and works well with low population numbers and includes both stochastic events and deterministic forces (Miller and Lacy 1999).

For many years, biologists in Wyoming used the POP-II computer program developed by Fossil Creek Software, Fort Collins, Colorado to simulate herd dynamics and harvest responses. Wyoming estimates pronghorn abundance for each herd about every 3 years with line-transects or “trend counts” which are then used to align population models. The survey data, together with harvest, sex and age composition information are then used to simulate population dynamics. Wyoming and Colorado are moving away from POP-II and using a spreadsheet simulation model developed in Colorado (White and Lubow 2002). These spreadsheet models better incorporate the types of data collected by agencies and make better use of survival rates obtained from telemetry studies.

These models work partly off changes in ratios. To facilitate modeling, populations are defined as those animals having < 10% interchange with adjacent populations. For modeling purposes it is essential to obtain adequate sample sizes of data on herd composition and unbiased harvest data. One advantage of modeling is that it identifies poor quality data. In many instances, having better data may be more important than the specific form of the simulation model.

Pronghorn are perhaps the easiest species to model because they are the most observable. The principal value of models is to project pronghorn populations into the future, and calculate the numbers, sexes, and ages of animals that need to be harvested to meet management goals. Hunting as a management tool has been challenged in the past and will continue to be challenged by anti-hunting groups. Population modeling provides support (not always accepted) for controlling and managing populations by hunters. Population models also allow wildlife managers, land managers, and public land users the ability to engage in productive discussions regarding the management of the pronghorn population in question and the habitat it occupies.

1. Pronghorn Population Estimates

Pronghorn numbers have been estimated on an irregular basis for over 70 years. Using survey data, population estimates are calculated for particular herds, for game management units and other specified areas, for states and provinces, and even for nations. The first reliable large-scale population estimate based on survey data was a compilation by Nelson (1925) for North America. Later, during the 1930s and 1940s, the U.S. Forest Service and the U.S. Fish and Wildlife Service compiled estimates for the national forests and the U.S. Since then Yoakum (1968, 1978, 1986, 2004*a*.) prepared estimates of populations based on questionnaires sent to state and provincial wildlife agencies in Canada, Mexico, and the United States. Such documentation is necessary for tracking long-term population trends and determining reasons for changes. Pronghorn numbers should be compiled every two years in conjunction with the Pronghorn Workshop. Such documentation on a province-by-province or state-by-state basis can be compared with land-use changes, weather, management practices, and other phenomena to better understand reasons for population increases and decreases. Such monitoring can best be accomplished by each provincial or state wildlife agency, but one organization should be in charge of compiling total population numbers for Canada, Mexico, and the United States, and ensuring that all data were obtained by similar procedures. The survey results of each state and province should, and have been, published in the Proceedings of the Biennial Pronghorn Workshops, which are sanctioned by the Western Association of Fish and Wildlife Agencies.

Pronghorn numbers are normally surveyed one or two times during the year—a July or August survey that estimates fawn recruitment (ff:dd) and male ratios (bb:dd), and a winter survey to estimate pronghorn numbers after the hunting season or a spring survey to estimate numbers just prior to fawning. State and provincial agencies traditionally have used the summer survey results for reporting annual herd sizes. Within the last few decades, however, some state wildlife agencies have reported annual population figures based on post-harvest (winter) surveys that reflect the time of year population objectives are set. When these are compared to other agency estimates, it is necessary to make sure that all numbers were obtained using comparable procedures for comparable areas during the same time of year. For example, some agencies allow legal harvests of from 10% - 40% of a given herd or herds. This harvest, coupled with crippling losses and illegal kills, can result in much smaller post-hunt population than was present the previous summer. Therefore, it is imperative that state and province surveys estimating total herd size are based on data derived through similar methods obtained at similar times of the year.

Harvest Management

After habitat management, harvest management is the most practical and effective method to ensure that pronghorn remain stable and viable components of the North American ecosystem. Population regulation is also necessary to keep the animals in balance with variable levels of human tolerance and to meet the demand for recreational use of pronghorn and their habitats. Information on harvest management is based on O'Gara and Morrison (2004) unless otherwise cited.

Human dependence on wild game for food has given way to other motivations and objectives for hunting, although meat is still an important component of the hunt. Early settlers in the West did not concern themselves with regulating the harvest of pronghorn, but took what was needed to feed and clothe themselves and their families. Unregulated market hunting took a significant toll on wildlife populations, including pronghorn. By the beginning of the 20th century, government agencies and sportsmen's organizations sought to regulate harvest to prompt the recovery of many species that had been overexploited. From that fairly recent origin, the science of wildlife harvest management has made extraordinary advances in helping the recovery and sustainability of pronghorn and other wildlife. A boon to pronghorn management was the practice of maintaining harvest records. As the environment continues to be altered and as human demands for wildlife expand and shift, harvest management strategies must be continually refined and improved.

Pronghorn harvest regulations fall into two categories, those that manipulate the type and number of animals harvested, and those that "manage" the hunter. Regulating the type of harvest includes setting the bag limits, season lengths, legal weapons, number of permits, and other rules to ensure that a strategy-specific number and sex composition of pronghorn are harvested. In many states, politics dictate the "correct" system as much as biology. Regulating the hunter consists of various restrictions of hunter behavior to assure that hunts are conducted legally, safely, and ethically, and to maximize the opportunities for participation and harvest within the guiding principle of sustained yield.

Today's pronghorn managers need to establish long-term goals for pronghorn populations and their habitats relative to current and projected demands for the use of pronghorn and pronghorn habitat. Based on such goals, management is defined by objectives and refined by short-term strategies. At all levels of planning and action, the needs of the resource, consumptive and non-consumptive users, and the landowners (public and private) must be considered and meshed if the goal is to be achieved. When developing harvest recommendations, several factors must be addressed. These include, but are not limited to, habitat conditions, sex and age ratios, other uses of an area's resources (both animal and plant), pronghorn behavior and hunter behavior (success rate, hunter density, hunter satisfaction, etc.).

Nearly all pronghorn hunting in the U.S. and Canada is via limited-quota or limited-entry licenses. In some states only residents are allowed to hunt pronghorn; in other states residents and non-residents are treated equally except that non-resident licenses and tags are priced measurably higher. In other states, a larger portion of the license quota is reserved initially for residents. Some agencies have implemented a preference point drawing system to address high demand for certain licenses in highly sought hunt areas. These restrictions reflect the low numbers of animals in some states, and the need to distribute hunters into certain areas, even in states with abundant pronghorn. Because pronghorn are very visible, most hunters will be successful, and most will kill a male unless required to do otherwise by specified permits. If the number of licenses to take "any pronghorn" are too high, the bb:dd ratio will widen, and it becomes difficult to attract hunters because of proportionally fewer and smaller males. Some people want to hunt only on public land and want trophy animals. Ranchers generally want pronghorn numbers held in check, but also want to charge for hunting (U.S. only), which discourages some hunters and may make licenses in areas of private land difficult to sell. The manager must consider all of these facets while maintaining some control of pronghorn numbers. No legal hunting of pronghorn has been allowed in Mexico since the species was protected by decree in 1922.

1. Habitat Considerations

Habitat is a prime factor in the establishment of harvest objectives. Abundant, quality rangelands during one season of the year cannot make up for poor quality rangelands during another. All elements of the animal’s annual habitat requirements must be considered, including use of movement corridors between seasonal rangelands. These corridors may be critical because of fences, roads, developments, or other barriers to movements. Also, assessment of habitat needs must consider "worst scenario" conditions that result from occasional severe winters, droughts, or other natural or human-related catastrophes. Seasonal distributions play a role in harvest management. Animals may be on one landowner’s property during the hunting season and on other lands in perhaps excessive numbers at other times of the year. In addition, migratory herds may experience multiple hunting seasons in some jurisdictions (i.e., Alberta (Suitor 2011)).

Too many or too few animals may occupy a particular rangeland, relative to habitat conditions and other management considerations. Harvest objectives must then be set to balance pronghorn numbers with habitat conditions in accordance with objectives developed to maintain animal numbers according to ecological, public, and bio-political factors. With proper harvest management, a pronghorn population can usually be balanced with its habitat within several years. In most cases where harvest strategies are used to increase or decrease a pronghorn herd relative to biological considerations, the strategy is implemented in concert with a program of habitat management. In Wyoming, where pronghorn are numerous, the numbers of licenses issued are based on the status of the herd (above or below population objective), potential for damage to stored or standing crops, and reproductive rates. Harvest rates range are 8 - 40% ($\bar{x} \cong 20\%$) in herds above objective and 6 - 28% ($\bar{x} \cong 15\%$) in herds below objective. The wide range in percentages taken from herds either above or below population objectives is related to depredation problems and recruitment rates. Naturally, a herd with 65ff:100dd cannot withstand as much hunting pressure as a herd with 120ff:100dd. Managers should consider harvesting females as many as 3 - 4 years before a herd reaches its population objective.

Securing an adequate harvest can be a problem in areas with large pronghorn populations during periods of high pronghorn numbers. The Wyoming experience indicates some of the techniques that have been used to address the problem. To control numbers of pronghorn, Wyoming began issuing licenses that required the hunter to take a female or fawn. "Any" pronghorn licenses were issued through drawings to prevent the over harvest of males, and hunters who drew an “any” pronghorn permit could then purchase female/fawn licenses over the counter. At first, only one or two female/fawn licenses were allowed per hunter. To make them more appealing, these licenses were sold for full price until opening day, and then the price was halved. Later, hunters were allowed 3 female/fawn licenses, then, unlimited numbers of such licenses could be purchased three days before the hunting season. As of 2012, Wyoming hunters could obtain up to 4 of these female/fawn licenses. These procedures were necessary to overcome the resistance of hunters to shooting females and fawns and to still obtain the needed harvest. In many cases, getting additional hunters into an area was difficult, so allowing hunters already there to kill more females was a logical solution.

2. Buck to Doe Ratios

Desired bb:dd ratios depend on the management goals set by wildlife agencies for particular pronghorn populations. A ratio of 25bb:100dd should be maintained for maximum recruitment into a population according to Salwasser (1980) and Hailey (1979). If the objective is to produce the maximum number of trophies, the bb:dd ratio should be $\geq$ 50bb:100dd (Hailey 1979). Unlike some other ungulates, younger pronghorn males, < 5 years of age, possess the largest horns (Mitchell and Maher 2001, Brown et al. 2002, Morton et al. 2008). With this ratio, there will be a relatively large number of males in the population, and many of them will be 3 - 4 years old or older; the age of most trophy males (Brown et al. 2002, Morten et al. 2008). Hunting permits then can be regulated to leave enough 3 and 4-year old males in the population to produce trophy horns. If the pronghorn management objective is to reduce the herd, prescribed bb:dd ratios can be maintained by issuing female/fawn permits and/or issuing hunters multiple permits. Although narrower male ratios may be desirable for trophy hunt objectives, a post-harvest ratio of 20bb:5100dd is biologically safe and probably within the number of males needed for complete breeding (Salwasser 1980). Buck to doe ratios, however, are sometimes set for political, not biological, reasons.

3. Timing of Seasons

Pronghorn have traditionally been hunted mid-August - mid-October. Throughout most of their range, pronghorn shed their horn sheaths starting in late-October, after which time the trophy quality of the males is decreased and differentiating males from females is more difficult. Hence, most states and provinces attempt to set hunting seasons before shedding occurs.

Game managers in a few states attempt, when possible, to hold concurrent deer and pronghorn seasons because non-resident hunters often travel long distance and do not want to spend travel money to hunt only one big game species. Availability of multiple licenses for one species also attracts out-of-state hunters. Concurrent bird seasons may also be used to turn pronghorn hunts into combination hunts.

A concern in determining the dates of pronghorn hunting seasons is that traditional season dates frequently coincide with the breeding season. Copeland (1980) indicated hunting during the pronghorn breeding season caused dominant males to abandon their harems and territories in a heavily hunted and geographically confined population in Idaho. The harvest of dominant males resulted in chaotic breeding in groups that included males of all age classes and increased harassment of females. Deblinger and Alldredge (1989) found a similar situation in Wyoming. However, because rifle hunters usually only remained in the field for one or two days, males were again actively defending their territories by the third day of the season. In Wyoming, pronghorn apparently have been hunted during the rut since open seasons were resumed in 1934. The state has more pronghorn than any other, a high pronghorn fawn survival rate, and many fine trophies are taken every year. Forrest (1985) used Wyoming Department of Game and Fish records to investigate the effect of hunting during the rut on reproductive rates. She found no statistical difference between areas, and killing dominant males did not appear to decrease ff:dd ratios. Even though Copeland (1980) observed significant social disruption from hunting during the rut, he could not show any adverse effect on subsequent ff:dd ratios.

Criticisms of hunting pronghorn populations during the rut include a supposed premature depletion of the females' energy reserves, that are vital to winter survival, and breeding by immature or inferior males that may contribute to lower genetic vitality. These concerns have yet to be proven; nonetheless, legitimate harvest management objectives such as providing recreation to the sporting public and adjusting pronghorn numbers to a goal-oriented level need to be carefully considered and weighed against weather, hunter pressure, hunter success, etc., when recommending hunting season dates.

If a hunt is set at the optimum time for hunter convenience, breeding may be disrupted and males in prime breeding condition may not be prime table fare. This dichotomy of choices generally confronts managers and has significant bearing on other harvest recommendations, such as length of season and the definition of legal animals. For this reason, harvest management decisions must be made on the basis of reliable, recent data carefully analyzed by experienced managers.

4. Length of Seasons

Season length depends principally on numbers of pronghorn to be harvested in an area and the type of legal weapon allowed. Seasons in various states and provinces are 2 days - 2 months. There are no pronghorn seasons in Mexico, and in states having only token populations. New Mexico restricts rifle and muzzleloader hunters to 2 - 4 days, while allowing archers 9 days while maintaining success rates of approximately 80, 50, and 30% respectively (R. Walker, personal communication). These are conservative seasons, especially for archers, and are dictated as much by administrative convenience or landowner pressures as by biological criteria. Montana, in contrast, had a 65-day archery season and 29-day general rifle season in 1991 with the last 29 days of the archery season concurrent with the rifle season.

Copeland's (1980) study in Idaho indicated that long, intense hunts were disruptive to pronghorn breeding, and he recommended that no hunting be allowed 15 September - 10 October. In the states with the most pronghorn, Wyoming and Montana, archery seasons may last $\geq$ two months and continue through the rut. Rifle seasons may run concurrently with archery seasons for as long as a month. Although this sounds like excessive disturbance, the density of archery hunters is low, due to the vast geographic areas occupied by pronghorn.

During the first weekend of the rifle season most of the permitted hunters are in the field, and about 90% of the harvest is taken; therefore, little disturbance to pronghorn occurs for the rest of the season. Several agencies schedule their hunts after the breeding season, that may be the best procedure for the long-term welfare of the species.

5. Legal Weapons

Harvest success and hunting opportunity objectives often dictate the type of weapons legal for hunting pronghorn in a particular area. Depending on the pronghorn population objective, most archery hunts have liberal bag limits and/or long seasons because of the low success achieved by bow-hunters. Innovative archers, however, continue to increase their success by hiding in blinds near water sources, using decoys and calls during the rut, and utilizing more sophisticated equipment. During the 1981 - 1983 archery seasons in Arizona, the average harvest success was 7%; a decade later in 1994 - 1996, archery hunt success in that state had increased to 18%. In northwest Colorado, where archers often use pit blinds near water, success typically exceeds 60%. Managers can usually provide more opportunity to more people with archery hunts while minimizing the impact on pronghorn. An exception to this low impact may occur when hunters wait at water sources in arid areas and cause the animals to avoid drinking. Muzzleloader and other special-weapons seasons, such as handgun hunts (Ochs 2000), usually have higher success rates than archery hunts, but their seasons still can be lengthier and with a more liberal bag than modern rifle hunting seasons. Because of the relatively high success achieved by modern rifle hunters, managers must make fairly precise calculations of the number of animals to be harvested and set permit numbers accordingly.

6. Legal Animals and Bag Limits

Legal animal definitions and bag limits vary according to pronghorn population levels and the state/provincial goals and/or objectives for that population. In Montana, Martinka (1966) reported that selection for adult males appeared to be based on hunter preference rather than herd structure. If the harvest management objective is herd reduction, a female/fawn bag limit or multiple female/fawn permits per hunter are ways to reduce the population during a short hunt. Female/fawn harvests usually are accomplished by issuing permits only for pronghorn with horns shorter than their ears. Even still, some hunters mistake yearling males for females, therefore regulations need to provide information to help hunters identify in the field, which animals are legal for the type of license they hold. The setting of a male-only or either-sex (any pronghorn) bag limit with female/fawn hunting allowed during the last few days of the season is confusing to the public and difficult to enforce. Archery hunters usually have an either-sex permit and their limited harvest normally has little effect on population levels.

Because adult male pronghorn establish and defend territories for breeding purposes (Bromley 1969, 1977, Kitchen 1974), or control and defend harems before and during the rut (Prenzlow et al. 1968, Deblinger and Ellis 1976), the larger males become easy prey for hunters during the rut. The hunting of large males to the exclusion of other herd members may cause a disruption in the dominance hierarchy, especially in small populations, and may have a direct influence on the fitness and "trophy quality" of the population (Copeland 1980, Deblinger and Alldredge 1989). Hunting can also induce non-territoriality behavior. If a hunt is to be held before or during the breeding season, consideration should be given to regulations that will either limit the number of males harvested or close selected areas to protect at least a portion of the dominant males.

7. Harvests on Public Versus Private Land

Proper management requires that, when setting pronghorn harvest regulations, managers consider the interests of landowners and land management agencies. Dood (1984) noted that "the basic social problem in pronghorn management is that pronghorn are a public commodity living on private land. About 62% of the pronghorn in Canada and the United States are found on private land (O'Gara and Morrison 2004). Private landowners, through leases, also control access to considerable areas of public land. Obviously, cooperation between private landowners, such as the Deseret Land and Livestock Ranch in Utah/Wyoming, and provincial/state wildlife management agencies is necessary for coordinated harvest programs. As of 2009, 10 provinces/states had a partnership program aimed at reducing wildlife - landowner conflicts (Schilowsky 2010). Some of these programs gave landowners some type of preference in obtaining pronghorn permits if they had substantial numbers of pronghorn on their land. Private landowners in Mexico could also obtain pronghorn permits if they had a sizable population of pronghorn on their land and filed a pronghorn management plan with the proper authorities.

Each state/province has adapted to the problem of managing pronghorn on private land in different ways. In New Mexico, the success of hunts on private land often reaches 95%. If New Mexico restricted the season on public lands to accommodate the private landowner, it would penalize the public land hunter. Consequently, the state sets private and public land seasons to run concurrently and with uniform bag limits. Landowners sign hunt agreements to allow for the management of pronghorn on their private lands. If the landowner has public land leased for livestock privileges, the public must be allowed to hunt on these allotments. The numbers of permits assigned to such ranches are therefore split into private and public permits, according to the percentage of the pronghorn population in each land status. This strategy allows New Mexico to set permit numbers that match the needs of both the landowner and pronghorn population objectives.

Sportsmen hunting on private land in New Mexico do not necessarily have to draw for a permit. They may instead purchase "trespass rights" from a private landowner and then the landowner or agent provides the hunter with an authorization to purchase a license from the state. This type of system is especially popular with wealthy non-resident hunters who do not need to go through the permit drawing process. On private lands containing "surplus" pronghorn, the state will set a female-only hunt if the landowner will sign an agreement allowing some public hunting.

In California, landowners who develop a management plan approved by the Department of Fish and Game, and increase the number of pronghorn on their property, may obtain longer seasons or more liberal bag limits than on public lands (Pyshora 1986). In Texas, almost all pronghorn hunting is on private land. Permits are issued to the landowner who then charges hunters for the permits along with access rights (Dvorak 1986).

During the late 1970s, many ranchers in eastern Montana were closing their land to public hunting because of large hunter numbers, an increasingly stagnant agricultural economy, and hardening attitudes towards public use of private land. In 1985, the Montana Department of Fish, Wildlife and Parks instituted the use of a statewide block management system to enable wildlife managers to harvest enough animals to maintain healthy herds and reduce damage to agricultural crops (Korn 1990). The block management system was still in use in 2009 (Schilowsky 2010).

Two management procedures were especially designed to open private lands to hunting. One eliminated the need for the landowner to deal with hunters, and the other was designed to reimburse the landowner for time spent meeting and directing hunters. Thus, in eastern Montana, the Department often provides personnel to manage hunters or pays the landowner for time spent directing hunters, filling out permission slips, patrolling property, helping hunters retrieve downed game, and other activities. This resulted in more than 5,000,000 acres (2,000,000 ha) of private land being opened to hunting (Korn 1990). To date, block management has worked well for everyone concerned. Perhaps one reason that Montana ranchers have embraced block management is the Department's approach. Agreements are conducted in the manner to which Montana ranchers are accustomed, a handshake, not long, involved contracts (M. Korn, personal communication). The Department, however, is reaching the limits of how much time and money can be expended on the program. Wyoming has implemented a similar hunter management program to increase access and harvest on private lands.

Wyoming has used a system for many years whereby a tag attached to each pronghorn permit can be detached for each pronghorn killed on private land and this “coupon” given to the landowner who is then reimbursed by the state. It is important to note that the landowner coupon is only for animals harvested on the landowner’s land. In 2012 landowners received $16.00 USD for each coupon, a reimbursement generally considered to be inadequate. Wyoming's landowner coupon program came about in 1934 when the Game and Fish Commission was responding to what was considered to be an overpopulation of pronghorn in some areas of the state. The Commission passed a regulation to pay the landowners $2.00 USD for each pronghorn killed by residents and $5.00 USD for animals killed by non-residents to cover the "administration expense of feeding said pronghorn." The coupon program has undergone several changes since then, and the differential in the worth between resident and nonresident coupons has since been removed. The intent of the program was, and still is, to reimburse landowners for forage consumed by wildlife residing on their property (Wyoming Game and Fish Department 1986). Nevertheless, a false notion evolved in the minds of some that the program was designed to encourage landowners to allow public hunting on their lands. The problems relating to private land access in Wyoming are significant and are worsening. Therefore, if there was any intent in this program to improve access to private land, it is failing. Landowners have expressed dissatisfaction with the program, citing two problems: the revenues are inadequate and not equitably distributed. The Wyoming Game and Fish Department researched the program and determined that the agricultural community was correct. The $16.00 USD amount does not compensate the landowner for the forage consumed by one animal, nor does it compensate for the animals not harvested by hunters. Also, pronghorn that reside on one landowner's property during the non-hunting season are often killed on another's land during the hunting season. Consequently, the landowner that gets to redeem the coupons may have sustained the least amount of forage loss (Wyoming Game and Fish Department 1986). Most resident female/fawn permits are sold at reduced price (2012 price was $22.00 USD) and license agents receive a commission per license sold. Thus, the Wyoming Department of Game and Fish is subsidizing female/fawn licenses to obtain an adequate harvest.

8. Establishing Permit Numbers

With rare exceptions, the number of animals to be taken from a given population must be regulated to prevent over harvest or an undesirable post-hunt sex ratio. Hence, managers restrict the number of permits issued to achieve particular harvest objectives. The number of permits in a game management unit or on a particular ranch usually is determined after annual surveys give an indication of population sizes and bb:dd ratios. The number of animals to be harvested is then calculated for individual herd units, and permit numbers are set using past hunter-success information as guidelines.

Drawings for permits by hunt units or districts are necessary to distribute harvest among pronghorn herds in a province or state. For instance, pronghorn herds in Montana are centered in the eastern part of the state, and human populations are centered in the western part of the state. Unless hunters are limited to particular areas, western pronghorn herds would be over-harvested, and some eastern areas would be largely un-hunted. The chances of drawing a permit in a western district are generally between 33 - 50%. Some eastern permits are usually available after the drawing and can be purchased over the counter.

In states where pronghorn numbers are more limited, but with a high percentage of trophy animals, hunting permits can attract considerable demand. In Arizona, for example, draw odds have been as high as 146 applicants per permit in some management units. Statewide the application rate is 22 applicants for each permit.

In addition to regular permits, a number of states also issue special fund-raising hunting permits. These special permits, variously called conservation tags or Governors' permits, are raffled or auctioned to produce revenue to fund pronghorn management activities. The state Legislature in Arizona authorized the use of up to two big game tags for each species to be used for fund raising purposes each year, with all of the revenue from these tags ear-marked for specific projects. Since 1985, the 20 special pronghorn tags in Arizona have generated $163,121 USD. The two tags auctioned in 1996 were sold for $19,500 USD and $16,000 USD. These revenues support pronghorn transplant activities and habitat improvements.

9. Estimating the Harvest

Reliable estimates of harvest, hunter success, and hunter days (effort) are necessary for effective wildlife management, regardless of the method used to formulate such estimates (Cada 1985). With this information, managers can assess the success or failure of harvest strategies and make adjustments to meet the pronghorn population objectives. If a manager can document a significant illegal take or crippling loss, then those losses should be considered when establishing harvest objectives.

Requiring hunters who harvested pronghorn to stop at a check station was the first method used to obtain harvest data. Biological information, such as body condition, horn size, sex and age distribution in the kill is gathered at such stations. In areas where biological data are collected, check stations give managers an opportunity to obtain a variety of timely information about the harvest. Check stations allow managers to interact directly with hunters, which has public relations and educational values for both hunters and managers. Check stations also serve a law enforcement function for compliance with regulations. Information gathered at check stations also may be used to cross-check the accuracy of responses to mail, internet, and telephone questionnaire surveys. To do this, hunting license or permit number data must be recorded along with the biological information. With acceptable levels of precision now obtainable from mail, internet, and telephone surveys, the check station method has become less popular among wildlife management agencies, partly because of the high cost of operation. Many agencies supplement their survey returns by allowing hunters to go online and complete the survey. They often have incentives such as being entered in a draw for a gift card or other perk to increase hunter participation especially in voluntary programs.

Check stations and hunter field checks are biased in several ways. Successful hunters, especially those with large males, are more likely to stop at check stations than are unsuccessful hunters or those with females or fawns. Some hunters even go out of their way to stop and show off their animals. Also, sample sizes at check stations often are low, unless access is restricted or regulations require hunters to check in and out of an area. Trophy hunters, non-residents, unsuccessful hunters, and those with multiple permits are also likely to stay in the field until after a check station is closed. Modern check stations are mainly for gathering biological data (Photograph 12), with harvest statistics secondary. Good sex and age data can sometimes also be gathered economically at locker plants.

Research has shown that mail questionnaires can be used to estimate harvest levels and hunter days in the field, as well as provide information on type of weapon used, the age class and sex of the animal(s) killed, area(s) hunted, and wounding rates. These data generally are accurate enough to provide trend information to wildlife agency personnel who then use the data for establishing season dates, bag limits, and weapon types.

A number of analyses have shown that biases exist within mail questionnaire data. Based on repeat mail-outs (to increase return rates) and on numerous comparisons with hunter checks, check station data, and telephone interviews, it appears that hunter numbers, success, and harvest tend to be overestimated. This bias results from successful hunters being more likely to return their questionnaire than unsuccessful hunters or those that did not go hunting. The biases generally result in overestimating the harvest by about 10%. If methods are consistent, however, the biases should also be consistent, and not compromise the comparability of data among years or areas. Reports regarding the sex of the animal taken and the number wounded generally result in errors of $< 5\%$. Many agencies routinely include secondary sampling to correct harvest estimates for such biases.

Through various studies, statistical equations have been developed to account for bias in mail questionnaires. The critical factor in conducting reliable surveys is to get the questionnaire in the hunter's hands as soon as possible after the hunt. One procedure is to issue the survey with the license, so the hunter can be prepared to identify answers to the questions. If this is not possible, the survey should be mailed within days of the close of the hunt. To improve sample sizes, many surveys can be completed on the internet and some

Photograph 12. The most commonly used methods to obtain harvest information today are through mail and telephone questionnaire surveys. Check stations still are useful for this purpose at times, but most are now operated to collect biological data, such as the age and horn measurements. Photograph by Paul Jones.

agencies offer incentives to encourage hunters to provide responses electronically. Several states that used to conduct follow-up surveys to non-respondents found the expense to not be justified by the small statistical improvement in the results (Strickland 1979, Couling and Smith 1980, Cada 1985, Pyshora 1986).

An alternative to the mail survey is the telephone questionnaire survey. Telephone surveys provide direct contact with the respondent and allow for precise answers. Cada (1985) found that the telephone survey saved money, was more acceptable to the public, and reduced sources of error. Another benefit of telephone surveys is that the manager does not have to wait on the mail system to gather responses. However, this type of survey is not without its own problems, such as unlisted phone numbers, phone-blocking devices, people who refuse to talk to agency personnel, and inaccurate responses.

Field checks also have been used to determine harvest. Where field checks are conducted, much time must be devoted to contacting enough hunters to give the data statistical validity. Conservation officers usually are the ones conducting field checks, and at times, the quality of the data may suffer due to the priority placed on the collection of law enforcement information. If field checks are used in compiling harvest statistics, managers must devote enough extra time and manpower to the effort to ensure that sufficient data are obtained. As a rule, field checks should only be used in small areas to gather data that can be compared with those gathered by mail or telephone surveys that obtain larger amounts of harvest data.

Aesthetic Management

As stated by Smith and Beale (1980): "besides hunters, many more people have enjoyed simply observing this unique, baffling, and splendid animal." Some pronghorn populations, such as the animals on the National Bison Range, in Montana, Antelope Island State Park in Utah, and Yellowstone National Park in Wyoming are managed almost solely on the basis of aesthetics. Similar situations precluding the harvest of pronghorn are also present on some military bases and in numerous urban interface areas. Still other populations are present in zoos and animal parks, and the photography and life history of such populations has become an important component of pronghorn literature (Turbak et al. 1995; Byers 1997, 2003; Geist and Francis 2001).

It should, nonetheless, be considered that such populations may require overt management actions to prevent overcrowding and unbalanced sex ratios. In addition to the periodic capture and removal of animals, other actions may be needed to provide public visibility of the animals, prevent undue disturbance, provide inoculation against diseases, ensure the medical treatment of injured or debilitated individuals, and allow for the sacrifice of particular animals.

Capture and Translocation

Capture and translocation have been and continue to be, integral to pronghorn management (Photograph 13). Although restoration of this species through translocations has been phenomenally successful, such programs remain important components of pronghorn management in some areas.

1. Pronghorn Capture

Pronghorn can be captured using a wide variety of nets, traps, drugs, and under certain conditions, without the aid of either mechanical or chemical means. Each method is designed to either reduce a pronghorn (or a group of pronghorn) to a restrained condition as a requisite management goal (i.e., re-introduction or augmentation) or a research need. Amstrup et al. (1980) suggested parameters to consider when selecting a capture method. Included were the number, age, and sex of animals needed; density of animals in the trapping area; the terrain and proximity to roads; whether pronghorn are accustomed or not to fences; how wary the animals are; the possibility and acceptability of mortalities; and the cost in terms of time and money per animal captured or marked.

Photograph 13. A small herd of pronghorn from New Mexico were translocated to the state of Coahuila in northern Mexico. The new location is a private ranch where herds previously roamed historic rangelands. Such international management cooperation strives to reestablish natural wildlife diversity in North America. Photograph by Patrico Robles-Gil.

a. Corral Traps

Corral traps were used by Native Americans and have proved their worth many times over as a cost-effective means of capturing large numbers of pronghorn. Various agencies have modified the basic design to meet their specific needs. Detailed accounts of corral trap design and operation were provided by Fisher (1942), Couey (1949), McLucas (1956), Hoover et al. (1959), Russell (1964), Spillett and Zobell (1967), Moody et al. (1982), and McKenzie (1984). Many of these authors have suggested modifications resulting in improvements to the basic corral trap. Unless otherwise stated, the following trapping guidelines are adapted from McKenzie (1984) and O'Gara et al. (2004).

Placement of a corral trap is of utmost importance (Figure 2). The basic corral trap design consists of 2 linear wings, a containment pen with curtains, a gated corral divided by a moveable burlap curtain, and sometimes, a loading chute. The woven-wire wings of a corral trap usually form a "V" funneling animals into the mouth of the trap proper. Workers in Wyoming (Moody et al. 1982) gradually narrowed the distance between these wings from between 1000 and 1300 feet (300 to 400 m) at the outside edges, and approximately

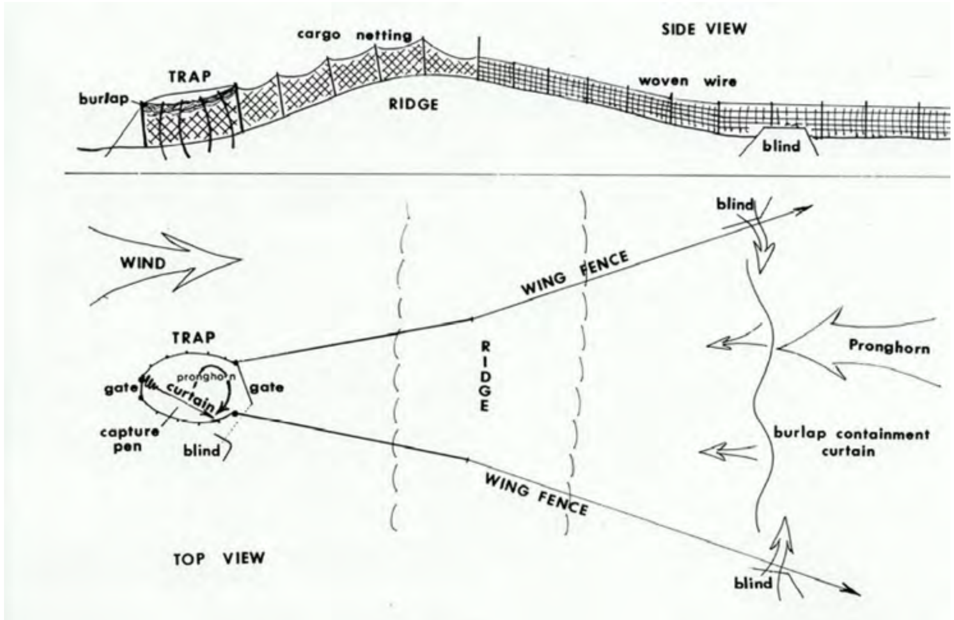


Figure 2. The basic corral trap design consists of 2 linear wings, a containment pen and curtain (gate), a gated corral divided by a moveable burlap curtain and, sometimes, a loading chute. Placement of a corral trap, taking advantage of topographic features to hide the corral, is of utmost importance and prevailing winds should be considered. A reconnaissance flight to select a good location for the trap site and to obtain an idea of the number and distribution of pronghorn should be made before erecting corral traps. Traps or nets should be hidden by vegetation or topographic features along known or suspected pronghorn travel routes. Natural and manmade barriers, steep terrain, or tall vegetation should be avoided within the funnel of a corral trap, unless pronghorn are observed routinely using such areas as travel lanes. Existing fences near a trap site should be carefully evaluated for inclusion in wing fences or temporary removal. Sketch by Larry Saslaw; courtesy of the U.S. Bureau of Land Management, Rawlings, Wyoming.

0.3 mile (0.5 km) from the trap to the funnel and first curtain. This eased the problem of pronghorn attempting to go over (or through) the trap wings. They also used cargo netting (the same as used in the trap proper) as trap wings for the first 350-400 feet (100 m) from the trap mouth to ease the same problem and reduce injury to pronghorn.

The burlap or canvas containment (Photograph 14) curtain extending across the funnel facilitates moving animals the final 650 feet (200 m), into the corral trap. The distance between the wings at this point should be about 150 feet (50 m). The curtain is folded in place on the ground between the wings at or near blinds on each side of the funnel. As the target animals cross the folded curtain, workers emerge from the blinds and form a line across the funnel. When the line of workers is complete, the curtain is raised to establish a visual barrier to discourage escape attempts back through the funnel. Alternatively, a netted gate curtained with burlap can be laid across the funnel entrance and raised after the

Photograph 14. Within a corral trap, a canvas curtain should be rigged so that it can be drawn across a portion of the trap to facilitate hand-capture of pronghorn. The smaller area makes capture easier and reduces stress on the animals. It also can be used to separate 6 - 10 animals from a larger group. This reduces stress on the animals in the larger portion of the trap. Alfalfa hay scattered on the ground before capture reduces the amount of dust kicked up and inhaled by pronghorn during capture. Photograph by Paul Wertz; courtesy of the California Department of Fish and Game.

pronghorn have passed through, allowing for the storage of animals in the funnel while another group is worked into and through the trap.

The corral portion of the trap should be an oval 40-100 feet (13-30 m) in diameter with nylon-netting walls and posts on the outside. The tops of the posts should be offset 3-foot (1 m) to increase the "give" when pronghorn hit the net and to prevent collisions with posts. A visual barrier curtain (Figure 3) is recommended for the top 2/3 of the trap proper. This burlap or canvas curtain reduces escape attempts (and injury to pronghorn) through the sides of the trap, and its suspension from the top of the trap walls discourages escape attempts over the top. Most importantly, the curtain is lowered simultaneously with the closing of the trap gate when the pronghorn enter the trap. Prior to being dropped, it is rolled up and secured at the top of the net with a quick-release string-washer-cotter pin assembly.

Correct trap placement, and taking advantage of topographic features, are vital for the success of any attempt to trap pronghorn with fixed traps or nets. A reconnaissance flight to locate the animals to be trapped and to select the best trap location are essential first steps in any trapping effort (McLucas 1956). To maximize the chances for success, it is also advisable to use vegetation or topographic features to conceal the traps or nets along known

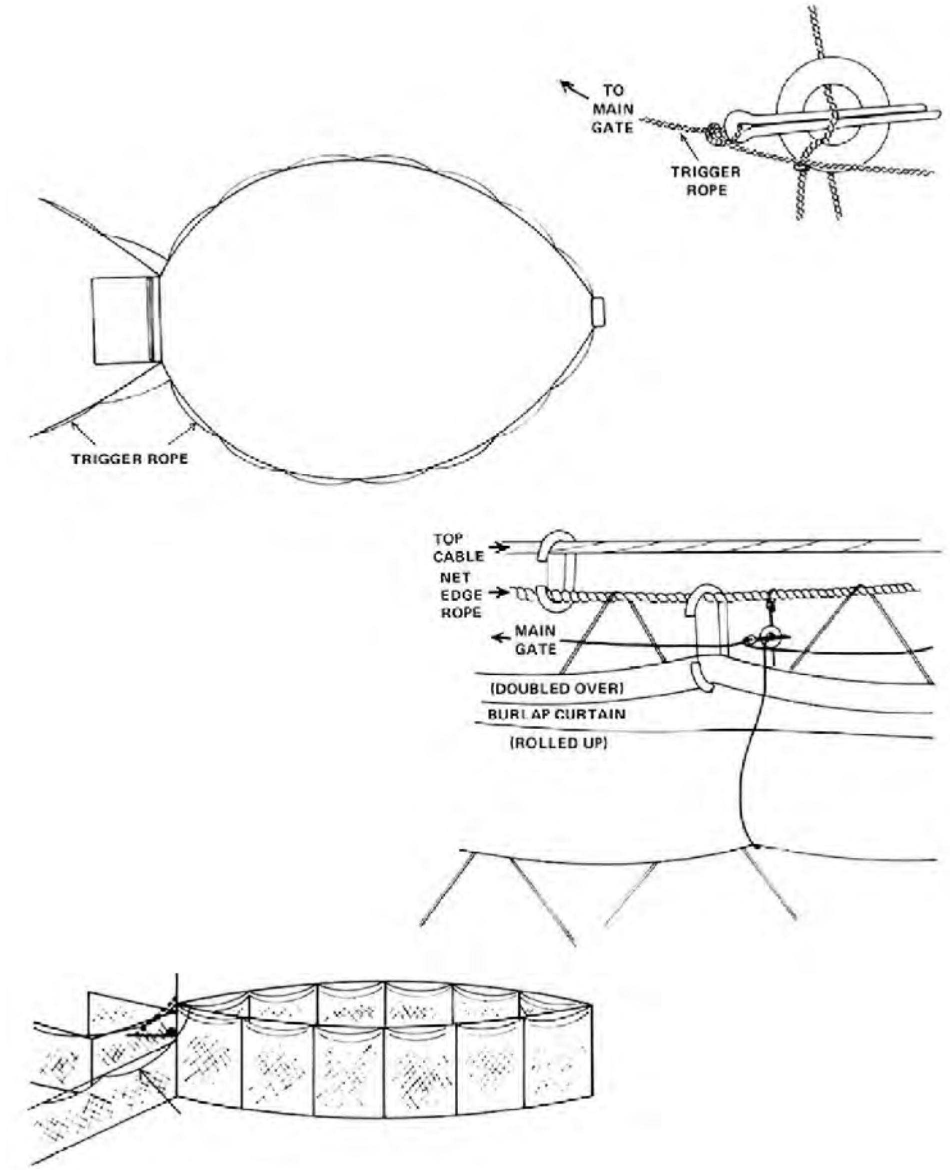


Figure 3. A visual barrier curtain reduces escape attempts and injuries to pronghorn. Trigger detail and placement of a trap drop curtain are shown here. Courtesy of the Texas Parks and Wildlife Department.

or suspected pronghorn travel routes. The funnel of a corral trap should not contain any natural or manmade barriers, steep terrain, or tall vegetation, unless pronghorn are observed routinely using such areas as travel lanes. Existing fences near a potential trap site should be carefully evaluated. Their presence may either aid or hinder a successful trapping operation depending on the reaction of the target pronghorn. Safety precautions for both workers and animals should be strictly followed. The mouth and wings of a corral trap should be positioned so that pronghorn run into the prevailing wind and are a safe distance from flight hazards (e.g. power lines or trees). Other flight precautions should depend on the pilot's judgment.

Herding pronghorn by aircraft during trapping operation stresses the animals. Thermal stress may occur during warm weather, and corral trapping is not recommended when the ambient air temperature is > 70ºF (21ºC) and, preferably, it should be < 50ºF (10ºC). Pronghorn are sometimes captured during the cool of the morning and placed in transport vehicles only to have the temperature rise to lethal levels later in the day during transport. During catch-and-release operations the temperature may not be as critical because of the short duration of captivity. Amstrup et al. (1980) and Reeves (1982) successfully trapped pronghorn during August, when ambient temperatures were high, but they usually trapped during early morning or late evening, and avoided handling or herding animals during the heat of the day.

A helicopter is the best tool for herding pronghorn into the wings of a corral trap. Constant pressure applied by a helicopter appears to stress pronghorn, so the pilot should hold back and let the animals drift toward the net at a moderate pace until time for the rush into the wings and corral. Extended chases may result in increased mortality. Workers in Wyoming found mortality rates of animals chased for 40 minutes to be twice as high as for those chased for 20 minutes. The maximum chase time should not exceed 20 minutes.

The line of people with the containment curtain should advance toward the trap mouth when the pronghorn move in that direction, stop when the pronghorn stop, and move when they move. Gentle, but constant pressure is used until the animals enter the corral, the gate is closed, and the curtain barrier is released. Noise should be kept to a minimum. Alternatively, if enough people are available a containment curtain is not required.

