Proceedings of the 20th Biennial Pronghorn Workshop 2002

Sanctioned by the Western Association of Fish and Wildlife Agencies

Hosted by
U.S. Forest Service, Nebraska National Forest
Nebraska Game & Parks Commission

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2002

Edited by
Jeffrey S. Abegglen
and
W. Sue Fairbanks

Holiday Inn Convention Center
Kearney, Nebraska, March 17 – 20, 2002

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TABLE OF CONTENTS

Preface iii

Dedication v

Bart W. O'Gara: 1923-2003 v

Summary of Pronghorn Workshops Held to Date vii

Section I 1

Workshop Agenda 1

Section II 5

Pronghorn State and Province Status Report: 2001 5

Section III 17

Technical Session 17

Pronghorn Horn Sheath Growth, Age, and Precipitation on a Ranch in Southern New Mexico 17
Fetal Rates and Sex Ratios in Three Pronghorn Populations in Wyoming 24
Reintroduction and Status of Pronghorn on the Carrizo Plain National Monument and Surrounding Areas in Southern California 25
A Pronghorn Metapopulation in Northern Arizona 42
Pronghorn Range Expansion in Middle Park, Colorado 60
Genetic Distinction of the Sonoran Pronghorn 72
Aerotransfer of American Pronghorn Fawns from Wyoming to Mexico: Another Step Toward the Assisted Reproduction of Pronghorn 84
A Bestiary of Ancestral Antilocaprids 87
Vegetation Health Relative to Pronghorn Health 112
Sonoran Pronghorn Habitat Use and Availability on a Military Range 113
Effects of Winter Range on a Pronghorn Population in Yellowstone National Park, Wyoming 114
Winter Precipitation and Pronghorn Fawn Survival in the Southwest 115
Choice of Fawning Areas and Fawn Bedsites with Respect to Vegetation Structure and Land Use in Northwest Nebraska 123
Using Range Manipulations to Increase Pronghorn Production and Abundance in Utah Sagebrush Steppe 124
Pronghorn Use of Shade 135
Distribution of Pronghorn Before and After Development of Recreational Trails in Antelope Island State Park, Utah 136
Motor Vehicle Associated Mortality in an Urban Pronghorn Herd 137
Pronghorn and a California Highway: Potential Impacts and Mitigation 143
Pronghorn Use of Modified FenceS in Northern Arizona 153

Section IV 160

List of Presenters 160

Section V 164

Business Meeting 164
Bylaws 168

2002 Workshop Attendees 174

Preface

The Nebraska Game and Parks Commission and the USDA Forest Service co-hosted the Twentieth Biennial Pronghorn Workshop at Kearney, Nebraska on March 17-20, 2002. The Workshop was considered a huge success. The official registered attendance was 85 participants. This was one of the highest attended Workshops since 1972.

Attendees included representation from Mexico, 2 Canadian Provinces, 9 Private organizations, 5 Federal agencies, 58 State agencies, and 10 Universities. This is the first time in many years that we have had this kind of diverse representation.

A state status report is included in these proceedings, along with technical papers presented at the workshop. Any discussion after the papers was not recorded. Notes regarding the business meeting were taken and are included. Editing and formatting of these proceedings was limited to identifying and maintaining consistency relative to format and grammar. I take full responsibility of any typographical and/or formatting errors, and omissions.

The 21st Biennial Pronghorn Workshop will be hosted by the State of North Dakota at Bismarck on May 2-4, 2004. Bill Jensen and Bruce Stillings will be Co-Chairs.

I would also like to personally thank Ritch Nelson, formerly with the Nebraska Game and Parks Commission, for his involvement on sub-committees and overall assistance with the workshop. I would like to extend a special thanks to Sue Fairbanks for her many hours of coordinating, editing and "pulling together" the technical papers and abstracts for the proceedings. Her diligence is greatly appreciated.