It is recommended that captured pronghorn be allowed to settle down in the trap without human harassment for 10 - 40 minutes (or whatever appears to be a reasonable period of time). This is a judgment call depending on how far and how long the pronghorn have been moved and the ambient temperature. Once handling begins pronghorn should be processed as quickly as possible.

Trapping usually requires many volunteers and others who are not familiar with the trapping operation and handling of animals. A thorough briefing of all of the participants in the operation is therefore essential. The briefing should include the purpose of the operation, description of the trapping process, proper handling of animals, how injured animals are to be dispatched, and precautions for the safety of workers and animals. A detailed protocol of the capture operation is also required by each jurisdiction (i.e., the Federal Animal Care and Use Act in the U.S., and Animal Care and Handling Permit in Alberta, Canada).

Within the trap proper, there should be a canvas curtain that can be drawn across a portion of the corral, hiding the workers from the animals. This curtain is used for segregating small groups of 6 - 10 animals from the main body of trapped pronghorn during the hand-capture phase. Segregating animals into small groups reduces the chance of injury to workers and pronghorn while expediting the handling of the animals.

b. Handling and Loading

Handling and loading, as described here, applies primarily to capturing pronghorn in corral traps. Other methods of capture usually involve smaller numbers of animals and are considered as hand captures.

For each pronghorn segregated by the catch net, two persons should be available to hand capture the animal and restrain it as quickly and effectively as possible. The front handler should control the head of the animal with one arm and lift it with the other arm just behind the front legs. The rear handler should grasp under the animal just forward of the hind legs. The animal should then be lifted just enough to get its feet off the ground and then blindfolded. Each restrained or carried pronghorn should be positioned with its sternum down and its head well above the level of the rumen to prevent aspiration of rumen contents. At this point, the period of restraint is dependent upon the number of procedures (tagging, injecting, measuring, etc.) deemed necessary and whether tranquilizing drugs are used; nevertheless, during a translocation effort, all procedures should be kept to a minimum.

Tranquilizing drugs promote tameness and ease of handling. Two such drugs, Valium (5 mg/cc) and Acepromazine (50 mg/cc) are routinely used by some biologists during pronghorn translocations. Dosages are 1 cc for adults and 0.5 cc for fawns. Use of drugs should be avoided in most cases, however, because of the added hazards to the animal. An animal during transport could become physically incapacitated and be trampled by other animals and a released animal may be more susceptible to predation or accident before the effects of the drug wears off.

When groups of pronghorn are to be translocated, and individual handling for marking is not required, the use of a cattle-type loading chute (Figure 4) can reduce stress to the animals and expedite the loading process. The chute should be constructed specifically for pronghorn with solid wooden sides and runway, canvas top, and a width of approximately 22.5 in. (0.5 m) (Mckenzie 1984).

Thomas and Allred (1943) described the conversion of ½ and ¾ ton trucks with stake beds to transport deer. Such vehicles are practical for transporting pronghorn. Vehicles especially built for hauling pronghorn should be well ventilated, completely covered with a canvas top to make them as dark as possible, compartmentalized (to segregate horned males), and easy to load. Additionally, the space requirement for each pronghorn during transportation should be about 3.2 ft^2 (0.3 m^2).

Blindfolding horned males during transportation may be advisable, even when they are segregated from other pronghorn. Blindfolds are an alternative to removing the horn tips and likely serve the same purpose.

Each vehicle should start the trip to the release site immediately upon loading. The vehicular motion has a definite calming effect on pronghorn during transit. Pronghorn

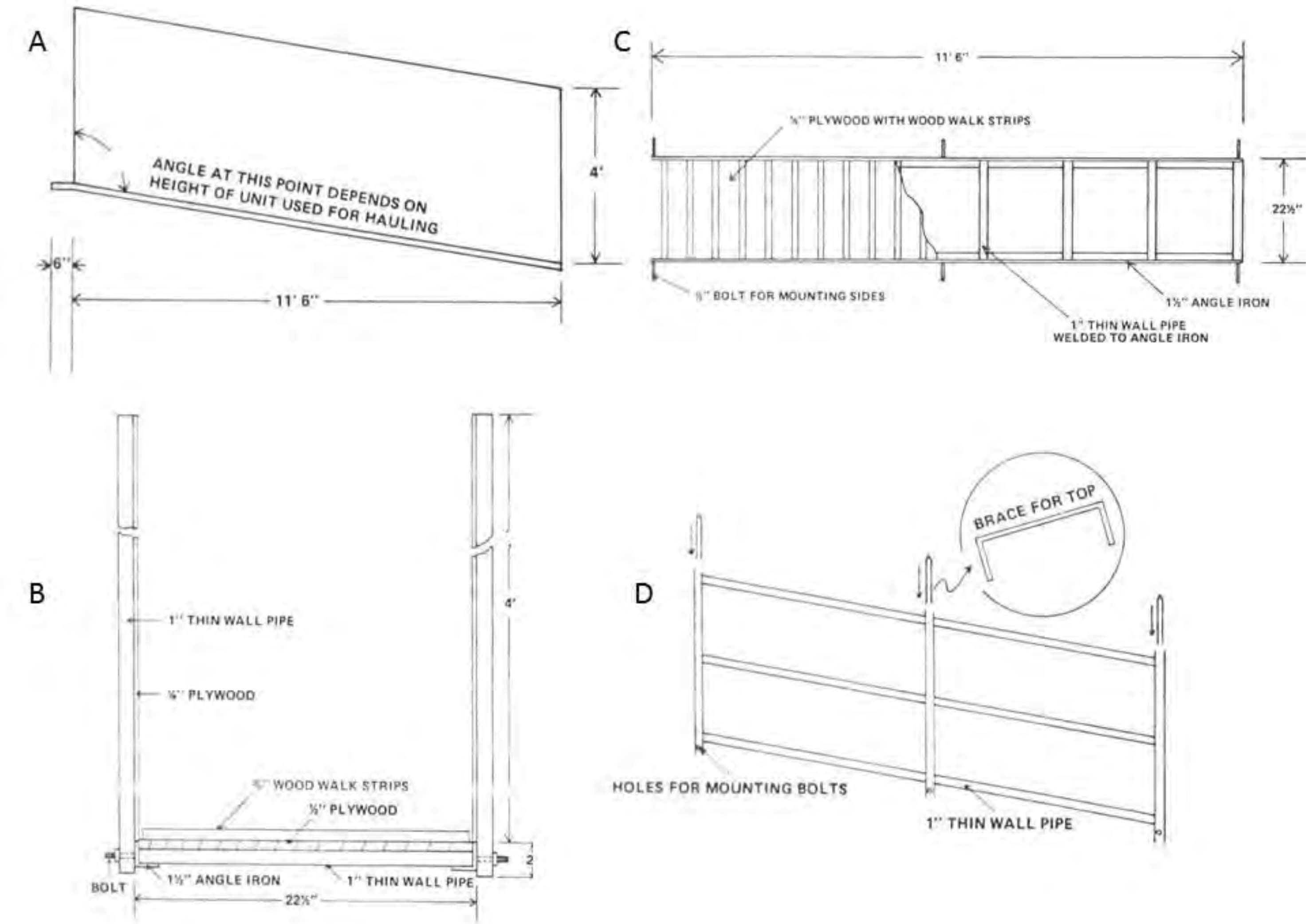


Figure 4. Construction details of pronghorn loading chute. A = side view, B = end view, C = details of the bottom frame, and D = details of the side frame (from McKenzie 1984).

should not be transported in ambient temperatures > 70°F (21°C), but if such a situation arises, the animals should be periodically sprayed with water.

Recommendations are for a gentle release (open the gates and walk away) as soon after arriving at the release site as possible or immediately after research needs are met. Should a transportation trailer be used, it is often beneficial to provide or build up a ramp to allow the pronghorn easy egress as newly released animals may fall down when jumping out of the trailer.

c. Linear Tangle Nets

Linear tangle nets have gained popularity in the capture of big game animals. Tangle nets are similar to corral traps in that animals must be herded into them. The axis of a tangle net should be positioned so pronghorn hit it while running into the wind. This helps to prevent animals from smelling the capture crew and facilitates control of the aircraft. These nets are best suited for the capture of a select number of target animals. A linear tangle net consists of a net 350 - 1,050 feet (100 - 300 m) long, approximately 8 feet (2.4 m) high, suspended vertically by notched wooden stakes or draped on vegetation. Sufficient nets to span at least 3,500 feet (1,000 m) are used in most operations. The best mesh size for pronghorn appears to be 7” (18 cm) squares. Nets should be anchored about every 100 yards (100 m) so pronghorn cannot knock down whole nets or run into any backup nets. Nets should be hung loosely, with about 1 foot (30 cm) of net remaining on the ground, because animals can often back out of tight nets.

Amstrup et al. (1980) found that the linear tangle net could be successfully employed to capture small groups of pronghorn. They deployed the net as a cul-de-sac below a pass through rim rocks or at the end of woven wire wing fences along travel routes. A helicopter was needed to herd pronghorn successfully into the net. A major problem was collapse of the net with the impact of the first animals, resulting in the rest of the herd jumping the net at that point. To prevent this, a second net was deployed a few yards beyond the first to form a double cul-de-sac to increase the catch. Amstrup et al. (1980) also thought a person hidden at the point in the net where lead animals tend to hit could stand up just before impact to scatter the herd and increase the number of contact points.

d. Clover Trap

Very little effort has been employed to capture pronghorn using clover traps. Two adult pronghorn females were caught in clover traps in Oregon (M. Willis, personal communication). The traps were pre-baited with alfalfa hay and salt (salt appeared to be the most effective). Several other pronghorn were observed in the trap, but the drop panel froze open preventing their capture. If the panel had functioned and not froze open, trapping success would have been 3 trap-days per animal.

e. Cannon Nets

The cannon net can be used to capture select numbers of pronghorn. Animals must be enticed to feed or drink at a central point, and when they are at the target site, rockets are fired, propelling a 40 × 60-foot (12 × 18 m) net over the animals, the net being secured on the side of the cannons. The only baits that consistently attracted pronghorn were apple pomace (pulp remaining after the cider is squeezed out) and salt blocks (Amstrup et al. 1980). In arid regions water may serve as bait (Beale 1966).

Amstrup et al. (1980) found that 1 of 13 pronghorn captured in 4 netting attempts died in the trap. Another 4 were known to have died within 2 weeks from either capture myopathy or coyote predation. Because of the high mortality rate, this technique was not recommended for pronghorn. Pronghorn are not excessively stressed by a moderate amount of running, but they do not struggle as violently in a tangle net as they do under a cannon net. Violent activity is probably more conducive to capture myopathy, when the muscles have not been warmed by running. Pronghorn hitting tangle nets lose their footing almost immediately and can only struggle against the flexible net and soon cease struggling. Those under a cannon net often kept their feet on the ground and fought the net with all of their strength, not giving up until restrained by hand or exhausted. Pronghorn captured under cannon or drop nets lose much of their hair during the struggle and should be a major consideration when trapping in cold weather.

f. Surround Net

Reeves (1982) devised a surround net for the capture of pronghorn. He constructed a 5-foot (1.5 m) woven-wire trap that arched around half of a pond or water hole. The remainder of the pond was surrounded by nylon netting 9 feet (2.7 m) high and with a 5.6 in. (14 cm) mesh. A 350-foot (100 m) section of the netting was furled on the ground. This section was lifted by counterweights suspended from four 12 foot (3.7 m) poles when pronghorn entered the trap. The releasing mechanism for the counter weights were electronically activated from a distant blind. The trapping crew then rapidly approached the trap from the woven wire side. The startled pronghorn flushed into the netting, collapsed it, and became entangled. Reeves (1982) reported no post-release mortality among the 17 animals caught. Costs were considerably less than a corral trap or a drive net due to fewer materials and personnel, and no aircraft being needed.

Cancino et al. (2002) described how a combination corral trap and surround net were used to capture pronghorn in Baja California Sur, Mexico. This technique employed fixed fences, an irrigation system, an observation tower with optical equipment, VHF radios and 2-person teams with vehicles. Advantages of these traps include the ability to select the number, age, and sex of the animal to be captured, and minimal stress to the pronghorn.

g. Net Gun

Using net gunning (Photograph 15) to capture large mammals, including pronghorn, has become a popular method because it is cost-effective and time-efficient (Jacques et al. 2009). The net gun is the tool of choice for capturing small numbers of pronghorn, particularly if few animals are present, if certain age or sex classes are needed for radio collaring, or if the capture area is difficult to reach by land-based vehicles. Scott (1994) compared the time and cost to capture pronghorn using net gunning from the ground and air and determined an average of 1 pronghorn was captured per 8-hour day from the ground at a cost of about $167 USD per animal while 17 pronghorn were netted from a helicopter during the same study in 3.5 hours of flight time (4.9 animals per hour), at a cost of about

Photograph 15. The net gun is the tool of choice for capturing small numbers of pronghorn (particularly if few animals are in an area), specific age or sex classes are needed for radio collaring, or the capture area is difficult to reach by vehicles. Net gunners should be thoroughly briefed before attempting captures as this technique can be dangerous for pilots and gunners. Photograph by Richard Ockenfels.

$403 USD per animal. Scott (1994) concluded that ground net gunning was simpler, safer, and less expensive than aerial net gunning in Yellowstone and caused fewer pronghorn mortalities and less public disturbance than did aerial captures These results were only possible because the animals were habituated to vehicles, a situation seldom encountered outside of parks, refuges, or other controlled areas. Pojar (2000) compared net gunning with the conventional corral trap method in terms of labor, equipment, and costs, and found net gunning using experienced commercial companies to be a practical and competitive capture method.

Barrett et al. (1982) concluded pronghorn are captured easily with a net-gun. Net gunning from a helicopter is usually employed, though successful captures from the ground have been made. Successful aerial net gunning of pronghorn has been achieved in Alberta (Barrett et al. 1982, Jones et al. 2005), Arizona (Hervert et al. 2005), Colorado (Firchow et al. 1986, Pojar 2000), Montana (A. Jakes, personal communication), North Dakota (Kolar 2009), Oregon (Dalton 2009), Saskatchewan (A. Jakes, personal communication), South Dakota (Sievers 2004), Utah (Pojar 2000), Texas (S. Gray, personal communication), and Wyoming (Scott 1994, Boccadori 2002, Sheldon 2005, Beckmann et al. 2012). In all cases adult pronghorn were captured with most being females. Most studies have not reported their capture success rates, but they are presumed to be high.

Barrett et al. (1982), after testing the potential for net gunning pronghorn determined that considerable effort may be required to reduce capture myopathy and losses from trauma. Scott (1994) in Yellowstone National Park, found net gunning from the pickup truck resulted in 14% mortality compared to 47% for those netted from the helicopter. Fifty pronghorn (16%) died during 311 individual captures in Arizona, > 50% from broken necks (Lee et al. 1998). Others were euthanized due to broken legs, and 2 died about 2 weeks after capture, apparently from capture myopathy (Lee et al. 1998). A commercial company was used to capture 68 pronghorn in Colorado and 30 pronghorn in Utah, with 1 mortality in the Utah operation and 0 in Colorado (Pojar 2000). Additional reported capture mortalities (during operation or shortly after and attributed to capture myopathy) were < 27% (Barrett et al. 1982, Firchow et al. 1986, Sievers 2004, Sheldon 2005, Jones et al. 2005, Jacques et al. 2009, A. Jakes, personal communication). Jacques et al. (2009) evaluated the mortality of pronghorn associated with helicopter net gunning in the Northern Great Plains and concluded at times and under unfavorable conditions, net gunning pronghorn can be problematic. Their results showed that the rate of post-release mortality was higher for pronghorn with increased pursuit times and with increased transport distances to processing sites (Jacques et al. 2009).

Because the immediate control of the capture operation is often out of the hands of agency personnel, it is important to have a detailed protocol that addresses critical aspects of animal treatment. This protocol should be reviewed with the capture crew prior to the capture effort. The protocol should include standards for chase time and handling of captured animals, as well as when animals should not be captured. Based on the recommendations from Pojar (2000), Jones et al. (2005), Jacques et al. (2009), and A. Jakes (personal communication) the following protocol for net gunning pronghorn from a helicopter is provided:

1. *Use professional helicopter capture company that has specific experience capturing and handling pronghorn. Spend a ½ day with capture crew going over capture and processing protocols and how to euthanize injured animals. Protocols outlined in the Animal Care and Use Guidelines should be adhered to when injured animals are to be euthanized.*

2. *Limit pursuit times ≤ 5 minutes.*

3. *Animals should not be captured in proximity to fences, roads, rivers, domestic livestock, or buildings.*

4. *Captures should occur during the winter when temperatures are cooler to reduce over heating during pursuit and handling. Where and when possible snow cover should be present to reduce the impact of the fall to the targeted animal.*

5. *Upon capture the animal should be blindfolded and hobbled to reduce stress and struggling which could potentially result in injury to the animal and handling personnel.*

6. *Handle animals at the capture site and do not transport them to a processing site unless specific study objectives require so (e.g., implanting vaginal transmitters, translocation).*

7. *Minimize handling time (i.e., ≤ 5 minutes) by taking only necessary samples.*

8. *Record quantitative data on pursuit time, group size and reaction during pursuit, total handling time, landscape features, and weather data to allow for modeling mortality as a means to inform future capture protocols.*

h. Capture of Fawns

Fawns are captured for various management and research purposes, including mortality studies. Most early captures were undertaken to raise fawns for eventual release in unoccupied, historical rangelands. In recent times, wildlife managers have conducted numerous studies to determine the causes of high fawn mortality by capturing newborn pronghorn and using radio telemetry to monitor their survival. Fawns have also been marked to determine dispersal patterns upon maturity (Hansen 1955, Yoakum 1957). Pronghorn fawns develop rapidly and can be easily captured only until about 3 days after birth. This short period necessitates specific procedures to minimize search time and ensure proper handling to avoid abandonment by females.

During fawning season, observers should position themselves at strategic observation points. Binoculars and spotting scopes are useful for observing preparturient females or female/fawn behavior. A female signals impending parturition by leaving her band, frequent standing and lying, raising her tail, humping her back, and licking her belly and flanks. Surveillance should continue for about 4 hours after birth until fawns have nursed and mother/young imprinting is completed. This waiting period is critical to reduce incidences of abandonment and insure that fawns are several hours old at time of capture. The exact bedding location should be carefully noted and the fawns should be allowed to settle down for 30 minutes before being approached.

Lone females with large udders should be observed carefully, as they typically nurse their fawns about every 4 hours. Early morning and late evening are the most productive times to watch an animal, the female sometimes glancing toward her fawns prior to nursing. After nursing and grooming, the fawns bed down and the female leaves the immediate area.

Bedded fawns should be approached slowly and quietly from their rear, and a large long-handled net about 36-in. (1 m) in diameter should be gently placed over them to assure capture. Blindfolding fawns keeps them calm during handling and wearing surgical gloves minimizes the transmission of human scent. Returning fawns to their original position and gently rubbing their tails reduces their tendency to run after release (Amstrup et al. 1980). The use of nets also allows the capture of some older fawns (< 7 days old) without a chase.

Fawns too old or wary for daylight capture can be caught with spotlights at night (Brownlee and Hailey 1970). Observations of single females at dusk often indicate the presence of fawns, and it may be worthwhile to conduct a spotlight search in that locality after dark (Tucker 1979).

From 1953 to 1957, an intensive fawn-capture project was conducted in adjoining regions of California (Ackerly and Regier 1956), Nevada (Foree 1956), and Oregon (Hansen 1955, Yoakum 1957, Compton 1958). More than 600 captures were made, some taking place 4 weeks after the first capture. A well-trained Labrador retriever, taught to heel behind a horse ridden by a biologist, assisted in recaptures of fawns > 1 week old. When a fawn was flushed and began to run, the dog chased, caught, and held it until the biologists arrived. This technique did not result in any injuries to fawns during 156 captures in a 3-year period. Horses greatly assisted in the captures as mounted biologists were able to concentrate on looking for hidden fawns, and had the advantage of a high vantage point, and ease and speed of travel. The average lone worker caught 25 fawns in a season, whereas the worker with the dog and horse caught 75 (J. Yoakum, personal communication).

Byers (1997) handled and marked fawns for 13 years on the National Bison Range, and found no significant correlation between capture effort and survival. He concluded that proper handling of pronghorn fawns did not increase the risk of predation or cause an increase in mortality.

i. Chemical Immobilization

Pronghorn are extraordinarily difficult to immobilize so one should be prepared for less than satisfactory sedation results. Pronghorn seem to have a narrow tolerance to most immobilizing drugs. Occupying open country, pronghorn are especially difficult to drug with darts. Having thin skins, small muscle masses, and slender, fragile bones, pronghorn also are susceptible to injury from darts.

Kreeger and Arnemo (2007) recommended 0.05 mg/kg Carfentanil plus 1 mg/kg Xylazine with a repeated full dose if the animal did not go down in 20 minutes, and 5 mg/kg Naltrexone plus 0.125 mg/kg Yohimbine to be used as an antagonist for Xylazine. Alternative drugs listed were: (1) 0.1 mg/kg Thiafentanil plus 1mg/kg Xylazine (antagonize with 2mg/kg Naltrexone) (2) 0.1 mg/kg Etorphine plus 1 mg/kg Xylazine (antagonize with 2 mg Diprenorphine per mg Etorphine given, plus 0.125 mg/kg Yohimbine); (3) 5 mg/kg Ketamine plus 0.3 mg/kg Medetomidine (antagonize with 1.5 mg/kg Atipamezole). To reduce renarcotization with Carfentanil, one should give a double dose of the antagonists, one intravenously (IV) and another intramuscularly (IM), which was mainly related to the use of Naloxone as the antagonist (Kreeger et al. 2002). However the more recent drug for antagonizing any opioid is Naltrexone, which avoids the problem of renarcotization due to its higher potency and longer half-life (Kreeger et al. 2002). Do not give Xylazine to a pronghorn if you are not going to use an antagonist, prolonged hyperexcitability may ensue. From all of the above combinations, the most satisfactory has been Thiafentanil and Xylazine. Although other doses have also been used successfully depending on the level of excitement of the animals. Thiafentanil dosages can range from 0.1 mg/kg (Kreeger and Arnemo 2007) to 0.3 mg/kg (P. O. Alcumbrac, personal communication) plus 1mg/kg of Xylazine. Recommended antagonist doses are 10 mg of Naltrexone per mg of Thiafentanil used (Wildlife Pharmaceuticals Inc., personal communication).

The Ketamine-Medetomidine combination has also been used with some success on unexcited captive pronghorn. Tiletamine hydrochloride with Zolazepam hydrochloride (Telazol or Zoletil®) administered at rates from 6 mg/kg IM for Zoletil (Virbac laboratory, personal communication) to 13 mg/kg for Telazol (B. Lance, personal communication), result in less than satisfactory outcomes.

Although accidents like breaking bones were not unusual some years ago, today the use of air-activated dart guns is safer and more reliable. Attempts should not be made to immobilize pronghorn during the rut. As soon as a female becomes unsteady on her feet, males in the area will attempt to breed her. This can result in an extended, fast chase and the death of the female. When a male becomes unsteady, other males attempt to kill him. If they do not succeed outright, the exertion can still result in death of the drugged male. Males have been observed running as far as two miles (3.2 km) at top speed to mount or fight an unsteady animal. Little is known concerning the effect of immobilizing drugs on fetuses of females immobilized during late pregnancy. Although chemical immobilization has improved in the last years, net guns and corral traps seem safer and more efficient for certain situations, especially for capturing large numbers of animals.

j. Tranquilizing Drugs

Tranquilizing drugs promote tameness and ease of handling. They act slowly, but last for a long time. Xylazine used with any opioid for immobilization, reduces the amount of the opioid needed. It also lessens convulsions and reduces excitement during handling.

Immobilizing or tranquilizing pronghorn with drugs administered orally in bait would eliminate many of the dangers associated with darting or drive-trapping. However, exact dosages cannot be administered, and the animals must be accustomed to feeding on the bait. Thus, the drug must have a wide safe-dosage range.

Diazepam has a wide safety margin, lacks toxicity, and has been administered orally to several species of deer in enclosures, resulting in successful captures. It has been administered orally in livestock feed and functioned well in quieting and facilitating the handling of farm animals. Pusateri et al. (1982) mixed oral tranquilizers with grain and fed it to pronghorn. Diazepam showed some possibilities, but dominance hierarchies established by gregarious pronghorn made the capture of large groups (≥ 10) unfeasible. Dominant animals consistently ingested most of the bait. When severely tranquilized, the animals required constant attention. Poorly tranquilized pronghorn showed signs of hyperexcitability, had difficulty gaining their feet when bedded, or stumbled and lurched when approached. Interactions with non-tranquilized animals and continued capture attempts can cause such animals to injure themselves. Extended recovery periods of up to

30 hours also pose problems. Tranquilized animals require constant attention to prevent bloat, exposure, and predation.

A dose of 2 - 17 mg/kg of Promazine hydrochloride given orally to wild pronghorn fawns, and one adult, did not produce visible signs of tranquility (Pusateri et al. 1982). Doses of up to 3 times that recommended for a 1,200 lb. (544-kg) horse were administered and still produced no signs of tranquilization. Pronghorn refused to eat bait containing doses of Promazine hydrochloride crystals that would result in dosages > 17 mg/kg.

The most recent drug used for tranquilizing pronghorn has been Haloperidol. It reduces anxiety and awareness for a period of 6 - 8 hours and has reduced mortality rates during transportation to release sites. A total doses of 5 - 10 mg of Haloperidol can be given IM or IV depending on the level of excitement, age and sex of the individual, with IV preferred to immediately reduce the stress of handling (P. O. Alcumbrac, personal communication).

2. Capture Myopathy

Pronghorn are delicate and excitable animals. Broken legs and necks are common occurrences when capturing pronghorn in corral traps or drive nets. Broken legs have also been reported when pronghorn were herded at high speed over rough country. A more subtle form of mortality, capture myopathy, sometimes results when pronghorn are captured and handled. Capture myopathy usually is associated with the animal's concerted and vigorous use of muscles during pursuit and capture, chemical immobilization, and transportation. Sub-lethal capture myopathy can predispose pronghorn to predation.

Using drive traps, Chalmers and Barrett (1977) captured 594 adult pronghorn in Alberta of which 29 succumbed to acute trauma. Some signs of capture myopathy appeared within an hour of capture, but most symptoms were delayed until handling or soon after release. A capture myopathy-like syndrome was associated with an estimated 20 additional deaths as the pronghorn were being processed.

Despite the normal appearance of 32 drive-trapped pronghorn that were radio collared and released, 6 were found dead or recumbent within 2 - 8 days, and within 0.5 - 5 miles (0.8 - 8 km) of the trap (Chalmers and Barrett 1977). Coyotes had consumed some of the carcasses, and only 1 animal was found intact, so determining the relative contributions of capture myopathy and predation was a problem. Some animals might not have been affected sufficiently to cause death, but were debilitated enough to become easy prey. Whatever the case, these data indicate an additional 19% of the processed and released pronghorn succumbed to capture myopathy and/or predation.

In Alberta, 70 drive-trapped pronghorn were transported to rangeland enclosures and four to holding pens; 3 of the 70 animals were injured during transport and subsequently euthanized (Chalmers and Barrett 1977). However, the main cause of death (17 animals) appeared to be associated with capture myopathy. Most of these animals died 2 - 5 days after capture and transport; 2 died after 13 days. These investigators also examined two 2-week old fawns that died after being pursued by a vehicle. Both animals displayed clinical signs typical of capture myopathy. O'Gara necropsied a fawn that was chased by a golden eagle and died of capture myopathy-like symptoms after its sibling had been killed by the same raptor (O'Gara 2004*d*).

Capture myopathy appeared more prevalent in pronghorn trapped during warm weather than cold weather and affected at least 4.2% of all pronghorn handled (Chalmers and Barrett 1977). During the later years of their study, these investigators found that the most effective practices in reducing acute cases of capture myopathy were less intensive aircraft pursuit, minimal handling, use of darkened trailers for transportation, and cold weather drive-trapping. Mortalities attributable to capture myopathy also were fewer when the transportation distance was short.

Although corral trap mortality of pronghorn generally is reported to be 2 - 5%, overall mortality due to a trap and translocation operation may be considerably higher. Mortality (probably acute trauma) at the trap site reported for 5,751 pronghorn (summation of reports) was 4.3%; mortality reported for 1,600 pronghorn transported to a release site was 7.5% (O'Gara et al. 2004). Combining these percentages with the Chalmers and Barrett (1977) estimates of capture myopathy, overall pronghorn mortality from a trap and translocation project may approach 30%, even under optimal conditions and reasonable precautions.

Chalmers and Barrett (1977) stated that chemical immobilization can also lead to capture myopathy. B. O'Gara (personal communication) noted that the only 2 pronghorn he immobilized with M-99 died within 2 days, even though they were immobilized for only a short time and appeared to recover without complications. One carcass was necropsied, and the cause of death was attributed to shock although clinical signs of capture myopathy were also present. S. Amstrup (personal communication) immobilized adult pronghorn with 8 - 10 mg of Succinylcholine chloride, but experienced a number of mortalities and observed symptoms of capture myopathy.

Pronghorn are highly susceptible to capture myopathy for a number of reasons. They have highly insulated coats that hold heat; their capture often involves long and occasionally arduous pursuit, contributing to metabolic acidosis; and their highly excitable nature appears to predispose them to the psychological stress of capture.

The first signs of capture myopathy include an increase in temperature, respiration, and heart rate. More advanced stages are recognized by stiffness, poor coordination, and variable paralysis. Terminal signs include a faint, irregular pulse, and a muffled heartbeat. The animal may then collapse and/or become prostrate. Severity of the disease ranges from minimal clinical signs to mortality (Harthoorn 1975).

Treatment of capture myopathy in North American ungulates has been highly variable. Vitamin E and selenium preparations sometimes are administered, and although Chalmers and Barrett (1982) concluded that the injections did not necessarily reverse clinical signs, they did reduce mortality rates when used in conjunction with corticosteroids. In Oregon, 5 mL of Dexamethasone has been administered IM to moderately stressed animals, and 100 mg of Prednisolone Sodium Succinate has been used IV to treat advanced cases. In acute cases, 500 mL of Ringers Lactate Solution administered IV with 400 mEq/100 kg Sodium Bicarbonate intraperitoneally.

3. Marking

Pronghorn are unique in that individuals can be identified without applying any artificial markers. Byers (1997) was able to identify untagged individual pronghorn by varying patterns in: a) horn shape, size and orientation, b) neck bands and c) small idiosyncratic features such as notched ears or hair tuffs. Considerable time in the field is required for one to become familiar with all individuals patterns and this approach is best suited to a closed system where immigration and emigration rates are minor.

Colored collars, ear tags (Photograph 16), or dyes have been used for years to identify individual pronghorn, but radio or global positioning system collars now are used most often to follow seasonal movements of pronghorn, identify causes of mortality, and delineate home ranges.

If visual recognition of individuals is desirable in addition to a radio transmitter, fairly wide (approximately 3 in. (76 mm)) colored collars are recommended. Narrow collars may be covered by mane and neck hair, making identification difficult. Wide collars can be

Photograph 16. Pronghorn are often marked as an aid for later location or identification. Such techniques are of special value during mortality and seasonal movement studies, or locating translocated herds. Pictured here is an adult buck with a small marker in the left ear. It is purposely small, thereby assisting in marking the animal for life history activities, but still not easily seen by many public viewers. Photograph by Jim D. Yoakum.

observed from the air and individual markings easily discerned. R. Deblinger (personal communication) flew 50 - 100 feet (15-30 m) over pronghorn using a Piper Super Cub, and by slowing the plane down to pronghorn speed, could read the symbols or numbers on collars with little problem. Obviously, this technique can stress pronghorn, so care should be taken concerning the time of year and length of pursuit.

Collars should be tight enough that the animals cannot get a front foot or shrubbery caught in them. However, collars on sub-adults must allow for growth, and those on adult males must allow for neck swelling during the rut. Measurements of pronghorn from Colorado, Idaho, Montana, Nevada, Oregon, and Wyoming (Bear et al. 1973, McNay 1980, Autenrieth 1984) indicate the following neck circumferences using as a maximum, the neck size immediately ahead of the shoulder, and the minimum as being just behind the ears. Adult males averaged 23.2 in. (590 mm) and 15.2 in. (386 mm), respectively. Adult females averaged 19.3 in. (491 mm) and 13 in. (330 mm). One-day-old fawns had neck measurements of 6.1 - 6.8 in. (155 - 172 mm). Yearlings were so similar to adults, that adult measurements can also apply for this age class.

Radio transmitters for fawns should be < 5% of body weight including the collar (i.e., 0.26 lbs. (120 g)) (Photograph 17). Generally, fawns are only 1 - 2 days old when collars are attached, requiring small, light batteries with a short life. The best radio collars for fawns have the transmitter and lithium battery hermetically sealed in a nickel-steel canister measuring about 1.5 x 1.4 x 1 in. (38 x 35 x 25 mm). The largest battery that should be put on a newborn fawn only has a life of 7 - 10 months and an expected range of 1.5 - 3 miles (2.4 - 4.8 km). Transmitters usually are riveted between strips of 1-in. (25 mm) nylon webbing that serves as the collar when the ends are joined. Most researchers do not want radio collars to remain on fawns for > 3 months so small, light batteries can be used.

Several designs allow the radio collar to fall off before the batteries expire so that the collars can be retrieved. A simple design for short-term monitoring has the ends of the nylon webbing cut short and sewn to 1-in. (25 mm) wide elastic strips with strong nylon thread. These strips are sewn together with about 5 strands of light cotton thread to form an expandable neck collar. The cotton thread weakens with exposure and, as the fawn grows, and the tension on the collar increases, the threads break in 2 - 3 months. Tucks can be taken in the elastic with 2 - 3 strands of thread so the collar fits snugly. Successive tucks break away as the animal grows until the ends break and the collar falls off. Surgical tubing that is flexible and decomposes in 3 - 6 months has also been used successfully for fawn collars in Arizona.

Photograph 17. Radio collars weighing no more than a ¼ of a pound (< 120 g) are used for marking 1 – 2 day old fawns. Fawn collars made of surgical tubing are flexible, allow for neck growth, and decompose in 3 - 6 months. Photograph by Richard Ockenfels.

When neck sizes increase greatly, nonadjustable collars may cause death. Keister et al. (1988) developed a durable, light-weight, self-adjusting radio collar for pronghorn fawns that allowed tracking animals through their first year. These collars were easy to attach and did not injure animals. Of 120 pronghorn fawns fitted with these collars, no deaths could be attributed to the collars, although 5 fawns were abandoned. The only problem was some fawns lost their collars during the first few days—a problem remedied by adding a foam liner. Although collars lost resiliency with use, all retained enough tension to remain attached to necks of various sizes without becoming too tight. In about 1 year, however, some collars became slightly brittle and cracked. This weathering, along with the animals crossing through a number of barbed wire fences, contributed to some collar loss. But, because collar life was about equal to transmitter life, the potential for injury from collars was eliminated at about the same time as their usefulness was terminated.

Metal transmitters for fawns should be wrapped with dull-colored tape or painted, and the entire collar rubbed with sagebrush or other local aromatic vegetation to mask unnatural odors. Carrying collars in a bag with vegetation from the study area also assists in this effort.

Solar-powered ear tag transmitters weigh about 0.06 lbs (25 g) compared to battery-powered adult collars, which weigh about 1 lb (454 g). Ear tag transmitters eliminate the risk of trying to fit a neck collar on a growing animal or a mature male whose neck circumference increases during the rut. The ear tag should be placed about mid-ear to prevent the long hairs of the lower ear area from covering the solar panels. T. Pojar (personal communication) used 25 solar ear tag transmitters on 5-month-old pronghorn fawns with variable results. Three of the solar transmitters attached to females tore out of the ear within 6 months indicating that the cartilage of female fawns may not be strong enough to retain the ear tag. This problem was not encountered in male animals of the same age. Signal strength of these 25 transmitters was highly variable, possibly due to manufacture design or position of the tag in the ear. Some transmitters performed as well as battery-powered transmitters while others were weak or sporadic.

Properly designed ear tag transmitters may provide long term tracking ability. A solar-powered ear tag on a male continued to emit a signal after 5 years in the field, even though, the antenna had broken off limiting the range of the signal (T. Pojar, personal communication).

Even with their shortcomings, solar-powered ear tags are worth considering for specific investigations. Ear tags are less cumbersome than collars, and although they may tear out, they may be the better choice for marking fawns depending on the duration of the study period. Further design improvements will facilitate marking male pronghorn because these transmitters do not need to consider changes in neck circumference. Ear transmitters can be built with watch batteries and specific duty cycles (i.e., 12 hours) that overcome some of the shortcomings of solar-powered units, while still providing several years of operation.

Pronghorn are flighty, nervous animals, and marking them with streamers or other materials that move in the wind is not recommended. Many pronghorn have been marked with metal ear tags, and such tags have been retained for 10 years in some cases. However, B. O'Gara (personal communication) handled a pronghorn in Montana that was sloughing metal ear tags, apparently after her ears had frozen around the tags when the temperature had fallen to below - 30°F (- 34°C) approximately 2 weeks earlier. Plastic tags for earmarking livestock are available in stores supplying farm and ranch equipment. Such tags have less chance of freezing ear tissue and are easier to see at a distance than metal tags. Although plastic ear tags became brittle after 1 - 2 years when first available, those used in recent years have held up well.

Pronghorn do not always have to be marked for individual identification. An animal’s horn shape, color, width of neck bands, the amount of white pelage, configuration of the black areas on the face, all serve to make an individual pronghorn recognizable by an observer who is familiar with the animals being studied. From 1988 through 1994, Byers (1997) was able to identify 84 - 136 adult pronghorn, depending on the year, on the National Bison Range by using sketches and photographs to help memorize their physical characteristics and coat patterns.

4. Translocations

Transplanting pronghorn should be considered only after it has been determined the new or additional animals can survive in a habitat possessing sufficient quantity and quality of forage, water, and space in historic rangelands without being in conflict with other environmental issues (McCarthy and Yoakum 1984). Translocation should be preceded by a feasibility study or management plan to document the objectives, translocation procedures, and post-release monitoring of the animals in their new habitat.

At times, sportsmen's organizations, conservation groups, agency personnel, or local governments recommend translocating pronghorn into unsuitable areas. Such endeavors resulted in the loss of all pronghorn transported to Florida (Elliot 1966) and Hawaii (Nichols 1960). Analysis of these two cases disclosed the proposed sites did not meet pronghorn habitat requirements. Ignoring basic biological needs results in the eventual death of translocated animals, misuses of public funds, and elicits a negative reaction from the public as to the credibility of wildlife managers (Yoakum 1978). Similar unsuccessful translocations have been made into other areas of unsuitable habitat in both the U.S. and Mexico.

One of the first procedures for determining potential suitability of an area for the translocation of pronghorn to grassland habitats was developed by the Colorado Division of Wildlife (Hoover et al. 1959). Twenty-eight years later, the International Union for Conservation of Nature and Natural Resources (1987) proposed almost the same criteria, and summarized them as consisting of a feasibility study, a preparation phase, a release or introduction phase, and a follow-up phase. In many cases, the feasibility studies and preparation phases have been inadequate and the follow-up phase neglected.

The trapping and translocation of pronghorn involve large amounts of manpower, time, and finances. Therefore, it is recommended that feasibility studies and management plans be developed prior to authorizing any release. These plans should provide detailed procedures for capture, transportation, and release into new habitats. Management plans should specify the numbers of animals to be captured, and identify specific release sites. To ensure the animals are captured and handled as safely as possible, the presence of a veterinarian at the capture site is highly recommended. The plan also should provide particular information regarding methods of release and follow-up monitoring.

Translocation goals should address the question of establishing a viable herd. Relocated herds that increase 20 - 30% within 5 - 10 years after release are indicative of herds that are responding to suitable habitat conditions. Franklin (1980) considered 50 breeding adults the minimum for a viable population. It therefore seems reasonable that translocations should contain ≥ 100 animals as recommended by Hoover et al. (1959). An exception might be an emergency situation if some animals already were present in a release area judged to be below carrying capacity. Franklin (1980) also suggested 500 randomly mating individuals as the minimum population size for sustaining genetic variation at a level that would enable the species to adapt to changes in the environment. This appears appropriate for pronghorn, especially on rangelands experiencing frequent severe winters and/or numerous droughts.

a. Determining Suitable Release Sites

The initial factor to be evaluated for a release site is whether the area was historically occupied by pronghorn. Sites not historically inhabited apparently lacked some necessary habitat component. Any proposed release site should be evaluated as to why the site is not currently supporting the desired number of animals. To this effect, the following questions must be answered: 1) what caused the animals to become extirpated and/or has the factor or factors responsible for their elimination been corrected, 2) has the limiting factor(s) now improved sufficiently to meet the pronghorn's habitat requirements, and 3) are current land uses and landowner attitudes favorable towards a re-introduction.

Translocations are one of several reasons pronghorn populations have increased from 30,500 in 1924 to > 1,000,000 in 1984 (Yoakum 1986). Many of the translocations during the last 50 years were successful (Fisher 1942, Thompson 1947, Stokes 1952, Hoover et al. 1959, Russell 1964, Menzel and Suetsugu 1966, Yoakum 1978, Britt 1980). Others, however, were unsuccessful (Alcérreca and Sotomayor 1981, Tsukamoto 1983, McCarthy and Yoakum 1984, Del Monte and Kothmann 1984). Improved techniques and knowledge from past experiences are therefore useful guides for future operations.

b. Feasibility Guide

Hoover et al. (1959) developed criteria for the selection of translocation sites for grasslands in Colorado. Eight of these criteria bear repeating with only slight modifications since they were originally drafted:

1. *Unless sufficient continuous rangeland is available to allow a translocated herd to be maintained or expanded, the site should be rejected. As a rule, each animal requires ≥1 square mile (2.6 km^2) of native grassland, and the number of animals should be > 100.*

2. *Pronghorn feed primarily on forbs and shrubs. Therefore, a good variety and production of these should be present. Rangelands in poor ecological condition or dense, high shrublands are not desirable.*

3. *Concurrent use of rangelands by domestic livestock (cattle, horses, and/or sheep) should be evaluated. This involves competition for forage and water as well as compatibility, the presence of fences, predator control practices, and whether pronghorn or livestock might transmit diseases from one animal to the other.*

4. *Depredation on agricultural crops is a potential conflict that needs evaluation. Isolated fields surrounded by rangelands usually are subject to more depredation than are numerous fields.*

5. *A map illustrating the land ownership pattern should be prepared, especially if private lands are involved. Public lands are preferred,*

followed by large blocks of private lands with one owner. The least desirable sites are private lands in small units with many owners.

6. *Reactions of people to an introduction should be considered, particularly those of local conservation organizations, personnel charged with administering public lands, livestock permittees, and private land-owners. It should also be ascertained whether the landowners would be agreeable to hunting on their property.*

7. *If all the above factors are satisfactory, written permission should be secured from all public land agencies and private land-owners in the area prior to the release.*

8. *It is also desirable to provide for alternate release sites to allow for last minute changes, inclement weather, and/or road conditions.*

As a guide for determining an appropriate release site, Hoover et al. (1959) developed a form recommended for completion prior to release on grasslands. Yoakum (1980) adapted the form for shrubsteppes, and this form warrants attention from managers planning translocations (Appendix A). A similar form is also in use by Arizona Game and Fish Department to evaluate semi desert and other grassland sites.

c. Habitat Suitability Criteria

Determining suitable habitat for pronghorn is related to the right amount and juxtaposition of all habitat characteristics meeting the species' biological requirements. Suitable habitat for pronghorn can be determined through a system of rating habitat characteristics. Too little or too much of any biotic or abiotic factor may limit pronghorn production and survival. Knowledge of these habitat requirements and relationships is the ecological foundation for managers making translocation and management decisions (Yoakum 2004*b*).

Quantitative rating systems have been developed to assess winter rangelands (Allen and Armbruster 1982), translocation sites (McCarthy and Yoakum 1984, Arizona Game and Fish Department 1993), suitable year-round habitat (U.S. Bureau of Land Management 1980, U.S. Soil Conservation Service 1989), effects of wildfires on vegetation (U.S. Bureau of Land Management 1980), and the compatibility of domestic sheep to pronghorn (Howard et al. 1990). These rating systems have been used to evaluate pronghorn habitat in documented reports, thereby advancing pronghorn management from earlier “professional judgment” efforts to using written scientific criteria.

Habitat suitability was used as the main criterion for evaluating 5 potential shrubsteppe translocation sites in Mono County, California (McCarthy and Yoakum 1984). Similar strategies for evaluating sites can be used in assessing other potential release sites, to establish priorities, and to provide insight into the feasibility of a transplant. Procedures for choosing the best 5 sites included an evaluation of 9 criteria:

1. *Habitat suitability was evaluated for water, vegetation quality (percentage forbs, shrubs, and grasses), vegetation height, and forage quantity using criteria established by Yoakum (1980).*

2. *Mean winter snow depths were interpolated using data from weather stations. Areas were considered suitable for winter use if mean snow depths were < 10 in. (25 cm).*

3. *Natural physical barriers were evaluated to determine potential for restriction of pronghorn movements. Major physical barriers included large ravines, mountain ranges, and dense shrub or timbered areas.*

4. *The potential size of each release site should be > 100 mi^2 (259 km^2).*

5. *Livestock fences were evaluated in relation to pronghorn permeability. A barbed-wire fence was considered passable if the bottom wire was ≥ 16 in. (41 cm) from the ground.*

6. *Potential for predation on pronghorn was subjectively rated in terms of high, moderate, or low. Predator abundance information was obtained from various government agency personnel, ranchers, and individuals familiar with the sites.*

7. *Potential for crop depredations was estimated on the basis of location of agricultural crops in relation to each site. Distances were determined to the nearest cultivated field and a depredation potential rating of high, moderate, or low assigned to each area.*

8. *Seasonal suitability was evaluated on the basis of food availability and whether or not an area could support pronghorn on a year-round basis.*

9. *Potential for forage competition with livestock was estimated on the basis of class of livestock, animal unit months, and grazing systems. Each site was rated as having high, moderate, or low potential for livestock/pronghorn conflicts.*

Following the evaluation of each site, limiting factors were addressed on the basis of the above criteria. The sites were compared with each other and prioritized in terms of the site(s) with the greatest potential for a successful pronghorn transplant. This system provided 2 components to help select the best potential release site thus providing a better chance for a successful translocation:. It was based on ecological data collected in the field, and a numerical rating denoted the site with the highest potential, and potential limiting factors were identified so that remedial measures could be taken prior to any releases.

The following guidelines are recommended for pronghorn translocations:

1. *Translocation sites should be evaluated for habitat suitability prior to any animals being captured. Each state or province should establish a rating system that considers regional conditions and topography. Areas that do not meet such specifications should not be considered feasible.*

2. *Multiple translocation sites should be prioritized to establish which areas have the highest potential for successful translocations. Ideally this should be done on a statewide, province-wide, or regional basis to assure that translocations are made only in the highest quality sites.*

3. *Habitat suitability criteria should be continually fine-tuned for site-specific release areas. Ratings for topography, vegetation, and water availability should be modified to reflect ecological conditions within a state, province, or region.*

4. *Translocation projects should include monitoring the success of animals after release. This is important in developing and modifying translocation guidelines and ensuring accountability in translocation endeavors.*

5. Care and Captive Management

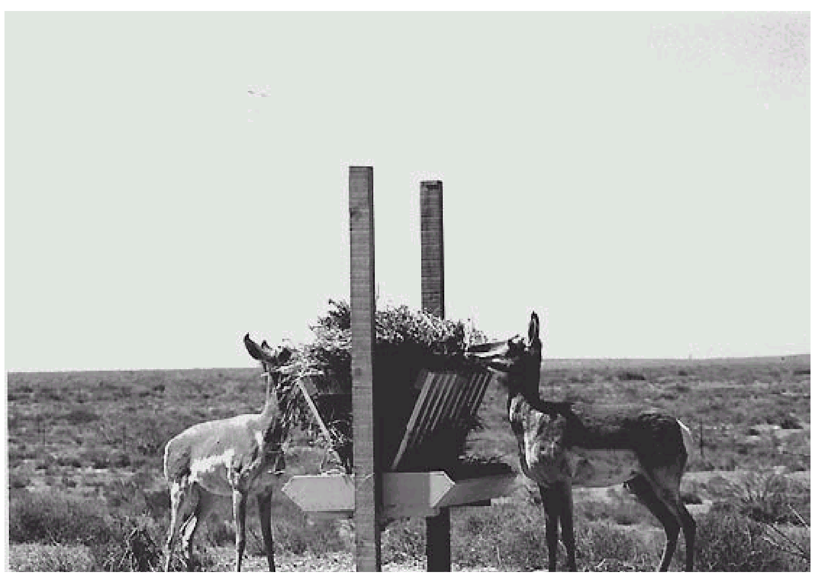
Captive pronghorn have had an important management role since the early 20th Century (Brunner 1910, Floyd 1924, Nelson 1925, Nichol 1942, Einarsen 1948), and continue to do so depending on the purpose involved. The main functions of captive pronghorn include public display, research, rehabilitation, and assistance in recovery efforts (Schwartz et al. 1976, Brinkley 1987, Wild and Miller 1991, Raisbeck et al. 1996, Blunt and Myles 1998, Lindstedt et al. 1991, Cancino et al. 2001). There are therefore captive pronghorn in zoos, on private ranches, at universities, and in public and private parks.

Depending on the objectives, a captive management program may employ a wide range of practices and facilities. For example, although the pronghorn on the National Bison Range are considered wild, all of the animals are fenced in, and essentially captives. The same holds true for the pronghorn on Antelope Island near Salt Lake City, Utah, and an enclosure on the El Vizcaíno Biosphere Reserve in Baja California Sur, Mexico (Photograph 18) even though the purpose of the former is primarily aesthetic, and the latter is part of a recovery effort for the endangered peninsular pronghorn (*A. a. peninsularis*) (Cancino et al. 2001, Tullous and Fairbanks 2002,). These and other facilities can be divided into 3 basic groups: 1) public display areas where animals are fed and receive medical care and other amenities on a regular basis; 2) research enclosures composed of corrals, pastures, and other facilities where the animals are more or less under constant observation (e.g., Sybille Wildlife Research Unit in Wyoming or the Foothills Wildlife Research Facility at Fort Collins, Colorado); and 3) large fenced areas within habitat that contain feeding and watering facilities (Byers 1997, Blunt and Myles 1998, Cancino et al. 2001). Depending on the objective the facilities may be used to hand-rear and wean captured fawns, provide “soft care” for animals under observation, or intensively train research subjects.

Hand rearing captured fawns is the simplest way to start a captive herd. Once the fawns are removed from the wild, there are several protocols for bottle raising them (Schwartz et al. 1976, Brinkley 1987, Wild et al. 1994, Martin and Parker 1997). The main differences are in the composition, mixing procedures, and volume of the formula. Although methods of alleviating gastrointestinal distress differ, all have the same goal, successfully raising fawns to the weaning stage. The hand raising process can be divided into 5 periods: adaptation, initiation, development, concluding, and weaning. The adaptation period is to accustom the fawns to feed from the bottle. Evaporated milk is used as a base, with or without boiled water. Eight days with an offer of a 5 - 8-ounce (0.15 - 0.24 L) bottle should be sufficient. The initiation phase using a 10-ounce (0.30 L) bottle for 2 weeks then begins.

The development period lasts about 50 days. During this phase, larger amounts of food are offered. According to the protocol selected (i.e., the amount of milk mixed with the boiled water), milk consumption gradually increases and the consumption of vegetation begins. Depending upon the situation, the vegetation eaten can be native plants, alfalfa hay (*Medicago* spp.), or a mixture of both. Salt blocks should also be accessible during this stage.

The length of the concluding period can be adjusted depending on the number of fawns involved and the weaning schedule desired. This adjustment should also consider the age when individual animals were captured, with the younger animals requiring more time than those caught earlier in the season. In pronghorn, permanent teeth replace the “baby teeth” at about 16 months of age (Jensen 1998).



Photograph 18. Two pronghorn feeding at a feed bunker that were raised for future releases to historic rangelands on the Vizcaino Desert, Mexico. Photograph by Ramon Castellanos.

Places like the National Bison Range require little overt care other than observation and other "soft care" techniques, and the periodic removal or restocking of individuals. Byers (1997) presents a detailed description of the monitoring and other procedures used at this location. Captive animals nonetheless always present the possibility for accidents (e.g., rattlesnake bites) (Miller et al. 1989) or surgical emergencies. Lumpy jaw lesions associated with infected teeth roots are common in captive animals, and bacteria isolated from these jaw and mandibular abscesses include *Arcanobacter pyogenes* and *Fusbacterium necrophorum*. In addition to lancing and draining abscesses, treatment with antibiotics is often required to manage lesions (M. Wild, personal communication). As a consequence, it is usually advisable to have veterinary staff on the premises, and under optimal conditions preventive medicine protocols would include yearly treatment with vaccines as is done for domestic sheep. Euthanasia should be considered in some cases.

Schwartz et al. (1976) described fawns subjected to intensive training for food habit studies, Lindstedt et al. (1991) discussed the laboratory use of pronghorn in energetic studies, and Raisbeck et al. (1996) evaluated the susceptibility to selenosis. The reader is urged to consult the original reports for greater detail.

Phylogenetics

Chromosome studies (Wurster and Benirschke 1968) aminoacid sequences (Beintema et al. 1979), and electrophoretic variation in allozymes (Baccus et al. 1983) used to establish the taxonomic status of pronghorn have confirmed its early radiation from other ruminants, highlighting a closer relationship of pronghorn with Giraffidae and Cervidae in contrast to Bovidae. The primitive status of pronghorn and its affinities within ruminants have recently been supported by DNA sequencing of the complete mitochondrial (mtDNA) genomes comprising approximately 15,000 base pairs (bp) (Hassanin et al. 2012).

1. Forensic Applications

Various methods for the genetic identification of pronghorn remains (e.g., carcasses, meat, blood, hides, feces) have been proposed using mtDNA, which is a haploid, maternally inherited and present in higher quantities within cells compared to nuclear DNA. The first applications used restriction fragment patterns separated by agarose gel electrophoresis, followed by southern blotting and hybridization mule deer mtDNA, producing a species-specific restriction pattern in terms of number and size of fragments when compared to other species of large mammals (Cronin et al. 1991). Similar assays using restriction fragments of the mtDNA control region allowed to distinguish pronghorn from 14 other species of ungulates (Murray et al. 1995). Current assays in pronghorn use DNA sequencing of genes amplified by the Polymerase Chain Reaction (PCR), and methods using conserved primers have been published, for instance, targeting the complete cytochrome b gene (approximately 1,100 bp) via the PCR, followed by DNA sequencing and comparison with sequence databases (e.g., GENBANK) using bio-informatic tools (e.g., BLAST) (Naidu et al. 2012). However, given the relatively large size of the PCR fragment, this protocol might have limited use in degraded or ancient DNA applications. For such, multiple PCR primer pairs targeting smaller regions (approximately 500 bp), from the mtDNA control region of the pronghorn (Klimova 2013) are useful for forensic applications in degraded samples such as feces recovered from hot and dry desert environments. Primers for genetic sex identification via PCR amplification of the X and Y zync-finger introns of the white-tailed deer (Lindsay and Belant 2007) proved useful for sex determination in blood, tissue and oral swabs from pronghorn (Klimova 2013), while tests targeting the amelogenine or SRY genes failed. Given the size of the Y chromosome intron in pronghorn is approximately 450 bp, this technique has limited application to degraded DNA such as that from feces. Protocols for the amplification of the DRB locus from the immune system Major Histocompatibility Vomplex genes of the pronghorn are also available, which appears to be duplicated within the species (Klimova 2013).

Microsatellite markers are nuclear, selectively neutral, bi-parentally inherited molecular markers that usually are very polymorphic, allowing the identification of individual genetic profiles and small genetic differences between populations, and thus are one of the most useful genetic markers. Microsatellites used in the pronghorn include: 34 loci isolated from pronghorn (Carling et al. 2003*a*, Dunn et al. 2010, Munguia-Vega et al. 2013), and 1 loci from the cow genome that was modified for its use in pronghorn (Stephen et al. 2005b) The usability of microsatellite loci in degraded samples such as feces depends on the size of the PCR product, with only a few loci < 200 bp amplifying with a success > 50% (Klimova 2013). Additionally, a 1477 bp satellite DNA, composed of degenerate 31 bp sub-repeats very similar in sequence to those of major satellite DNA from cattle and sheep was described in pronghorn (Denome et al. 1994). However, variation at the individual and population level has not been studied. The complete mtDNA genome from one individual pronghorn became available recently (Hassanin et al. 2012).

2. Subspecies Taxonomy, Population Genetics and Genetic Diversity

The first population genetic study of pronghorn applied to management used allozymes to compare 6 populations from western Texas, reporting levels of observed heterozygosity of 0.012 - 0.046 (average 0.027) and 1.1 - 1.2 alleles per locus (average 1.18) among 5 polymorphic loci (Lee et al. 1989, 1991). The study showed 1 population (Marathon Basin herd) to be significantly different from the rest (Rogers' genetic distance from 0.036 - 0.064), suggesting that translocation of pronghorn into this genetically isolated area was not recommended. An expansion of the previous study included 29 populations from 3 subspecies (Oregon (*A. a. oregona*), Mexican (*A. a. mexicana*) and Americana (*A. a. americana*)) from Canada and the U.S. using 20 allozyme loci and restriction-fragment analysis of the entire mtDNA and 2,290 bp from the mtDNA NADH dehydrogenase 2-gene (Lee et al. 1994). This study found levels of heterozygosity of 0 - 0.076 (average 0.024) and 1 – 1.5 (average 1.15) alleles per loci, and did not find support among any of the markers used for any genetic differences among samples. This questioned the validity of the Oregon subspecies, which had close affinities to Americana subspecies. Rogers' distances from allozyme data were 0.010 - 0.071, and samples generally clustered according to geography with no clear subdivisions. Four haplotypes were found for the entire mtDNA restriction fragment analyses, and all populations shared 1 common (ancestral) haplotype. The NADH restriction analyses showed 9 haplotypes, with 1 haplotype found in most populations. The Yellowstone population showed the largest number of haplotypes (4) probably because this population never suffered from large population bottlenecks. The data suggested low genetic variation within pronghorn in comparison to other species and fitted a model of intermediate levels of gene flow among populations where new mutations have not yet spread throughout the range of the species, probably due to restricted dispersal. Gene flow between Americana and Mexican subspecies (i.e., a natural intergrade zone) was evident in western Texas and southern New Mexico. However, two clearly separated clusters in the NADH data were present, including one cluster in the north with animals from Kansas to Montana, and the rest from the south. A similar analysis among 5 populations further suggested 4-restriction haplotypes at the mtDNA NADH gene in Arizona (Reat et al. 1990, Rhodes et al. 2001). While the most frequent haplotype found throughout the pronghorn range (excluding Sonorian and Peninsular populations) was common in northern Arizona (Arizona strip), but not in central and southern populations, probably as a result of reintroductions. The analysis of 16 allozyme loci in the same 5 populations in Arizona also supported significant differences in allele frequencies among populations. High levels of variation in Arizona (average expected heterozygosity = 0.101, mean 2.2 alleles per locus), is likely a result of reintroductions from multiple sources including Arizona, Colorado, Montana, Texas, Utah and Wyoming (Rhodes et al. 1999). An analysis of 282 bp of the mtDNA control region and 3 microsatellite loci in 14 populations of pronghorn throughout much of their range (including few samples from the Sonoran subspecies) showed 28 haplotypes and 2 distinct groups showing moderate differentiation (microsatellites *F*st = 0.086, mtDNA *G*st 0.111): in the north (Colorado, Kansas, Montana, Idaho, Wyoming and Oregon), and in the south (including Sonoran pronghorn and individuals from southwestern Arizona and Texas) (Lou 1998).

An analysis of approximately 500 bp of the mtDNA control region and 5 microsatellite loci among 9 populations including the Sonoran, Americana and Mexican subspecies sampled between 1998 - 2001 supported a history of recent isolation of Sonoran pronghorn from those in Arizona, New Mexico and Texas, although the Sonoran subspecies was not considered very distinct from the rest (Stephen et al. 2005*a*). The study reported 38 haplotypes across the 3 subspecies. The number of haplotypes ranged from 3 (Arizona Sonoran pronghorn) to 16 (Central Arizona), haplotype diversity ranged from 0.55 (Arizona Sonoran) to 0.89 (Oregon), number of alleles ranged from 4.4 (Sonoran) to 8 (Arizona Central), observed heterozygosity ranged from 0.502 (Arizona Sonoran) to 0.734 (Oregon), and the inbreeding coefficient ranged from − 0.057 (Arizona central) to 0.143 (Arizona Sonoran). Overall, *F*st values ranged from 0.034 (Arizona central vs. east) to 0.205 (Arizona Sonoran vs. Texas). Although the locus showed little phylogenetic resolution and slight geographic structure, 2 out of 4 haplotypes were unique to the Sonoran pronghorn in Mexico but not in Arizona, and 2 other haplotypes were much more common in the Sonoran subspecies in both Mexico and the U.S. than in other localities. However, many other populations also showed unique haplotypes. The microsatellite data showed more similarity between the 2 Sonoran samples (*F*st = 0.073) than with any other samples (*F*st range 0.104 - 0.205), suggesting a closer relationship between them. The 2 Sonoran populations divergence was likely due to obstructions to gene flow (highways, fences, and canals) and small population sizes, suggesting augmentation of populations across the U.S. – Mexico border might be recommended. Low genetic diversity was present in the Sonoran subspecies, particularly in Arizona where only 3 haplotypes were detected, low haplotype diversity (h = 0.55), 4.4 microsatellite alleles on average per locus, comparatively low observed heterozygosity (H_o = 0.502) and high inbreeding (F_{is}= 0.143). Higher genetic diversity and lower levels of inbreeding were observed in the Sonoran pronghorn from Mexico (4 haplotypes, h= 0.70, H_o= 0.573, F_{is}= 0.019). However, both Sonoran populations had similar allelic diversities (4.4 alleles per locus).

In a recent study of 2 captive populations of endangered pronghorns in the Sonoran Desert (Munguia-Vega et al. 2013), strong levels of genetic differentiation were found between the Peninsular and Sonoran subspecies with no shared mtDNA haplotypes (F_{st} = 0.562) (Klimova 2013) and large differences in allele frequencies at 18 microsatellite loci (F_{st} = 0.402) (Klimova et al. unpublished data). However, the haplotypes between the 2 subspecies only differ by 1 nucleotide substitution. Although genetic differences between the 2 subspecies could have increased as a result of small population sizes in captive breeding programs, these results suggest that the Peninsular and Sonoran subspecies currently represent 2 distinct evolutionary significant units (Moritz 1994), contradicting a previous genetic study analyzing 452 bp of the mtDNA control region that detected 29 haplotypes but failed to detect the strong genetic differentiation of the Peninsular subspecies (Amor et al. 2006), likely due to lower number and resolution of molecular markers. However, a comparison of these results in a species-wide study including samples from the entire range of all pronghorn subspecies and multiple loci representative of the pronghorn genome is currently lacking, as noted previously by others (O'Gara 2004*e*).

3. Anthropogenic Barriers to Gene Flow

A study of pronghorn living on opposite sides of U.S. Route 89 and State Route 64 (both built in 1932) in northern Arizona found that, according to 2 bayessian methods and microsatellite genotypes for 8 loci, individuals on opposite sides of the highways were assigned to distinct genetic clusters, suggesting they act as strong barriers to gene flow (Theimer et al. 2012). However, no evidence of inbreeding or reduced genetic variation was evident, probably because they may take longer to appear (Theimer et al. 2012). These results highlight concerns about the effects of anthropogenic barriers in wild populations, such as the border fence between the U.S. and Mexico that divides populations of the Sonoran and Mexican pronghorn (Cohn 2007, List and Valdéz 2009).

4. Founder Events

A low number of founders with subsequent loss of genetic diversity by genetic drift and increase in genetic differentiation are common among many recently founded wild pronghorn populations. In Oregon, 17 pronghorn reintroduced in 1969 had about half the genetic diversity as its source population and another population located nearby, regardless that the population expanded to 350 individuals in 17 years. This was evident at the number of mtDNA haplotypes (4 and 10 - 12 in 550 bp of the control region, respectively), average number of microsatellite alleles/locus (5.6 and 8.6 - 9.2 averaged among 5 loci, respectively) (Stephen et al. 2005*b*). The loss of expected heterozygosity was comparatively slower (0.66 and 0.75 - 0.69, respectively). Relatedness in the founder population increased about 3.5 times compared to the source population (r = 0.168 and 0.046, respectively). Significant genetic differentiation was detected in the bottlenecked population when compared to its source (microsatellite F_{st} = 0.078) compared to 2 reference populations (microsatellite F_{st} = 0.021). This was caused by rare alleles in the source population that were found in high frequency in the translocated population. A natural founder event from 28 founders that in 7 years increased to 277 individuals in Colorado also showed rapid changes in the allele frequencies of 5 allozyme loci, despite the small spatial scale of the study (Lee and Fairbanks 1998). However, a population founded in 1913 by 13 individuals in Wind Cave National Park that increased to approximately 300 individuals in the 1960's and were reduced to approximately 30 individuals in 2002 showed similar levels of microsatellite diversity at 5 loci, low inbreeding coefficients and no genetic differentiation when compared with other nearby populations. The lack of genetic differentiation was likely due to the contribution from non-founder pronghorn to reproduction (Jenks et al. 2006), and sampling the same year as the bottleneck event.

5. Parentage

Using 8 microsatellite markers to assign paternity, a study at the National Bison Range found that 44% of the young born in the wild were sired by different males (Carling et al. 2003*b*), suggesting complex patterns of female choice and/or sperm competition. This mechanism might increase genetic quality and diversity that could increase fawn survival. It has been suggested that females incite competition among males by switching harem groups to assess male vigor as a case of mate selection by a good genes criterion (Byers et al. 1994). Genetic pedigree analyses support the view that offspring from the few males that sire most young have higher survival rates accomplished by faster growth rates, while females that mate with other males of less quality compensate by increased rates of milk delivery (Byers and Waits 2006). A recent study with larger sample sizes in the same population estimated 19% of litters were sired by 2 different males (Dunn et al. 2012*b*).

6. Inbreeding

Population viability analyses of Sonoran (Hosack et al. 2002) and Peninsular (Cancino et al. 2010) pronghorn have suggested that below a population size of 100 individuals, inbreeding in small pronghorn populations might increase the risk of extinction due to slower population growth and increase fluctuations in numbers, particularly when combined with an increase in the mortality of fawns and breeding females. However, these models have assumed there had been no inbreeding previously, and thus they might have underestimated the actual increase in the risk of extinction due to genetic factors. In Yellowstone, it was estimated that the effective size (N_e) of breeding adults is about 1/3 of the total number of adults (Scott 1990). Given that only a small number of pronghorn are commonly available for the start of a new captive breeding program or reintroduced population, it is important to ensure genetic diversity is maintained during the process

(DeVos and Miller 2005, SEMARNAT 2009). This is particularly important for the Peninsular and Sonoran subspecies, which have sustained low population sizes for several decades (Stephen et al. 2005*a*, Cancino et al. 2010) before the start of captive breeding programs from few founders. For instance, the captive breeding program for the Peninsular subspecies started in 2000 from 16 wild fawns and 9 wild adults captured during 2000 - 2003 (Cancino et al. 2005), while the captive breeding program for the Sonoran subspecies started in 2005 from 3 adults from Sonora and 11 from Arizona captured during 2004 - 2006 (Wilson et al. 2010). Ways to minimize inbreeding in captive programs include changing the breeding male in captivity each year (Cancino et al. 2005), and implementing breeding management schemes that either minimize pairwise relatedness estimated from genetic markers between potential mates or avoiding known pedigree relationships. Molecular pedigrees are useful to assign offspring to their genetic parents.

Recent surveys using 16 microsatellite loci in captive individuals from the Sonoran pronghorn in Arizona indicated that levels of genetic diversity are similar to those observed in the wild (1998 - 2001) before the captive population was established, indicating that no significant genetic diversity was lost during the start of the captive program in 2005. Average number of alleles per locus in the Sonoran subspecies was 4.86 (range 2 - 8), and observed mean heterozygosity was 0.48 (range 0.13 - 0.78) (Munguia-Vega et al. 2013), while analysis of 906 bp of the mitochondrial control region revealed 4 haplotypes separated by single nucleotide substitutions (h= 0.470) (Klimova 2013). The inclusion of Sonoran pronghorn from Mexico at the start of the captive program in Arizona likely contributed to maintaining diversity. Genetic diversity estimated from 14 microsatellite loci in the Peninsular subspecies suggested they currently have the lowest variation observed within the species, with 2.5 alleles per locus (range 1 - 4), and observed mean heterozygosity of 0.31 (range 0.00 - 0.61) (Munguia-Vega et al. 2013). Analysis of 906 bp mtDNA of the control region showed only 2 haplotypes (h= 0.396) (Klimova 2013). The mean TrioML relatedness coefficient calculated from 18 microsatellite loci among pairs of individuals was higher between captive Peninsular (0.109±0.02) than between captive Sonoran individuals (0.079±0.01) (Klimova et al. unpublished data). Breeding management at the individual level informed by genetic markers is needed to maintain genetic diversity and viability in captive breeding programs in the long-term.

Using 19 microsatellite loci, it was possible to assign paternities to fawns in a wild population at the National Bison Range, Montana, and construct a genetic-based pedigree (Dunn et al. 2011). Estimates of inbreeding coefficients demonstrated an increase in inbreeding after a bottleneck that reduced the population to 7 males and 41 females in 2003, and showed evidence of inbreeding depression resulting in lower fawn survival to weaning, birth mass, foot length, and condition. The number of lethal equivalents estimated empirically (24.17 - 28.72) was much higher than the average value (3.14) calculated from 40 other mammals and used in previous population viability analysis of Peninsular and Sonoran pronghorn (Hosack et al. 2002, Cancino et al. 2010). For pronghorn, heterozygosity was not a good predictor of inbreeding and had a small influence on fitness. In the same population, there was evidence from paternity analyses derived from genetic data of inbreeding avoidance during the female estrus period. As a result, females were more related to all males in the population than they were to their mates (Dunn et al. 2012*a*). However, a female-biased sex ratio did not predict the genetic mating system inferred from multigenerational pedigrees that indicated higher sexual selection on males and multiple mating by females. Reproductive success, assessed with genetic data, was skewed to only a few highly fruitful males per year (Dunn et al. 2012*b*).

Predator Control

1. Fawn Mortality

Vriend and Barret (1978) reviewed literature and concluded that low pronghorn fawn survival was a primary management concern throughout most of North America. Fawn losses ranging from 25 to 65% of the annual production occur regularly, often in the first months of life (Photograph 19). Low fawn recruitment has been considered the most important factor limiting pronghorn population numbers in the Southwest (Brown et al. 2002). Predation is often cited as the leading cause of fawn mortality.

In areas where predator control is deemed beneficial for fawn survival, predator removal is most effective just prior to fawning, but the control method must be done repeatedly to be cost-efficient (Smith et al. 1986). Hailey (1979), in an area of Texas, and Willis (1988), in an area of Oregon, reported significant increases in fawn survival where coyotes were intensively controlled. Connolly (1978) lists numerous cases of predator control increasing fawn survival. Menzel (1994) reported that 2 years of coyote control

Photograph 19. A study in Oregon of predation on neonates documented an average loss of around 50% for 10 years. Although mortality appeared high, the herd increased > 80% during the 10 year study. The availability of abundant quality and quantity of forage appeared to influence population trends more than predation. Photograph by Jim D. Yoakum.

increased fawn survival, but that subsequent surveys revealed no increases in pronghorn populations.

A report, in the 2004 Proceedings of the Pronghorn Workshop, reviewed the findings for 35 predator/fawn mortality studies during the last 60 years and concluded that predator control practices often resulted in increased fawn recruitment, but predator control rarely resulted in increased herd numbers (Yoakum et al. 2004). Also, coyotes respond to removals/decreased populations by increasing their litter size, increasing the number of reproductive females, and decreasing their age of reproduction, resulting in higher predator numbers within 1 breeding season (Knowlton et al. 1999). Jones and Yoakum (2010) concluded that low fawn recruitment is a natural phenomenon in pronghorn and as long as the habitat is maintained pronghorn populations will have the ability to maintain themselves.

The availability of quality forage for pronghorn is a primary factor in fawn survival according to Ellis (1970). He compared population dynamics and habitat characteristics for herds in the Great Basin with those on the Great Plains during the last 2 months of gestation and the first 2 months of lactation. Ellis concluded that fawn survival was twice as high on the Great Plains because of the availability of more nutritious forbs. Thus, the lower availability of preferred, succulent, and nutritious forage, exacerbated by its consumption by livestock, resulted in Great Basin rangelands having a lower carrying capacity for pronghorn (Ellis 1970).

Predators kill some pronghorn (Photograph 20), especially fawns, and predation can be significant on marginal pronghorn rangelands or in areas where predator numbers are high in relation to pronghorn numbers (Smith et al. 1986, O'Gara and Shaw 2004). Most fawns killed are 1 - 3 weeks of age, while separated from their mothers. Trainer et al. (1983) reported that 87% of fawn mortality occurred during the first 3 weeks of life in Oregon.

Pronghorn, although having made an impressive comeback, often are restricted in their movements by fenced farms, highways, and right-of-ways as well as urban developments. Thus, some herds are localized and relatively small. Under such artificial circumstances, predators may keep pronghorn populations from increasing or even eliminate them (Udy 1953). Predator control to benefit a big game population often involves a reduction of predators over a large area, however, and even if desired, such control seldom is economically feasible (Berger 2006). However, Smith et al. (1986) indicated that selective, time-specific application of aerial gunning in areas of high coyote density could be an economically beneficial means of increasing fawn survival on Anderson Mesa in north central Arizona.

As pointed out by Hornocker (1970), if suitable habitat is unavailable, no amount of predator control will bring about a flourishing population of a prey species. Also, controlling 1 species of predator may be compensated for by increased predation by other species, as happened on the National Bison Range when coyotes were reduced and predation by bobcats and golden eagles increased (Corneli et al. 1984). The overriding influences on pronghorn mortality are changes in carrying capacity and the quantity and quality of habitat available. As an example, Pyrah (1987) found that coyote density in the

Photograph 20. Each species of predator has characteristic feeding patterns and often leaves evidence at a carcass in their attempts to bury or cover it. Here a bobcat has scratched out hair in an attempt to camouflage a carcass from carrion-eating birds. Cats often do this if ground litter is not available to cover a carcass. Feeding and covering patterns should not be considered conclusive evidence of a predator kill. Kills can only be determined by the typical wound patterns inflicted by a species of predator plus hemorrhages showing the prey was alive when the wounds were inflicted. Photograph by Rod Canutt.

Yellow Triangle area of Montana was positively correlated with pronghorn numbers, presenting the possibility that coyote and pronghorn populations reacted concurrently to habitat factors.

Recognizing the many investigations relative to pronghorn neonate-predator relationships, a comprehensive report assessed > 35 publications from 1945 to 2006 (Yoakum et al. 2004). A summary of these findings regarding pronghorn fawn relations to predators and predator control include:

1. *Native predators currently exist in all habitats occupied by pronghorn. Prey and predators have coevolved.*

2. *Pronghorn are prolific fawn producers, averaging 180 - 190 ff:100dd. Mortality of fawns are generally high at 50 – 80% of annual production. Predation averaged 53% of overall fawn mortality for the 12 studies using radio telemetry.*

3. *Predation is highest during the first 30 days following parturition – the hiding period for fawns before they grow large and swift enough to evade predators. Documenting low fawn recruitment is not necessarily justification for a large scale predator control program. Low fawn*

recruitment may be a symptom of low quality habitat or other predisposing factors.

4. *For most habitats, coyotes are the main predator of pronghorn neonates. Bobcats and golden eagles take smaller percentages.*

5. *Rates of neonatal mortality are generally higher in marginal pronghorn habitats or when a population is at or above ecological carrying capacity. Mortality rates are likewise high for areas suffering from high density-dependent functions.*

6. *Even when predation has been identified as a major limiting factor for pronghorn and fawn recruitment below management objectives, other important mortality factors affecting carrying capacity should be considered before initiating predator control. Low fawn recruitment may be a symptom of low quality habitat or other predisposing factors: e.g., low abundance of alternate prey, large numbers of predators, poor health of prey, inclement weather, or unhealthy vegetation condition. Predation rates generally vary temporally and geographically, and recommendations for predator control should be supported by long-term studies (generally > 5 years) that assess which environmental factors are truly responsible for limiting population size.*

7. *Effects of predation are greatest when prey numbers are small and predators are many. Predation rates are generally higher for shrubsteppes and deserts than grasslands.*

8. *Numerous studies confirm that effective coyote control programs can increase initial fawn survival; however, it is rare that such practices result in increased pronghorn herd size. Generally, the condition and health of vegetation influences rates of predation.*

9. *A ratio of 15 - 20ff:100dd in summer surveys is probably needed to sustain a population.*

10. *A predator control program to enhance pronghorn productivity may be justified if predation rates are high and the pronghorn population is well below carrying capacity.*

11. *A short-term predator control program may be justified to assist the growth of a newly translocated population or to protect a captive herd.*

12. *To be effective, a coyote control program must remove > 70% of the predators prior to the fawning season and be conducted for 2 consecutive years.*

The effects of predators and predator control on adult pronghorn mortality rates is less reported in the literature. This may be the result of fewer acts of predation on adult pronghorn compared to deer or elk that inhabit sites occupied by cougars and bears. O'Gara and Shaw (2004) provide examples of limited cases of predation on adults. Ockenfels (1994*a*, *b*) reported increased cougar depredation when adult pronghorn moved to marginal habitats with abundant cougars.

2. Recommendations

In treating a problem situation in which pronghorn populations are reduced and predators are prevalent, the following guides should be used:

1. *Determine what pronghorn herd parameters are desired. This may be in terms of total number, recruitment rate, age classes present, etc. Determine the year-round distribution of pronghorn and the habitat types involved. Consider other population influences including, but not limited to, predation.*

2. *If predation is determined to be a significant inhibitor of a particular population, the cost of actually controlling predators in the short-term must be balanced against the long-term return. At present, two methods appear to be economically feasible for controlling coyotes: aerial gunning of coyotes immediately prior to and during the fawning season (Smith et al. 1986)* or *by surgical sterilization (Seidler 2009).*

3. *If it is determined that an increase in pronghorn numbers justifies the cost, predator control should be done on those herd units where documentation indicates predator reduction can meet management objectives.*

4. *In some captive situations, predator control may also take the form of preventive maintenance. In these situations double fence enclosures to control coyotes and overhead netting to discourage predations by golden eagles may even be desirable in small areas.*

3. Protection from Harassment

Little information is available concerning the impact of harassment on pronghorn. Although generally considered unethical, chasing animals with vehicles during hunting seasons is a common practice. Such stress probably also increases crippling loss as necropsies done by Chalmers and Barrett (1974) showed that pronghorn dying during drive trap operations exhibited muscle hemorrhages in the hind limbs, and concluded that stress may be highly detrimental to the pronghorn's wellbeing. McNay (1980) reported that females in late pregnancy and females with young fawns reacted negatively to any form of harassment, and pregnant females moved out of a fawning area when cattle moved in.

Road closures, seasonal use restrictions, and closed areas have all recently been employed as means to reduce pronghorn stress during the fawning season and at other critical times, especially in winter. Although numerous studies have documented the negative effects of human disturbance (Baker 1955, Scott 1976, Helms 1978, Crowe and Strickland 1979, Markham et al. 1980, Constan et al. 1981, Segerstrom 1981, Medcraft and Clark 1984, Andrews et al. 1986, Clark and Medcraft 1986, Dickens and Andrews 1986, Haag 1986, Hess 1988, Howard et al. 1990, Bastian et al. 1991, Chervick 1991, U.S. Fish and Wildlife Service 1994, Smith and Guenzel 2002, Tullous and Fairbanks 2002, Yoakum 2003), few scientific studies on the efficacy of closing pronghorn habitats to humans have been conducted. Such data are sorely needed.

4. Supplemental Feeding

The quality of game animals and the quality of human enjoyment of them result from good wildlife management (Murie 1951). Pressed by a public who want more animals to hunt or otherwise enjoy, and faced with limited or below-par habitat, wildlife managers may turn to artificial feeding or other measures that affect the "gameness" of a species and thereby foster inferior animals. According to Leopold (1933), the recreational value of a herd of game is inverse to the artificiality of its origin, and a proper game policy seeks a happy medium between the intensity of management necessary to maintain a game supply and that which would deteriorate its quality or recreational value. The desirability of a maintenance-free population should always be kept in mind when considering supplemental feeding.

Pronghorn populations are most stable on natural rangelands with unimpeded access to key seasonal habitats. Maintaining movement corridors to key habitats, some of which may be used no more than 1 year in 10, is becoming more and more difficult. Consequently, emergency feeding may be the only way to save large numbers of pronghorn during critical conditions. However, supplemental feeding usually comes with considerable expense and logistical challenges.

When an emergency situation arises, pronghorn usually move toward key habitats unless stopped by fences or other human-made impediments. Generally, emergency feeding should begin within a couple of days of the onset of stress for best results. Pronghorn that are starved for 10 days or more usually will not survive no matter what measures are taken to save them (Pearson 1969). Thus, palatable rations that are immediately accepted are needed.

K. Clay (personal communication) reported that the only pronghorn to survive a catastrophic die-off in Arizona during the winter of 1966 - 67 were fed clippings that had been mowed by highway department personnel. Animals fed alfalfa or other hay all died. Torbit et al. (1984) developed and tested a winter pellet ration formula that was economical, nutritionally complete, digestively safe, and acceptable to pronghorn. These researchers also investigated the most practical ways to deliver these rations to wild populations. As a result, a pelleted commercial ration for emergency use is now available from Ranch-Way Feeds in Fort Collins, Colorado (Baker and Hobbs 1985). This ration was used successfully in 2 situations encountered in Colorado, and demonstrated that emergency supplemental feeding of wild pronghorn is possible.

While experiencing a severe summer drought on the Carrizo Plain National Monument in southern California, wildlife managers reported a shortage of succulent nutritious forage and drinking water for a herd of wild, free-roaming pronghorn (Koch and Yoakum 2002). Consequently, emergency action was taken by providing alfalfa hay and fresh drinking water. Pronghorn readily located and consumed the forage and water. Soon after the first autumn rains arrived and herbaceous forage sprouted, the pronghorn quickly reverted to foraging on native vegetation. Field investigations located no pronghorn mortalities during and after the drought emergency program.

Habitat Management

The foundation for habitat management is a base inventory of the quality and quantity of food, water, physiographic features, etc. Once the base inventory has been completed, periodic monitoring studies should determine whether habitat conditions are static, improving, or declining. How often monitoring studies should be conducted varies with the degree of change in the habitat; however, it appears that every 5 years is adequate for relatively stable habitats. Rangelands experiencing rapid environmental changes should be monitored more frequently. Both the quality and quantity of forage and waters should be monitored on a prearranged schedule. Techniques to monitor habitat are provided by Yoakum (2004*b*) and Cooperrider et al. (1986).

1. Evaluating Habitat Suitability and Habitat Models

After the base inventory has been completed, evaluating the suitability of an area for pronghorn is possible. This is accomplished by comparing the habitat characteristics with pronghorn habitat requirements. Suitable habitat for pronghorn can be determined through a system of rating the amount and juxtaposition of habitat characteristics. Too little or too much of any biotic or abiotic factor may become the primary component limiting pronghorn production and survival (Dasmann 1964). Knowledge of these relationships becomes the ecological foundation for making management decisions.

Wildlife biologists today often use habitat models to evaluate pronghorn habitat suitability (quality), however, many of these models are based on professional judgment and lack quantified data. Models are used to synthesize knowledge of habitat components and apply information systematically towards management goals. Managers may find habitat suitability evaluations of assistance in making resource decisions. This is especially true when developing a plan to translocate herds, or when completing an environmental impact study to determine the relationships between livestock and pronghorn using the same habitat or the impact of human involvement on pronghorn habitat. The utility of a model should be tested over a sufficiently long period of time, and on a large enough scale to sample a variety of conditions (Yoakum 2004*d*).

Models are generally of 2 types, either conceptual or quantitative. Conceptual models represent thoughts and ideas in a qualitative way rather than in terms of numbers. Quantitative models are based on ideas and relationships contained in conceptual models, but augmented by numeric data. Using measurable sets of environmental factors and relationships can often be used to predict the outcome of a future event.

Habitat models may also be either extensive or intensive. Extensive models may be used to differentiate occupied from unoccupied pronghorn environments on a broad geographic scale. One such endeavor was accomplished in Arizona by rating suitable pronghorn habitat in a statewide survey (Ockenfels et al. 1996).

Intensive quantitative models for pronghorn have been developed to assess winter rangelands (Allen and Armbruster 1982), translocation sites (McCarthy and Yoakum 1984, Arizona Game and Fish Department 1993), suitable yearlong habitat (U.S. Bureau of Land Management 1980, U.S. Soil Conservation Service 1989), effects of wildfires on vegetation (U.S. Bureau of Land Management 1980), and the compatibility of domestic sheep with pronghorn (Howard et al. 1990). Each model has contributed to evaluating pronghorn habitat through documented reports, thereby advancing pronghorn management from earlier "professional judgment" efforts to written scientific rating systems (Yoakum 2004*d*).

Examples of working systems for the Great Basin region are provided by Salwasser (1980), Yoakum (1980), and Kindschy et al. (1982). For the sagebrush/grasslands of Wyoming, a different system was used, which stressed the evaluation of winter habitats (Allen and Armbruster 1982, Cook et al. 1984, Cook and Irwin 1985).

At least 10 models are presently used to assess pronghorn habitat: Hoover et al. (1959), Yoakum (1974), U.S. Bureau of Land Management (1980), Allen and Armbruster (1982), Kindschy et al. (1982), McCarthy and Yoakum (1984), U.S. Soil Conservation Service (1989), Howard et al. (1990), Arizona Game and Fish Department (1993), and Ockenfels et al. (1996). Ockenfels et al. (1996) reviewed 9 habitat suitability methods developed since 1959, noting the strengths and weaknesses of each model, and presenting a landscape-level model for Arizona. In general, all models are based primarily on terrain physiognomy and vegetative structure and condition. Other factors are typically of secondary importance.