Jeffrey S. Abegglen
Workshop Chairman

A special thanks to the following individuals that graciously agreed to help review the submitted manuscripts and abstracts. They include:

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Dedication

BART W. O'GARA: 1923-2003

The 20th Pronghorn Workshop dedicates its proceedings to Dr. Bart W. O'Gara, who passed away 21 May 2003. He was a scientist, researcher, professor, author, mentor and avid hunter – specializing in pronghorn biology and management. His life was dedicated to sharing information that could be used to enhance the welfare of wildlife.

Bart was born in the rural area of Laurel, Nebraska, on 21 March 1923. While attending High School, he joined the U.S. Navy during World War II. Twenty years later, after achieving the rank of Machinist Chief Petty Officer, he retired from military service.

Bart then commenced his second career when he obtained a B.S. degree in fish and wildlife management at Montana State University, Billings, followed with a Ph.D. in zoology a the University of Montana, Missoula. His dissertation pertained to the reproduction of pronghorn. It provided a tremendous amount of new scientific data on the species' physiology and anatomy, earning him the distinction as one of the world's authorities on pronghorn.

For the next 24 years, Bart worked as a wildlife biologist for the U.S. Fish and Wildlife Service at the Montana Cooperative Wildlife Research Unit and the University of Montana, Missoula. During this time he was assistant leader for the Unit for a decade, and then leader for another 14 years. He authored/coauthored more than 70 technical papers on wildlife, of which 30 were on pronghorn – 12 were published in the Pronghorn Workshop Proceedings. During his career, he attended all the Pronghorn Workshops since 1970, except one, and therefore was one of the most faithful attendees of these international pronghorn meetings.

In addition, for the last 25 years, he has been coauthoring a reference tome entitled "The Pronghorn: Ecology and Management", the first and only comprehensive text on the biology and management of pronghorn since Art Einarsen's monograph published 55 years ago. The text is currently at the printer and scheduled for distribution during the summer of 2004 by the Wildlife Management Institute.

Bart was totally dedicated to pronghorn and other wildlife. His scientific writings remain a cornerstone of biological knowledge. He was an advisor to close to 100 graduate students. For his 80th birthday, he traveled to Africa and collected three species of antelope. Bart is a sterling legacy that has provided opportunities for wildlife and wildlife biologists to be richer, healthier, and happier – many thanks Bart.

--- Jim D. Yoakum, 11 August 2003

Photograph: Portrait of an adult pronghorn buck on the National Bison Range, Montana, by Bart W. O'Gara.

Summary of Pronghorn Workshops Held to Date

Meeting Dates and Locations	Number Attending	Chairman	Host Agency
April 14-16, 1965 Santa Fe, NM	18	W. Huey	New Mexico Department of Fish and Game
February 16-17, 1966 Denver, CO	32	G.D. Bear	Colorado Game, Fish and Parks Department
February 5-6, 1968 Casper, WY	97	J.L. Newman	Wyoming Game and Fish Commission
January 27-28, 1970 Scottsbluff, NE	85	K.I. Menzel	Nebraska Game and Parks Commission
June 19-22, 1972 Billings, MT	85	H.O. Compton	Montana Fish and Game Department
February 19-21, 1976 Salt Lake City, UT	52	D.M. Beale	Utah Division of Wildlife Resources
February 24-26, 1976 Twin Falls, ID	68	R. Autenreith	Idaho Department of Fish and Game
May 2-4, 1978 Jasper, Alberta	84	M.W. Barrett	Alberta Fish and Wildlife Division
April 8-10, 1980 Rio Rico, AZ	64	J.S. Phelps	Arizona Game and Fish Department
April 5-7, 1982 Dickinson, ND	69	J.V. McKenzie	North Dakota Game and Fish Department
April 10-12, 1984 Corpus Christi, TX	45	C.K. Winkler	Texas Parks and Wildlife Department
March 11-13, 1986 Reno, NV	43	M. Hess	Nevada Department of Fish and Wildlife
May 31-June 2, 1988 Hart Mt., OR	43	D. Eastman	Oregon Department of Fish and Wildlife
May 22-24, 1990 Silver Creek, CO	45	T.M. Pojar	Colorado Division of Wildlife
June 8-11, 1992 Rock Springs, WY	91	P. Riddle	Wyoming Game and Fish Commission
April 18-21, 1994 Emporia, KS	49	K. Sexson	Kansas Department of Wildlife and Parks
June 5-7, 1996 Lake Tahoe, CA	75	L. Colton	California Department of Fish and Game
March 23-27, 1998 Prescott AZ	92	R.A. Ockenfels	Arizona Game and Fish Department
March 17-20, 2000 Kearney, NE	85	J.S. Abegglen	Nebraska Game and Parks Commission U.S. Forest Service, Nebraska National Forest

Section I.

Workshop Agenda

20th Biennial Pronghorn Antelope Workshop

Sunday evening, 17 March, 5:00-8:00 pm

5:00	Registration
6:00-8:00	Social (cash bar)

Monday morning, 18 March, 8:30-11:45am

8:00	Registration
8:30	Welcome to the 20th Biennial Pronghorn Antelope Workshop -- *Jeff Abegglen*, USDA Forest Service, Chadron, NE
8:35	*Don Bright*, Forest Supervisor, USDA Forest Service, Chadron, NE
8:50	*Jim Douglas*, Nebraska Game and Parks Commission, Lincoln, NE
9:05	Announcements, *Jeff Abegglen*, USDA Forest Service, Chadron, NE
9:15	**State Status Reports** -- *Mace Hack*, *Karl Menzel*, Nebraska Game and Parks Commission, Lincoln, NE
10:00-10:30	**BREAK** (sponsored by **North American Pronghorn Foundation)**
10:30	**Pronghorn horn sheath growth and age on a ranch in southern New Mexico** -- *David E. Brown*, Arizona State University, Tempe, and *David Verhelst*, Telonics, Inc., Mesa, Arizona.
10:55	**Fetal rates and sex ratios in three pronghorn populations in Wyoming** -- *Jason E. Zimmer and Fred G. Lindzey*, Wyoming Cooperative Research Unit, University of Wyoming, Laramie.
11:20	**Reintroduction and present status of pronghorn on the Carrizo Plain National Monument and surrounding area** -- *Alice J. Koch*, California Department of Fish and Game, Templeton, and *James D. Yoakum*, Western Wildlife Consultants, Verdi, Nevada.
11:45-1:30	**BREAK FOR LUNCH** (on your own)

Monday afternoon, 18 March, 1:30-4:00pm

1:30 **A pronghorn meta-population in northern Arizona** -- *Richard A. Ockenfels, Lindsey M. Monroe*, Arizona Game and Fish Department, Phoenix, *Leander W. Luedeker*, Arizona Game and Fish Department, Flagstaff, and *Susan R. Boe*, Arizona Game and Fish Department, Phoenix.

1:55 **Pronghorn range expansion in Middle Park, Colorado** -- *Thomas M. Pojar, Bob Thompson*, Colorado Division of Wildlife, Kremmling, *Chuck Wagner*, Colorado Division of Wildlife, Monte Vista, and *Perry Handyside*, Blue Valley Ranch, Kremmling, Colorado.

2:20 **Genetic distinction of the Sonoran pronghorn antelope** -- *Catherine L. Malone*, Department of Forestry and Natural Resources, Purdue University, West Lafayette,Indiana, *James C. Devos, Jr.*, Arizona Game and Fish Department, Phoenix, *James R. Heffelfinger*, Arizona Game and Fish Department, Tucson, and *Olin E. Rhodes, Jr.*, Department of Forestry and Natural Resources, Purdue University, West Lafayette,Indiana.

2:45–3:10 **BREAK**

3:10 **First steps toward the assisted reproduction of pronghorn in Mexico** -- *Jorge Cancino*, Centro de Investigaciones Biológicas del Noroeste, La Paz, Baja California Sur, México, and *Rich Guenzel*, Wyoming Game and Fish Department, Laramie.