2. Maintaining Quality Habitats

When a natural site is in good condition relative to its ecological potential, maintenance of that condition should be a major objective. Implementing this ecological principle, however, will not always favor some objectives, such as producing maximum numbers of pronghorn. For example, some shrubsteppe communities in the Intermountain West naturally have ≥ 60% shrubs; this is not conducive to high pronghorn densities, because such sites have low carrying capacities for pronghorn (Photograph 21). Managers should not expect such sites to produce high numbers of pronghorn or try to manipulate the vegetation for that purpose, ignoring the site's ecological potential.

Habitats that provide optimal resources for pronghorn will produce optimum numbers of pronghorn. Recognizing habitats in good quality ecological condition and maintaining them, by objective, is important. This is especially true where the land is managed for multiple-use. However, some land managers are not aware of optimum pronghorn habitat conditions and may suggest changing the vegetation composition favoring livestock production. Under such circumstances the wildlife manager should know the habitat conditions required for pronghorn, and advocate the maintenance of those conditions for the welfare of pronghorn populations.

Dunbar (2001) disclosed that playas (shallow intermittent lake beds) on the Hart Mountain National Antelope Refuge in Oregon were key habitats for pronghorn. Although these playas represented 3% of pronghorn habitat, they were occupied by > 2/3 of the pronghorn population during autumn because the sites contained drinking water and an abundance of succulent, nutritious, preferred forage. The importance of quality playas in providing water and forage during dry seasons helped managers recognize the importance of these key sites in quality conditions, and protecting them from severe competitive use by cattle and feral horses.

Photograph 21. Rangelands with dominant, dense, tall shrubs are not productive pronghorn habitats. These shrub lands decrease opportunities for pronghorn to see and flee from enemies. Extensive shrub communities also compete for moisture and soil nutrients and often lack adequate quantities of nutritious forbs and grasses. Photograph by David E. Brown.

3. Enhancing Poor Quality Habitats

Improving rangelands for a specific objective of restoring or increasing forage, cover, or water, is termed "habitat improvement" (Yoakum et al. 1980). When rangelands are in poor ecological condition, and the site is capable of better forage and/or cover, projects should be designed to improve vegetation conditions (Photograph 22). For example, a site having a vegetation composition of 5% grasses, 10% forbs, and 85% shrubs, can be improved for pronghorn. Prescribed treatment of shrubs followed by seeding with mixtures of grasses, forbs, and shrubs can change the site to a more favorable composition of 35% grasses, 25% forbs, and 40% shrubs. In some areas, a desirable habitat factor may be inadequately distributed, and this situation also can be improved through management practices. For example, streams and springs may be abundant in half of an area, but water may be lacking or limited in the other half. By developing waters in the latter portion, managers can provide a more equitable distribution and increase carrying capacity throughout the area (Yoakum 2004*e*).

a. Water Developments

During a 5-year pronghorn study in the Red Desert (1966 - 1970), pronghorn were observed using every type of water source available (Sundstrom 1968). These water sources consisted of springs, creeks, rivers, lakes, reservoirs, stock water developments, galvanized troughs fed by windmills, and troughs filled by springs.

Photograph 22. Today's dominant shrub lands can be treated to improve forage for pronghorn. Managers can use control techniques to decrease shrubs, resulting in vegetative communities with a greater mixture of forbs, shrubs, and grasses, meeting the habitat requirements of pronghorn. Photograph by David E. Brown.

Water improvement projects to increase drinking water for livestock and pronghorn are varied (Yoakum 1980, 2004*e*, Vallentine 1989). Springs and seeps are used extensively because they are abundant in some habitats and pronghorn are accustomed to using them. Such sources can also often be improved with proper development techniques. Improper development techniques, however, can also impair or remove the water source. No 2 springs are alike; consequently, an experienced hydrologist should be consulted before any alterations are made.

Hundreds of small reservoirs have been constructed to trap and retain precipitation. Many of these have been built on public lands through cooperative funding by state and federal management agencies for the benefit of livestock, with some participation by private landowners. Such developments often are natural in appearance and serve a variety of wildlife, contributing to the well-being and range expansion of some pronghorn herds. In Malheur County, Oregon, 1,037 small reservoirs have been developed for livestock and wildlife needs on public lands (Heady and Bartolome 1977).

Another water development used by pronghorn, especially during late summer, is the dugout or trench reservoir (Photograph 23). Dugouts commonly are placed in areas of comparatively flat, but well-drained terrain. A natural pothole or dry lake bed may be a good location for a dugout (Good and Crawford 1978). Heavy use by livestock and other wildlife species may negatively impact forage surrounding these areas.

Precipitation catchments (guzzlers) on ranges lacking natural waters have been successful in providing water for pronghorn (June 1965). Such water developments serve a variety of wildlife. A surrounding fence should be constructed to protect the facility from trampling damage and competition by livestock. Any water development, including catchments, must be properly maintained if pronghorn are to benefit. Catchments that go dry for whatever reason, or fail to provide water at critical times, may do more harm than good.

b. Water Quality

Little information is available concerning water quality as it affects pronghorn. However, total dissolved solids and pH are probably important concerns. In the Red Desert, Sundstrom (1968) found little or no use by pronghorn of water sources that contained total dissolved solids in excess of 5,000 ppm. Some use occurred on a water source with dissolved solids of 4,620 ppm. The maximum total dissolved solids recommended are about 4,500 ppm (McKee and Wolf 1963).

Photograph 23. Water improvement project to increase drinking water for livestock may also aid wildlife. Dugouts or dirt stock tanks are commonly used by pronghorn if placed in flat, well-drained terrain. Photograph by George Andrejko.

Livestock may be impaired by drinking water that contains excessive dissolved solids, and it is a good assumption that this may also apply to pronghorn. Continuous use of such water may cause general loss of condition, weakness, scouring, reduced milk production, bone degeneration, and death. However, animals can temporarily drink highly saline waters that would be harmful if used continuously. Animals also can adjust gradually to the use of waters with a higher solids concentration than that which they normally drink, although sudden change from slightly to highly mineralized water causes acute distress and diarrhea of varying severity. The limits of tolerance depend upon the particular salts present, the species of animal, its diet, age, physiological condition, season of year, and climate (McKee and Wolf 1963).

The recommended pH range for most uses, such as domestic water supplies, irrigation, fish and other aquatic life, and recreational uses, is 6.5 - 8.5 (McKee and Wolf 1963). In Wyoming's Red Desert, when water sources exceeded a pH of 9.2, pronghorn appeared to seek other water sources (Sundstrom 1968).

Where water sources are available to pronghorn, but appear to be avoided, a complete water chemistry test should be made and measures taken to correct the problem. Where the water quality cannot be improved, and no other water source is in the vicinity, water catchments should be installed.

In addition to being designed to provide a continuous supply of water, water developments in pronghorn range should provide maximum safety for animals using them. Wilson and Hannan (1977) listed the rationale and criteria needed to assure wildlife friendly use of water developments designed to supply livestock with drinking water. To help prevent animals from being entrapped and drowned, the authors suggested a number of recommendations for pronghorn:

1. *Troughs or other water containers should not extend > 20 in. (51 cm) above the ground so that both adult and fawn pronghorn have access to the water.*

2. *Deeper troughs should be set into the ground to achieve the desired height.*

3. *Barricades should be considered in some situations that would prevent the accidental entry of animals into unsafe areas and drowning.*

4. *Distance from the rim of the trough to the barricade should be < 20 in. (51 cm).*

5. *Where water depths are > 20 in (51 cm), rocks or other material should assist animals that accidentally enter the water in obtaining a footing to find their way back to dry ground.*

Food Habit Studies

The term diet selection is defined as what and how much of each plant species an ungulate consumed relative to quantities available in the vegetative community. The term food habit studies includes diet consumption, plus other factors that influence diet consumption (e.g., weather patterns, forage similarities and competition with other herbivores, nutritional values). Different techniques have evolved and the findings between the various methods are not always comparable (Sundstrom et al. 1973, Yoakum 1990, 2004*d*). Pronghorn food habits can be determined by direct or indirect observations, using rumen contents, fecal analysis, or cafeteria trials. The various techniques are described in detail below.

1. Direct Versus Indirect Observations

Direct observations require observing feeding pronghorn at close range in the field and estimating the amount of each plant species consumed. Sometimes this procedure is referred to as "bite counts" or "feeding-minute" studies, and has been used with varying success (Büechner 1950, Hoover 1971, Schwartz et al. 1976, Schwartz 1977). Tame, semi-tame, or constrained animals are generally used. Often these animals are raised in captivity and accustomed to humans. The animals are taken to the field and allowed to forage while the biologist closely monitors the pronghorn and records what is eaten. The accuracy of direct observations of tame animals has been questioned, but Schwartz (1977) found food habit results similar for reared and wild pronghorn using the same plant community. Another source for direct observation studies are animals in national parks or other refuges where the animals have become accustomed to human presence and tolerate proximity for observation.

Indirect observations or "feeding site" examinations of foraging wild animals is one of the oldest methods used for pronghorn food studies. Rouse (1941) used the procedure of trailing pronghorn after a fresh snow and recording the species and numbers of plants consumed. Since then the method has been used by Büechner (1950), Cole (1956), Severson (1966), Beale and Smith (1970), and Campbell (1970). Basically, pronghorn are located in the field, the exact location where the animals were feeding is examined and any use of the plants is recorded. The system calls for little equipment other than a pair of binoculars (or a spotting scope) and a field notebook. This procedure can be extremely time consuming, however, and it is often difficult to determine use on certain vegetation (e.g., sagebrush).

2. Rumen Contents

Rumen contents or stomach analysis is a method commonly used to determine food habits for pronghorn (Ferrel and Leach 1950, Mason 1952, Baker 1953*b*, Cole 1956, Hoover et al. 1959, Dirschl 1963, Russell 1964, Severson 1966, Tsukamoto and Deibert 1968, Bayless 1969, Beale and Smith 1970, Campbell 1970, Mitchell and Smoliak 1971, Taylor 1972, Jacobs 1973, Schwartz et al. 1976). Korschgen (1980) described the technique in detail, including preservation of materials and identification of food items. Dirschl (1962) elaborated on sieve mesh size based upon working with pronghorn samples. Food habits can be quantified by: 1) number and species, 2) frequency of occurrence, 3) volume, or 4) weight (Cooperrider et al. 1986).

Rumen analysis can be misleading in several ways. Certain plant species, such as graminoids, digest more quickly than forbs and shrubs. Therefore, if the samples have not been timely or thoroughly preserved, these plants can be difficult to identify. Rumen sample collections usually also require dead animals, which can be costly, unacceptable to the public, or prohibited in the case of endangered species. For these reasons fecal analysis has become increasingly popular during the last 3 decades.

3. Fecal Analysis

Fecal analysis is now the most common technique used to determine pronghorn food habits (Jacobs 1973, Schwartz et al. 1976, Sneva and Vavra 1978, Meeker 1979, Bodie 1979, Sexson 1979, Bailey and Cooperrider 1982, Howard et al. 1983, Goldsmith 1988, Cancino 1994, Hansen et al. 2001). Although samples are easy to collect, the accuracy of the technique has been questioned (Holechek et al. 1982). The procedure is similar to rumen analyses except that fecal samples are collected rather than a rumen sample. Since fecal analyses requires a great deal of laboratory preparation and expertise, it is usually more efficient for wildlife biologists to pay for such laboratory work rather than doing it themselves. Field procedures for this method were evaluated and considered relatively cost-effective by Cooperrider et al. (1982).

Six major advantages of the fecal analysis method are: 1) it does not interfere with the normal behavior of animals, 2) it permits practically unlimited sampling, 3) it is particularly valuable for sampling animals ranging over mixed vegetative communities, 4) it is the most feasible procedure to use when studying secretive or endangered species, 5) it can be used to compare the diets of > 2 ruminants at the same time, and 6) it requires little equipment (Holechek et al. 1982).

Holechek et al. (1982) and Gill et al. (1983) concluded that inaccuracy could be the greatest limitation to the method. Regardless, the method remains the most popular today for accomplishing food habit studies and has even been accepted as admissible evidence in judicial proceedings (Cooperrider et al. 1986).

When using fecal analysis, individual sample size should be ≥ 0.5 lbs (227 g) and air dried, in order to have sufficient material for forage identification, nutrient analysis, rechecks of earlier results, or samples for additional studies later in a project. Simple food habit studies, in which the only purpose is to identify the species of plants consumed can consist of ≥ 25 pellets from 5 pellet groups (T. McKinney, personal communication).

If fecal samples are collected, the individual animal producing the pellets should be identified if possible. Random collections of fecal samples in the field without observing the animal responsible for the sample can result in misidentification and misjudgment of season (pellets dry quickly in arid ecosystems). Collection sites should be representative of major areas where animals forage, and include location data on crucial habitats such as wintering grounds, fawning areas, seasonal movement corridors, etc.

Depending on study design, pellet collections should be made monthly throughout the year. A good food habit study should include a minimum of 3 years of data. Findings are of greatest value when taken over a period of years because, as precipitation patterns change, animal foraging habits respond to differences in forage availability. It may also be desirable to collect samples from other ungulates using the same sites by season. This allows the computation of dietary overlap and species preferences for various forage classes.

4. Cafeteria Trials

Cafeteria trials are a method used to determine the food preferences of confined pronghorn. An observer records what plants are selected by animals from a number of equally accessible plants made available in approximately equal quantities. These plant species can then be analyzed for comparative nutritional values. The method was used by Smith et al. (1965) to study pronghorn preferences for different species of shrubs in Utah. Smith (1974) related artificial diets with different protein levels to pronghorn production and survival. Jacobs (1973) used cafeteria trials to test the validity of different food habit gathering techniques in Wyoming.

More than 200 food habit studies have been conducted during the past 50 years. However, different techniques were involved and the findings between the various methods often are not comparable (Sundstrom et al. 1973, Yoakum 1990). To provide consistency for comparisons in future studies, recommendations within the following sections are provided.

5. Plant Collections and Forage Composition

Plant collections are needed for identifying forage in food habit studies and nutrition analysis. Plant collections should be from the same sites where pellet samples were obtained. Plant samples should include all forage classes (grasses, forbs, shrubs) by season. Although placing some plants in a particular forage class may be artificial, each sample should be assigned a category and an explanation as to what species each category contains. Lichens, mosses, cacti, and half-shrubs often have been placed in the forbs category. Plant samples need to be preserved and stored as herbarium collections. Forage preference by category can be determined by taking line-transects (Gysel and Lyon 1980) or using the step-point method (Evans and Love 1957) of sampling vegetation composition in the sample areas. The step-point method is quick and allows for many transect readings in a relatively short period of time.

6. Ecological Factors

Recording ecological data at the time that pellet and plant collections are made is important. This information is needed when analyzing or relating findings. Examples of such information are: precipitation quantities by type (i.e., rain, snow) for all seasons of the year; the behavior(s) of pronghorn and other ungulates at the time of collections, especially foraging characteristics; and the phenology of the vegetation, especially those species producing seed. It is also especially important to record the implementation dates of any grazing systems involved; record other ungulate use or non-use of the site to evaluate dietary overlap, and note ungulate intensities and the effects on the vegetation. Those forage species which have been lightly, moderately, or heavily used should be noted.

7. Laboratory Analysis

Laboratory facilities and trained personnel are often lacking when food habit studies are attempted. Thus, sending fecal and plant samples to a specialty laboratory for analysis may be cost effective. Also, specialized laboratories often are more efficient in fecal analyses than a well-meaning technician or graduate student with a part-time commitment.

Some food habit studies may not have portrayed a true picture because no correction factors were used to compensate for differences in digestibility of various forage plants (Meeker 1979, McInnes 1984). The problem of differential digestibility of various plants has plagued laboratory personnel conducting rumen and fecal analysis for years. However, recent studies have developed correction factors that are especially important for forbs and shrubs, the two most common forage classes in pronghorn diets (Yoakum 2004*c*).

8. Data Compilation and Evaluation

All diet collections should be compiled by plant species, and then totaled into species and forage classes by period of use. If analysis is by percent volume, list all plants, even those found in trace quantities (< 1%), as this information may be needed for evaluating use of trace nutrient elements or noxious plants.

When field collections include quantitative data for diet selection and forage availability by season, computing dietary overlap for different ungulates is possible. Including ecological condition data is therefore important because the analysis may show species overlap. However, if other herbivores are not using the site during the particular season, it is important to note the lack of overlap or competition.

Vegetation Manipulation

Pronghorn thrive on rangelands in a sub-climax vegetative condition. Such conditions were created historically by wildfires and, where precipitation was sufficient, seasonal grazing by herbivores such as bison (*Bison bison*) and elk. On western rangelands today, most vegetation manipulation efforts are for livestock needs. These projects can be beneficial or detrimental to pronghorn. To benefit pronghorn, vegetation manipulation must increase the number of nutritious forbs and shrubs, and provide habitat diversity. Low diversity grasslands, and shrubsteppes of natural or artificial origin, can be improved by adding species that provide food or cover, whichever is most limiting (Yoakum 2004*e*).

Shrub control and artificial seedlings that develop monocultures have limited value for pronghorn (Yoakum 1980, Kindschy et al. 1982, Pyrah 1987), especially when accomplished in large blocks of 2,000 - 6,000 ha (5,000 - 15,000 acres). Large habitat projects require pronghorn to travel long distances for preferred shrubs during plant succession.

1. Shrub Control

Areas dominated by shrubs and shrubby trees are not desirable habitat because shrubs compete for moisture and nutrients with forbs, and thick or high vegetation prevents pronghorn from seeing and escaping enemies. Shrub or tree control may or may not enhance pronghorn habitat depending on local conditions and how the treatment is implemented. Controlling woody vegetation has not improved pronghorn habitat in Texas (C. Winkler, personal communication). However, numerous reports have documented that shrub control (mostly junipers and sagebrush) can increase the carrying capacity for pronghorn in the Great Basin region (Kindschy et al. 1982, Aoude and Danvir 2002, Yoakum 2004*c*). An ongoing study in Wyoming indicates that plants grow more vigorously on previously "controlled" areas than on "uncontrolled" areas (H. Harju, personal communication). This can be good or bad for pronghorn as areas of tall dominant shrubs (> 50% canopy cover) make for marginal or low-density pronghorn habitat. This is especially true where shrubs are ≥ 30 in. (76 cm) (Willis et al. 1988, Ockenfels et al. 1994); such areas should be treated to decrease shrub quantity and height. Limiting the size of projects to < 400 ha (1,000 acres) blocks is recommended, and each project should ideally maintain 5 - 20% shrub canopy cover. In general, shrub/tree control should attempt to mimic natural conditions (e.g. conditions maintained by periodic fires).

Wintering and spring fawning areas should be included in shrub control projects only when shrubs are decadent or so dense as to increase predation rates. Shrub control projects should not attempt to eradicate preferred shrubs that provide nutritious forage during fall and winter. Shrubs are of utmost importance where snowfall exceeds 12 in. (30 cm) because they often protrude out of the snow and are available for forage.

Shrub control frequently is accomplished by mechanical practices such as plowing and chaining. Plowing with large plows can remove 90 - 95% of the shrubs (Vallentine 1989), but often kills forbs that are highly preferred by pronghorn. Chaining is accomplished by pulling a heavy anchor chain between 2 large tractors. This practice does not kill as many shrubs and is less damaging to grasses and forbs. However in some areas it may promote rather than inhibit the production of mesquite, juniper, and other small trees and shrubs (R. Miller, personal communication).

Chemical spraying is another shrub control technique. The spray (usually 2-4-D) controls shrubs without harming native grasses and can be targeted to specific species of plants (Vallentine 1989). However, this chemical has been shown to have deleterious effects on forbs when applied at inappropriate seasons. To avoid killing forbs, spraying should not be conducted during the late spring and summer.

Wild and prescribed fires are one of the surest disturbance agents for restoring and maintaining grasslands (Sauer 1950), and burning grasslands is the oldest known practice used by man to manipulate vegetation (Vallentine 1989). Although accidental burns can be more deleterious than beneficial to rangeland resources, prescribed burning can be a beneficial and economical habitat improvement technique. Prescribed burning involves systematic planning so fires are set when weather and vegetation are in a condition to mimic natural conditions and maximize benefits. Timing is important as, when properly accomplished, prescribed burns can decrease shrubs and not seriously harm grasses and forbs (Beardahl and Sylvester 1974). Investigators have reported immediate stimulation of plant growth after burning, resulting in greater forb production and forage yields (Deming 1963, Courtney 1989, Yoakum 2004*e*).

Valentine (1989) provided a thorough discussion on objectives, techniques, and results of burning shrublands. Pechanec et al. (1954) recommended burning sagebrush only where this species is dense and forms > 50% the plant cover. Other recommendations included burning only when fire-resistant perennial grasses and forbs form > 20% of the plant cover, or where the area will be seeded after burning, and where the economic and biological needs of all users (e.g., livestock forage, big game habitat, watershed values) have been adequately considered. They also recommended burning sagebrush during late summer or early fall at least 10 days after the perennial grasses have ripened and dried, and the seeds have been scattered (Pechanec et al. 1954).

2. Artificial Seeding

When proper planning has shown vegetation plantings to be desirable for pronghorn, Plummer et al. (1968) recommended seeding a mixture of 10 - 30 species of grasses, forbs, and shrubs. Seeding with a monoculture frequently results in low densities and fewer varieties of forbs. Many manipulated rangelands have been planted to exotic perennial graminoids seldom consumed by pronghorn, such as crested wheatgrass (*Agropyron* sp.). When feeding on grasses, pronghorn prefer finer textured native species such as Sandberg's bluegrass (*Poa sanbergii*).

Although seeding with mixtures of native grasses and forbs is more costly, the result is a greater diversity of species, somewhat comparable to many rangelands in a natural condition. Also, native seed mixtures are in conformity with Federal laws (e.g., National Environmental Protection Act (1969), Federal Land Policy and Management Act (1976), Surface Mining Act (1977)) that mandate public lands be managed for their natural vegetation, including sagebrush (*Artemisia* spp.).

Ten principles for large-scale restorations of rangelands used by wildlife in Utah were developed by Plummer et al. (1968). These procedures have wide application on similar sites throughout the West, although some modifications may be necessary to meet ecological conditions in the Southwest and in other local environments. The procedures are:

1. *Changes in plant cover by the proposed measures must be desirable. Often lighter grazing by livestock, so that desirable species can grow, may be all that is required.*

2. *Terrain and soil types must be suited to the changes selected. The soil and terrain should be carefully considered to determine where appropriate treatment would produce the most forage for wildlife.*

3. *Precipitation must be adequate to ensure establishment and survival of seeded plants. The amount of precipitation, along with the occurrence of indicator plants, is the most important guide to what species may be seeded successfully.*

4. *Vegetative competition must be low enough to ensure that desired species can be established. Anchor chaining is a highly versatile, effective, economical, and a widely applicable method for eliminating unwanted competition from trees and shrubs.*

5. *Only species and strains of plants adapted to an area should be planted. Seeded species must be able to establish and maintain themselves. There should be a mixture of grasses, forbs, and shrubs.*

6. *Mixtures, rather than single species, should be planted. Planting mixtures is advantageous when the major purpose of restoration is for the improvement of diversity needed by wildlife.*

7. *Sufficient seed of acceptable purity and viability should be planted to assure a stand. The amount per acre depends on seed purity, size, viability, and whether seeds are drilled or broadcasted.*

8. *Seeds must be covered sufficiently. Planting deeper than 0.5 in. (13 mm) is seldom desirable; likewise, leaving seed exposed is unsatisfactory.*

9. *Planting should be done in the season of optimum conditions for establishment. Whenever climate permits, seeding in winter (December - February) is best. Transplanting of nursery stock seedlings is most successful when completed while the ground is still wet from spring moisture.*

10. *The planted area must be adequately protected. Young plants and seedlings should not be grazed or trampled by livestock or big game.*

When properly accomplished, artificial seeding has been proven to be beneficial to pronghorn. An evaluation of an 11-year, large-scale restoration project near Vale, Oregon showed herd increases of nearly 100% near areas seeded mainly with dryland alfalfa compared to adjacent untreated lands where populations increased 30% (Kindschy et al. 1982). Pioneering pronghorn herds in California, Oregon, and Nevada moved to manipulated rangelands having the pronghorn's habitat requirements of a variety of grasses, forbs, and shrubs (Yoakum 2004*e*).

Wildlife managers on the Deseret Land and Livestock Ranch, in northeast Utah and adjacent lands in Wyoming, reported on their vegetation restoration program with the objective of increasing forbs for pronghorn and livestock (Aoude and Danvir 2002). Various methods of brush control were accomplished and some sites were seeded to herbaceous plants. The authors concluded that vegetation restoration projects increased pronghorn fawn production and carrying capacity compared to non-treated adjacent sites. Results of this study suggested that treating sites as small as 2% of the rangeland annually contributed to increased pronghorn herd numbers.

Fire Management

Most grasslands have evolved under the influence of natural and human ignited fires, and indeed, fire is essential to their long-term welfare. Many grassland plant species are so fire-adapted, that they depend upon burning for maintenance. Fires stimulate plant succession, reduce the incidences of woody plants, provide ash and nutrients to the soil, and increase herbaceous vegetation. Fires can be beneficial or detrimental to pronghorn habitat, depending on how they influence vegetation in specific sites at specific times (Riggs et al. 1996, Yoakum 2004*e*).

The California Department of Fish and Game (1997) assessed the pros and cons of the effects of fire on pronghorn habitats. Wildfires were recognized as the principal factor changing shrublands to grasslands favorable to pronghorn. Nonetheless, extensive and repetitive burns can, at times, decrease preferred shrubs for winter browsing and when grazed by livestock, increase the invasion of noxious and alien plants.

1. Wildfires

Lightning ignited fires are, or were, of frequent occurrence on many western rangelands. Wildfires occur naturally during the spring dry season, when sufficient fuel, in the form of litter, is available. Wildfires were historically common in the grassland and shrubsteppe biomes and rare in the deserts. Courtney (1989) observed pronghorn grazing new grass and forb growth soon after fires burned grasslands in Alberta. Stelfox and Vriend (1977) reported pronghorn moved into burns within 1 month after prairie fires. At such times, pronghorn readily consumed large quantities of burned prickly pear cactus (*Opuntia* spp.).

Deming (1963) observed that pronghorn readily foraged on burned shrubsteppes in Oregon. He attributed this to the grazing of new succulent forage growth that remained greener into the autumn compared with unburned sites. Similar use was confirmed by Van Dyke (1990) who speculated that wildfires enhance pronghorn habitat. A valley occupied historically by pronghorn in California, but devoid of herds > 75 years, experienced a pioneering herd move into the valley and remain permanently after a wildfire of > 12,000 ha (30,000 acres ha). Apparently the lightning-caused fire, followed with rangeland seeding, changed habitat conditions from poor to good quality, allowing pronghorn to become successfully established (Yoakum 2004*e*).

2. Prescribed Fires

Prescribed fires can, and should be, used to simulate the role of wild fires for changing and invigorating grassland vegetation (Photograph 24). Fire management is especially appropriate for tall-grass prairie and grasslands dominated by shrubs and small trees. The Hart Mountain National Antelope Refuge in Oregon suppressed fires prior to 1990. Now, prescribed fires are one of the primary vegetation management practices (Pyle and Yoakum 1994, Gruell 1995). Field studies revealed that > 90% of the shrublands were in late succession, with little herbaceous undercover. The landscape objective was to sustain a mosaic of vegetation in different serial stages and to increase the abundance of forbs and grasses. Providing diversity is essential for ecosystem health and resilience. Diverse

Photograph 24. Prescribed fires can be used to simulate the role of disturbance for changing vegetation, especially in tall-grass prairies and shrubsteppes. Prescribed fire is being used to reduce brush encroachment in a shrubsteppe in northeastern Utah. Photograph courtesy of Deseret Land and Livestock Ranch, Utah.

vegetative communities generally support more vigorous wildlife populations, including pronghorn. Present objectives of the refuge include maintaining 20 - 30% of shrubs in early and mid-succession; consequently, a prescribed fire program was implemented in 1994. Prescribed fires have been used since to produce a mixed pattern of burned and unburned patches in roughly equal proportion. There have been no major problems with the invasion of alien plants primarily due to their scarcity prior to burning, and perhaps to the lack of livestock grazing. Burning has been practiced only on spring and summer pronghorn habitats where there is a need to increase herbaceous forage. No treatments have been performed on winter rangelands where shrubs are key forage for pronghorn.

Tall-grass prairies are historic and extant landscapes for pronghorn in eastern Kansas (Eccles et al. 1994). These prairies grow grasses 9 feet (2.7 m) high; however, they can be changed to suitable habitat for pronghorn when the vegetation structure is lowered through burning and/or grazing by large herbivores (historically bison, now cattle). This vegetation manipulation changes tall, old growth herbaceous vegetation to low growing forage meeting pronghorn habitat requirements. When fires are started, the vegetation is low to medium height, the weather cool, and much of the burning is done at night when temperatures are lowest and humidity highest. Prescribed fires are timed to take advantage of slightly damp vegetation; therefore, fire intensity generally is not high or catastrophic. Simpson (1992) reported pronghorn did not flee from the fires, but wandered in and around, seeking unburned sites for forage.

Fire is also essential to maintain semidesert grasslands as pronghorn habitat. Without fire, or with fire suppression, these grasslands are converted to shrublands, brushlands or dense savannas, thus reducing or eliminating pronghorn populations. As with fires in the shrubsteppe, reduced grazing is often necessary to provide sufficient fuel for a burn, which should be done in May or June to emulate natural conditions (Brown 1994). Failure to instigate proper grazing and fire regimes is one of the biggest threats to shrubsteppe and semidesert grassland populations of pronghorn.

Recommended practices for prescribed fires are provided by Yoakum et al. (1980), Vallentine (1989), Payne and Bryant (1998), and Riggs et al. (1996). Yoakum (2004*e*) provides a thorough discussion of objectives, current techniques, and results of prescribed fires to enhance ecosystems for wildlife, including pronghorn.

Competition and Conflicts

1. Livestock Competition

Pronghorn and livestock (Photograph 25) have co-existed to various degrees on western rangelands for over 450 years in Canada, Mexico and the United States (Wagner 1978, Leftwich and Simpson 1978, Yoakum and O'Gara 1990, Yoakum et al. 1996). Cattle, sheep, and horses, are the animals of principal concern, because they are the primary domestic animals on rangelands occupied by pronghorn today. Goats, however, were

Photograph 25. When rangelands are in healthy ecological conditions with an abundance of grasses, forbs, and shrubs, foraging by pronghorn and livestock together can be compatible. Here, pronghorn and cattle can be seen foraging together in a short-grass prairie community in central Arizona. Photograph by George Andrejko.

serious competitors with pronghorn in the past, and may remain so in parts of Texas and Mexico (Büechner 1950).

The chronology of livestock and pronghorn numbers was well documented by Wagner (1978). He graphically portrayed this relationship, illustrating the degree of forage consumed by both, emphasizing that pronghorn today consume < 1% of the vegetation on western rangelands.

All livestock use probably has some effect on pronghorn, the degree depending upon ecological factors in different habitats. These will be discussed first, then those factors warranting management considerations will be covered for cattle, horses, and sheep.

a. Livestock in General

Rangelands can be rapidly or slowly altered by livestock (Wagner 1978, Kindschy et al. 1978, 1982, Wald and Alberswerth 1989, Yoakum et al. 1996). These changes can affect both the quality and abundance of preferred forage needed to sustain 30 pronghorn herds (Ellis 1970, Howard et al. 1990). Decreasing vegetative cover brought about by livestock grazing was reported by Autenrieth (1982) to be a serious factor affecting fawn survival. Heavy use of forage by livestock during a severe drought forced pronghorn to turn to poisonous plants, resulting in direct mortality and poor reproductive performance (Hailey 1979). Domestic grazing can also inhibit fire, can favor the proliferation of woody and shrubby vegetation, and otherwise alter pronghorn habitat (Humphrey 1950).

McNay and O'Gara (1982) reported displacement of parturient females by livestock. Female used traditional fawning areas when livestock were not present, but moved to adjacent sites when livestock were allowed on fawning areas. Such competition for space resulted in females moving to sites with less desirable vegetative height. Management guides to alleviate this problem include excluding or delaying the turning-out of livestock in traditional fawning areas until after the pronghorn's parturition period.

At times, and in certain locations, livestock and pronghorn have a commensal relationship (Yoakum et al. 1996). Although case histories are rare, livestock grazing on rangelands with an abundance of grasses can cause increased production of forbs and shrubs preferred by pronghorn. Then too, pronghorn consume many plants known to be noxious or poisonous to livestock such as larkspur (*Delphinium* sp.), death camas (*Zygadenus* spp.), locoweed (*Astragalus* spp.), and halogeton (*Halogeton* spp.) (Büechner 1950, Yoakum and O'Gara 1990). Predator control programs intended to benefit livestock may also benefit pronghorn. Connolly (1978) lists numerous cases of predator control increasing pronghorn populations. Nonetheless, livestock can at times be reservoirs of diseases and parasites that deleteriously affect pronghorns (O’Gara 2004*c*).

Careful assessment needs to be used in identifying the assets and liabilities of livestock compatibility or competition on rangelands occupied by pronghorn. Here is a topic that warrants greater research conducted and reported for field conditions on sites in grasslands, shrubsteppes, and deserts.

b. Cattle

Aggressive behavior between cattle and pronghorn appears to be minimal (Roebuck 1982, Pyrah 1987). However, forage competition can be an issue depending on the vegetation composition and production. For rangelands with abundant native grasses, forbs, and shrubs in an ecological healthy condition, interspecific competition can be minimal. This is because cattle are primarily grazers of grasses, whereas pronghorn predominantly forage on forbs and shrubs (Yoakum 2004*f*). It cannot be stressed too strongly that these compatible relationships may occur on rangelands with abundant, healthy native vegetation. However, for monoculture grasslands or rangelands with low quantities or diversity of forbs and shrubs there can be serious competition for preferred forage classes (Yoakum 2004*f*). Hoover et al. (1959) reported that the 10,000 pronghorn in Colorado at that time would not eat as much grass as would 200 head of cattle. Apparently, there is a low dietary overlap between cattle and pronghorn; a survey of 10 studies revealed ratings of < 30% overlap in 9 cases (Yoakum and O'Gara 1990). One study found serious competition for grasses and forbs on Great Basin rangelands during spring and early summer, resulting in low fawn survival rates compared to Great Plains grassland (Ellis 1970). These are generalized tabulations over many different habitats, but are consistent in depicting the low rate of dietary overlap. Hence, on a year-round basis, competition is relatively low because of the consumption of different forage classes by the 2 species.

c. Domestic Sheep

Investigators are not always in agreement concerning the social compatibility of pronghorn and domestic sheep. Authors finding problems of competition included Einarsen (1948), Büechner (1950), Campbell (1970), Freeman (1971), and Pyrah (1987). However, Severson (1966) observed no apparent stress on either species as a result of the other's presence. Forage competition, due primarily to both animals consuming large quantities of forbs and shrubs was found in 6 food habit studies evaluated by Yoakum and O'Gara (1990). Sheep trailing through pronghorn fawning areas can also be a problem, and should be prohibited from 15 days before to 15 days after the peak of fawning activity.

Regardless of dietary overlap concerns, domestic sheep on rangelands can be carriers of parasites and diseases common to pronghorn, and sheep herders encourage the construction of fences unfavorable to pronghorn movements.

d. Horses

Domestic and feral horses occupy a number of rangelands with pronghorn; however, only 2 studies have investigated interspecific competition between the 2 species (Meeker 1979, Berger 1986). Both noted little aggression between species, but horses were dominant at all times. Dietary overlap was minor on rangelands with an abundance of grass according to Yoakum and O'Gara (1990).

e. Other Ungulates

Bison (Photograph 26) and elk occur on pronghorn habitats in Arizona, in Yellowstone National Park, on the National Bison Range in Montana, in Alberta, and elsewhere (Yoakum 2004*f*). Excessive numbers of any ungulate can result in forage competition with pronghorn, and large numbers of elk may be responsible for some of the decline in pronghorn populations in Yellowstone National Park (Boccadori 2002, Boccadori and Garrot 2002) and on Anderson Mesa in northern Arizona (Brown et al. 2004). Yoakum (2004*f*) summarizes the relation pronghorn have with other herbivores including ungulates, lagomorphs, and rodents.

f. Grazing Systems

Livestock grazing systems are designed to maintain or improve forage conditions. There are a number of different systems (e.g., deferred grazing, year-round grazing, flash grazing, rest-rotation, holistic, short-duration grazing) (Stoddart and Smith 1955, Heady and Child 1994, Holechek et al. 1997). Livestock managers are turning more each year to established grazing systems.

When forage is being allocated, plant species preferred by pronghorn should be reserved as forage for pronghorn. These include grasses, forbs, and shrubs identified by

Photograph 26. Prior to the early 1800s, millions of pronghorn and bison grazed the central grassland prairies of North America from Canada south through the western United States to northern Mexico. They still do but in much lower numbers as depicted in this scene taken in eastern Wyoming. Photograph by Robb Hitchcock.

food habit studies in the same or a similar ecosystem. Consideration should be given to ensuring that key forbs and shrubs are not grazed beyond their sustainable tolerance. The forage reserved should also accommodate a reasonable number of pronghorn. Reasonable numbers should be based on management objectives of wildlife and land management agencies (Yoakum and O'Gara 1990).

When grazing systems are designed around key plant species, forbs and shrubs should be included as key species. Grazing systems that simulate serial vegetation conditions closely resembling ecological potential are most favorable to pronghorn. Grazing systems that restrict, alter, limit, or deleteriously affect any of the habitat requirements of pronghorn should include mitigating and alternative procedures for enhancing pronghorn habitat. For example, any grazing system should require that livestock be restricted from fawning areas during the fawning season.

g. Animal Equivalents

The allocation of forage for livestock and pronghorn is a complex procedure. Various methods of calculating animal equivalents have been used, but none has been completely satisfactory (Büechner 1950, Hoover et al. 1959, Severson et al. 1968, Taylor 1972, Kniesel 1988, Yoakum et al. 1996).

The most common system for calculating an animal unit months (AUM) of forage consumed by livestock and pronghorn is the ratio of metabolic weights (Heady and Child 1994). Based on this system, 6 pronghorn were considered equivalent to 1 AUM. In Idaho, Anderson and Denton (1980) used a system of comparing quantities of forage consumed per day, resulting in 14.8 pronghorn being the equivalent of 1 AUM. But when dietary overlap ratios were considered, Anderson and Denton (1980) recalculated their equivalents and determined that it took 59.2 pronghorn to equal 1 AUM.

Kniesel (1988) reviewed past procedures and practices for using equivalent ratios. He stressed the tremendous variation in ratios of pronghorn per cow used by management agencies (e.g., 105:1 in Colorado, 59:1 in Idaho, 39:1 in Texas, 7 - 14:1 in Oregon, 5:1 in Montana). Kniesel (1988) attributed the wide variation to different methodologies and information used. Some investigators primarily used weight differentiations, while others included such considerations as dietary overlap and rangeland condition. Kniesel (1988) concluded that assessing AUM equivalents for pronghorn and livestock would remain a problem as long as there was little agreement between state and federal management agencies when it came to standardized animal equivalents for forage use on multiple-use ranges.

2. Crop Depredations

Although pronghorn can generate considerable income to some landowners, they can also damage agricultural crops (Photograph 27). Such losses appear modest when viewed on a statewide or provincial basis, but can be important to the individual landowners

Photograph 27. Alfalfa crop depredation is one of the most prevalent agricultural damage cases attributed to pronghorn. However, it can at times serve management as was the case for this area in northern California where excess pronghorn were captured and translocated to other sites. Photograph by Bob Schaffer.

affected. In nearly all cases, crop depredations are brought about by human-caused landscape changes. Examples include fences and sub-divisions that block movements, plowing summer or winter rangelands to grow crops, converting shrubsteppes to grass, prohibiting hunting, or charging too much for hunter access. Crop depredation complaints appear to be increasing, apparently because pronghorn numbers generally are increasing while traditional pronghorn habitat is being lost to "improved" pastures, grain fields, and human development. Results of a survey sent to conservation agencies in 18 western states and provinces in 1991 indicated that depredations were stable in 9 states or provinces and increasing in 8. Only in Nebraska were depredation complaints decreasing, apparently because pronghorn numbers in that state were depressed. Almost every agency reported some damage to alfalfa and wheat; a few others added soy beans, field peas, and fall rye to the list. Most state agencies did not pay compensation for crop damage; those that did paid a total of about $64,000 USD in 1990 (O’Gara and Morrison 2004).

Because of resistance to expanding pronghorn hunting seasons in California, translocations were used to reduce depredations to irrigated alfalfa fields. Translocations are only practical, however, if suitable habitat is available for the released animals. Apparently because of political pressure, the pronghorn were translocated into marginal habitat (McCarthy and Yoakum 1984), resulting in the eventual death or movement of remaining animals to adjacent, more favorable habitats in Nevada. Thus, translocations designed to save pronghorn from harvest resulted in a loss of both pronghorn and of funds that could have been better used to benefit animals elsewhere.

Other agencies, such as the Nevada Division of Wildlife, have the option of holding depredation hunts (Tanner et al. 2003). Where depredation problems are expected, the Division plans a special depredation hunt in conjunction with the season setting process. Hunt applicants apply for these special hunts during the spring, and when a depredation complaint is received, a depredation hunt can be initiated within 2 weeks. Unsuccessful applicants in the regular hunt process for that hunt unit are also contacted and awarded tags if necessary. Such hunting seasons, staggered during the depredation period, alleviate much of the problem by removing and harassing the pronghorn involved.

The Nevada Legislature authorized the Division to develop procedures and regulations whereby big game tags can be allocated to landowners having depredation problems. Under this system, the landowner cannot use the tags, but can sell them. The number of tags a landowner is qualified for is based on the number of animals found on the property, and the ratio of tags to numbers of animals is to be negotiated.

The most practical method for solving crop depredation complaints appears to maintain a pronghorn population capable of living mostly on uncultivated rangelands through the issuance of sufficient numbers of female/fawn permits during the regular hunting season. If problems persist, special permits issued for hunts in the affected fields, and at the time of depredation, may solve the problem. Early season depredation hunts should only be authorized for males, because fawns would be orphaned by shooting females. The same is true for translocation captures. However orphaning fawns would only result in their deaths during about 2 months (June and July) of the year (Bromley and O'Gara 1967). Shooting males may do little to reduce pronghorn numbers in an area, but accompanying animals often stay away from fields after a few males are shot. In some cases, simply fencing a haystack will solve a problem. This approach is only practical if climatic conditions (i.e., no drought) are favorable.