3:35 **A bestiary of ancestral Antilocaprids** -- *James R. Heffelfinger*, Arizona Game and Fish Department, Tucson, *Bart W. O'Gara*, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, *Christine M. Janis*, Department of Ecology and Evolutionary Biology, Brown University, Providence, Rhode Island, and *Randall Babb*, Arizona Game and Fish Department, Mesa.

Tuesday morning, 19 March, 8:30-11:50am

8:30	**Vegetation health relative to pronghorn health** -- *James D. Yoakum*, Western Wildlife Consultants, Verdi, Nevada.
8:55	**Sonoran pronghorn habitat use and availability on a military range** -- *Paul R. Krausman*, University of Arizona School of Renewable Natural Resources, Tucson, *Lisa K. Harris, Sarah K. Haas, Kiana Koenen, Pam Landin, Jennifer Leverish, and Dean A. Whittle*, Harris Environmental Group, Inc., Tucson, Arizona.
9:20	**Effects of winter range on a pronghorn population in Yellowstone National Park** -- *Sylvanna J. Boccadori and Robert A Garrott*, Department of Ecology, Montana State University, Bozeman.
9:45-10:10	**BREAK** (sponsored by **Advanced Telemetry Systems**)
10:10	**Winter precipitation and pronghorn fawn survival in the Southwest** -- *David E. Brown*, Arizona State University, Tempe, *Ray Lee*, Contract Biologist, Cody, Wyoming, and *Harley G. Shaw*, Hillsboro, New Mexico.
10:35	**Choice of fawning areas and fawn bedsites with respect to vegetation structure and land use in northwest Nebraska** -- *W. Sue Fairbanks and Patricia L. Stastny*, Department of Biology, University of Nebraska at Omaha.
11:00	**Using range manipulations to increase pronghorn carrying capacity**. *Anis Aoude and Rick E. Danvir*, Deseret Land and Livestock, Woodruff, Utah
11:25	**Pronghorn use of shade**. *James D. Yoakum*, Western Wildlife Consultants, Verdi,Nevada.
11:50-1:30	**BREAK FOR LUNCH** (on your own)

Tuesday afternoon/evening, 19 March, 1:30-4:30pm

1:30 **Distribution of pronghorn before and after development of recreational trails in Antelope Island State Park, Utah** -- *Randy Tullous and W. Sue Fairbanks*, Department of Biology, University of Nebraska at Omaha.

1:55 **Motor vehicle associated mortality in an urban pronghorn herd** -- *Thomas Smith*, U.S.Army Corps of Engineers, Champaign, Illinois.

2:20 **Pronghorn antelope on California's central coast: potential highway impacts and proposed mitigation** -- *David G. Hacker*, California Department of Transportation, San Luis Obispo.

2:45 **Pronghorn use of modified fences in northern Arizona** -- *Cindy L. Ticer, James C. Devos, Jr.*, Arizona Game and Fish Department, Phoenix, *William Cordasco*, Babbitt *Ranches, Inc.*, Flagstaff, Arizona, and *Richard A. Ockenfels*, Arizona Game and Fish Department, Phoenix.

2:45-3:15 **BREAK**

3:15-4:30 **General Discussion** – *Mace Hack*
- Fencing/roads and pronghorn
- Other topics of interest

6:00 **Social** (cash bar)

6:30 **Banquet**
- Buffet
- Entertainment provided by Patent Pending barbershop quartet
- Awards

Wednesday morning, 20 March, 8:30-12:00 am

8:30 – 12:00 Business meeting.

Adjourn

Section II.