Fences

1. History and Interaction

Within a decade of erecting barbed wire fences on western rangelands, Caton (1877:48) was reporting that 4-foot (1.2 m) high fences were restricting pronghorn movements: "t*his inability to leap over high objects may no doubt be attributable to the fact that they live upon the plains, where they rarely meet with such obstructions, and so they and their ancestors for untold generations have had no occasion to overleap high obstructions, and thus from disuse they do not know how to do so, and never attempt it when they do meet them."*

Caton (1877) was essentially correct. Pronghorn had adapted over the millennia to open landscapes without vertical barriers. In the relatively short time since the fencing of the West, restricting the movement of nearly all pronghorn populations, these animals have shown themselves unable to go through fences as do bison, or to vault them as do deer and elk. Instead, pronghorn have learned to negotiate fences by crawling underneath them. But if the bottom wires are too low, by virtue of design or the buildup of sand, soil, vegetation or snow, pronghorn movement is seriously impeded. Often, past efforts were concerned primarily with ways to modify pronghorn behavior to minimize the effect of fences. It cannot be assumed that pronghorn will adapt to changes resulting from livestock use, or that they will learn behavior patterns allowing these animals to adjust to habitats altered by fences. Observations in Wyoming indicate no marked increase in the number of pronghorn learning to jump fences. However, older individuals have a greater tendency to jump fences than fawns, which have never been observed in wild populations jumping fences (H. Harju, personal communication). In addition to restricting and/or impeding pronghorn movement, fences can leave lasting impression on pronghorn when the fences' barbs strips hair and/or skin off their back causing lacerations (Photograph 28) and making them vulnerable to increased exposure to thermal stresses, increased metabolic rates and hypothermia during severe winters (Jones 2014).

Pronghorn welfare has suffered as a result of increased fencing efforts across their range. In the United States in 1879, 5 tons (4,500 kg) of barbed wire was manufactured and only 6 years later it had increased to 40,000 tons (36,000,000 kg). By 1945 the annual production of barbed wire had reached 234,000 tons (210,600,000 kg) (Leftwich and Simpson 1978). Initially most of the fences were "drift fences" which resulted in large numbers of pronghorn being trapped to freeze to death in blizzards (Hailey 1979). Later, the fencing of pastures became more and more commonplace, further restricting the movement of pronghorn populations until the species was excluded from much of its former range (Russell 1964, Martinka 1967, Spillett et al. 1967, Hailey 1979).These fences present complete or partial barriers to movements of pronghorn, and have obstructed migrations, seasonal movements, and travel to water or feeding areas. As a result, pronghorn populations have continued to decline on some rangelands. Extensive mortality has also occurred when animals became entangled or trapped as they attempted to negotiate these barriers (Oakley 1973).

Since the first Antelope States Workshop held in 1965, the interaction between

Photograph 28. Sequence of photographs showing a pronghorn crossing under a fence. Note how low the animal gets in the first image and how the barb wire scratches the back and removes the hair in the second and third images. Photographs provided by the Alberta Conservation Association.

pronghorn and fences has been a regular topic of conversation and presentation. One of the first extensive evaluations into pronghorn/fence interrelationships was accomplished in Montana and Wyoming by Rouse (1954). He noted fences were obstacles unless the bottom wire was ≥ 15 in. (38 cm) above the ground, and that fences with lower bottom wires were totally impassable. The first intensive field study of the effects of fencing on pronghorn was conducted in Wyoming by Spillett et al. (1967). These investigators tested 22 types of fences to evaluate pronghorn movements under controlled conditions. Results indicated a fence 32 in. (81 cm) high was the maximum most pronghorn would readily jump.

Even though work has been done to evaluate fence modifications to make them pronghorn friendly, many fences still exist that influence pronghorn habitat selection. Sheldon (2005) found that pronghorn selected seasonal ranges that had lower fence densities than compared to her study area in Wyoming. She also found that pronghorn home ranges were bound by fences, which has also been reported by Ockenfels et al. (1997) and Ticer et al. (1999) for Arizona. Suitor (2011) noted areas of high densities of impermeable fences in Alberta that may be impacting known migrations as he detected very constrained movement patterns with no migrations. Increased effort is required on the public education side to ensure knowledge gained from studies on fence designs are implemented on a landscape or geographical scale. Additional work needs to be completed to identify location of fences on a large scale and to determine if they are acting as barriers, this work will assist in directing stewardship activities.

2. Purpose of Fence

Today, the majority of fences built on western rangelands are to control domestic livestock. Additional fences are erected to control access along roads, highways, and railroads; to protect agricultural crops; to limit access to mining operations, military installations, and private property; and for other purposes. How these fences are designed and constructed determines their effect on pronghorn welfare. Fences can be built to (1) fully restrict and control pronghorn movement (Photograph 29), (2) control cattle and horses, but allow pronghorn passage, or (3) control all domestic livestock (including domestic sheep and goats) and ungulates, as well as pronghorn movements.

a. Livestock

The most abundant fence on the prairies are those used to control the distribution of domestic livestock, in particular cattle and horses. These fences are typically constructed with barbed-wire (Kindschy 1996) with either wooden or metal posts for support. The number of barbed wires along the fence varies, but typically consists of 3 - 4 wires (Figure 5). Equally variable is the spacing of the wires but typically the bottom wire is 12 - 16 in. (30 - 40 cm) above the ground, with the top wire typically 48in. (120 cm) above the ground. Depending on the fence design and configuration it may or may not be a barrier to pronghorn movement. Suspension fences are a slight modification to the standard barbed-wire fence and usually consist of metal fence posts spaced further apart with 1 - 2 stays in

Photograph 29. The Vizcaino pronghorn facility, located in Baja California Sur, Mexico, contains all interior fences with 6 strands of smooth wire for 7 separate small pens. The smooth wire fences have been effective for more than a decade (Cancino et al. 2002). Photograph by Ramon Castellanos.

between to strengthen the tension of the fence. These fences tend to be more detrimental to pronghorn due to the fence being less visible (Kindschy 1996) and the fact there is usually less "give" by the bottom wire to allow pronghorn to push up and raise the bottom strand when trying to cross (Brown and Ockenfels 2007).

Ranchers in the Southwest US often encircle water sources with fences to trap or redistribute livestock. These enclosures often are built of woven-wire, and contain ≥ 10 strands of barbed wire, or snow fencing. Such structures are highly detrimental to pronghorn, especially young animals inexperienced in negotiating such obstacles. The fencing of water holes in such a manner appears to violate the same basic mandate prohibiting sheep-tight fences on public lands dedicated to multiple use (Yoakum 1980, Yoakum and O'Gara 1990).

b.Sheep

Net-wire, woven wire or page wire (Photograph 30) are similar fences used to control domestic sheep and are particularly disastrous for pronghorn seeking preferred forage in the arid Southwest US (Büechner 1950, Hailey 1979). In northern habitats, fences often severely impede pronghorn movements during winter (Spillet et al. 1967, Oakley and Riddle 1974, Mitchell 1980, Barrett 1982, Pyrah 1987). Woven wire and sheep-tight fences prevent pronghorn from drifting ahead of severe storms to rangelands with preferred forage or less snow. By restricting free movements, fences cause pronghorn to remain in areas offering little protection or food during storms, resulting in malnutrition and death from

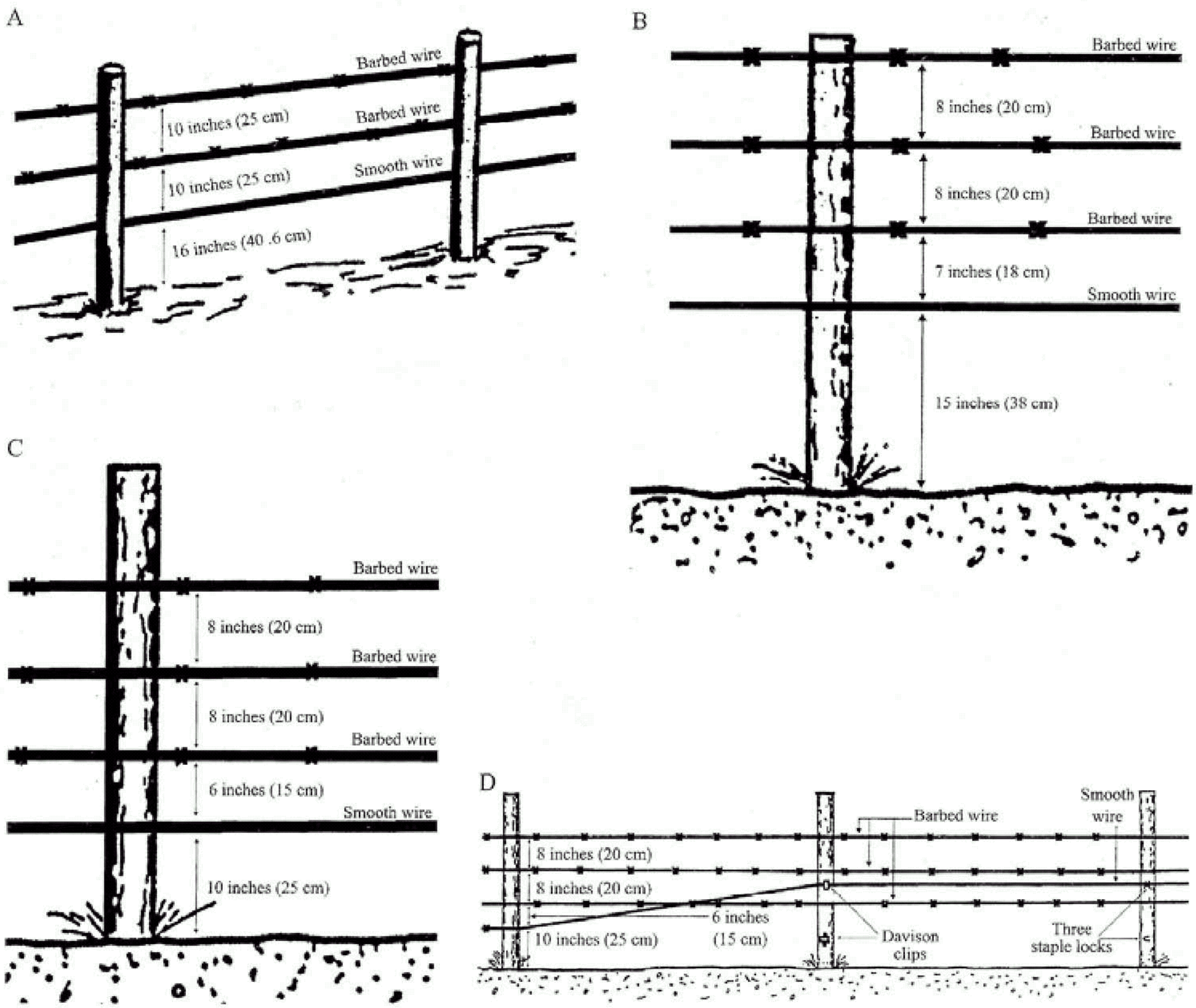
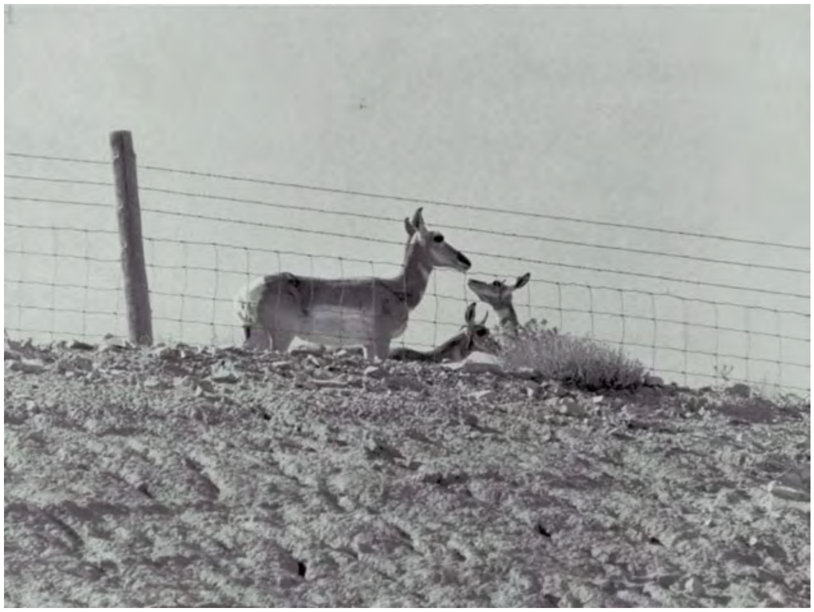


Figure 5. Specifications for (A) 3-strand (Karsky 1988) and (B) suggested 4-strand wire fences on rangelands used by cattle and pronghorn and (C) barbed and smooth wire fencing recommended for fences on rangelands grazed by domestic sheep, cattle and pronghorn (Karsky 1988). The latter fence will restrict pronghorn movements because the lower wire is too close to the ground, so it will not allow pronghorn to crawl underneath. However, it can be modified to allow pronghorn access through the fence when the bottom wire is raised as illustrated in (D) (from Yoakum 2004*e*).

winter-kill. Popowski (1959) aptly summarized the seriousness of this issue by stating "when pronghorn are denied freedom in seeking seasonal food requirements, they sicken and die of malnutrition; and when they can't drift to avoid severe winter storms they often collect in fence-corners and freeze to death." Deep snow filling depressions where pronghorn normally crawl under fences can make fences pronghorn-proof. Crusted or wind-packed snow covering the fence's lower wires prohibited pronghorn from crawling



Photograph 30. Woven-wire fences topped with 2 - 3 strands of barbed wire, often present complete barriers to the movement of pronghorn. This is especially true for fawns that are less capable of jumping over wire fences. Photograph taken on the Sybille Wyoming Wildlife Research Unit by J. Ward.

underneath, and snow does not provide a solid enough surface for launching an effort to jump the fence. In such situations, fences on pronghorn movement corridors and wintering areas need to be laid down.

After > 100 years' experience with fences, pronghorn primarily still go under rather than through or over fences. Büechner (1950) observed that most pronghorn seem unaware of their ability to jump, and often die of starvation rather than jump sheep-tight fences. Yet, during pronghorn trapping operations in Wyoming, adult pronghorn jumped over an 8-foot (2.4 m) fence (Spillet et al. 1967), and have jumped 7-foot (2.1 m) horizontal structures (Mapston 1968). Spillett et al. (1967) reported that a pronghorn's ability to see over a fence was an important factor in their willingness to jump fences; they also observed pronghorn using snowdrifts to cross fences.

c. Highways

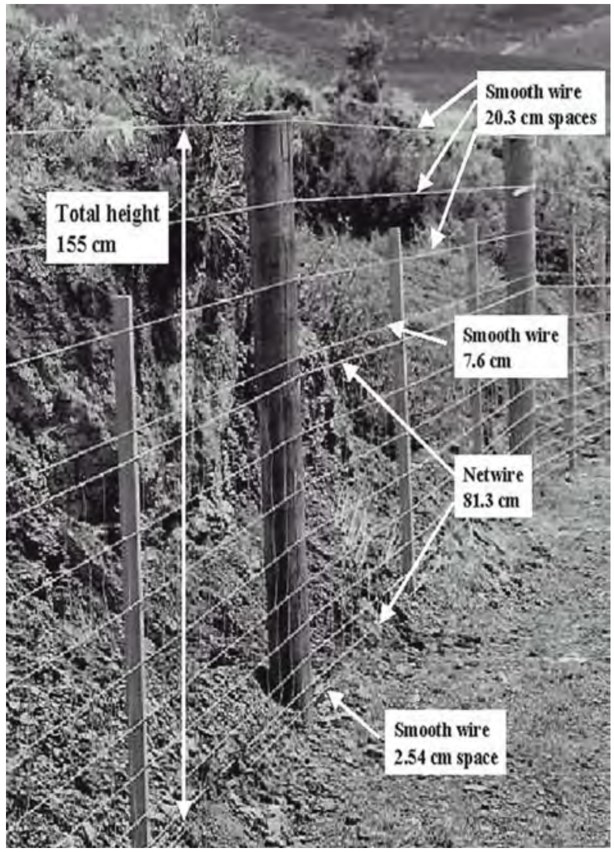
Büechner (1950) recognized early on that fenced highways impacted pronghorn movements. Fenced highways and railroad rights-of-way effectively fragment habitat and isolate pronghorn herds (Ockenfels et al. 1994, 1997). The combination of multiple fences and nearly constant traffic seriously restricts, but does not necessarily prevent, movement across highways. The ability of pronghorn to negotiate highways is often critical to their survival. Devastating winter-kills have occurred when snow cover prevented pronghorn from going under highway fences (White 1969). Ockenfels et al. (1994) present a list of possible mitigation features to use at highway rights-of-way. Removing or taking down fences during severe winter weather should also be considered, even though such action may require much coordination and planning. With increased speed and volume of motor vehicle traffic on interstate and alternate highways, crossing structures are needed in pronghorn habitat to protect the animals and vehicle passengers. The fence design depicted in Photograph 31 would control pronghorn movement and assist guiding them to less hazardous areas to cross.

3. Fence Designs

Depending on the design of the fence it can either be a barrier and control pronghorn movement or it can allow passage by pronghorn. Fences used to control pronghorn movement do so to keep the animals out of agricultural fields, landing strips, highways, and other hazardous areas. Such exclusions can be permanent or temporary. Past research and field testing of the many different fencing configurations have determined the fence designs most appropriate for various control needs. Spillett et al. (1967) emphasized that pronghorn in captivity react differently to fences under different motivational levels, with the level of motivation being the key factor in determining the extent of the barrier required. If not stressed by harassment, or lack of forage or water, pronghorn can be controlled with a low fence with the bottom wires close to the ground. Some situations, however, are inadequate to control highly motivated animals, which require a higher barrier to restrict movement.

The following discussion pertains to a fence design that has been proven to contain highly motivated pronghorn (Photograph 31). Of 2 successful applications of this fence design, one involved keeping pronghorn away from an irrigated alfalfa field surrounded by sagebrush steppe during the late summer and fall when native vegetation became mature and dry. Another highly motivated situation was the enclosure of pronghorn that had been trapped and transported 60 mi (100 km) from their native range (Pojar et al. 2002). In both cases, there was direct visual and track evidence that the animals paced the fence indicating a desire to cross. This fence design precluded any breech of the fence by pronghorn while allowing jumpers such as mule deer and elk passage over the fence.

The fence (Photograph 31) is 61 in. (155 cm) high and was a combination of smooth wire and net wire with 6 in. (15.25 cm) squares (Pojar et al, 2002). The first smooth wire was 1 in. (2.54 cm) above the ground and 1 in. (2.54 cm) below the bottom of the net wire. The net wire was 32 in. (81.3 cm) high. Above the net wire there were an additional 4 strands of smooth wire. The first was spaced 3 in. (7.6 cm) above the net wire with 3 more strands spaced equally at 8 in. (20.3 cm) intervals. For additional strength, it would be desirable to have the top wire replaced with 1 in. (2.54 cm) wide metal impregnated nylon tape (as is used for electric fences). This should be some color other than white so the jumpers can see it against a snow background. Of course it is important to make sure the bottom of the fence adequately seals all geographic depressions and drainages to prevent pronghorn crawling under the fence.



Photograph 31. Effective fence design for controlling pronghorn movement under moderate to strong motivation. This type of fence has been successfully used as both an enclosure for newly translocated pronghorn and as an exclosure to prevent pronghorn from using an irrigated alfalfa field. Photograph by Tom Pojar.

To hold pronghorn in a large rangeland enclosure containing adequate food, water, and space throughout the year, the fence specifications in Photograph 31 can also be used. Gates should be constructed of wire rather than wood, thereby allowing the pronghorn to see through the fence. Many miles of these sheep-tight fences (including the wolf-type variation to control coyote movements) are almost complete barriers to pronghorn. Should the fenced area be small, and the possibility for harassment from domestic dogs and other sources exist, the fence should be at least 8 feet (2.4 m) high to keep pronghorn from jumping over.

Smaller fences, designed to hold captive animals, present certain unique problems, and are often best constructed of wood to prevent panicky or adventurous animals from getting caught between wires or in net-wire openings (T. Hill, personal communication). For larger enclosures, an electric fence outside of a net- or woven-wire fence is used. To reduce cost, one of the fences can consist of 7 smooth wires provided that a visual barrier is also present to reduce the chances of pronghorn colliding with the wire (R. Castellanos, personal communication). This barrier may consist of cloth, plastic, or be a “snow fence.” In these larger enclosures, such as the pens built on the Cabeza Prieta National Wildlife Refuge and near Guerrero Negro in Baja California Sur, it may be advantageous to have 32 feet (10 m) dividers of woven wire fence to facilitate the segregation and movement of animals.

a. Wolf and Anti-Coyote Fences

A wolf-type fence was designed in Texas and New Mexico during the 1940s to exclude coyotes from rangelands containing domestic sheep. Their design was essentially a 36-in. (91 cm) roll of net wire fence with the bottom 12 in. (30 cm) buried below the ground. Three to 4 strands of barbed wire were then strung above the woven wire to a height of 50 - 60 in. (127 - 152 cm). Other anti-coyote fences have been designed using combinations of barbed and electric wires (Karsky 1988, Kie et al. 1994), with all having the objective of preventing coyotes from digging under, passing through, or jumping over the fence. Although successful in their intended purpose, these fences also prohibit pronghorn movement and are illegal on public lands where multiple-use is a land-use objective (Yoakum 1980).

b. Electric Fences

Electric fences can be designed to either control pronghorn movements or control domestic livestock while allowing pronghorn movements. Management objectives may at times seek to prevent pronghorn from entering a certain area or to restrict their movements to within an area (Yoakum 1980, Yoakum et al. 1996). Such restrictions can be accomplished with an electric fence that carries intermittent electrical charges that shock animals coming into contact with the fence. Once pronghorn are exposed and conditioned to an electric fence, such fences can pose a psychological barrier as well as being a physical obstacle. Such fences are relatively easy to install, have a reasonable service life, and may result in a 25 - 30% savings in the cost of labor and materials (Karsky 1988). Standard, 2 wire electric fences, have effectively managed livestock on western rangelands, and kept pronghorn out of newly planted rangeland seedlings in Malheur County, Oregon (R. Kindschy, personal communication).With recent innovations, electric fences, formerly considered temporary structures, can now be virtually permanent. Standard energizers can electrify up to 6 miles (9.7 km) of wire with a useful life of up to 4 years. New Zealand energizers can effectively electrify > 75 miles (120 km) for a period of 10 - 15 years (Karsky 1988).

In central Colorado, a 3 strand electroplastic-twine fence was installed around an alfalfa field visited by pronghorn (Pojar et al. 2002). In addition, the field was fenced with sections of 4 strand barbed and net wire to control livestock. Before the electric fence was installed, the daily mean number of pronghorn on the field over a 6 day period was 38.7. After the electric fence was erected, the mean daily number was 2.16. This study indicated that electric fences can be a substantial barrier to pronghorn movement, especially where the animals come into contact with the live wire. Hence, to facilitate pronghorn passage, electric wires should not be strung so that the bottom wire is live (Figure 6). When erecting a permanent electric fence to exclude pronghorn, Pojar et al. (1994), suggested building a

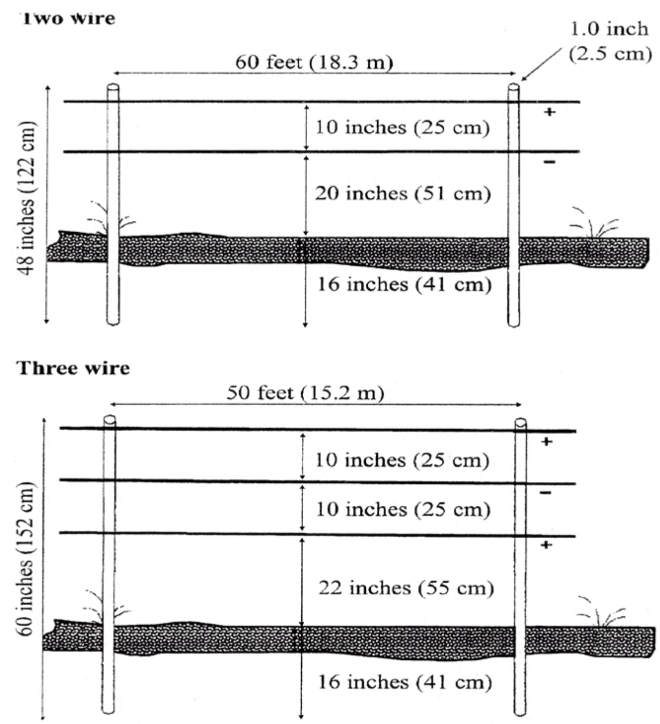


Figure 6. Two-(top) and three-wire (bottom) electric fence designs featuring 0.75 - 1.0 in. (1.9 - 2.54 cm) diameter, solid, fiberglass line posts. The wire is 21.5 gauge, class III galvanized, with a maximum tensile strength of 170,000 lb./in.^{2} (11,953 kg/cm2) and a maximum breaking strength of 1,308 lb. (626 kg). The wires are connected to the line posts and stays by metal clips (from Patritch 2005).

60 in. (150 cm) tall 5 strand (or more) high-tensile wire fence, as described by Palmer et al. (1985). Such a fence would result in a fence with a long life, low maintenance costs, and less expense than conventional net-wire fencing that can be an effective barrier for both pronghorn and deer.

Preliminary results of a long-term study relative to the effects of electric fences on bison, elk, deer, pronghorn, and cattle for fences constructed on rangelands were reported by Patritch (2005). Specifics of the fence designs tested are in Figure 6. When a pronghorn or other ungulate came in range, a camera recorded the animal's reaction to the electric fence resulting in 191 recordings for pronghorn. Findings indicated pronghorn were not often severely shocked. The insulating quality of pronghorn hairs, combined with generally dry soils, allow animals to contact the hot wires, and feel little or no pain. They may be more susceptible to shock when the soils are wet. The author contended that a 3 wire fence is an effective structure to meet the goals of controlling bison and livestock, and allowing pronghorn, deer, and elk access to rangelands (Patritch 2005). Karhu and Anderson (2006) evaluated the effects of high-tensile electric fences on ungulates and domestic livestock. They concluded that if managing for pronghorn that either the 3 - 4 wire electric fence was appropriate to allow passage by pronghorn while still containing domestic livestock (cattle and bison).

c. Wildlife Friendly Livestock Fences

Figure 7A illustrate suggestions for barbed wire fence specifications that allow pronghorn of all ages to go under the bottom wire, yet control movements of cattle and horses (Kindschy et al. 1982). Fences constructed according to these specifications have been built for hundreds of miles on pronghorn habitat, and have proven effective for rangelands experiencing dual use (livestock and wildlife) since the fence design was originally published during the 1950s (Griffith 1962). Although arguable by some livestock personnel that the fences allow calves to go under the fence, the return reply has been that such calves can likewise return back to the cows. More than a half century of hundreds of miles of rangeland fences built appears to confirm that this is a reality. This case record stands as one of the most successful fence designs on western US rangelands used by pronghorn and cattle. Figure 7B depicts the same fence with a Goat-bar placed in a strategic location to allow even easier passage by pronghorn.

4. Enhancements for Pronghorn

Hundreds of thousands, if not millions, of miles of fences currently exist across the entire range of pronghorn that may or may not be passable by pronghorn. All of these fences do not have to be redesigned but instead specific fence sections can be enhanced to allow passage by pronghorn. There are a number of enhancement designs specific to fence sections that have been used to allow pronghorn to pass under fences.

a. Let-down Fences

A let-down fence is designed to allow sections of wire to be laid on the ground, thus allowing pronghorn the opportunity to pass over the barrier during times of seasonal movement or after deep snows (Karsky 1988). One design uses a wire loop at the top of the fence post and a pivot bolt at the bottom to hold a stay in place (Figure 8). Such a design allows sections of the fence to be easily let down and be re-erected. Another design allows the let-down section to be pulled back against a section of standing fence. Such fences must be designed to provide for an adjustment of the wire's tension as the wire cannot be so taut as to not allow the fence to lay flat nor so loose that loops of wire create a hazard to pronghorn. Experience over the last 3 decades indicates that labor is often unavailable to let-down these fences prior to severe snow storms. Inherent problems concerning who puts them up and takes them down are common. When a bad storm hits, ranchers take care of their livestock first, and wildlife agencies generally do not have enough personnel to let down the panels when needed. Pronghorn tend to become conditioned to fence lines, and in some instances when let down panels have been installed, migrating pronghorn have

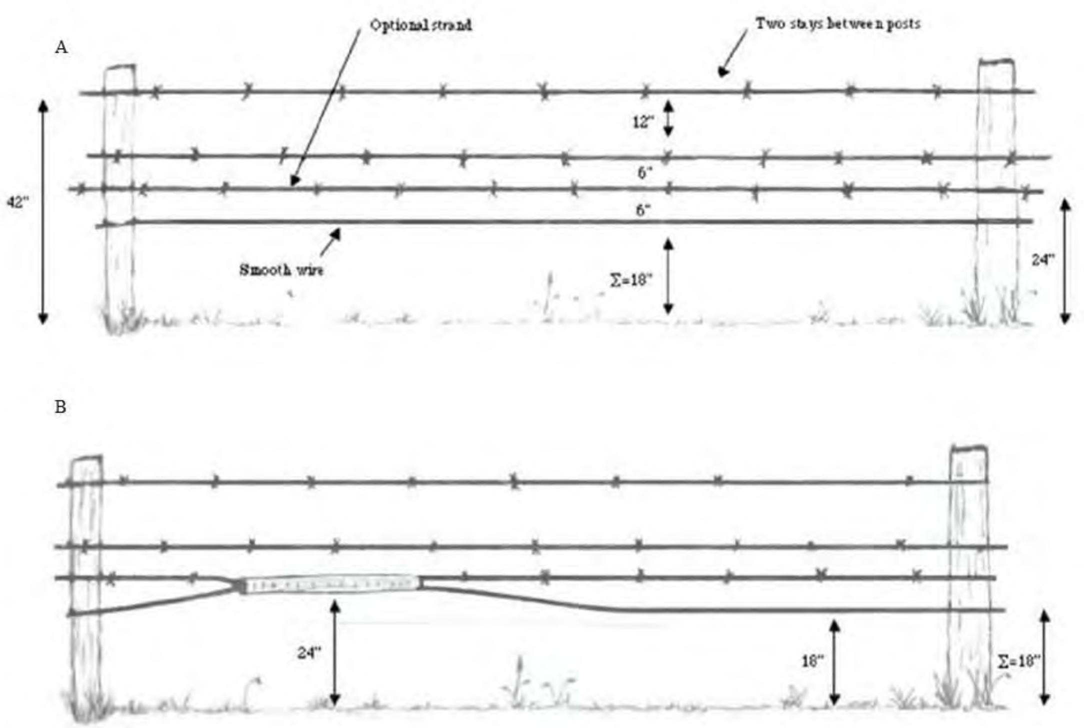


Figure 7. Suggested wire fence specifications using barbed and smooth wires for rangelands used by cattle and pronghorn (A). Such fences have been most effective on extensive rangelands. They are less effective surrounding agriculture fields and drinking water facilities (Kindschy et al. 1982). Same fence with a Goat-bar in strategic location (B).

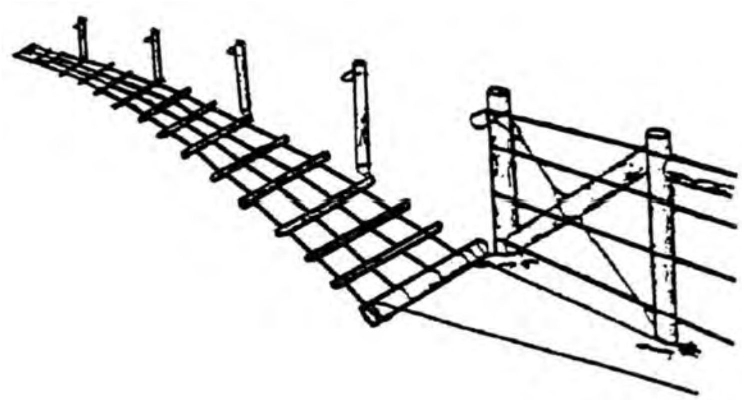


Figure 8. Let-down fence to permit pronghorn and other wild ungulates to cross (Karsky 1988). Letting down the wires from at least 4 posts should suffice, and distances between gaps would depend on the local conditions (from Yoakum 2004*e*).

walked past the downed area, seemingly unaware of the opening. Leaving gates open in such areas when livestock are not present might help alleviate this problem.

b. Adjustable or Staple-lock Fences

The adjustable fence illustrated in Figure 9 was designed in Idaho (Anderson and Denton 1980) to allow the lower strand of wire to be raised from 16 in. (41 cm) to 38 in. (97 cm) above the ground. This design is especially beneficial to pronghorn in areas where the snow depth can exceed 12 in. (30 cm). One person can adjust 1 mile (1.6 km) of wire in approximately 30 minutes. L. Anderson (personal communication) reported that pronghorn repeatedly selected the sites having the bottom wire higher than those sections of fence where these wires had not been raised. Raising fences has special merit for areas experiencing snow depths ≥ 12 in. (30 cm) or more. However, such a system requires that habitat managers have adequate personnel available to manipulate the wires lest the fence be a detriment rather than a benefit to pronghorn and other wildlife.

c. Goat-bars

A better solution, although one still not as ideal as no fence at all, is the provision of goat-bars in strategic passageways. These goat-bars consist of pieces of a longitudinally slit polyvinyl chloride (PVC) pipe from 6 - 12 feet (2.5 – 3 m) in length, into which the bottom 2 strands of fence are inserted into the slit, thus lifting the "bottom strand and facilitating the passage of pronghorn under the fence (Figure 7B, Photograph 32). The effectiveness of the goat-bar is restricted to the height of the second wire above the ground and if it is not ≥ 20 in. (50 cm) the likelihood of raising the bottom wire to 18 in. (45 cm) is diminished. Further research is required to assess the effectiveness of allowing passage by pronghorn (P. Jones, personal communication).

d. Buck and Pole Fences

Wood fences constructed of aspen or pine logs are no longer widely used on rangelands due to their labor intensive construction, the local scarcity of materials, and difficulty of transportation. Nonetheless, such fences are still found due to their aesthetic values and durability in areas of heavy snow.

Scott (1992) reported on the ability of pronghorn and other wild ungulates to negotiate through a buck and pole fence on the northern boundary of Yellowstone National Park in which the bottom rail was 18 in. (46 cm) above the ground. Of the pronghorn that attempted to reach the other side, 72% either passed around the fence or crawled under the fence even though they sometimes experienced some difficulty in the process. Pronghorn encountered more problems on the park side of the fence, which had 4 wood rails as

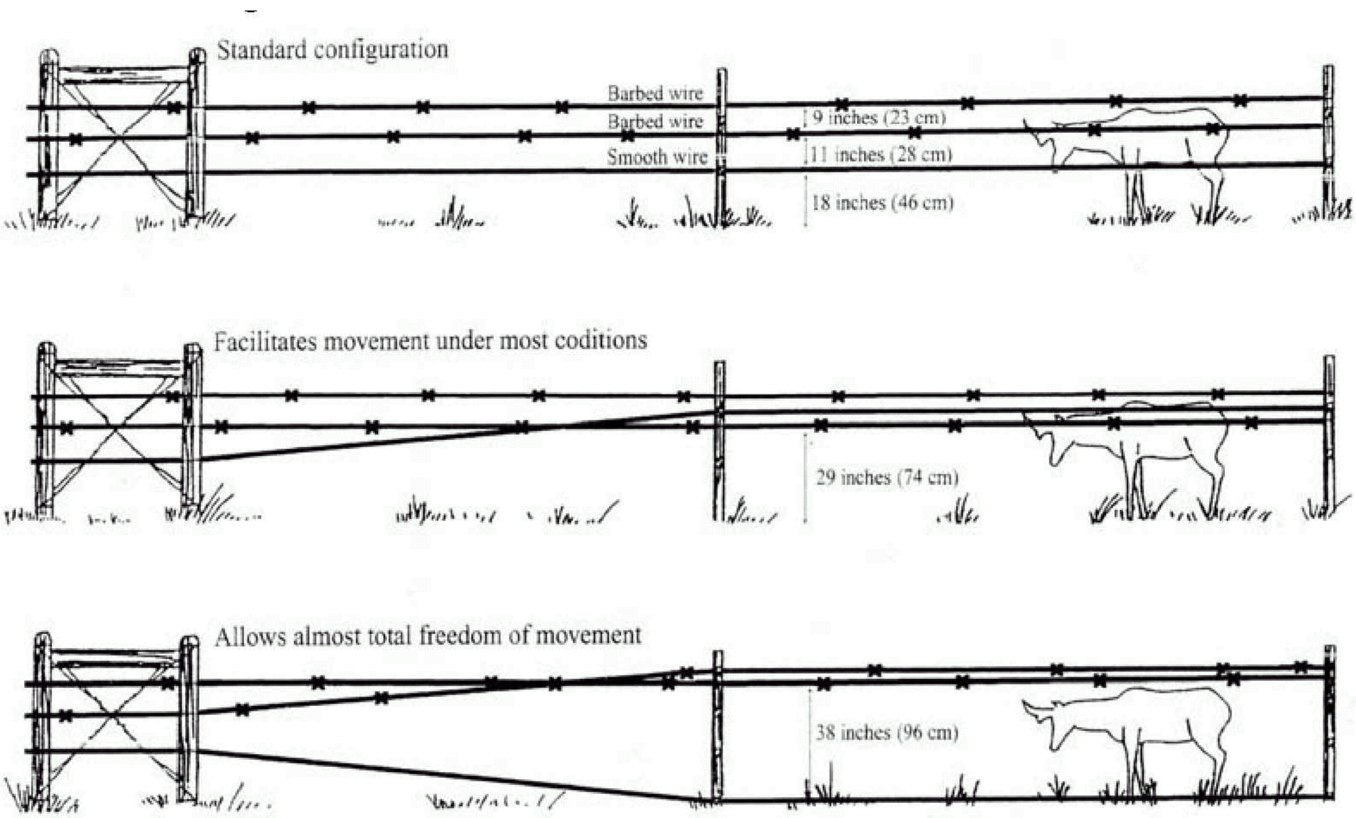


Figure 9. Three-strand barbed wire fence with modifications for pronghorn access (Anderson and Denton 1980). This design especially is beneficial when snow makes it difficult for pronghorn to crawl under the fence. The configuration depicted in the center would suffice during most winters. The 38-in. (97 cm) clearance would be needed with snow depth > 20 in. (51 cm). If the fence blocked a movement corridor from summer to winter rangelands, long areas of modification might be required to accommodate pronghorn moving with a snowstorm (from Yoakum 2004*e*).

opposed to only 1 brace rail on the other side. Pronghorn too inhibited to pass through the fence walked along the barrier until finding an open gate or other opening. A suggested design that allows pronghorn to pass through a buck and pole fence is provided by Karsky (1988) in Figure 10.

Photograph 32. Pronghorn crossing under a fence by using a goat-bar in southern Alberta. Photograph provided by Alberta Conservation Association.

e. Antelope Passes

Special facilities allowing pronghorn movement through livestock fences were developed in Wyoming by Spillett et al. (1967) and later modified by Mapston (1972) and Howard et al. (1990). These so-called antelope passes (Mapston 1968, Mapston and Zobell 1972) were essentially a miniature cattle guard that capitalized on the tendency for

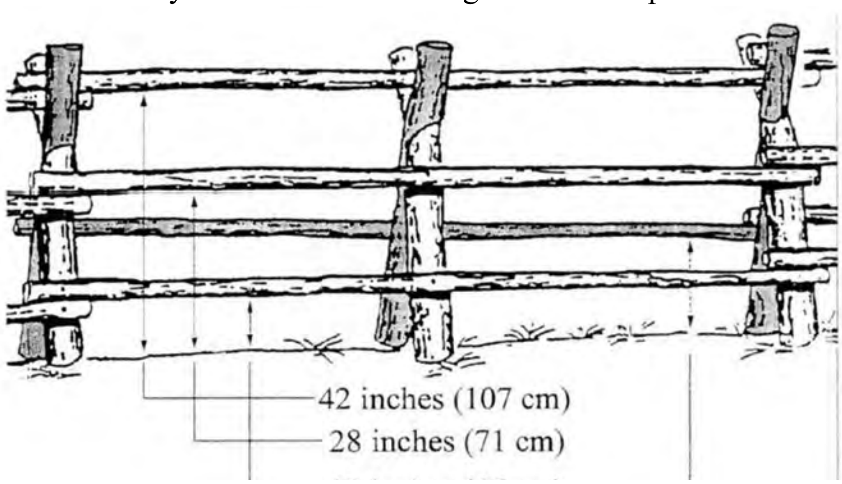


Figure 10. Typical section of a 3-rail buck and pole fence that will allow pronghorn to pass through (Karsky 1988). An attribute of this type of fence is that it enables snow to be scoured out by turbulent winds, making the fence negotiable during times of deep snow without the requirement of seasonal removal (from Yoakum 2004*e*).

pronghorn to broad jump rather than high jump. These antelope passes were placed in strategic locales, usually near a fence corner, and monitored for use by pronghorn (Figure 11). Unfortunately, later field tests showed that although some adult animals jumped over the guards, others refused to negotiate them. Fawns could not easily leap over the structures and some suffered leg injuries in the attempt. Investigators concluded that, even with a doubling of the passes width, the antelope pass was of limited value and should only be used if no other means of passage could be provided (Newman 1966, Kerr 1968, Mapston 1968, Bear 1969). Antelope passes therefore, have limited application and are not recommended for mitigating pronghorn movements through woven-wire fences (Yoakum et al. 1996).

5. Litigation

Two major lawsuits have involved livestock fences and pronghorn welfare on public lands. On the Roswell Grazing District in New Mexico, fences were modified wolf type by the federal government to permit the passage of pronghorn. The decision to modify fencing on public land was contested by livestock permittees. But the appeal was dismissed in administrative hearings, resulting in a major victory for pronghorn and multiple-use. Hence, modifying fences for pronghorn on public lands dedicated to multiple-use are on solid grounds and should continue (Yoakum 1980).

The second legal case also established an important precedent. A rancher near Rawlins, Wyoming constructed a fence around approximately 3,885 ha (9,600 acres) of private and public lands, thereby excluding pronghorn from critical winter rangelands. Many pronghorn died due to being denied access to favored winter foraging areas. The case went to the U.S. District Court for the District of Wyoming and the judge decreed that the rancher’s woven- and barbed-wire fence was in violation of the federal Unlawful Enclosures Act of 1885. The rancher immediately appealed the ruling and the case went to the Tenth Circuit Court of Appeals, where 3 judges unanimously upheld the lower court's decision. The case then went to the U.S. Supreme Court, which upheld the decisions of the District and Circuit courts.

6. Stewardship

Pronghorn should be given high priority when considering fencing and a greater effort should be made to harmonize rangeland use by livestock and pronghorn. U.S. Bureau of Land Management (1985) manual H-1741-1 states that all means of livestock control (e.g., herding, use of natural land forms, exclusion of certain kinds and types of livestock, distribution of salt and water sources) should be considered before deciding to use a specific fencing configuration. The manual also directs that the potential effects of fencing, including costs, on other resources be considered carefully before deciding what fencing to use. Provincial and state wildlife managers should ensure that federal land managers

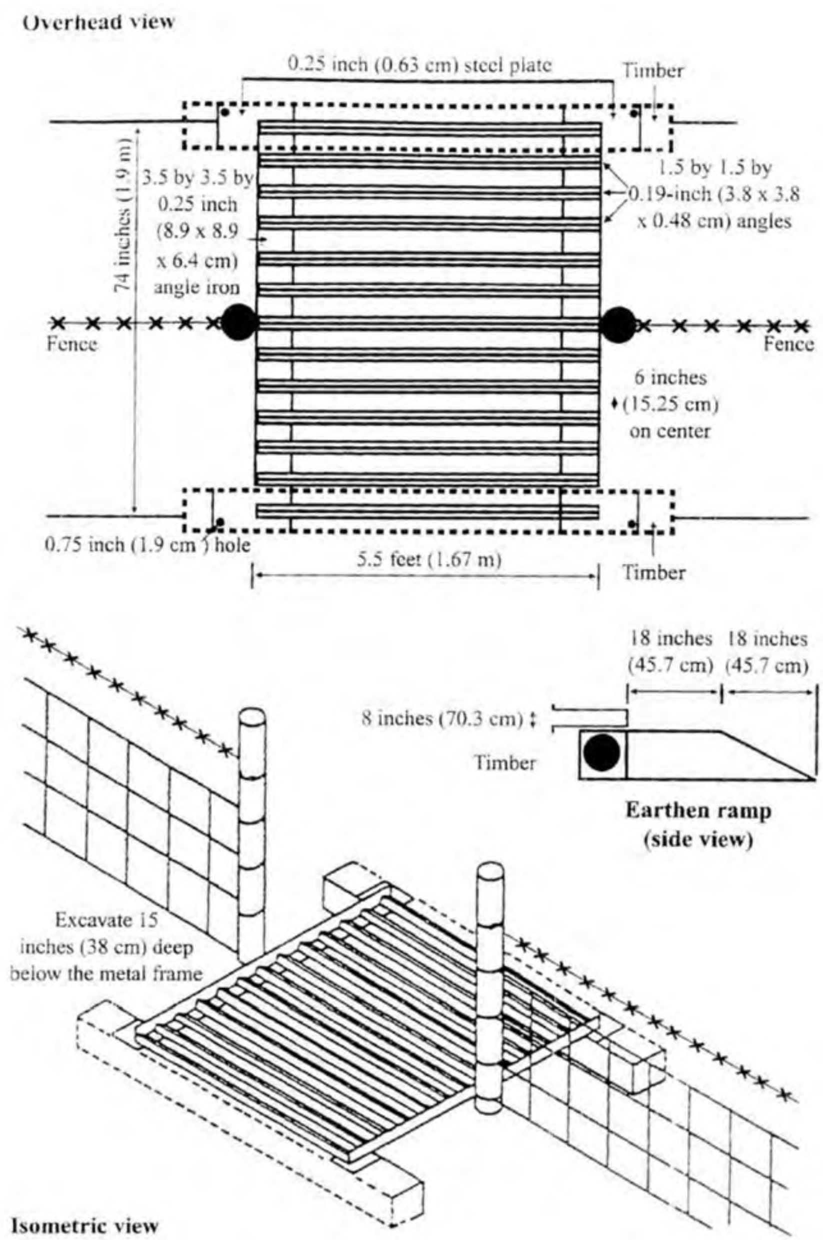


Figure 11. Antelope passes were designed and tested to allow pronghorn passage through woven-wire fences on public lands in Wyoming (Mapston 1968). These structures were about half the size of standard cattle guards and designed to prevent vehicle access. Because they are narrow, the cost of materials to build an antelope pass is about half that of cattle guards (Mapston and Zobell 1972).

comply with these important directives. Wyoming Game and Fish Department fencing guidelines maintain that no fencing should occur perpendicular to major migration routes or on transitional and winter rangelands used by pronghorn (Lee et al. 1998). Additionally other manuals (e.g., Paige 2012*a*, *b*) have been developed to assist landowners/ranchers in the design of their fences to make them wildlife friendly while still controlling their domestic livestock.

Existing fences that restrict pronghorn movements should be modified to allow free passage for these animals. Modifications should include the total removal of unnecessary fences, removal of excess wire strands, ensuring bottom wires are >16 - 18 in. (41 - 46 cm) above ground level, replacing barbed bottom wires with smooth wire, and installation of passage devices (e.g., goat bars, let-down panels, adjustable fences).

Dysfunctional fences in pronghorn habitat that no longer serve their intended purpose should be removed. Abandoned fences, together with cattle guards, corrals, and other structures, have the potential to cause injury and impede the movement of wildlife, especially pronghorn.

Although funds are often requested to construct new fences, funding to remove dysfunctional fences are often difficult to come by due to the lack of an immediate objective. As the disassembly of fences, is rarely part of a government agency's budget, it is important that periodic evaluations and management plans address this need. Similar procedures should also be employed on private and other lands as a responsibility of land stewardship.

Fortunately, problems associated with abandoned or unnecessary livestock fences are increasingly being recognized. This is especially so on wildlife refuges, and to a lesser extent on lands administrated by the U.S. Forest Service and Bureau of Land Management. As a result, such agencies are encouraging public organizations to remove and salvage unwanted fences—especially those in pronghorn habitat. Sportsmen and conservation groups, working with volunteers are increasingly taking up the challenge and are themselves requesting land management agencies to conduct fence inventories and participate in cooperative fence removal projects. Since the 1990s, the Alberta Fish and Game Association, Arizona Antelope Foundation, Oregon Natural Desert Association, the Order of the Antelope, The Nature Conservancy, The Nature Conservancy Canada, Wyoming Land Trust, and numerous other conservation organizations, have assisted in dismantling or enhancing existing fences for passage by pronghorn on hundreds of miles of fence in pronghorn habitat, not only on federal land, but also on state and private lands.

7. Recommendations

The issue of pronghorn/fence interrelationships involves biological, managerial, and legal decisions; therefore, the following checklist should be reviewed prior to installing fences on pronghorn habitats (Yoakum 2004).

1. *No fencing should be constructed until a comprehensive evaluation has been made for each proposed project site. The probable effect the proposed fencing would have on pronghorn and the benefit to livestock management should be evaluated and determined to the extent possible.*

2. *Where fencing is deemed necessary, only the minimum amount for livestock management should be permitted. Where fencing is required, provisions should be made for unrestricted passage for all pronghorn age classes during all seasons, and under all climatic conditions.*

3. *Fencing a waterhole may be as detrimental as fencing a seasonal movement route. Critical pronghorn habitats (e.g., winter concentration areas, seasonal movement corridors, fawning areas, water sources) should be designated as special biological areas requiring specific justification to be fenced.*

4. *Barbed-wire fences for cattle that allow pronghorn movements should consist of 3 strands of wire with the bottom wire smooth and > 16 - 18 in. (41 - 46 cm) above the ground, with a maximum heights of 36 in. (91 cm).*

5. *For rangelands having domestic sheep the problem is more complex. Any fence that effectively controls sheep will most likely restrict pronghorn movements. Net-wire fences should not be built in pronghorn habitats. Where net wire must be used, mitigating provisions such as let-down panels or adjustable fences should be incorporated into the fence line at strategic pronghorn movement sites.*

6. *Specially designed fences (e.g., buck and pole, rail, suspension,) should be no > 34 in. (86 cm) from ground level, with a bottom gap ≥ 16 in. (41 cm) above the ground.*

7. *All new fences should have flagging tied to the top wire between each post to improve visibility of the new hazard. Pronghorn may become accustomed to the new fence by the time the flagging deteriorates. Grey camouflage steel posts should be avoided.*

8. *Wolf-type fences to exclude coyotes from pastures completely restrict pronghorn movements. The construction of this fence design should not be allowed on public rangelands occupied by pronghorn.*

9. *Antelope passes have been shown to be of limited value because fawns have been observed to break legs trying to jump over the guards. This is particularly true where such devices are infrequently used, as in areas with low pronghorn densities, or seasonal movement corridors.*

10. *No more than 2 stays should be permitted between fence posts to allow sufficient slack in the bottom wire. If > 3 stays are used, < 2 stays should be attached to the bottom wire. Many highway and pasture fences are too tight for easy pronghorn passage.*

11. *Let-down fences serve well under some circumstances. A major concern is the managerial guarantee that the fence will be let-down prior to severe snowstorms.*

12. *Where rangeland operations switch from domestic sheep to cattle, net wire fences should be removed or extensively modified to allow pronghorn movement.*

13. *Emphasis should be placed on reduced fencing and other livestock control methods such as herding, should be considered as alternative management practices. Livestock operations, especially for domestic sheep, should be implemented with minimal fencing.*

Industrial and Infrastructure Development

Pronghorn populations plummeted with the advancement of Euro-American colonization across the West (O'Gara and McCabe 2004). In the 1800's, westward expansion was dominated by cattle and sheep ranching, and associated fencing; the conversion of native grasslands to croplands; unregulated hunting for sport, food, and market sale; and the improved hunting efficiency via railroads and modernization of weaponry, all of which affected pronghorn populations (Yoakum 2004*a*). Contemporary development pressures have shifted and now include infrastructure development such as roads, fences, and suburban sprawl. These elements continue to have substantial effects on pronghorn populations including direct and indirect habitat loss and potential effects on demographic rates. In this section, the industrial and infrastructure developments that affect pronghorn today are reviewed, and management recommendations to address these threats are offered.

1. Review of Current Threats

Pronghorn range through wide-open country and rely on the ability to move through sagebrush and grassland habitats in order to selectively forage and to escape predators (Byers 1997, O'Gara 2004*a*). Habitat fragmentation and loss from industrial and infrastructure development is perhaps one of the most pressing modern threats to pronghorn. This includes fragmentation and loss from railroads, roads, and fences (Ockenfels et al. 1997) as well as energy development (Riley et al. 2012).

Railroads originally provided access for large numbers of people into the West, increasing the impact of market and sport hunting on pronghorn populations in the 19th Century (Yoakum 2004*a*). Railroads continue to contribute to mortality of pronghorn, however today's consequences result from train-pronghorn collisions. Although these types of mortality events are infrequent, a single collision often kills large numbers of pronghorn. O'Gara (*2004a*) reported train collisions in Idaho, Wyoming and Alberta, involving hundreds of pronghorn mortalities in single accidents. These types of events are often associated with deep winter snow where railroad tracks are kept clear by passing trains (Gates et al. 2012). Pronghorn move onto the tracks likely to ease their mobility. When a train arrives the pronghorn attempt to outrun the train down the tracks rather than leave the track where snow hinders their ability to move. In a challenging winter, these deaths may add to overall mortality from starvation. When tracks are fenced, ostensibly to reduce collisions with livestock and wildlife, they can decrease the permeability of the landscape (Van Riper III et al. 2001). This decreased permeability isolates populations on either side of the fenced tracks, with the potential to reduce pronghorn access to resources such as food, water, and mates (O'Gara 2004*a*). Further, impermeable fences may limit genetic and demographic exchange within a population, reducing fitness (Stephen et al. 2005*a*), or could result in a population sink if pronghorn are unable to run to escape predation (Boone and Hobbs 2004).

Akin to railroad tracks, roads, and highways pose threats to pronghorn especially when they bisect migration routes. Wildlife-vehicle collisions (O'Gara 2004*a*, Maffly 2007, French 2011), stress responses (Gavin and Komers 2006) and barrier effects from roads and associated fencing contribute directly and indirectly to pronghorn mortality (Yoakum 2004*a*, Sawyer and Rudd 2005, Beckmann and Hilty 2010, Dodd et al. 2011). Pronghorn often need to move great distances in order to escape snow depths that make movements and access to food difficult in the winter (O'Gara 2004*a*, Gates et al. 2012). In Wyoming, fences (Johnson 1988) and highways (Ward et al. 1976) have both been identified as complete barriers to pronghorn attempts to reach winter range. In 1983, at least 700 migrating pronghorn in southern Wyoming perished because newly erected fence bisected and blocked their migration route to more southerly range in that extreme winter (Johnson 1988). When historical migration routes cross rivers that are now dammed, reservoirs can also create risks for pronghorn attempting to reach seasonal ranges (French 2011). Urban and exurban development and expansion increases the number of challenges faced by migrating pronghorn by removing habitat and fragmenting access to seasonal ranges with roads and fences (Gates et al. 2012).

Oil and natural gas developments often coincide with pronghorn habitat in the West. Not only are these developments common in sagebrush-steppe (Riley et al. 2012), but in some areas development also utilizes crucial winter range where mesas, containing deep gas pockets, are also windswept due to their uplifted topography (Beckmann et al. 2012). These windswept plateaus allow pronghorn to access forage through the winter more easily than areas that accumulate deep snow. This crossroad pits the drive for energy independence against wildlife resources.

Petroleum and natural gas extraction, wind and solar power developments and the pipelines, transmission lines, and roads needed to transport the resource and access the sites all pose threats to pronghorn (Sawyer et al. 2002, 2013, Hebblewhite 2008, Beckmann et al. 2012). The pace of domestic energy development has expedited approval of public land leases (Copeland et al. 2011). Both direct and indirect (e.g., disturbance caused by human activity) habitat loss from energy development affect pronghorn.

Pronghorn avoided oil fields where disturbance from drilling and associated human activities occurred in the Rattlesnake Hills of central Wyoming (Easterly et al. 1992). In western Wyoming, habitat loss and fragmentation led to abandonment of high quality winter range by pronghorn in the Upper Green River Basin (Beckmann et al. 2012). Although this study did not detect changes in survival rates, reproduction, or physiological health of pronghorn wintering in the gas fields when compared to those outside the gas fields, the authors suggest that because the population was below carrying capacity, due to pressures from hunting, only changes in behavior were realized at that level of gas field development. As the gas fields continue to grow, increasing habitat loss may push the population past an additive or synergistic threshold that may reduce the long-term population viability of pronghorn populations wintering in the Upper Green River Basin.

Energy development is not only limited to an oil or gas field, but necessitates transportation for workers and transportation of the product. In addition to the extractive facilities, infrastructure such as roads, power lines, or pipelines can create barriers (complete or semi-permeable) to wildlife movement (Sawyer et al. 2013, R. Seidler, unpublished data) and exacerbate wildlife-vehicle collisions (Coffin 2007). The National Resource Defense Council speculates that the Keystone XL Pipeline will fragment important pronghorn migratory routes in eastern Montana and elsewhere (Swift et al. 2011). There is also concern that power lines may create impediments for migrating pronghorn (Braun 2009, Duval 2009), but field research on pronghorn responses to power lines has not yet been published.

Development of wind turbines as a renewable source of energy has been growing with an international focus on reducing greenhouse gases (Johnson and Stephens 2011). Wind energy development is one of the most land-intensive energy extraction activities in terms of the number of hectares/exajoule of energy produced (Copeland et al. 2011) and is associated with large amounts of habitat loss and fragmentation (Kuvlesky et al. 2007). Few studies have been completed that look at the effects of wind energy facilities on ungulates. A 4-year study in southern Wyoming contracted by the SeaWest wind energy facility failed to demonstrate any effects on pronghorn abundance during construction of the facility (Johnson et al. 2000). These researchers used fixed-wing surveys and pellet densities to estimate pronghorn numbers. However, this study was not designed to evaluate fine-scale movement or behavioral responses of ungulates, and did not assess demographic parameters. An on-going study in south-central Wyoming has not detected changes in pronghorn survival in relation to wind energy development (K. L. Taylor and J. L. Beck, in progress). This study, in contrast to the Johnson et al. (2000) report, deployed GPS radio collars on pronghorn. K. L. Taylor and J. L. Beck (in progress) anticipate examining resource selection and survival of pronghorn in relation to environmental and anthropogenic variables associated with 2 wind energy facilities.

On average, 1 million hectares (2.4 million acres) are required to produce 1 exajoule of energy per year by solar plants and associated infrastructure (for reference, global primary energy consumption was 550 exajoules in 2010). This is about ½ the land use intensity for wind power development (Copeland et al. 2011). California contains the greatest number of solar arrays in the US (Copeland et al. 2011). Due to the large expanse of land that solar collection requires, concern has arisen for pronghorn regarding proposed solar power developments in the Carrizo Plain and the Mohave Desert (Center for Biological Diversity and Western Watersheds Project 2010, the Desert Renewable Energy Conservation Plan

(DRECP) Independent Science Panel 2012). However, with a dearth of studies on pronghorn responses to solar infrastructure installations, assumptions can only be made regarding the effects of habitat fragmentation and loss associated with these developments.

Military activity overlapping with pronghorn habitat in general is minimal. However, in Arizona, the endangered subspecies of Sonoran pronghorn extensively utilizes habitat within the Barry M. Goldwater Military Range (Krausman et al. 2004). Multiple factors are likely limiting this population, and sound from military ground activities appeared to contribute to behavioral changes. Pronghorn foraged less, and stood and traveled more in areas exposed to military activity (Krausman et al. 2004). Indeed, pronghorn used areas with lower levels of noise more than expected and conversely used areas with higher levels of noise less than expected (Landon et al. 2003).

The effects of industrial development on greenhouse gas emissions contribute greatly to the tenuous future of wildlife. Pronghorn likely will be (and are) affected by climatic changes, including drought, flooding, and epic weather events. Drought is of particular concern in areas where water is already scarce. Precipitation equates to forage for pronghorn and populations in the desert southwest US have declined due to starvation in years with severe drought conditions (Bright and Hervert 2005, Brown et al. 2006, Cancino et al. 2010). Variation in the effects of climate change between climate models allows for speculation on the effects to pronghorn in the Greater Yellowstone Ecosystem. A warm-wet scenario could lead to local extinctions of pronghorn while a warm-dry scenario may actually increase habitat availability (Romme and Turner 1991). In areas where climate change is forecast to increase precipitation, flooding may increase mortality rates for migrating pronghorn especially when severe winters perpetuate unusually long migrations (French 2011).

Although threats to pronghorn populations due to industrial and infrastructure development have grown over the last century, we have gained some understanding of and have opportunities to mitigate these impacts. Beyond simply describing how development affects pronghorn, many biologists, managers, and developers have demonstrated improved development plans and methods to help conserve pronghorn populations.

2. Management Recommendations

Planning for new developments and mitigating existing developments have many elements in common. For example, erecting a wildlife-friendly fence or modifying an existing fence to accommodate pronghorn movements will result in similar end products. However, the planning process and resources available may be quite different. For that reason, these topics were separated. For new projects, specific planning and post-development recommendations are provided. For existing problem developments, the focus is on implementation and specifications for mitigation. Finally, energy development, in particular fossil fuels development, was addressed as a template for specific management concerns and potential remedies.

Generally, management of and mitigation for industrial development effects on pronghorn requires participation of state, federal, provincial and/or tribal agencies. Navigating through various mandates and policies as well as agendas can create challenges for conservation of pronghorn. Thus, involving the appropriate agencies and organizations in planning and specific research goals from the beginning can be a productive approach. In many situations, stakeholders such as industries, which stand to gain financially from decisions made in their favor, will want to be involved in the scientific process (see Beckmann et al. 2011 Chapter 4 for example). However, this is a conflict of interest and should be avoided.

Management recommendations which are *made prior* to changes planned for the landscape can include lessons learned from other areas and should allow for monitoring and research to support an adaptive management framework when possible (Walters 1986). At a minimum, research undertaken to understand the effects of industrial and infrastructure development on pronghorn need to include baseline data. Mitigation plans to address post-development issues should also include monitoring to determine whether the mitigation was effective.

a. New Development

Any new development on federal lands in the U.S. will undergo evaluation through the National Environmental Policy Act (NEPA 1969). Much of pronghorn habitat coincides with public lands. In the U.S., this is primarily lands managed by the Bureau of Land Management (BLM) but also includes National Park Service (NPS), National Grasslands and Forest Service (USFS) lands, and these agencies typically bear the responsibility of conducting the environmental review process. In Canada, the approval of developments on Crown land is under the authority of the provincial government and administered by different agencies, depending on the jurisdiction. In most circumstances, the approval of an oil or gas development is on a case-by-case basis and not an entire field. An exception occurs when the development potentially affects water ways or migratory birds, in which case the federal government is responsible for approval of the development, with input from provincial agencies. In addition to regulatory policies, planning beyond the requirements of NEPA, provincial government, or other regulations may be necessary in order to temper a skewed balancing act between development needs and wildlife protection (Benson 2011). A landscape-level conservation plan which assesses impacts at the eco-region is highly recommended in order to understand the full scale of development impacts (Kiesecker et al. 2011).

On private lands, involving communities in how to best plan or modify existing developments depends on educated guidance committees (i.e., planning and zoning commissions), willing land owners, and open, transparent opportunities for local people to participate in the planning process. Conservation oriented developments combine residential development and land conservation. Cultivating the marketing strategies of conservation developments can increase awareness of the need for ecologically-informed planning while providing financial benefits to developers (Hannum et al. 2012). In pronghorn habitat, planning should include minimization of the development footprint in areas important to wintering, fawning, or migratory herds.

When newly proposed development is considered, creating an appropriate planning team of experts to evaluate the effects of development on wildlife is the first step (Beckmann and Hilty 2010). Research and monitoring goals and metrics of success must be clearly defined upfront and should be evaluated by scientific experts who study pronghorn populations, and are familiar with the literature, science, and quantitative limitations before field studies begin. Describing the needs of pronghorn in the given area, which includes the entire ecosystem with which that population interacts, will be the initial task of the team. This information will be based upon available assembled data sets and synthesized literature. Further targeted data collection may be needed to augment existing data and fill knowledge gaps. If no resources are available to collect necessary data then a delay of the project should be considered. Costs and benefits of the development, alternative development designs, and involvement in decision making by the public can contribute to comprehensive assessments that balance development and environmental interests (Beckmann and Hilty 2010). Modeling such as Population Viability Analysis, which can assess the potential impacts of different development scenarios on population trajectories, or spatially-explicit models using build-out scenarios can demonstrate thresholds for longevity of local pronghorn populations (Morris et al. 1999, Hebblewhite 2008, Copeland et al. 2009, Cancino et al. 2010).

In 2006, an interagency team established an ecosystem-based strategy termed Eco-Logical in order to streamline infrastructure project delivery while targeting strategic mitigation for conserving ecosystems (Brown 2006, Hardy and Wambach 2010). This approach brings together multiple agencies and public input early in planning stages in order to address unavoidable impacts of concurrent projects by mitigating for the cumulative effects to protect multiple resources at a large scale. Advanced mitigation for the effects of the project are outlined and a variety of performance measurements are evaluated to inform further mitigation and offer lessons learned to future projects. By addressing the ecological impacts, processes, and environmental permitting early in the planning process, project delivery proceeds more efficiently while offsets of impacts are tactically applied where the opportunities to conserve ecological processes and ecosystem services are still available and are not yet cost-prohibitive. Eco-Logical may serve a valuable function for developments planned in pronghorn habitat.

b. Post Development

Once a development project is complete, monitoring of pronghorn that utilize the area should continue. Survival rates, reproduction, habitat selection, movement patterns, disease, and body condition can all be affected by anthropogenic developments. Due to varying population thresholds and life-history traits, these effects may not be detected until post development (Hebblewhite 2008). Ideally, studies of effects are continuations of studies designed and conducted before development began with a rigorous before-after control-impact (BACI) design (Underwood 1994, Smith 2002, Gotelli and Ellison 2004, Hebblewhite 2008). Including data from before development and from control areas without development in order to compare to data collected in the area of development impact offers a rigorous, quantitative approach to determine the effects of development on pronghorn.

As development proceeds and once it is complete, managers must remain vigilant and flexible to enable detection of issues and address new threats to pronghorn. Some effects of development on pronghorn are challenging to predict and once certain mitigation triggers are met (e.g., metrics delineated in the design and monitoring plans such as a particular level of population decline, survival rate change or abandonment of habitat) the appropriate responses must begin. On BLM lands, the agency has contractual power under their lease agreement with the leaseholder to "cease any operations that would result in the destruction of resources that are statutorily protected, or substantially different, unanticipated, environmental effects" (Benson 2011). When necessary, cessation of development or extractive activity can be a practical and valuable mitigation tool to reduce impacts to pronghorn populations.

In cases where development has a proposed end date (e.g., when natural gas or oil production is complete) or in cases where the process of development disturbs excess pronghorn habitat (e.g., roads were created to enable transport of materials and workers), reclamation should be part of the design. Unfortunately, restoration of sagebrush habitat is very difficult (Wisdom et al. 2002, Meinke et al. 2009) and expensive when compared to alternative approaches (Downey et al. 2013). Disturbance is wrought with growth of non-native species and experts in sagebrush-steppe restoration should be employed to give this challenging process every advantage.

Upon completion of a development, the impacts to pronghorn must continue to be assessed. Development can have lasting effects on local populations and these cannot always be predicted or properly mitigated for during planning and development phases. Cumulative impacts may impede movement to seasonal ranges or degrade the fitness of a population resulting in additive loss due to mortality. Without monitoring beyond the life of a development project these changes may go undetected. Continued monitoring will determine if reclamation efforts are effective and if further mitigation is necessary.

c. Mitigating Existing Developments

When adverse effects of development on pronghorn meet a predetermined level of concern or threshold, mitigation should be employed. Mitigation steps should have been planned prior to development. However, unforeseen effects of industrial or infrastructure development on pronghorn populations can occur, often arise from developments that were created without knowledge of consequences, and/or were built in tandem with one or more disjointed projects (see Eco-Logical in the *Planning* section for ways to address this; Brown 2006, Hardy and Wambach 2010).

Since habitat fragmentation from linear developments such as fences and roads is one of the greatest threats to pronghorn, it will be addressed first. Modifications to or removal of fences can restore connectivity between populations, reduce mortality, and ease movement across ranges, especially transition ranges which allow pronghorn to reach accessible or higher quality forage or traditional reproductive and fawning grounds. However, careful consideration of unintended consequences should be reviewed before the mitigation process begins. For example, increased road mortality with access to a road surface when fencing is modified may increase wildlife-vehicle collisions. Or, increased disease or parasite spread, such as *Haemonchus* spp., may occur with increased connectivity (Gray 2013). Most state agencies recommend that fences be designed to allow pronghorn passage and recommendations for making fences pronghorn friendly are discussed above.

Road mitigation for wildlife often involves some sort of wildlife crossing structure combined with 8 foot (2.4 m) high fencing to direct animals to these passages. For pronghorn this means a landscape bridge or a wildlife overpass (Clevenger and Huijser 2011), though some pronghorn do use underpasses (Plumb et al. 2003, Sawyer and Rudd 2005). From observations at newly constructed wildlife crossing structures in western Wyoming (Photograph 33), a wildlife overpass to accommodate pronghorn movements over roadways may be preferable to an underpass (R. Seidler, unpublished data, Koshmrl 2012). An ongoing study funded by the Wyoming Transportation Department will compare side-by-side use between overpass and underpass structures by pronghorn (H. Sawyer, personal communication). Overpass construction can be expensive and requires extensive planning to determine placement, design, construction, and ongoing maintenance, but when done correctly can greatly reduce wildlife-vehicle collisions saving costs over the long-term (Clevenger and Waltho 2005, Sawyer and Rudd 2005, Bissonette and Adair 2008, Clevenger and Huijser 2011). Sawyer and Rudd (2005) recommend an overpass that is minimally 100 feet (30 m) wide for pronghorn. Creating quiet zones along a roadway where crossing structures are constructed using recessed approaches, sound berms, and rubberized asphalt may improve the likelihood of pronghorn use in areas where movement had been previously blocked (Dodd et al. 2011). In fall 2012, at the Trapper's Point overpass in western Wyoming, thousands of pronghorn displayed confusion and/or hesitancy at the 8 foot (2.4 m) high impermeable woven wire fence which prevented pronghorn from crossing on the road surface and guided the animals to the overpass, but eventually the animals successfully crossed the newly installed structure (R. Seidler unpublished data, Koshmrl 2012).

Pronghorn are mobile and hence somewhat adaptable to landscape changes (O'Gara 2004*a*), but environmental factors which shift from year to year and expanding development can result in adverse consequences for pronghorn given poorly targeted protections and conservation easements. For example, rare severe winters in Montana, Saskatchewan and Alberta appear to be associated with the distance pronghorn must travel during their fall migration. Due to anthropogenic landscape changes (i.e., trains and railroads, highways, and Fort Peck Reservoir) that hindered migratory movements, large portions of the migrating herd perished due to an inability to find accessible forage (French 2011, Robbins 2011).

Being able to recognize when mitigation is required to conserve pronghorn comes from careful planning and monitoring of populations. Once the cause of impacts are delineated a strategy forward can be devised. Energy development, and other types of development, not

Photograph 33. Pronghorn using the overpass at Trapper`s Point in Wyoming. Photograph by Jeff Burrell/Wildlife Conservation Society.

only fragments habitat but can inundate a part or whole seasonal range for pronghorn with habitat loss.

3. Energy Development as a Template for Best Management Practices

Recommendations for energy development which address impacts to wildlife and habitat are applicable in many situations and may be useful when mitigating other types of landscape disturbances as well. Much of the recent research on industrial and infrastructure development and pronghorn has focused on oil and natural gas production.

Energy development is driven by industry and land management agencies (Benson 2011). Management changes can only be enacted by developers and enforced by the federal government in the U.S. Other agencies, such as state wildlife and regulatory agencies and organizations can influence the process by staying engaged and informed, monitoring permit stipulations, and providing rigorous scientific input. It is difficult for local communities to have influence on decisions and activities that may affect the health of local wildlife populations (Neudecker et al. 2011). However, with transparency and local involvement, planners can better assure efficiency in the process (Hardy and Wambach 2010).

Beckmann et al. (2011) provided specific recommendations for natural gas field development on pronghorn winter range derived from their results of a 5 year study of pronghorn in the Upper Green River Basin, Wyoming. The predominant finding of the study showed habitat fragmentation and density of development influenced pronghorn habitat selection on winter range and that habitat patches fragmented < 300 ha (600 acres) reduced pronghorn probability of use by 50% (Berger et al. 2006, Beckmann et al. 2011).

Mitigating development by conserving land separate from the development impacts can be an important part of a landscape-level conservation strategy for pronghorn (Kiesecker et al. 2011), however this idea is under debate. Given that pronghorn exhibit high site fidelity to winter range (Sawyer and Lindzey 2000, White et al. 2007), any off-site mitigation efforts, whether planned *a priori* or post development, generally do not benefit the populations affected by development Beckmann et al. (2011). This is especially important when considering populations or segments of populations which are already displaced from quality habitats or provide an umbrella effect that benefits other species in the area. The authors also review how to appropriately monitor pronghorn populations during development, and how to include peer-reviewed and third party science (Beckmann et al. 2011).

Recommendations for future developments to reduce and mitigate impacts to pronghorn included:

1. *Minimization of the drilling footprint, specifically:*

    - *Phase-based paced development (i.e., deferment of development in secondary areas until initial development areas are reclaimed).*

    - *Spatial configuration (i.e., size, density, and placement of infrastructure).*

    - *Directional (horizontal) drilling to limit surface disturbance.*

2. *Winter closures to protect pronghorn winter habit.*

3. *Habitat reclamation (planting of native species and weed treatment) that keeps pace with development.*

The Wyoming Game and Fish Department (WGFD) recommends various management prescriptions for pronghorn on winter range undergoing energy developments based upon the Category of Impact, or development density (Wyoming Game and Fish Department 2009). At extreme impact thresholds of 16 well pads/mi^2 (6 well pads/km^2) or 32 hectares of disturbance/mi^2 (31 acres of disturbance/km^2), in addition to standard management practices, WGFD (2009) recommends seasonal use restrictions, additional management prescriptions, habitat mitigation options, and compensatory off-site mitigation within the landscape planning unit of the affected population. Standard management practices, management prescriptions, and habitat mitigation options are offered in multi-page appendices at the end of the WGFD document and include very specific details regarding planning, development, activities, noise, chemical pollution, easements, and more.

The Wildlife Society warns of disturbance as a potential for malnutrition-caused mortality and decreased neonatal survival rates (Riley et al. 2012). They list 10 management recommendations for mitigating impacts of gas field development to pronghorn and other ungulates. In addition to similar recommendations proposed by Beckmann et al. (2011), they include:

1. *Liquid gathering systems and remote monitoring of equipment to reduce activity disturbance associated with workers doing on-site monitoring.*

2. *Travel plans to minimize trip frequency and gated roads to reduce public use.*

3. *Off-site mitigation if habitat function is impossible to maintain.*

4. *Special protections for migration corridors (migration is maintained through the life of development or no surface occupancy).*

In a review of the impacts of energy development on ungulates, Hebblewhite (2008) specifically cites the lack of long-term, large-scale studies for understanding the impacts of energy developments on ungulates. He emphasizes the need to use an adaptive management framework (Walters 1986) which utilizes experimentation, controls, and adequate monitoring.

North Dakota is experiencing a boom in fossil fuel developments. To protect their fish and wildlife resources, the state Game and Fish Department has written a scoping report which describes the predicted cumulative impacts to fish and wildlife, and provides mechanisms to offset these impacts (Dyke et al. 2011). Of interest, the department provides an appendix with specific mitigation measures which are described as potential mechanisms/tools to alleviate impacts. Unfortunately, the state wildlife agency cannot require these mechanisms to be utilized, as that is the purview of the land owner. However, some novel practices have been suggested, especially in the last section of mechanisms to offset oil and gas development. Consider the admonition to keep Pittman-Robertson and Dingell-Johnson funds for their specified purposes while staff time is pulled towards processing energy related development work. The suggested mechanism to prevent this situation is to improve coordination and consultation with energy industry through additional staff (Dyke et al. 2011).

As energy developments increase across western North America so should the vigilance over pronghorn populations. Although biologists are subsequently increasing the level of scrutiny with which they monitor pronghorn populations that overlap development, there are still lessons being learned and our level of understanding of the impacts is in its infancy. Employing current best management practices while improving our planning mechanisms and expanding research and monitoring to understand the effects of an ever-changing landscape will promote pronghorn conservation.

4. Conclusions

Historical and contemporary industrial and infrastructure developments have negative impacts on pronghorn. The types of developments have shifted through the centuries, but have been present since westward expansion. Those that have the greatest impact on pronghorn today include roads, railroads, fences, housing, and energy production. The primary factors associated with industrial and infrastructure development which change pronghorn demographics and behavior are habitat fragmentation and loss. These account for loss of summer and winter range, and a severing of connectivity for pronghorn migration in Canada, the U.S., and Mexico. The aim of these management recommendations is to reduce these impacts on pronghorn populations.

Mitigating the effects of industrial and infrastructure development on pronghorn begins with broad communication with a variety of stakeholders regarding unavoidable impacts and opportunities to offset such impacts, whether the development is being planned or is already developed. Many models and tools exist to bring together stakeholders, experts, concerned citizens and relevant data. Existing data need to be reviewed carefully, and new studies and monitoring thoughtfully designed to assess impacts, and evaluate the effectiveness of mitigation efforts in reducing negative impacts to pronghorn populations. Decisions should be made for the entire landscape utilized by pronghorn populations, including the most distant winter ranges that are only used in extreme winters. Conserving the migration corridors which pronghorn use allows them to access important seasonal foraging opportunities.

As pronghorn habitat is fragmented and lost through industrial and infrastructure development, it is clear from past history and recent research that populations will not be maintained without deliberate conservation measures. At the core of these measures is habitat. Pronghorn are a nomadic species with movement requirements as variable as the extreme winters and lengthy droughts that typify the landscapes they utilize. As industrial and infrastructure developments grow across pronghorn habitat, managers must remain vigilant to new research findings, new development practices, and retain enthusiasm to continue to work through the challenges of managing wildlife amongst multiple agendas. With proper planning, monitoring, and mitigation pronghorn populations can be sustained.

Pronghorn Management Plans

With the growth of human populations and society's expanded use of the land, the need to document pronghorn requirements for forage, water, and space has increased. Pronghorn have thrived during the past half-century, but the need exists to manage for healthy populations and compatible human use. One way to meet these needs is by Management Plans that list the objectives, goals, and procedures to best manage the species by maintaining and/or improving forage, water and space; and by coordinating pronghorn management into holistic land-use plans.

Wildlife Management Plans usually are initiated by state or provincial wildlife agencies. They emphasize practices to protect, reduce, maintain, or enhance populations. They typically spell out methods to inventory populations, alleviate limiting factors, and methods to harvest or translocate surplus animals.

Habitat Management Plans are generally prepared by government or private-land agency personnel. Such plans emphasize the maintenance or improvement of forage, water, and space for pronghorn, and attempt to identify to what degree pronghorn are compatible or competitive with other land uses.

Management Plans or Recovery Plans for endangered species are mandatory in accordance with the U.S. Congress (1973). Such plans identify possible procedures to increase a species or sub-species to a level sufficient for de-listing. For example, the Sonoran pronghorn was listed as endangered in the U.S. in 1967 (United States Department of the Interior, Office of the Secretary 1967) and a final recovery plan was completed in 1998 (USFWS 1998). To achieve the goals outlined in the recovery strategy continued monitoring and assessment of the remaining population (Bright and Hervert 2005, deVos, Jr. and Miller 2005, Morgart et al. 2005) and an establishment of a second population are required (O'Brien et al. 2005).

The various guides suggesting techniques and practices to manage pronghorn and their habitat are aids to biologists developing Management Plans. To date, these include: *Wildlife Management Techniques Manual* (Ripley 1980); *Habitat Management Guides for the American Pronghorn Antelope* (Yoakum 1980); *Range/Wildlife Habitats in Managed Rangelands-The Great Basin of Southeastern Oregon: Pronghorn* (Kindschy et al. 1982); *Pronghorn Antelope Populations and Habitat Management in Northeastern Great Basin Environments* (Salwasser 1980), *Programa para la Conservación, Manejo y Aprovechamiento Sustentable del Berrendo* (Antilocapra americana) *en Méxíco* (Cancino et al. 2000, Dirección General de Vida Silvestre 2001); *The Peninsular Pronghorn Recovery Plan* (Cancino et al. 2004); the Programa de Acciones para la Conservación de Especies: Berrendo (Ramírez et al. 2010); and the Pronghorn Management Plan F. E. Warren Air Force Base, Wyoming (Russ 2004). In addition, Yoakum (2004*d*) provides a discussion and listing of Management Plans specific for pronghorn, their habitat, and enhancements for the recovery of imperiled populations.

LITERATURE CITED

Ackerly, W. F., and V. Regier. 1956. Northeastern California antelope studies. Special report. California Department of Fish and Game, Sacramento, California, USA.

Alcérreca, C. A., and V. S. Sotomayor. 1981. El berrendo. Bosques y Fauna 4:19-26.

Alexander, A., and R. A. Ockenfels. 1994. Juniper densities relative to pronghorn use in central Arizona. Proceedings of Pronghorn Antelope Workshop 16:75-85.

Allen, A. W., and M. J. Armbruster. 1982. Preliminary evaluation of habitat suitability model for the pronghorn. Proceedings of Pronghorn Antelope Workshop 10:93-105.

Allen, S. M., and S. W. Samuelson. 1987. Precision and bias of a summer aerial transect census of pronghorn antelope. Prairie Naturalist 19:19-24.

Amor, D. C., S. O. Kolokotronis, R. R. Ramey, II, R. A. Medellin, and O. A. Ryder. 2006. Genetica de la conservacion del berrendo. Pages 27-33 *in* M. Valdes, E. De la Cruz, E. Peters, and E. Pallares, editors. El berrendo en Mexico. Agrupacion Sierra Madre, S.C., Comision Nacional de Areas Naturales Protegidas, Direccion General de Vida Silvestre, Instituto Nacional de Ecologia, U.S. Fish and Wildlife Service, Unidos para la Conservacion, Mexico, D.F.

Amstrup, S. C., J. Meeker, B. W. O'Gara, and J. McLucas. 1980. Capture methods for free-roaming pronghorn. Proceedings of Pronghorn Antelope Workshop 9:98-131.

Anderson, L. D., and J. W. Denton. 1980. Adjustable wire fences for facilitating big game movement. Technical Note 343. U.S. Bureau Land Management Service Center, Denver, Colorado, USA.

Andrews, S. G., G. Dickens, and R. Miller. 1986. Urbanization and pronghorn antelope. Pages 172-174 *in* K. Stenberg, and W. W. Shaw, editors. Wildlife conservation and new residential developments. Arizona Department Ecology and Evolution Biology, Tucson, Arizona, USA.

Aoude, A., and R. E. Danvir. 2002. Using range manipulations to increase pronghorn production and abundance in Utah sagebrush steppe. Proceedings of Pronghorn Workshop 20:124-134.

Arizona Game and Fish Commission. 2011. Guidelines for the 2012-2013 and 2014-2015 Hunting Seasons (Dec 2011 revision). Arizona Game and Fish Department, Phoenix, Arizona, USA.

Arizona Game and Fish Department. 1993. Game management program. Appendix 8: Prioritizing antelope transplant sites. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Autenrieth, R. E. 1976. A study of birth sites selected by pronghorn does and the bed sites of fawns. Proceedings of Pronghorn Antelope Workshop 7:127-134.

Autenrieth, R. E. editor. 1978. Guidelines for the management of pronghorn antelope. Proceedings of Pronghorn Antelope Workshop 8:473-526.

Autenrieth, R. E.1982. Pronghorn fawn habitat use and vulnerability to predation. Proceedings of Pronghorn Antelope Workshop 10:112-127.

Autenrieth, R. E. 1984. Little Lost Valley pronghorn fawn study—condition, habitat use and mortality. Proceedings of Pronghorn Antelope Workshop 11:49-70.

Autenrieth, R. E., and E. Fichter. 1975. On the behavior and socialization of pronghorn antelope fawns. Wildlife Monograph 42:1-111.

Autenrieth, R. E., D. E. Brown, J. Cancino, R. M. Lee, R. A. Ockenfels, B. W. O'Gara, T. M. Pojar, and J. D. Yoakum, compilers. 2006. Pronghorn management guides. Pronghorn Workshop and North Dakota Game and Fish Department, Bismarck, North Dakota, USA.

Baccus, R., N. Ryman, M. H. Smith,C. Reuterwall, and D. Cameron. 1983. Genetic variability and differentiation of large grazing mammals. Journal of Mammalogy 64:109-120.

Bailey, J. A., and A. Y. Cooperrider. 1982. Final report: Trickle Mountain research study. U.S. Bureau Land Management Service Center, Denver, Colorado, USA.

Baker, D. L., and N. T. Hobbs. 1985. Emergency feeding of mule deer during winter tests of a supplemental ration. Journal of Wildlife Management 49:934-942.

Baker, T. C. 1953*a*. Antelope movement and migration studies. Wyoming Wildlife 17:31-36.

Baker, T. C. 1953*b*. Food habit study of game animals. Wyoming Wildlife 17:24-26.

Baker, T. C. 1955. Big game survey: study of antelope mortality factors, other than hunting. Wyoming Game and Fish Commission, Cheyenne, Wyoming, USA.

Barrett, M. W. 1974. Importance, utilization and quality of *Artemisia cana* on pronghorn winter ranges in Alberta. Proceedings of Pronghorn Antelope Workshop 6:26-57.

Barrett, M. W. 1982. Ranges, habitat, and mortality of pronghorn at the northern limits of their range. Thesis, University of Alberta, Edmonton, Canada.

Barrett, M. W., J. W. Nolan, and L. E. Roy. 1982. Evaluation of a hand-held net-gun to capture large mammals. Wildlife Society Bulletin 10:108-114.

Bastian, C. T., J. J. Jacobs, L. J. Held, and M. A. Smith. 1991. Multiple use of public rangeland: antelope and stocker cattle in Wyoming. Journal of Range Management 44:390-394.