Pronghorn State and Province Status Report: 2001

Mace A. Hack, Ph.D., Chief - Research, Analysis, and Inventory Section, Nebraska Game & Parks Commission, 2200 N. 33rd Street, Lincoln, NE 68503-0370

Karl Menzel, Big Game Program Manager*, Nebraska Game & Parks Commission, 524 Panzer Street, Bassett, NE 68714-0508 (*retired 2002)

Abstract:

Standardized surveys sent to all range states and provinces in the United States, Mexico, and Canada asked about hunting seasons, population surveying, management philosophies and activities, and active research. Survey return rate was nearly perfect. Population estimates indicate that only 5 range states host over 85% of the global pronghorn population. Seventeen of 19 states/provinces allow firearm hunting of pronghorn; 16 have special seasons for archery hunting, but only 7 have muzzleloader seasons. Hunting opportunity for nonresidents of a state/province is generally limited. Firearm kill in 2001 decreased substantially when compared with ten years prior.

Introduction:

Standardized questionnaires similar to those used in previous survey years were sent in the winter of 2001 to all states and provinces in Canada, the United States, and Mexico that are known to harbor free-ranging pronghorn populations. Data were returned for all 16 range-states in the USA, both Canadian range-provinces, but only Baja California Sur in Mexico. Following the Workshop in March 2002, a supplemental survey was sent to all previous respondents to clarify responses on several topics, including population estimates, population survey methods, and harvest estimation methodology. Twelve of 19 original respondents returned their supplemental surveys, and subsequent communication provided at least population estimates for all 19 states and provinces. For hunting season data, less than half of the states and provinces reported kill figures and hunter numbers from the season most recently ended (2001); others reported data from one (2000) or two (1999) seasons prior.

Population survey methods:

Because states and provinces vary widely in the methods they use to survey their pronghorn populations and the detail with which they have reported these methods, it is difficult to summarize and compare methods in a concise form. Below are short descriptions of methods used by each state/province with **bolding** to highlight comparable features. Almost all states/provinces conduct aerial surveying to sample population sizes in at least parts of the range, and they also collect sex and age class data either by air or ground surveying. Very few employ population modeling to produce rangewide population estimates.

Alberta – **Aerial strip** transects (1/2 mile width) are conducted by **helicopter** during the **post-fawning period June-August**. A subset of **fixed, evenly distributed blocks** in each of 8 management areas are surveyed so that approximately 20% of the pronghorn population is observed per year. Funding determines how many blocks are surveyed per year, but every block is surveyed at least once every two years. Strip transect totals are used to

extrapolate up by **habitat type** to estimate total population size in the province. Buck, doe, and fawn ratio data are obtained. Alberta staff **do not consider current methods satisfactory** since they do not provide any basis for statistical precision testing nor do they account adequately for habitat and potential use differences across fixed survey blocks.

Arizona – A variety of **aerial** surveys are conducted using **fixed-wing** aircraft, including **strip transects, line transects, targeted searching/counting, and random searching/counting**. Surveys generally occur annually during the **post-fawning period June-August**, and result in an estimated 50-70% of the population being observed per year. The entire range is covered every 2-3 years. **Ground** surveys also are conducted in **targeted concentration areas**. Buck, doe, and fawn ratio data are obtained. **Population modeling** (POP II) assists in population estimation. Staff did not comment on their satisfaction with these methods.

Baja California del Sur – A combination of aerial and ground surveys are used to estimate population size in this state.

California – **Aerial fixed-wing** and **helicopter** surveys during the **winter** are focused in northeastern California where in excess of 90% of the population is observed. **Complete counts** are conducted annually within pre-set polygons. Staff are **satisfied** with methods used in the northeast, but survey methodology in the rest of the state is less rigorous.

Colorado – **Aerial strip transects, line transects, and targeted searching/counting** surveys are conducted annually by **fixed-wing** aircraft and **helicopter**. Surveys occur in both **pre-fawning March-May** and **post-fawning June-August** periods. The percentage of the state's population observed each year varies but the entire range is covered every 3 years. Buck, doe, and fawn ratio data are obtained. **Population modeling** assists in population estimation. Staff are **satisfied** with these methods.