Bayless, S. R. 1969. Winter food habits, range use, and home range of antelope in Montana. Journal of Wildlife Management 33:538-551.

Beale, D. M. 1966. A self-collaring device for pronghorn antelope. Journal of Wildlife Management 30:204-211.

Beale, D. M., and A. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. Journal of Wildlife Management 34:570-578.

Beale, D. M., and R. C. Holmgren. 1975. Water requirements for pronghorn antelope survival and growth. Utah Division Wildlife Resources, Salt Lake City, Utah, USA.

Bear, G. D. 1969. Antelope and net wire fences. Proceedings Western Association State Game and Fish Commissioners 49:265-271.

Bear, G. D., A. E. Anderson, J. P. Goeltt, R. Keiss, and F. Fields. l973. Antelope investigations, physiological studies. Pittman-Robertson Job Final Report, Job 3 Project W-40-R-l3, Colorado Game, Fish and Parks Department, Denver, Colorado, USA.

Beardahl, L., and V. Sylvester. 1974. Spring burning for removal of sagebrush competition in Nevada. Proceedings of Tall Timbers Fire Ecology Conference 14:547-569.

Becker, B. S. 1972. Pronghorn-cattle range use and food habit relationships in an enclosed sagebrush control area. Thesis, Montana State University, Bozeman, USA.

Beckmann, J. P., and J. A. Hilty. 2010. Connecting wildlife populations in fractured landscapes. Pages 3-16 *in* J. P. Beckmann, A. P. Clevenger, M. P. Huijser, and J. A. Hilty, editors. Safe passages: highways, wildlife, and habitat connectivity. Island Press, Washington, D.C., USA.

Beckmann, J. P., K. Murray, R. G. Seidler, and J. Berger. 2012. Human-mediated shifts in animal habitat use: sequential changes in pronghorn use of a natural gas field in Greater Yellowstone. Biological Conservation 147:222-233.

Beckmann, J. P., R. G. Seidler, and J. Berger. 2011. Wildlife & energy development: pronghorn of the Upper Green River Basin - Final Report. Wildlife Conservation Society, Bronx, New York, USA.

Beintema, J. J., W. Gaastra, and J. Munniksma. 1979. Primary structure of pronghorn pancreatic ribonuclease: close relationship between giraffe and pronghorn. Journal of Molecular Evolution 13:305-316.

Benson, M. H. 2011. Resource policy, adaptive management, and energy development on public lands. Pages 195-210 *in* D. E. Naugle, editor. Energy development and wildlife conservation in western North America. Island Press, Washington, D.C., USA.

Benson, W. A. 1956. A general view of the antelope in Saskatchewan. Federal-Province Wildlife Conference 20:23-24.

Berger, J. 1986. Wild horses of the Great Basin: social competition and population size. University of Chicago, Chicago, Illinois, USA.

Berger, J. 2004. The last mile: how to sustain long-distance migration in mammals. Conservation Biology 18:320-331.

Berger, B. J., K. M. Berger, and J. P. Beckmann. 2006. Wildlife & energy development: Pronghorn of the Upper Green River Basin - Year 1 Summary. Wildlife Conservation Society, Bronx, New York, USA.

Berger, K M. 2006. Carnivore-livestock conflicts: Effects of subsidized predator control and economic correlates on the sheep industry. Conservation Biology 20:751-761.

Bever, W. 1950. Parasites and diseases of South Dakota antelope. Pages 12-16 *in* Pittman-Robertson Job Completion Report Project 12-R-7, South Dakota Fish and Game Department, Pierre, South Dakota, USA.

Bever, W. 1957. The incidence and degree of the parasitic load among antelope and the development of field techniques to measure such parasitism. Pittman-Robertson Project 12-R-14, Job Number 1-5, 2, South Dakota Fish and Game Department, Pierre, South Dakota, USA.

Bissonette, J., and W. Adair. 2008. Restoring habitat permeability to roaded landscapes with isometrically-scaled wildlife crossings. Biological Conservation 141:482-488.

Blunt, F. M., and A. T. Myles. 1998. Successful rearing and handling of big game animals at the Sybille Wildlife Research Unit. Wyoming Game and Fish Department, Cheyenne, Wyoming, USA.

Boccadori, S. J. 2002. Effects of winter range on a pronghorn population in Yellowstone National Park, Wyoming. Thesis, Montana State University, Bozeman, USA.

Boccadori, S. J., and R. A. Garrot. 2002. Effects of winter range on a pronghorn population in Yellowstone National Park. Proceedings of Pronghorn Workshop 20:114.

Bodie, W. L. 1979. Factors affecting pronghorn fawn mortality in central Idaho. Thesis, University of Montana, Missoula, USA.

Boone, R. B., and N. T. Hobbs. 2004. Lines around fragments: effects of fencing on large herbivores. African Journal of Range and Forage Science 21:147-158.

Bowden, D. C., E. Anderson, and D. E. Medin. 1984. Sampling plans for mule deer sex and age ratios. Journal of Wildlife Management 48:500-509.

Braun, D. 2009. Pronghorn migration circuit found in Idaho. National Geographic. <http://newswatch.nationalgeographic.com/2009/11/02/pronghorn_migration_found_in_idaho/>. Accessed 5 Jul 2013.

Bright, J. L., and J. J. Hervert. 2005. Adult and fawn mortality of Sonoran pronghorn. Wildlife Society Bulletin 33:43-50.

Brinkley, K. 1987. Pronghorn hand-rearing protocol (*Antilocapra americana americana)*. Zoo Keepers' Forum 14:234-237.

Britt, T. L. 1980. Reestablishment of pronghorn antelope on the Arizona Strip. Proceedings of Pronghorn Antelope Workshop 9:226-245.

Bromley, P. T. 1969. Territoriality in pronghorn antelope on the National Bison Range, Moiese, Montana. Journal of Mammalogy 50:81-89.

Bromley, P. T. 1977. Aspects of the behavioral ecology and sociology of the pronghorn (*Antilocapra americana*). Dissertation, University of Calgary, Calgary, Canada.

Bromley, P. T., and B. W. O'Gara. 1967. Orphaned pronghorn survive. Journal of Wildlife Management 31:843.

Brown, D. E. 1994. Grasslands. Part 4. Pages 106-141 *in* Biotic communities; southwestern United States and northwestern Mexico. University Utah Press, Salt Lake City, USA.

Brown, D. E., D. Bayer, and T. McKinney. 2006. Measuring the effects of mid-summer drought on doe pronghorn mortality. Southwestern Naturalist 51:220-225.

Brown, D. E., W. F. Fagn, R. Lee, H. G. Shaw, and R. B. Turner. 2002. Winter precipitation and pronghorn fawn survival in Southwest. Proceedings of Pronghorn Workshop 20:115-122.

Brown, D. E., W. F. Fagn, J. Lonie, and H. Provncio. 2004. Elk as a factor affecting pronghorn productivity and population levels on Anderson Mesa, Arizona. Proceedings of Pronghorn Workshop 21:38-53.

Brown, D. E., and R. A. Ockenfels. 2007. Arizona's pronghorn antelope; a conservation legacy. Arizona Antelope Foundation, Phoenix, USA.

Brown, J. W. 2006. Eco-Logical: an ecosystem approach to developing infrastructure projects. Washington, D. C., USA.

Brownlee, S., and T. L. Hailey. 1970. Development of a technique for night trapping antelope fawns. Proceedings of Antelope States Workshop 4:78-81.

Brunner, E. A. 1910. An antelope caught by hand. Forest and Stream February:293.

Bruns, E. H. 1969. A preliminary study of behavioral adaptations of wintering pronghorn antelope. Thesis, University of Calgary, Calgary, Canada.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, New York, USA.

Büechner, H .K. 1950. Life history, ecology and range of the pronghorn antelope in Texas. American Midland Naturalist 43:257-354.

Burnham, K. P., and D. R. Anderson. 1984. The need for distance data in transect counts. Journal of Wildlife Management 48:1248-1254.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach Second edition. Springer-Verlag, New York, New York, USA.

Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line-transect sampling of biological populations. Wildlife Monographs 72:1-202.

Byers, J. A. 1997. American pronghorn: social adaptations and the ghosts of predators past. University Chicago Press, Chicago, USA.

Byers, J. A. 2003. Built for speed: a year in the life of pronghorn. Harvard University Press, Cambridge, USA.

Byers, J. A., J. D. Moodie, and N. Hall. 1994. Pronghorn females choose vigorous mates. Animal Behaviour 47:33-43.

Byers, J. A., and L. Waits. 2006. Good genes sexual selection in nature. Proceedings of the National Academy of Sciences of the United States of America 103:16343-16345.

Cada, J. D. 1985. Evaluations of the telephone and mail survey methods of obtaining harvest data from licensed sportsmen in Montana. Pages 117-128 *in* S. L. Beasom and S. F. Roberson, editors. Game harvest management. Ceasar Kleberg Wildlife Research Institute, Kingsville, Texas, USA.

California Department Fish and Game. 1997. Final environmental document regarding pronghorn antelope hunting. California Department Fish and Game, Sacramento, California, USA.

Campbell, R. B. 1970. Pronghorn, sheep, and cattle range relations in Carter County Montana. Thesis, Montana State University, Bozeman, USA.

Cancino, J. 1994. Food habits of the peninsular pronghorn. Proceedings of Pronghorn Antelope Workshop 16:176-185.

Cancino, J. 2001. Nutritional values of some plants ingested by peninsular pronghorn. Proceedings of Pronghorn Antelope Workshop 19:118-119.

Cancino, J., R. Castellanos, J. Holland, F. Ramirez, and V. Sánchez. 2004. The peninsular pronghorn recovery plan: 20 years. Proceedings of Pronghorn Antelope Workshop 21:96-101.

Cancino, J., R. Castellanos, and V. Sánchez. 2001. Capture, hand rearing, and captive management of peninsular pronghorn. Proceedings of Pronghorn Antelope Workshop 19:108.

Cancino, J., C. Castillo, C. Manterola, R. Medellín, F. Ramírez, J. M. Reyes, R. Rodríguez-Estrella, and V. Sánchez. 2000. National pronghorn recovery plan for Mexico. Proceedings of Pronghorn Antelope Workshop 17:45-49.

Cancino, J., P. Miller, J. Bernal-Stoopen, and J. Lewis, editors. 1995. Population and habitat viability assessment for the peninsular pronghorn (*Antilocapra americana peninsularis*). International Union for

Conservation Nature, Species Survival Commission, Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

Cancino, J., A. Ortega-Rubio, and R. Rodríguez-Estrella. 1998. Population size of peninsular pronghorn in Baja California Sur, Mexico. California Fish and Game 84:25-30.

Cancino, J., R. Rodrigues-Estrella, and P. Miller. 2010. Using a population viability analysis for management recommendations of the endangered endemic peninsular pronghorn. Acta Zoológica Mexicana 26:173-189.

Cancino, J., V. Sánchez-Sotomayor, and R. Castellanos. 2002. Alternative capture technique for the peninsular pronghorn. Wildlife Society Bulletin 30:256-258.

Cancino, J., V. Sanchez-Sotomayor, and R. Castellanos. 2005. From the field: capture, hand raising, and captive management of peninsular pronghorn. Wildlife Society Bulletin 33:61-65.

Canon, S. K., and F. C. Bryant. 1992. Survival of Trans-Pecos pronghorn. Proceedings of Pronghorn Antelope Workshop 15:67-77.

Carling, M. D., C. W. Passavant, and J. A. Byers. 2003*a*. DNA microsatellites of pronghorn (*Antilocapra americana*). Molecular Ecology Notes 3:10-11.

Carling, M. D., A. P. Wiseman, J. A. Byers. 2003*b*. Microsatellite analysis reveals multiple paternity in a population of wild pronghorn antelopes (*Antilocapra americana*). Journal of Mammalogy 84:1237-1243.

Caton, J. D. 1877. The antelope and deer of America. Hurd and Houghton, New York, New York, USA.

Caughley, G. 1974. Interpretation of age ratios. Journal of Wildlife Management 38:557-562.

Center for Biological Diversity and Western Watersheds Project. 2010. Draft environmental impact report for First Solar's Topaz Solar Farm/Twisselman conditional use permit (DRC2008-00009) SCH#2008091026.

Chalmers, G. A., and M. W. Barrett. 1974. Some problems associated with chasing pronghorn. Proceedings of Pronghorn Antelope Workshop 6:67-77.

Chalmers, G. A., and M. W. Barrett. 1977. Capture myopathy in pronghorn in Alberta, Canada. Journal of American Veterinary Medicine Association 171:918-923.

Chalmers, G. A., and M. W. Barrett. 1982. Capture myopathy. Pages 84-94 *in* G. L. Hoff, and J. W. Davis, editors. Noninfectious diseases of wildlife. Iowa State University Press, Ames, USA.

Chervick, T. M. 1991. Big game animal crossing study along an overland coal conveyor structure in northwest Colorado. Proceedings Issues Technological Management Impacted Wildlife 5:112-119.

Clark, W. R., and J. R. Medcraft. 1986. Wildlife use of shrubs on reclaimed surface-mined land in northeastern Wyoming. Journal of Wildlife Management 50:714-718.

Clemente, F. 1992. Influences of range condition, cattle, and watering hole distribution of the pronghorn population in south New Mexico. Dissertation, New Mexico State University, Las Cruces, USA.

Clemente, F., R. Valdez, J. L. Holechek, P. J. Zwank, and M. Cardenas. 1995. Pronghorn home range relative to permanent water in southern New Mexico. The Southwestern Naturalist 40:38-41.

Clevenger, A. P., and M. P. Huijser. 2011. Wildlife crossing structure handbook: design and evaluation in North America. Western Transportation Institute, Bozeman, Montana, USA.

Clevenger, A. P., and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation 121:453-464.

Coffin, A. W. 2007. From roadkill to road ecology: a review of the ecological effects of roads. Journal of Transport Geography 15:396-406.

Cohn, J. P. 2007. The environmental impacts of a border fence. BioScience 57:96.

Cole, G. F. 1956. The pronghorn antelope; its range use and food habits in central Montana with special reference to alfalfa. Technical bulletin 516, Montana Agriculture Experimental Station, Bozeman, Montana, USA.

Compton, H. O. 1958. The effects of predation on pronghorn antelope numbers in southcentral Oregon. Thesis, Oregon State College, Corvallis, USA.

Compton, H. O. 1970. Southeastern Montana antelope population trends in relation to severe winters. Proceedings of Antelope States Workshop 4:50-54.

Connolly, G. E. 1978. Predators and predator control. Pages 369-394 *in* J. L. Schmidt, and D. L. Gilbert, editors. Big game of North America. Stackpole Books, Harrisburg, USA.

Constan, K., D. Hook, and R. Berg. 1981. Middle Missouri River drainage investigations: Middle Missouri River planning project. Montana Department Fish, Wildlife, and Parks, Helena, Montana, USA.

Cook, J. G. 1984. Pronghorn winter ranges: habitat characteristics and a field test of a habitat suitability model. Thesis, University of Wyoming, Laramie, USA.

Cook, J. G., and L. L. Irwin. 1985. Validation and modification of a habitat suitability model for pronghorn. Wildlife Society Bulletin 12:440-448.

Cook, J. G., and L. L. Irwin, A. W. Allen, and M. J. Armbruster. 1984. A field test of a winter pronghorn suitability index model. Proceedings of Pronghorn Antelope Workshop 11:207-211.

Cooperrider, A. Y., J. A. Baile, and R. M. Hansen. 1982. Cost efficient methods of estimating ungulate food habits and fecal analysis. Pages 399-406 *in* Arid land resource inventories development of cost efficient methods, General technical report WO-28, U.S. Forest Service, Washington, D.C., USA.

Cooperrider, A. Y., J. Boyd, and H. R. Stuart, editors. 1986. Inventory and monitoring of wildlife habitat. U.S. Bureau Land Management Service Center, Denver, Colorado, USA.

Copeland, H. E., K. E. Doherty, D. E. Naugle, A. Pocewicz, and J. M. Kiesecker. 2009. Mapping oil and gas development potential in the US Intermountain West and estimating impacts to species. PloS one 4:1-7.

Copeland, H. E., A. Pocewicz, and J. M. Kiesecker. 2011. Geography of energy development in western North America: potential impacts on terrestrial ecosystems. Pages 7-25 *in* D. E. Naugle, editor. Energy development and wildlife conservation in western North America. Island Press, Washington, USA.

Copeland, G. L. 1980. Antelope buck breeding behavior, habitat selection, and hunting impact. Wildlife. Idaho Fish and Game Department Bulletin 8, Boise, Idaho, USA.

Corneli, P. S., B. Von Gunten-Moran, and B. W. O'Gara. 1984. Pronghorn fawn mortality on the National Bison Range. Proceedings of Pronghorn Antelope Workshop 11:41-48.

Couey, F. M. 1949. Review and evaluation of big game trapping techniques. Proceedings of Western Association State Fish and Game Commissioners 29:39-47.

Couling, L, and G. E. J. Smith. 1980. Impact of a postcard follow-up on harvest survey returns. Canadian Wildlife Service Progress Note 116, Ottawa, Ontario, Canada.

Courtney, R .F. 1989. Pronghorn use of recently burned mixed prairie in Alberta. Journal of Wildlife Management 53:302-305.

Cronin, M. A., D. A. Palmisciano, E. R. Vyse, and D. G. Cameron. 1991. Mitochondrial DNA in wildlife forensic science: species identification of tissues. Wildlife Society Bulletin 19:94-105.

Crowe, D. M., and M. D. Strickland. 1979. Wildlife and development - there's more than meets the eye. Wyoming Wildlife 43:6-8.

Czaplewski, R. L., D. M. Crowe, and L. L. McDonald. 1983. Sample sizes and confidence intervals for wildlife population ratios. Wildlife Society Bulletin 11:121-128.

Dalton, K. A. 2009. Pronghorn: migration triggers and resource selection in Southeastern Oregon. Thesis, Washington State University, Pullman, USA.

Dasmann, R. F. 1964. Wildlife biology. John Wiley and Sons, New York, New York, USA.

Deblinger, R. D., and J. E. Ellis. 1976. Aspects of intraspecific social variations in pronghorns. Proceedings of Pronghorn Antelope Workshop 7:26-48.

Deblinger, R. D., and A. W. Alldredge. 1989. Management implications of variations in pronghorn social behavior. Wildlife Society Bulletin 17:82-87.

Del Monte, B. E., and H. G. Kothmann. 1984. Evaluation of Texas antelope transplants. Proceedings of Pronghorn Antelope Workshop 11:146-150.

Deming, O. V. 1963. Antelope and sagebrush. Transactions Interstate Antelope Conference 17:55-61.

Denome, R. M., B. O'Callaghan, C. Luitjens, E. Harper, and R. Bianco. 1994. Characterization of a satellite DNA from *Antilocapra americana*. Gene 145:257-259.

DeVos, J. D., Jr., and W. H. Miller. 2005. Habitat use and survival of Sonoran pronghorn in years with above average rainfall. Wildlife Society Bulletin 33:35-42.

DeVos, J. D., Jr., and L. Thompson-Olais. 2000. Using the Vortex model to assess minimum viable populations for Sonoran pronghorn. Proceedings of Pronghorn Antelope Workshop 17:108.

Dickens, G. C., and S. G. Andrews. 1986. The pronghorn plan for promoting conscientious growth. Pages 46-47 *in* K. Stenberg, and W. W. Shaw, editors. Wildlife conservation and new residential developments. Department Ecology and Evolution Biology, University Arizona, Phoenix, Arizona, USA.

Dirección General de Vida Silvestre. 2001. Programa para la conservacion manejo y aprovechamiente sustenable del berrendo (*Antilocapra americana*) en México. Proceedings of Pronghorn Antelope Workshop 19:120.

Dirschl, H. J. 1962. Sieve mesh size related to analysis of antelope rumen contents. Journal of Wildlife Management 26:327-328.

Dirschl, H. L. 1963. Food habits of the pronghorn in Saskatchewan. Journal of Wildlife Management 27:81-93.

Dodd, N. L., J. W. Gagnon, S. Sprague, S. Boe, and R. E. Schweinsburg. 2011. Assessment of pronghorn movements and strategies to promote highway permeability: US Highway 89. Arizona Department of Transportation: Research Center, Phoenix, Arizona, USA.

Dood, A. 1984. The history of antelope management in southeastern Montana. Proceedings of Pronghorn Antelope Workshop 11:91-102.

Downey, B. A., F. Blouin, J. D. Richman, B. L. Downey, and P. F. Jones. 2013. Restoring mixed grass prairie in southeastern Alberta, Canada. Rangelands 35:16-20.

Drake, M. L. 2009. Pronghorn antelope food habits and diet quality on Anderson Mesa and Garland Prairie, Arizona. Thesis, Arizona State University, Phoenix, USA.

Dunbar, M .R. 2001. Distribution and nutrition of key forage plants and pronghorn use on three playa lake beds on Hart Mountain National Antelope Refuge, Oregon. Special report. U.S. Fish and Wildlife Service, Lakeview, Oregon, USA.

Dunn, S. J., K. K. Barnowe-Meyer, K. J. Gebhardt, N. Balkenhol, L. P. Waits, and J. A. Byers. 2010. Ten polymorphic microsatellite markers for pronghorn (*Antilocapra americana*). Conservation Genetics Resources 2:81-84.

Dunn, S. J., E. Clancey, L. P. Waits, and J. A. Byers. 2011. Inbreeding depression in pronghorn (*Antilocapra americana*) fawns. Molecular Ecology 20:4889-4898.

Dunn, S. J., E. Clancey, L. P. Waits, and J. A. Byers. 2012*a*. Genetic evidence of inbreeding avoidance in pronghorn. Journal of Zoology 288:119-126.

Dunn, S. J., L. P. Waits, and J. A. Byers. 2012*b*. Genetic versus census estimators of the opportunity for sexual selection in the wild. The American Naturalist 179:451-462.

Duval, J. 2009. Narrow migration corridor could be affected by highway widening of power line. Idaho Mountain Express, Sun Valley, Idaho, USA.

Dvorak, D. F. 1986. Texas antelope status report. Proceedings of Pronghorn Antelope Workshop 12:34-35.

Dyke, S., D. Fryda, D. Kleyer, J. Williams, B. Hosek, W. Jensen, S. Johnson, A. Robinson, F. Ryckman, B. Stillings, M. Szymanski, S. Tucker, and B. Wiedmann. 2011. Potential impacts of oil and gas development on select North Dakota natural resources; a Report to the Director. North Dakota Game and Fish department, Bismarck, North Dakota, USA.

Easterly, T. G., T. R. Litchfield, and A. K. Wood. 1992. Responses of pronghorn and mule deer to petroleum development on crucial winter range in the Rattlesnake Hills: completion report. Wyoming Game and Fish Department, Cheyenne, Wyoming, USA.

Eberhardt, L. L. 1987. Calibrating population indices by double sampling. Journal of Wildlife Management 51:665-675.

Eccles, A. W., E. J. Finck, and K. E. Sexson. 1994. Pronghorn in tallgrass prairie: status of the Flint Hills herd. Proceedings of Pronghorn Antelope Workshop 16:50-53.

Einarsen, A. S. 1948. The pronghorn antelope and its management. Monument Printing Press, Baltimore, Maryland, USA.

Elliot, C. 1966. Antelope play in Florida. Outdoor Life 137:52-55.

Ellis, J. E. 1970. A computer analysis of fawn survival in the pronghorn antelope. Dissertation, University of California, Davis, USA.

Evans, R. L., and R. M. Love. 1957. The step-point method of sampling - a practical tool in range management. Journal of Range Management 10:208-212.

Ferrel, C., and H. Leach. 1950. Food habits of the pronghorn antelope of California. California Fish and Game 36:21-26.

Firchow, K. M., M. R. Vaughn, and W. R. Mytton. 1986. Evaluation of the hand-held net gun for capturing pronghorn. Journal of Wildlife Management 50:321-322.

Firchow, K. M., M. R. Vaughn, and W. R. Mytton. 1990. Comparison of aerial survey techniques for pronghorn. Wildlife Society Bulletin 18:18-23.

Fisher, L. W. 1942. Live trapping Texas antelope. Journal of Wildlife Management 6:231-236.

Floyd, J. M. 1924. Capturing antelope kids: how uncle Sam aids in perpetuating the fleet pronghorn. Forest and Stream, December 12:744-746.

Foree, W. W. 1956. Black Rock District Pittman-Robertson report. Four State Antelope Meeting, Reno, Nevada, USA.

Forrest, C. A. 1985. Analysis of supplemental feeding and effects of hunting during the rut on recruitment in pronghorn antelope. Thesis, University of Wyoming, Laramie, USA.

Fox, L. M. 1997. Nutritional content of forage in Sonoran pronghorn habitat. Thesis, University of Arizona, Tucson, USA.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 35-149 *in* M. Soule, and B. Wilcox, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer Association, Sunderland, Massachusetts, USA.

Freeman, J. S. 1971. Pronghorn range use and relation to livestock in southeastern Montana. Thesis, Montana State University, Bozeman, USA.

French, B. 2011. Prairie drama: pronghorn migration fraught with trauma, tragedy this year http://billingsgazette.com/lifestyles/recreation/prairie-drama-pronghorn-m... Billings Gazette 2011:1–5.

Frick, C. 1937. Horned ruminants of North America. American Museum Natural History Bulletin 69:1-699.

Gasson, W., and L. Wollrab. 1986. Integrating population simulation modeling into a planned approach to pronghorn management. Proceedings of Pronghorn Antelope Workshop 12:86-98.

Gates, C. C., P. Jones, M. Suitor, A. Jakes, M. S. Boyce, K. Kunkel, and K. Wilson. 2012. The influence of land use and fences on habitat effectiveness, movements, and distribution of pronghorn in the grasslands of North America. Pages 277-294 *in* M. J. Somers, and M. Hayward, editors. Fencing for conservation: restriction of evolutionary potential or a riposte to threatening processes? Springer New York, New York, New York, USA.

Gavin, S., and P. Komers. 2006. Do pronghorn (*Antilocapra americana*) perceive roads as a predation risk? Canadian Journal of Zoology 1780:1775-1780.

Geist, V., and M. H. Francis. 2001. Antelope country. Krause Publications, Iola, Wisconsin, USA.

Gilbert, B. K. 1973. Scent marking and territoriality in pronghorn (*Antilocapra americana*) in Yellowstone National Park. Mammalia 37:25-33.

Gill, R. B., L. H. Carpenter, R. M. Bartman, D. L. Baker, and G. G. Schoonveld. 1983. Fecal analysis to estimate mule deer diets. Journal of Wildlife Management 47:902-915.

Goldsmith, A. E. 1988. Behavior and ecology of pronghorn after reintroduction to Adobe Valley, California. Dissertation, University of California, Berkeley, USA.

Goldsmith, A. E. 1990. Vigilance behavior of pronghorn in different habitats. Journal of Mammalogy 71:460-462.

Good, J. R., and J. A. Crawford. 1978. Factors influencing pronghorn use of playas in southcentral Oregon. Proceedings of Pronghorn Antelope Workshop 8:182-205.

Gotelli, N. J., and A. M. Ellison. 2004. A primer of ecological statistics. First edition. Sinauer Associates, Inc, Sunderland, Massachusetts, USA.

Graham, A., and R. Bell. 1989. Investigating observer bias in aerial survey by simultaneous double count. Journal of Wildlife Management 53:1009-1016.

Gray, S. S. 2013. Pronghorn restoration. Texas Parks and Wildlife Department Federal Aid Project No. W-127-R-20, Austin, Texas, USA.

Griffith, G. K. 1962. Guidelines for antelope management. Transactions Interstate Antelope Conference 13:102-114.

Gruell, G. E. 1995. Historic role of fire on Hart Mountain National Antelope Refuge, Oregon, and Sheldon National Wildlife Refuge, Nevada. Special Report. U. S. Fish and Wildlife, Lakeview, Oregon, USA.

Guenzel, R. J. 1997. Estimating pronghorn abundance using aerial line-transect sampling. Wyoming Game and Fish Department, Cheyenne, Wyoming, USA.

Guenzel, R. J., L. L. Irwin, and T. J. Ryder. 1982. A comparison of pronghorn movements and distributions during a normal and a mild winter in the Red Rim area, Wyoming. Proceedings of Pronghorn Antelope Workshop 10:156-172.

Gysel, L. W., and W. J. Lyon. 1980. Habitat analysis and evaluation. Pages 305-327 *in* S. D. Schemnitz, editor. Wildlife management techniques manual. The Wildlife Society, Washington, D.C., USA.

Haag, R. W. 1986. Recent changes in cultivated lands within the pronghorn antelope range. Alberta Forest, Lands and Wildlife Resources, Publications T-108, Calgary, Alberta, Canada.

Hailey, T. L. 1979. A handbook for pronghorn antelope in Texas. Texas Parks and Wildlife Department Federal Aid Report Series 20, Austin, Texas, USA.

Hailey, T. L., J. W. Thomas, and R. M. Robinson. 1966. Pronghorn die-off in Trans-Pecos, Texas. Journal of Wildlife Management 30:488-496.

Haley, J. E. 1949. Charles Goodnight: cowman and plainsman. University Oklahoma Press, Norman, USA.

Hannum, C., S. Laposa, S. E. Reed, L. Pejchar, and L. Ex. 2012. Comparative analysis of housing in conservation developments: Colorado case studies. Journal of Sustainable Real Estate 4:149-176.

Hansen, E. L. 1955. Survival of pronghorn antelope in southcentral Oregon during 1953 and 1954. Thesis, Oregon State University, Corvallis, USA.

Hansen, M. C., and R. Anthony. 1999. Diet composition and quality of pronghorn, mule deer, bighorn sheep, wild horses, and wild burros on the Sheldon/Hart Mountain National Wildlife Complex. Oregon Cooperative Wildlife Research Unit, Corvallis, Oregon, USA.

Hansen, M. C., J. D. Yoakum, W. H. Pyle, and R. G. Anthony. 2001. New strategies for pronghorn food habitat studies. Proceedings of Pronghorn Antelope Workshop 19:71-94.

Hardy, A., and D. Wambach. 2010. An eco-logical approach to transportation project delivery in Montana. Pages 99-125 *in* J. P. Beckmann, A. P. Clevenger, M. P. Huijser, and J. A. Hilty, editors. Safe passages: highways, wildlife, and habitat connectivity. Island Press, Washington, D.C., USA.

Harthoorn, A. M. 1975. The chemical capture of animals: a guide to the chemical restraint of wild and captive animals. Baillier-Tindell Publishers, London, England.

Hassanin, A., F. Delsuc, A. Ropiquet, C. Hammer, B. Jansen van Vuuren, C. Matthee, M. Ruiz-Garcia, F. Catzeflis, V. Areskoug, T. T. Nguyen, and A. Couloux. 2012. Pattern and timing of diversification of Cetartiodactyla (Mammalia, Laurasiatheria), as revealed by a comprehensive analysis of mitochondrial genomes. Comptes rendus biologies 335:32-50.

Heady, H. F., and R. D. Child. 1994. Rangeland ecology and management. Westview Press, San Francisco, California, USA.

Heady, H. F., and J. Bartolome. 1977. The Vale rangeland rehabilitation program: the desert repaired in southeastern Oregon. U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station Resources Bulletin PNW-70, Portland, Oregon, USA.

Hebblewhite, M. 2008. A literature review of the effects of energy development on ungulates: implications for central and eastern Montana. Report prepared for Montana Fish, Wildlife and Parks, Miles City, Montana, USA.

Helms, B. 1978. Antelope and energy development. Proceedings of Pronghorn Antelope Workshop 8:206-215.

Hepworth, W. G. 1965. Investigations of pronghorn antelope in Wyoming. Proceedings of Pronghorn Antelope Workshop 1:1-12.

Hepworth, W. G., and F. Blunt. 1966. Research findings on Wyoming antelope. Special Antelope Issue, Wyoming Wildlife 30:24-29.

Hervert, J. J., L. A. Priest, W. Ballard, R. S. Henry, M. T. Brown, and S. Boe. 1997. Sonoran pronghorn population monitoring progress report. Arizona Game and Fish Department, Nongame and Endangered Wildlife Program Technical Report 126, Phoenix, Arizona, USA.

Hervert, J. J., R. S. Henry, and M. T. Brown. 1998. Preliminary investigations of Sonoran pronghorn use of free-standing water. Pages 126-137 *in* Proceedings of a Symposium on Environmental, Economic and Legal Issues Related to Rangeland Water Development. The Center for the Study of Law, Science and Technology, Arizona State University, Tempe, Arizona, USA.

Hervert, J. J., J. L. Bright, M. T. Brown, L. A. Priest, and R. S. Henry. 2000. Sonoran pronghorn monitoring: 1994-1998. Arizona Game and Fish Department, Nongame and Endangered Species Program Technical Report 16, Phoenix, Arizona, USA.

Hervert, J. J., J. L. Bright, R. S. Henry, L. A. Priest, and M. T. Brown. 2005. Home range and habitat use patterns of Sonoran pronghorn in Arizona. Wildlife Society Bulletin 33:8-15.

Hess, M. 1988. Wildlife research: pronghorn antelope response to a systematic removal and pronghorn antelope delineation. Nevada Department Wildlife, Reno, Nevada, USA.

Hoffman, J. D., and H. H. Genoways. 2012. Examination of annual variation in the adult sex ratio of pronghorn (*Antilicapra americana*). American Midland Naturalist 168:289-301.

Holechek, J. L., M. V. Vavra, and R. D. Pieper. 1982. Botanical composition determination of range herbivore diets: a review. Journal of Range Management 68:309-315.

Holechek, J. L., R. D. Pieper, and C. H. Herbel. 1997. Range management: principles and practices. Prentice-Hall, New York, New York, USA.

Hoover, J. P. 1971. Food habits of pronghorn antelope on Pawnee National Grasslands, 1970. Thesis, Colorado State University, Fort Collins, USA.

Hoover, R. L., C. E. Till, and S. Ogilvie. 1959. The antelope in Colorado. Colorado Department Game and Fish Technical Bulletin 4, Denver, Colorado, USA.

Hornocker, M .G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildlife Monographs 21:1-39.

Hosack, D. A., P. S. Miller, J. J. Hervert, and R. C. Lacy. 2002. A population viability analysis for the endangered Sonoran pronghorn. Mammalia 66:207-229.

Howard, V. W., Jr., J. L. Holechek, and R. D. Pieper. 1983. Roswell pronghorn study. New Mexico State University, Las Cruces, New Mexico, USA.

Howard, V. W., Jr., J. L. Holechek, R. D. Pieper, K. Green-Hammond, M. Cardenas, and S. L. Beasom. 1990. Habitat requirements for pronghorn on rangeland impacted by livestock and net wire in eastcentral New Mexico. New Mexico State University Experiment Station Bulletin 750, Las Cruces, New Mexico, USA.

Humphrey, R. R. 1950. The desert grassland. University Arizona Press, Tucson, USA.

International Union for Conservation of Nature and Natural Resources Council. 1987. Introductions, reintroductions, and restocking. International Union for Conservation of Nature and Natural Resources Council, Gland, Switzerland.

Jacobs, J. 1973. A microtechnique index to pronghorn diet and sagebrush digestion coefficients. Thesis, University Wyoming, Laramie, USA.

Jacques, C. N., J. A. Jenks, and R. W. Klaver. 2009. Seasonal movements and home-range use by female pronghorns in sagebrush-steppe communities of western South Dakota. Journal of Mammalogy 90:433-441.

Jeffers, J. A. 1985. Botanical composition and nutritional quality of pronghorn, cattle and sheep diets in northcentral New Mexico. Thesis, New Mexico State University, Las Cruces, USA.

Jenks, J. A., C. N. Jacques, J. D. Sievers, R. W. Klaver, R. T. Bowyer, and D. E. Roddy. 2006. Evaluating genetic viability of pronghorn in Wind Cave National Park. The Prairie Naturalist 38:155-165.

Jensen, W. 1998. Aging antelope: it's all in the teeth. North Dakota Outdoors 61:16-20.

Johnson, B. K., F. G. Lindzey, and R. J. Guenzel. 1991. Use of aerial line-transect surveys to estimate pronghorn populations in Wyoming. Wildlife Society Bulletin 19:315-321.

Johnson, D. 1988. When antelope don't roam free. New York Times, November.

Johnson, G. D., and S. E. Stephens. 2011. Wind power and biofuels: a green dilemma for wildlife conservation. Pages 131-155 *in* D. E. Naugle, editor. Energy development and wildlife conservation in western North America. Island Press, Washington, D.C., USA.

Johnson, G. D., D. P. Young, W. P. Erickson, C. E. Derby, M. D. Strickland, and R. E. Good. 2000. Final report: wildlife monitoring studies Seawest Windpower Project, Carbon County, Wyoming. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA.

Jones, P. F. 2014. Scarred for life: the other side of the fence debate. Human-Wildlife Interactions. in-press.

Jones, P. F., M. Grue, and J. Landry-Deboer. 2005. Resource selection by pronghorn antelope in the Grassland Natural Region of Alberta; progress report #1. Alberta Conservation Association, Lethbridge, Alberta, Canada.

Jones, P. F., and J. D. Yoakum. 2010. Where are all the pronghorn fawns: is low fawn recruitment an issue revisited. Proceedings of Pronghorn Workshop 24:65-78.

June, J. W. 1965. Water development. Proceedings Western Sage Grouse Workshop, Waldon, Colorado, USA.

Karhu, R., and S. Anderson. 2006. The effect of high-tensile electric fence designs on big-game and livestock movements. Wildlife Society Bulletin 34:293-299.

Karsky, R., compiler. 1988. Fences. U.S. Forest Service Technical and Development Center, Missoula, Montana, USA.

Keister, G. P., Jr., C. E. Trainer, and M. J. Willis. 1988. A self-adjusting color for young ungulates. Wildlife Society Bulletin 33:16-20.

Kerr, R. M. 1968. A discussion of the woven-wire fence antelope situation on BLM lands in New Mexico. Proceedings of Antelope States Workshop 3:22-27.

Kie, J. G., V. C. Bleich, A. L. Medina, J. D. Yoakum, and J. W. Thomas. 1994. Managing rangelands for wildlife. Pages 663-668 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Kiesecker, J. M., H. E. Copeland, B. A. McKenney, A. Pocewicz, and K. E. Doherty. 2011. Energy by design: making mitigation work for conservation and development. Pages 159-181 *in* D. E. Naugle, editor. Energy development and wildlife conservation in western North America. Island Press, Washington, D.C., USA.

Kindschy, R. R. 1996. Fences, waterholes, and other range improvements. Pages 369-381 *in* P. R. Krausman, editor. Rangeland wildlife. Society for Range Management, Denver, Colorado, USA.

Kindschy, R. R., C. Sundstrom, and J. D. Yoakum. 1978. Range/wildlife interrelationships - pronghorn antelope. Proceedings of Antelope States Workshop 8:216-269.

Kindschy, R. R., C. Sundstrom, and J. D. Yoakum.1982. Range/wildlife habitats in managed rangelands - the Great Basin of southeastern Oregon: Pronghorn. U.S. Forest Service General Technical Report PNW-145, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, USA.

Kitchen, D. W. 1974. Social behavior and ecology of the pronghorn. Wildlife Monographs 38:1-96.

Klimova, A. 2013. Diversidad gen t ica y diferenciaci n poblacional de dos subespecies amenazadas del berrendo (*Antilocapra americana*). Thesis, Universidad Autonoma de Baja California Sur, La Paz, Mexico. [Spanish].

Kniesel, M. 1988. AUM equivalence and its use in rangeland planning. Proceedings of Pronghorn Antelope Workshop 13:83-87.

Knowlton, F. F., E. M. Gese, and M. M. Jaeger. 1999. Coyote depredation control: an interface between biology and management. Journal of Range Management 52:398-412.

Koch, A. J., and J. D. Yoakum. 2002. Reintroduction and present status of pronghorn on the Carrizo Plain National Monument and surrounding areas in southern California. Proceedings of Pronghorn Workshop 28:25-41.

Kohlman, S. G. 2004. Population dynamics and modeling. Pages 675-704 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Kolar, J. 2009. Pronghorn migration and resource selection in southwestern North Dakota. Thesis, University of Missouri, Columbia, USA.

Korn, M. 1990. Old values, new times. Montana Outdoors 212:27-29.

Koshmrl, M. 2012. Preserving our pronghorn: new wildlife crossing structures benefit antelope, mule deer, and people. Jackson Hole News & Guide October 2012. Jackson, Wyoming.

Korschgen, L. J. 1980. Procedures for food habits analysis. Pages 113-127 *in* S. D. Scheminitz, editor. Wildlife management techniques manual. The Wildlife Society, Washington, D.C., USA.

Krausman, P., L. Harris, C. Blasch, K. Koenen, and J. Francine. 2004. Effects of military operations on behavior and hearing of endangered Sonoran pronghorn. Wildlife Monographs 157:1-41.

Krebs, C. J. 1999. Ecological methodology. Second edition. Addison-Wesley Educational Publishers, Inc., Menlo Park, California, USA.

Kreeger, T. J., and J. M. Arnemo. 2007. Handbook of wildlife chemical immobilization. Third edition. International Wildlife Veterinary Services, Laramie, Wyoming, USA.

Kreeger, T. J., J. M. Arnemo, and J. P. Raath. 2002. Handbook of wildlife chemical immobilization. International edition. Wildlife Pharmaceuticals Inc., Fort Collins, Colorado, USA.

Kuvlesky, W., L. Brennan, M. Morrison, K. Boydston, B. Ballard, and F. Bryant. 2007. Wind energy development and wildlife conservation: challenges and opportunities. Journal of Wildlife Management 71:2487-2498.

Laake, J., R. J. Guenzel, J. L. Bengston, P. Boveng, M. Cameron, and M. B. Hanson. 2008. Coping with variation in aerial survey protocol for line-transect sampling. Wildlife Research 35:289-298.

Lance, W. R., and T. M. Pojar. 1984. Diseases and parasites of pronghorn: a review. Colorado Division Wildlife Special Report 57, Denver, Colorado, USA.

Landon, D., P. Krausman, K. Koenen, and L. Harris. 2003. Pronghorn use of areas with varying sound pressure levels. The Southwestern Naturalist 48:725-728.

Lee, R. M. 2000. Antelope survey considerations in Arizona. Proceedings of Pronghorn Antelope Workshop 17:67-68.

Lee, R. M., J. D. Yoakum, B. W. O'Gara, T. M. Pojar, and R. A. Ockenfels, compilers. 1998. Pronghorn management guides. Pronghorn Antelope Workshop, Arizona Game and Fish Department, and Arizona Antelope Foundation, Prescott and Phoenix, Arizona, USA.

Lee, T. E. J., J. W. Bickham, and D. M. Scott. 1994. Mitochondrial DNA and allozyme analysis of North American pronghorn populations. Journal of Wildlife Management 58:307-318.

Lee, T. E. J., J. N. Derr, J. W. Bickham, and T. L. Clark. 1989. Genetic variation in pronghorn from west Texas. Journal of Wildlife Management 53:890-896.

Lee, T. E. J., J. Derr, J. Bickham, and D. J. Schmidly. 1991. Distribution of genetic variation in Texas pronghorn antelope. Applied Animal Behavior Science 29:502.

Lee, T. E. J., and W. S. Fairbanks. 1998. The genetics of a founder event. Southwestern Naturalist 43:415-418.

Leftwich, T. J., and C. D. Simpson. 1978. The impact of domestic livestock and farming on Texas pronghorn. Proceedings of Pronghorn Antelope Workshop 8:307-320.

Lehman, V. W., and J. B. Davis. 1942. Experimental wildlife management in Texas chaparral. Texas Game, Fish and Oyster Commission Pittman-Robertson Quarterly Project 1-R; Unit C: Section 1, Austin, Texas, USA.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, New York, USA.

Lindsay, A. R., and J. L. Belant. 2007. A simple and improved PCR-based technique for white-tailed deer (*Odocoileus virginianus*) sex identification. Conservation Genetics 9:443-447.

Lindstedt, S. L., J. F. Hokanson, D. J. Wells, S. D. Swain, H. Hoppeler, and V. Navarro. 1991. Running energetics in the pronghorn antelope. Nature 353:748-750.

List, R., and M. Valdéz. 2009. Diagnóstico de la población del berrendo (*Antilocapra americana*) en la zona colindante entre México y Estados Unidos y sus potenciales afectaciones por el muro fronterizo. Informe final para el Instituto Nacional de Ecología. Instituto de Ecología, UNAM, México, D. F. [Spanish].

Lou, Y. 1998. Genetic variation of pronghorn (*Antilocapra americana)* populations in North America. Dissertation, Texas A&M Unioversity, College Station, USA.

Maffly, B. 2007. Deadly roadkill in Wyoming kills 21 pronghorn. New West Network 2007:1–7.

Mapston, R. D. 1968. The use of structures to facilitate antelope movement through sheep-tight fences. Thesis, University of Arizona, Tucson, USA.

Mapston, R. D. 1972. Guidelines for fencing on antelope ranges. Proceedings of Antelope States Workshop 5:167-170.

Mapston, R. D., and R. S. Zobell. 1972. Antelope passes: their value and use. U.S. Bureau Land Management Service Center Technical Note 6500, Portland, Oregon, USA.

Markham, O. D., D. K. Fhalford, and R. E. Autenrieth. 1980. Strontium-90 concentrations in pronghorn antelope bones near a nuclear fuel reprocessing plant. Health Physiology 38:811-816.

Martin, S. K., and K. L. Parker. 1997. Rates of growth and morphological dimensions of bottle-raised pronghorns. Journal of Mammalogy 78:23-30.

Martinka, C. J. 1966. The international antelope herd. Montana Wildlife 7:28-30.

Martinka, C. J. 1967. Mortality of northern Montana pronghorn in a severe winter. Journal of Wildlife Management 31:159-164.

Mason, E. 1952. Food habits and measurements of Hart Mountain antelope. Journal of Wildlife Management 16:387-389.

McCarthy, C., and J. D. Yoakum. 1984. An interagency approach to evaluating pronghorn transplant sites in Mono County, California. Proceedings of Pronghorn Antelope Workshop 11:134-143.

McInnes, M. L. 1984. Ecological relationships among feral horses, cattle, and pronghorn in southeastern Oregon. Dissertation, Oregon State University, Corvallis, USA.

McKee, J. E., and H. W. Wolf. 1963. Water quality criteria. State Water Quality Control Publication 3-4, Sacramento, California, USA.

McKenzie, J. V. 1970. Two "killer winters", 1964 - 1965, in North Dakota. Proceedings of Pronghorn Antelope Workshop 4:36-40.

McKenzie, J. V. 1984. Management guidelines: trapping and translocation. Proceedings of Pronghorn Workshop 11:237-251.

McLucas, J. 1956. Montana big game trapping and transplanting techniques and accomplishments, 1945 - 1956. Montana Fish, Wildlife and Parks Pittman-Robertson Federal Aid Project, Helena, Montana, USA.

McNay, M. E. 1980. Causes of low pronghorn fawn:doe ratios on the Sheldon National Wildlife Refuge, Nevada. Thesis, University of Montana, Missoula, USA.

McNay, M. E., and B. W. O'Gara. 1982. Cattle-pronghorn interactions during the fawning season in northwestern Nevada. Pages 593-606 *in* J. M. Peek, and P. D. Dalke, editors. Proceedings Wildlife-Livestock Relationships Symposium. Forest, Wildlife and Range Experiment Station, University Idaho, Moscow, Idaho, USA.

Medcraft, J. R., and W. R. Clark. 1984. Impact of native herbivores on seeded shrubs on reclaimed mined land in northeastern Wyoming. Annual Meeting Society Range Management 37:33-36.

Meeker, J. O. 1979. Interactions between pronghorn antelope and feral horses in northwestern Nevada. Thesis, University of Nevada, Reno, USA.

Meinke, C. W., S. T. Knick, and D. A. Pyke. 2009. A spatial model to prioritize sagebrush landscapes in the Intermountain West (U.S.A.) for restoration. Restoration Ecology 17:652-659.

Menzel, K. 1994. Nebraska pronghorn status report - 1994. Proceedings of Pronghorn Antelope Workshop 16:11-12.

Menzel, K., and H. Y. Suetsugu. 1966. Re-introduction of antelope in the Sandhills of Nebraska. Proceedings of Antelope States Workshop 2:50-54.

Miller, M. W., M. A. Wild, B. J. Baker, and A. T. Tu. 1989. Snakebite in captive Rocky Mountain elk (*Cervus elaphus nelsoni*). Journal of Wildlife Diseases 25:392-363.

Miller, P. S., and R. C. Lacy. 1999. VORTEX: a stochastic simulation of the extinction process. Version 8 user's manual. International Union Conservation Nature, Species Survival Committee, Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

Mitchell, C. D., and C. R. Maher. 2001. Are horn characteristics related to age in male pronghorns? Wildlife Society Bulletin 29:908-916.

Mitchell, G. J. 1967. Minimum breeding age of female antelope. Journal of Mammalogy 48:489-490.

Mitchell, G. J. 1980. The pronghorn in Alberta. Alberta Department Lands and Forests, Fish and Wildlife Division, and University Regina, Regina, Saskatchewan, Canada.

Mitchell, G. J., and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. Journal of Wildlife Management 35:238-250.

Mix, C. H., and W. H. Miller. 2010. Diet composition and quality of pronghorn in southern Arizona. Proceedings of Pronghorn Workshop 24:136-137.

Moody, D. S., L. Saslaw, and A. W. Alldredge. 1982. Drive trapping pronghorn antelope in southcentral Wyoming. Proceedings of Pronghorn Antelope Workshop 10:225-228.

Morgart, J. R., J. J. Hervert, P. K. Krausman, J. L. Bright, and R. S. Henry. 2005. Sonoran pronghorn use of anthropogenic and natural water sources. Wildlife Society Bulletin 33:51-60.

Moritz, C. 1994. Defining evolutionary significant units for conservation. Trends in Ecology & Evolution 9:373-375.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy.

Morton, K., P. F. Jones, and M. Grue. 2008. Comparison between pronghorn age and horn size in southern Alberta. Proceedings of Pronghorn Workshop 23:96-106.

Munguia-Vega, A., A. Klimova, and M. Culver. 2013. New microsatellite loci isolated via next-generation sequencing for two endangered pronghorn from the Sonoran Desert. Conservation Genetics Resources 5:125-127.

Murie, O. J. 1951. The elk of North America. Stackpole Books, Harrisburg, Pennsylvania. USA.

Murphey, R. C. 1917. Natural history observations from the Mexican portion of the Colorado Desert. Proceedings of Linnean Society 28:43-101.

Murray, B. W., R. A. McClymont, and C. Strobeck. 1995. Forensic identification of ungulate species using restriction digests of PCR-amplified mitochondrial-DNA. Journal of Forensic Science 40:943-951.

Naidu, A., R. R. Fitak, A. Munguia-Vega, and M. Culver. 2012. Novel primers for complete mitochondrial cytochrome b gene sequencing in mammals. Molecular Ecology Resources 12:191-196.

Nelson, E. W. 1925. Status of the pronghorn antelope, 1922 - 1924. U.S. Department Agriculture Bulletin 1346, Washington, D.C., USA.

Neudecker, G. A., A. L. Duvall, and J. W. Stutzman. 2011. Community-based landscape conservation: a roadmap for the future. Pages 211-230 *in* D. E. Naugle, editor. Energy development and wildlife conservation in western North America. Island Press, Washington, D.C., USA.

Newberry, J. S. l855. Report upon the zoology of the route. No. 2. Pages 70-71 *in* H. L. Abbot, editor. Reports of exploration and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean. U. S. Senate, Washington, D.C., USA. Executive Document 78, Vol. VI.

Newman, J. L. 1966. Effects with woven wire fence with cattle guards on a free-living antelope population. Proceedings of Antelope States Workshop 2:6-8.

Nichol, A. A. 1942. Gathering, transplanting, and care of young antelopes. Journal of Wildlife Management 6:281-287.

Nichols, J. D. 1992. Capture-recapture models using marked animals to study population dynamics. Biological Science 42:92-102.

Nichols, L. 1960. The history of the antelope introductions on Lanai Island, Hawaii. Transactions Interstate Antelope Conference 11:101-104.

Nielson, A. E. 1962. Brief history of antelope in Idaho. Transactions Interstate Antelope Conference 13:64-70.

O'Brien, C. S., S. S. Rosenstock, J. J. Hervert, J. L. Bright, and S. R. Boe. 2005. Landscape-level models of potential habitat for Sonoran pronghorn. Wildlife Society Bulletin 33:24-34.

Oakley, C. 1973. The effects of livestock fencing on antelope. Wyoming Wildlife 37:26-29.

Oakley, C. and P. Riddle. 1974. The impact of a severe winter and fences on antelope mortality in southcentral Wyoming. Proceedings of Pronghorn Antelope Workshop 6:155-173.

Ochs, E. 2000. Handgun adds challenge to hunt. Western Outdoor News. August 25:19.

Ockenfels, R. A. 1994*a*. Mountain lion predation on pronghorn in central Arizona. Southwest Naturalist 39:305-306.

Ockenfels, R. A. 1994*b*. Factors affecting adult pronghorn mortality rates in central Arizona. Arizona Game and Fish Department Wildlife Digest 16, Phoenix, Arizona, USA.

Ockenfels, R. A., C. L. Dorothy, and J. D. Kirkland. 1992. Mortality and home range of pronghorn fawns in central Arizona. Proceedings of Pronghorn Antelope Workshop 15:78-92.

Ockenfels, R. A., A. Alexander, C. L. Dorothy-Ticer, and W. K. Carrel. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona. Arizona Game and Fish Department Technical Report 13, Phoenix, Arizona, USA.

Ockenfels, R. A., W. K. Carrel, and C. van Ripper III. 1997. Home ranges and movements of pronghorn in northern Arizona. Biennial Conference of Research on the Colorado Plateau 3:45-61.

Ockenfels, R. A., C. L. Ticer, A. Alexander, and J. A. Wennerlund. 1996. A landscape-level pronghorn habitat evaluation model for Arizona. Arizona Game and Fish Department Technical Report 19, Phoenix, Arizona, USA.

O'Gara, B. W. 1968. A study of the reproduction cycle of the female pronghorn (*Antilocapra americana* Ord). Dissertation, University of Montana, Missoula, USA.

O'Gara, B. W. 2004*a*. Behavior. Pages 145-194 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W. 2004*b*. Reproduction. Pages 275-298 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W. 2004*c*. Diseases and parasites. Pages 299-336 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W. 2004*d*. Mortality factors. Pages 379-408 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W. 2004*e*. Physiology and genetics. Pages 231-274 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W., C. J. Knowles, P. R. Knowles, and J. D. Yoakum. 2004. Capture, translocation and handling. Pages 705-761 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W., and R. E. McCabe. 2004. From exploitation to conservation. Pages 41-73 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W., and B. Morrison. 2004. Managing the harvest. Pages 673-704 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W., and H. G. Shaw. 2004. Predation. Pages 337-377 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

O'Gara, B. W., and J. D. Yoakum. 1990. Additional capture methods and habitat suitability criteria for pronghorn translocation. Proceedings of Pronghorn Antelope Workshop 14:51-62.

O'Gara, B. W., and J. D. Yoakum, editors. 1992. Pronghorn management guides. Pronghorn Antelope Workshop, Rock Springs, Wyoming, USA.

Oregon State Game Commission. 1961. Pronghorn antelope. Oregon State Game Commission Wildlife Service Leaf 2, Portland, Oregon, USA.

Paige, C. 2012*a*. A landowner's guide to fences and wildlife: practical tips to make your fences wildlife friendly. Wyoming Land Trust, Pinedale, Wyoming, USA.

Paige, C. 2012*b*. A landowner's guide to wildlife friendly fences. 2nd edition. Private Land Technical Assistance Program, Montana Fish, Wildlife and Parks, Helena, Montana, USA.

Palmer, W. L., J. M. Payne, R. G. Wingard, and J. L. George. 1985. A practical fence to reduce deer damage. Wildlife Society Bulletin 13:240-245.

Patritch, M. J. 2005. Electric fences - shocking to livestock, benefit to wildlife. Wyoming Wildlife May:44.

Payne, N. F., and F. C. Bryant. 1998. Wildlife habitat management of forestlands, rangelands, and farmlands. Krieger Publishing Company, Malabar, Florida, USA.

Pearson, H. A. 1969. Starvation in antelope with stomachs full of feed. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station Note RM 148, Fort Collins, Colorado, USA.

Pechanec, J. F., G. D. Pickford, and G. Stewart. 1937. Effects of the 1934 drought on native vegetation of the Upper Snake River Plains, Idaho. Ecology 18:490-505.

Pechanec, J. F., G. Stewart, and J. P. Blaisdel. 1954. Sagebrush burning, good and bad. Revised edition. U.S. Department of Agriculture Farmers bulletin 68-3, Washington, D.C., USA.

Plumb, R. E., K. M. Gordon, and S. H. Anderson. 2003. Pronghorn use of a wildlife underpass. Wildlife Society Bulletin 31:1244-1245.

Plummer, A. P., D. R. Christensen, and S. B. Monsen. 1968. Restoring big game range in Utah. Utah Fish and Game Department Publication 68-3, Salt Lake City, Utah, USA.

Pojar, T. M. 2000. Helicopter net-gun capture of pronghorn. Proceedings of Pronghorn Antelope Workshop 19:69-71.

Pojar, T. M. 2004. Survey methods to estimate populations. Pages 631-694 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Pojar, T. M., D. C. Bowden, and R. B. Gill. 1995. Aerial counting experiments to estimate pronghorn density and herd structure concurrently. Journal of Wildlife Management 59:117-128.

Pojar, T. M., and R. J. Guenzel. 1999. Comparison of fixed-wing line-transect and helicopter quadrant pronghorn surveys. Proceedings of Pronghorn Workshop 18:64-68.

Pojar, T. M., K. D. Pojar, C. Wager, and R. Firth. 1994. Observations of pronghorn response to an electric fence. Proceedings of Pronghorn Antelope Workshop 16:131-142.

Pojar, T. M., B. Thompson, C. Wager, and P. Handyside. 2002. Pronghorn range expansion in Middle Park, Colorado. Proceedings of Pronghorn Workshop 20:60-71.

Popowski, B. 1959. Hunting pronghorn antelope. The Stackpole Company, Harrisburg, Pennsylvania, USA.

Prenzlow, E. J., D. L. Gilbert, and F. A. Glover. 1968. Some behavior patterns of the pronghorn. Colorado Department of Game, Fish and Parks Special Report 17, Denver, Colorado, USA.

Pusateri, F. M., C. P. Hibler, and T. M. Pojar. 1982. Oral administration of diazepam and promazine hydochloride to immobilize pronghorn. Journal of Wildlife Diseases 18:9-16.

Pyle, W. H., and J. D. Yoakum. 1994. Status of pronghorn management at Hart Mountain National Antelope Refuge. Proceedings of Pronghorn Antelope Workshop 16:23-34.

Pyrah, D. B. 1974. Fawn bedding cover selection. Pages 3-19 *in* D. B. Pyrah, and H. E. Jorgensen, editors. Ecology of sagebrush control. Montana Fish, Wildlife, and Parks Pittman-Robertson Project W-105-R-9, Helena, Montana, USA.

Pyrah, D. B. 1978. Montana state report. Proceedings of Pronghorn Antelope Workshop 8:25-26.

Pyrah, D. B. 1987. American pronghorn antelope in the Yellow Water Triangle, Montana. Montana Fish, Wildlife, and Parks, Helena, Montana, USA.

Pyshora, L. 1986. California antelope status report. Proceedings of Pronghorn Antelope Workshop 12:8-10.

Raisbeck, M. F., D. O'Toole, R. H. Schamber, E. L. Belden, and L. J. Robinson. 1996. Toxicologic evaluation of a high-selenium hay diet in captive pronghorn antelope (*Antilocapra americana*). Journal of Wildlife Diseases 32:9-16.

Ramírez, O., J. Cancino, and L. Cruz. 2010. Current federal plan for the pronghorn in Mexico. Proceedings Pronghorn Workshop 24:23-26.

Reat, E. P., O. E. Rhodes, Jr., J. R. Heffelfinger, and J. C. Devos. 1990. Regional genetic differentiation in Arizona pronghorn. Proceedings of Pronghorn Antelope Workshop 18:25-31.

Reeves, A. F. 1982. Trapping pronghorn at a water hole. Proceedings of Pronghorn Antelope Workshop 10:209-224.

Rhodes, Jr., O. E., E. P. Reat, J. R. Heffelfinger, and J. C. Devos. 2001. Analysis of reintroduced pronghorn populations in Arizona using mitochondrial DNA markers. Proceedings of Pronghorn Antelope Workshop 19:45-54.

Rhodes, Jr., O. E., R. N. Williams, J. R. Heffelfinger, L. K. Page, E. P. Reat, and J. C. Devos. 1999. Genetic variation in pronghorn antelope from Arizona. Proceedings of Pronghorn Antelope Workshop 18:53-63.

Riddle, P. 1990. Wyoming antelope status report: 1990. Proceedings of Pronghorn Antelope Workshop 14:24.

Riddle, P., and C. Oakley. 1973. The impact of severe winters and fences on antelope mortality in southcentral Wyoming. Proceedings of Western Association State Fish and Game Commissioners 53:174-188.

Riggs, R. A., S. C. Bunting, and S. E. Daniels. 1996. Prescribed fire. Pages 295-319 *in* P. R. Krausman, editor. Rangeland wildlife. Society Range Management, Denver, Colorado, USA.

Riley, T. Z., E. M. Bayne, B. C. Dale, D. E. Naugle, J. A. Rodgers, and S. C. Torbit. 2012. Impacts of crude oil and natural gas developments on wildlife and wildlife habitat in the Rocky Mountain region. The Wildlife Society Technical Review 12-02, Bethesda, Maryland, USA.

Ripley, T. H. 1980. Planning wildlife management investigations and projects. Pages 1-6 *in* S. D. Schemnitz, editor. Wildlife management techniques manual. The Wildlife Society, Bethesda, Maryland, USA.

Robbins, J. 2011. For weary antelope, a perilous swim. The New York Times Green.

Roebuck, C. M. 1982. Comparative food habits and range use of pronghorn and cattle in the Texas Panhandle. Thesis, Texas Tech University, Lubbock, USA.

Romme, W., and M. Turner. 1991. Implications of global climate change for biogeographic patterns in the Greater Yellowstone Ecosystem. Conservation Biology 5:373-386.

Rouse, C. H. 1941. Notes on winter foraging habits of antelopes in Oklahoma. Journal of Mammalogy 22:57-60.

Rouse, C. H. 1954. Antelope and sheep fences: preliminary report. U.S. Bureau Land Management, Washington, D.C., USA.

Russ, J. 2004. Pronghorn management plan F. E. Warren Air Force Base, Wyoming. Jacobs Engineering Group Inc., Cheyenne, Wyoming, USA.

Russell, P. 1964. Antelope in New Mexico. New Mexico Department Game and Fish Bulletin 12, Santa Fe, New Mexico, USA.

Salwasser, H. 1980. Pronghorn antelope population and habitat management in the northwestern Great Basin environments. Interstate Antelope Conference, Alturas, California, USA.

Samuel, M. D., E. O. Garten, M. W. Schlegal, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. Journal of Wildlife Management 51:622-630.

Sauer, C. O. 1950. Grassland climax, fire and man. Journal of Range Management 3:16-21.

Sawyer, H., M. J. Kauffman, A. D. Middleton, T. A. Morrison, R. M. Nielson, and T. B. Wyckoff. 2013. A framework for understanding semi-permeable barrier effects on migratory ungulates. Journal of Applied Ecology 50:68-78.

Sawyer, H., and F. Lindzey. 2000. Jackson Hole pronghorn study; final report. Wyoming Cooperative Fish and Wildlife Resource Unit, Laramie, Wyoming, USA.

Sawyer, H., F. Lindzey, D. McWhirter, and K. Andrews. 2002. Potential effects of oil and gas development on mule deer and pronghorn populations in western Wyoming. Transactions of the North American Wildlife and Natural Resources Conference 67:350-365.

Sawyer, H., and B. Rudd. 2005. Pronghorn roadway crossings: a review of available information and potential options. Federal Highway Administration, Wyoming Department of Transportation and Wyoming Game and Fish Department, Cheyenne, Wyoming, USA.

Schilowsky, R. D. 2010. Pronghorn state and province status report - 2010. Proceedings of Pronghorn Workshop 24:5-22.

Schwartz, C. C. 1977. Pronghorn grazing strategies on the short-grass prairies. Dissertation, Colorado State University, Fort Collins, USA.

Schwartz, C. C., J. G. Nagy, and S. M. Kerr. 1976. Rearing and training pronghorn for ecological studies. Journal of Wildlife Management 40:464-468.

Scott, M. D. 1976. Pronghorn antelope management potential of mining industry lands. Proceedings of Pronghorn Antelope Workshop 7:135-151.

Scott, M. D. 1990. Determining a minimum genetically viable population size for Yellowstone pronghorn. Proceedings of Pronghorn Antelope Workshop 14:26-27.

Scott, M. D. 1992. Buck-and-pole fence crossings by 4 ungulate species. Wildlife Society Bulletin 20:204-210.

Scott, M. D. 1994. Capturing pronghorn by net-gunning from the ground versus the air. Proceedings of Pronghorn Antelope Workshop 16:186-197.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameter. Second edition. MacMillan Publishing Company, New York, New York, USA.

Seidler, R. 2009. Surgical sterilization of coyotes to reduce predation on pronghorn fawns. Thesis, Utah State University, Logan, USA.

Segerstrom, T. B. 1981. Effects of an operational coal mine on pronghorn antelope. Thesis, Montana State University, Billings, USA.

SEMARNAT. 2009. Programa de accion para la conservacion de la especie: berrendo (*Antilocapra americana*). Secretaria de Medio Ambiente y Recursos Naturales. [Spanish].

Severson, K. E. 1966. An analysis of food and feeding habits of pronghorn antelope and domestic sheep in the Red Rock region of Wyoming. Proceedings of Antelope States Workshop 2:22-23.

Severson, K. E., M. May, and W. Hepworth. 1968. Food preferences, carrying capacities and forage competition between antelope and domestic sheep in Wyoming's Red Desert. Science Agriculture Experiment Station Monograph 10, Laramie, Wyoming, USA.

Sexson, M. L. 1979. Ecogeographic relations of the pronghorn (*Antilocapra americana*) in Kansas. Thesis, Fort Hayes State University, Fort Hays,Kansas USA.

Sheldon, D. P. 2005. Movement and distribution patterns of pronghorn in relationship to roads and fences in southwestern Wyoming. Thesis, University of Wyoming, Laramie, USA.

Sievers, J. D. 2004. Factors influencing a declining pronghorn population in Wind Cave National Park, South Dakota. Thesis, South Dakota State University, Brookings, USA.

Simpson, B. D. 1992. Behavior, home range, and habitat use of pronghorn translocations to tallgrass prairie in eastcentral Kansas. Thesis, Emporia State University, Emporia, Kansas, USA.

Smith, A. D. 1974. Production and survival of pronghorn antelope on artificial diets with different protein levels. Proceedings of Antelope States Workshop 6:74-91.

Smith, A. D., and D. M. Beale. 1980. Pronghorn antelope in Utah: some research and observations. Utah Division Wildlife Resources Publication 80-13, Salt Lake City, Utah, USA.

Smith, A. D., D. M. Beale, and D. D. Doell. 1965, Browse preferences of pronghorn antelope in southwestern Utah. Transactions of North American Wildlife and Natural Resources Conference 13:136-141.

Smith, A. D., and J. C. Malechek. l974. Nutritional quality of summer diets of pronghorn antelopes in Utah. Journal of Wildlife Management 38:792-798.

Smith, E. 2002. BACI design. Encyclopedia of Environmetrics 1:141-148.

Smith, R. H., D. J. Neff, and N. G. Woolsey. 1986. Pronghorn response to coyote control: a benefit/cost analysis. Wildlife Society Bulletin 14:226-231.

Smith, T., and R. Guenzel. 2002. Motor vehicle associated mortality in an urban pronghorn herd. Proceedings of Pronghorn Workshop 20:137-142.

Smyser, T. J. 2005. Responses of pronghorn (*Antilocapra americana*) populations to habitat conditions with modification to survey methods. Thesis, University of Idaho, Moscow, USA.

Sneva, F. A., and M. Vavra. 1978. Botanical composition of feces from antelope grazing the Oregon high desert. Proceedings of Antelope States Workshop 8:78-93.

Spillett, J. J., J. B. Low, and D. Sill. 1967. Livestock fences—how they influence pronghorn antelope movements. Agriculture Experiment Station Bulletin 470, Utah State University, Logan, Utah, USA.

Spillett, J. J., and R. S. Zobell. 1967. Innovations in trapping and handling pronghorn antelopes. Journal of Wildlife Management 3l:347-35l.

Stelfox, J. G., and H. G. Vriend. 1977. Prairie fires and pronghorn use of cactus. Canadian Field Naturalist 91:282-285.

Stephen, C., J. Devos, Jr., T. E. Lee, Jr., J. W. Bickham, J. R. Heffelfinger, and O. E. Rhodes, Jr. 2005*a*. Population genetic analysis of Sonoran pronghorn (*Antilocapra americana sonoriensis*). Journal of Mammalogy 86:782-792.

Stephen, C. L., D. G. Whittaker, D. O. N. Gillis, L. L. Cox, and O. E. Rhodes, Jr. 2005*b*. Genetic consequences of reintroductions: an example from Oregon pronghorn antelope (*Antilocapra Americana*). Journal of Wildlife Management 69:1463-1474.

Stoddart, L. A., and A. D. Smith. 1955. Range management. McGraw-Hill Book Company, New York, New York, USA.

Stokes, J. D. 1952. Antelope management in California. Proceedings of Western Association State Game and Fish Commissioners 32:99-101.

Strickland, D. 1979. Annual report of big game harvest, 1978. Wyoming Game and Fish Department Pittman-Robertson Project W-27-R-3, Project Objective 1, Job l, Cheyenne, Wyoming, USA.

Suitor, M. J. 2011. Factors influencing pronghorn movements in the Northern Mixed Grasslands Ecoregion. Thesis, University of Calgary, Calgary, Alberta, Canada.

Sundstrom, C. W. 1968. Water consumption by pronghorn antelope and distribution related to water in Wyoming's Red Desert. Proceedings of Pronghorn Antelope Workshop 3:39-47.

Sundstrom, C. W. 1969. Some factors influencing pronghorn antelope distribution in the Red Desert of Wyoming. Proceedings of Association Fish and Game Commissioners 49:255-264.

Sundstrom, C. W., G. Hepworth, and K. L. Diem. 1973. Abundance, distribution and food habits of the pronghorn. Wyoming Game and Fish Commission Bulletin 12, Cheyenne, Wyoming, USA.

Swift, A., S. Casey-Lefkowitz, and E. Shope. 2011. Tar sands pipelines safety risks. Natural Resources Defense Council, New York, New York, USA.

Talbot, L. M. 1976. New principles for management for wild living resources. Western Wildlands 3:28-32.

Tanner, G., K. Beckstrand, L. Gilbertson, C. Mortimore, and J. Hines. 2003. Nevada's pronghorn antelope: ecology, management, and conservation. Nevada Division of Wildlife, Biological Bulletin 13, Reno, Nevada, USA.

Tarrant, B. L., L. A. Harveson, S. S. Gray, and K. Waldrup. 2010. Gastrointestinal nematode concentrations of pronghorn in Trans-Pecos, Texas. Proceedings of Pronghorn Workshop 24:112-118.

Taylor, E. R. 1972. Food habits and feeding behavior of pronghorn antelope in the Red Desert of Wyoming. Proceedings of Antelope States Workshop 5:211-221.

Taylor, E. R. 1975. Pronghorn carrying capacity of Wyoming's Red Desert. Wyoming Game and Fish Department Technical Report 3, Cheyenne, Wyoming, USA.

The DRECP Independent Science Panel. 2012. Final report - independent science review for the California Desert Renewable Energy Conservation Plan (DRECP). The DRECP Independent Science Panel.

Theimer, T., S. Sprague, E. Eddy, and R. Benford. 2012. Genetic variation of pronghorn across US Route 89 and State Route 64: final report 659. Arizona Department of Transportation Research Center, Flagstaff, Arizona, USA.

Thomas, G. M., and W. J. Allred. 1943. Mass trapping of mule deer. Journal of Wildlife Management 7:407-411.

Thompson, K. 1947. Air-herding the pronghorn. American Forests 53:348-349 and 380-381.

Thorne, E. T., E. S. Williams, T. R. Spraker, W. Helms, and T. Segerstrom. 1988. Bluetongue in free-ranging pronghorn antelope (*Antilocapra americana*) in Wyoming:1976 - 1984. Journal of Wildlife Diseases 24:113-119.

Thwaites, R. G., editor. 1904 - 05. Original journals of the Lewis and Clark expedition 1804-1806. 8 volumes. Dodd, Mead, and Company, New York, New York, USA.

Ticer, C. L., S. R. Boe, R. A. Ockenfels, and J. C. deVos, Jr. 1999. Factors affecting home ranges and movements of pronghorn on a shortgrass prairie in northern Arizona. Proceedings of Pronghorn Antelope Workshop 18:84-90.

Torbit, S. C., J. G. Nagy, and E. M. Rominger. 1984. Development of an emergency feeding system for pronghorn antelope. Proceedings of Pronghorn Antelope Workshop 11:113-128.

Trainer, C. E., M. J. Willis, G. P. Keister, Jr., and D. P. Sheely. 1983. Fawn mortality and habitat use among pronghorn during spring and summer in southeastern Oregon, 1981 - 82. Oregon Department Fish and Game Wildlife Resources Report 12, Portland, Oregon, USA.

Tsukamoto, G. K. 1983. Pronghorn antelope species management plan. Nevada Division of Wildlife, Reno, Nevada, USA.

Tsukamoto, G. K., and W. J. Deibert. 1968. A preliminary report of Nevada pronghorn antelope food habits during August and September. Transactions of Interstate Antelope Conference 19:10-23.

Tucker, R. D. 1979. Pronghorn antelope fawn mortality, home range, habitat and behavior in Brewster County, Texas. Thesis, Sul Ross State University, Alpine, Texas, USA.

Tullous, R., and W. S. Fairbanks. 2002. Distribution of pronghorn before and after development of recreational trails in Antelope Island State Park. Proceedings of Pronghorn Workshop 20:25.

Turbak, G., A. Carey, and S. Carey. 1995. Pronghorn: portrait of the American antelope. Northland Publishing, Flagstaff, Arizona, USA.

Udy, J. R. 1953. Effects of predator control on antelope populations. Utah Department Fish and Game Publication 5, Salt Lake City, Utah, USA.

Underwood, A. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4:3-15.

U.S. Bureau Land Management. 1980. Manual supplement 6630-big game studies: guidelines for the evaluation of pronghorn antelope habitats. U.S. Bureau Land Management, Reno, Nevada, USA.

U.S. Bureau Land Management. 1985. H-1741-1 fencing. manual release 1-1419. U.S. Bureau Land Management, Washington, D.C., USA.

U.S. Congress. 1973. Endangered species act. U.S. Code, Volume 16, Section 1534-1544. U.S. Government Printing Office, Washington, D.C., USA.

U.S. Department of the Interior, Office of the Secretary. 1967. Federal register 32. 11 March 1967.

U.S. Fish and Wildlife Service. 1994. Final environmental impact statement: Hart Mountain National Antelope Refuge comprehensive management plan. 2 volumes. U.S. Fish and Wildlife Service, Lakeview, Oregon, USA.

U.S. Fish and Wildlife Service. 1998. Final revised Sonoran pronghorn recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

U.S. Soil Conservation Service. 1989. Wildlife habitat evaluation guides for antelope in Arizona. U.S. Soil Conservation Service, Phoenix, Arizona, USA.

Vallentine, J. F. 1989. Range development and improvements. Third edition. Academic Press, San Diego, California, USA.

Van Dyke, W. 1990. Oregon pronghorn status report: 1990. Proceedings of Pronghorn Antelope Workshop 14:14-16.

Van Riper, III, C., J. Hart, and J. Bright. 2001. Effects of fenced transportation corridors on pronghorn antelope movements in Petrified Forest National Park, Arizona. Pages 71-74 *in* D. Harmon, editor. Crossing boundaries in park management. Proceedings of the 11th Conference on Research and Resource Management in Parks and on Public Lands. The George Wright Society, Hancock, Michigan, USA.

Vriend, H. G., and M. W. Barrett. 1978. Low pronghorn recruitment - is it an issue? Proceedings of Pronghorn Antelope Workshop 8:360-377.

Wagner, F. H. 1978. Livestock grazing and the livestock industry. Pages 121-145 *in* H. P. Brokaw, editor. Wildlife and America. U.S. Government Printing Office, Washington, D.C., USA.

Wald, J., and D. Alberswerth. 1989. Our ailing public rangelands. National Wildlife Federation, Washington, D.C., USA.

Walters, C. 1986. Adaptive management of renewable resources. Macmillan Publishing, New York, New York, USA.

Ward, A. L., J. J. Cupal, G. A. Goodwin, and H. D. Morris. 1976. Effects of highway construction and use on big game populations. Rocky Mountain Forest and Range Experimental Station and Federal Highway Administration, Fort Collins, Colorado, and Washington, D.C., USA.

West, D. R. 1970. Effects of prolonged deep snow and cold winters on pronghorn mortality and reproduction in South Dakota. Proceedings of Antelope States Workshop 4:41-49.

Whisler, S. 1984. Seasonal adaptations of pronghorn antelope to water deprivation. Dissertation, University of Wyoming, Laramie, USA.

White, G. C. 1996. NOREMARK: population estimation from mark-resighting surveys. Wildlife Society Bulletin 24:50-52.

White, G. C., R. M. Bartmann, L. H. Carpenter, and R. A. Garrott. 1989. Evaluation of aerial line-transects for estimating mule deer densities. Journal of Wildlife Management 53:625-635.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.

White, G. C., and B. C. Lubow. 2002. Fitting population data to multiple sources of observed data. Journal of Wildlife Management 66:300-309.

White, P. J., T. L. Davis, K. K. Barnowe-Meyer, R. L. Crabtree, and R. A. Garrott. 2007. Partial migration and philopatry of Yellowstone pronghorn. Biological Conservation 135:502-510.

White, R. W. 1969. Antelope winter kill, Arizona style. Proceedings of Western Association State Game and Fish Commissions 49:251-254.

Wild, M. A., and M. W. Miller. 1991. Bottle-raising wild ruminants in captivity. Colorado Division Wildlife Outdoor Facts 114:1-6.

Wild, M. A., M. W. Miller, D. L. Baker, N. T. Hobbs, R. B. Gill, and B. J. Maynard. 1994. Comparing growth rates of dam and hand-raised bighorn sheep, pronghorn, and elk neonates. Journal of Wildlife Management 58:340-347.

Willis, M. J. 1988. Impacts of coyote removal on pronghorn fawn survival. Proceedings of Pronghorn Antelope Workshop 13:30.

Willis, M. J., G. P. Keister, and D. P. Sheehy. 1988. Pronghorn habitat preference in southeastern Oregon. Proceedings of Pronghorn Antelope Workshop 13:92-111.

Wilson, L. O., and D. Hannan. 1977. Guidelines and recommendations for design and modification of livestock watering developments to facilitate use by wildlife. U.S. Bureau Land Management Technical Note 305, Denver Service Center, Denver, Colorado, USA.

Wilson, R. R., P. R. Krausman, and J. R. Morgart. 2010. Recovery efforts for the Sonoran pronghorn in the United States. Pages 283-292 *in* W. L. Halvorson, C. van Riper, and C. R. Schwalbe, editors. Southwestern Desert Resources. University of Arizona Press, Tuzson, USA.

Wisdom, M., M. Rowland, B. Wales, M. Hemstrom, W. Hann, M. Raphael, R. Holthausen, R. Gravenmier, and T. Rich. 2002. Modeled effects of sagebrush-steppe restoration on greater sage-grouse in the interior Columbia Basin, USA. Conservation Biology 16:1223-1231.

Wishart, W. D. 1970. A brief historic of the pronghorn antelope in Alberta. Proceedings of Antelope States Workshop 4:128-130.

Woolley, T. P., and F. G. Lindzey. 1997. Relative precision and sources of bias in pronghorn sex and age composition surveys. Journal of Wildlife Management 61:57-63.

Wright, P. L., and S. A. Dow, Jr. 1962. Minimum breeding age in pronghorn antelope. Journal of Wildlife Management 26:100-101.

Wurster, D. H., and K. Benirschke. 1968. Chromosome studies in the superfamily Bovoidea. Chromosoma 25:152-171.

Wyoming Game and Fish Department. 1986. Landowner coupons: do they work? Wyoming Wildlife 50:34-35.

Wyoming Game and Fish Department. 2009. Recommendations for development of oil and gas resources within important wildlife habitats. Wyoming Game and Fish Department, Cheyenne, Wyoming, USA.

Yoakum, J. D. 1957. Factors affecting the mortality of pronghorn antelope in Oregon. Thesis, Oregon State College, Corvallis, USA.

Yoakum, J. D. 1968. A review of the distribution and abundance of American pronghorn antelope. Proceedings of Antelope States Workshop 3:4-14.

Yoakum, J. D. 1974. Pronghorn habitat requirements. Proceedings of Antelope States Workshop 6:16-25.

Yoakum, J. D. 1978. Pronghorn. Pages 103-121 *in* J. L. Schmidt, and D. L. Gilbert, editors. Big game of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Yoakum, J. D. 1980. Habitat management guides for the American pronghorn antelope. U.S. Bureau Land Management Service Center Technical Note 347, Denver, Colorado, USA.

Yoakum, J. D. 1986. Trends in pronghorn populations: 1800 - 1983. Proceedings of Pronghorn Antelope Workshop 12:77-84.

Yoakum, J. D. 1990. Food habits of the pronghorn. Proceedings of Pronghorn Antelope Workshop 14:102-110.

Yoakum, J. D. 2002. Pronghorn use of shade. Proceedings of Pronghorn Workshop 20:135.

Yoakum, J. D. 2003. An assessment of pronghorn and habitat conditions on Anderson Mesa, Arizona: 2001 - 2002. Western Wildlife, Verdi, Nevada, USA.

Yoakum, J. D. 2004*a*. Distribution and abundance. Pages 75-105 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Yoakum, J. D. 2004*b*. Habitat characteristics and requirements. Pages 409-446 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Yoakum, J. D. 2004*c*. Foraging ecology, diet studies and nutrient values. Pages 447-502 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Yoakum, J. D. 2004*d*. Management plans, environmental impact statements and guides. Pages 541-570 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Yoakum, J. D. 2004*e*. Habitat conservation. Pages 571-630 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Yoakum, J. D. 2004*f*. Relationship with other herbivores. Pages 503-538 *in* B. W. O'Gara, and J. D. Yoakum, editors. Pronghorn: ecology and management. University Press Colorado, Boulder, USA.

Yoakum, J. D., W. P. Dasmann, R. Sanderson, C. Nixon, and H. Crawford. 1980. Habitat improvement techniques. Pages 329-403 *in* S. Schemnitz, editor. Wildlife management techniques manual. The Wildlife Society, Bethesda, Maryland, USA.

Yoakum, J. D., and B. W. O'Gara. 1990. Pronghorn/livestock relationships. Transactions North American Wildlife and Natural Resource Conference 55:475-487.

Yoakum, J. D., B. W. O'Gara, and V. W. Howard. 1996. Pronghorn on western rangelands. Pages 211-226 *in* P. R. Krausman, editor. Rangeland wildlife. Society for Range Management, Denver, Colorado, USA.

Yoakum, J. D., H. G. Shaw, T. M. Pojar, and R. H. Barrett. 2004. Pronghorn neonates, predators and predator control. Proceedings of Pronghorn Workshop 21:73-95.

Zarn, M. 1981. Wild ungulate forage requirements - a review. Special Report. U.S. Bureau Land Management, Washington, D.C., USA.

APPENDIX A. Form used for selecting pronghorn transplant sites in shrubsteppe (modified from Hoover et al. (1959) for shrubsteppes by Yoakum (1980)).

1. LOCATION:
   County ____________ Nearest town ____________
   Nearest ranch ____________ Accessibility by road ____________
   Township ____________ Range ____________

2. SIZE (Number of square miles of estimated habitat): ____________

3. TOPOGRAPHY: ____________ Physical Barriers: ____________
   Constructed Barriers:
   Fences (Location) (Construction Specifications)
   ____________ ____________
   ____________ ____________

   Major Highways, freeways: ____________

   Other: ____________

4. CLIMATE: ____________ Elevation: ____________
   Mean depth of snow ____________ Annual Precipitation ____________

5. WATER:

	Springs	Reservoirs	Lakes	Streams	Wells	Catchments
Number	______	______			______	______
Acres			______			
Miles				______		
Production:						
Surface Ac.		______				
Gal/Min	______			______		
Gal/Storage						______

   Mean distribution of water sources ____________
   Year-round water? ____________

6. VEGETATION:

Major Types	No. Acres	Mean Ht.	Estimated Percent Grass	Forbs	Shrubs
______	______	______	______	______	______
______	______	______	______	______	______
______					
______	______	______	______	______	______
______					

7. LAND OWNERSHIP (number of acres):

   Private ____________
   Public ____________

Other ______________________________

8. LAND USE:
Class of livestock ______________________________
Stocking rate ______________________________
Grazing system ______________________________
Cultivated crops ______________________________
Other ______________________________

9. PREDATION:
Natural: Coyotes __________ Eagles __________ Bobcat __________
Human: ______________________________

10. TRANSPLANT CONSIDERATIONS:
Is site historical pronghorn range? ______________________________
Attitude of ranchers ______________________________
Attitude of conservation organizations ______________________________
Attitude of local sportsmen's clubs ______________________________
____
Attitude of public land-management agencies ______________________________
Is land manager(s) agreeable to management objectives of state or provincial wildlife agency? ______________________________
Suggested number of pronghorn for transplant ______________________________
Route of trucks carrying pronghorn and release point ______________________________
____
____

Has a "habitat management plan" been developed? ______________________________
____
____
Are cooperative agreements completed?
Private landowners ______________________________
Public land agencies ______________________________
Has a follow-up monitoring study been planned to document success of project or reasons for failure? ______________________________
____
____
Other ______________________________
____
____