Idaho – **Aerial helicopter** and **fixed-wing** surveys of quadrats are conducted in scattered areas on an irregular basis. Both **line transect** and **targeted searching/counting** methods are used during the **post-fawn June-August** period. Buck, doe, and fawn ratio data are obtained. The whole range has not been surveyed to date (2001). Staff are **not satisfied** with these methods and see a need for a standardized technique to be applied on a regular basis throughout the whole pronghorn range in the state.

Kansas – **Aerial fixed-wing line transect** surveys are conducted during **winter**. An estimated 60-75% of the population is observed per survey. Staff are **satisfied** with these methods but their line transect methodology could be refined and detection rates quantified.

Montana – **Aerial fixed-wing** surveys are conducted with complete coverage on 1-mile **transects. Spot checks** of core habitats are also conducted. It is unknown what percentage of the population is observed per survey. Statewide population estimates are not obtained from these surveys, but data collected allow some trend estimation. Staff are **satisfied** with these methods.

Nebraska – **Aerial fixed-wing line transect** surveys are conducted annually in the **pre-fawning period March-May**. The 4 (of 9 total) management units with the highest pronghorn densities are covered, and approximately 25% of the population is observed per survey in the these units. Aerial fixed-wing **counts** in a few additional targeted areas are conducted in **winter** to count animal concentrations. **Ground** surveys are conducted annually in the **post-fawning June-August** period to obtain buck, doe, and fawn ratios. In some winters, ground surveys are also used to count animal concentrations in targeted areas. Staff are **not satisfied** with aerial line transect surveys due to insufficient observations in many areas, poor model fit, and low confidence in population estimates. The entire range in the state has not been surveyed to date (2001) since there are too many low density areas to make surveying economical.

Nevada – **Aerial helicopter** and **ground** surveys are conducted annually in the **fall post-harvest** period. **Targeted searching** for herds (40% by helicopter, 60% by ground) in concentration areas allows observation of 20-90% of the unit population per survey. Direct population estimates from survey results are not made, but buck, doe, and fawn ratios per herd are used in population models to estimate herd population size per unit. Staff are **satisfied** with these methods but time, logistical, and resource constraints are causing less aerial and more ground surveying.

New Mexico - **Aerial fixed-wing strip transect** surveys are conducted annually in the **pre-fawning period March-May**. The areas surveyed depend annually on available funding and landowner desires. Certain areas (e.g. ranches) are surveyed annually while others are done every 2-3 years; the entire pronghorn range in the state has not been surveyed to date (2001). Survey results are not used to develop statewide population estimates. Buck and doe ratio data are obtained. Staff are **satisfied** with these methods given that most pronghorn occur on private land and state management of these populations is limited.

North Dakota – **Aerial fixed-wing** surveys are conducted annually in the **post-fawning June-August** period. **Targeted searching and complete counting** (100% coverage) occurs in selected areas. Rotation of selected

areas leads to the entire range being surveyed every 3-4 years. An estimated 50-75% of the state's population is observed per survey. Staff are **satisfied** with these methods.

Oklahoma – Occasional **strip transect** surveys are conducted by **air** with **fixed-wing** aircraft in the **winter**. An estimated 50-60% of the total population is observed per survey. **Ground** surveys are used in **targeted concentration areas** in both **winter** and the **post-fawning period June-August**. Buck and doe ratio data are obtained. Staff are **satisfied** with these methods but surveys are done too infrequently to be useful.

Oregon – **Aerial** and **ground** surveys are used to determine **trends** in **winter** populations. Buck, doe, and fawn ratio data are obtained in late summer. No formal estimate for the state's total population is made. According to staff, use of a formal survey protocol would be an improvement but current funding levels prohibit its implementation.

Saskatchewan – **Fixed-wing aerial line transect** surveys of priority management units are conducted in early **June**. Only adult animals are recorded and approximately 15% of the population is observed per survey. In late **July**, **helicopter aerial** surveys are conducted to obtain buck, doe, and fawn ratio data. Staff are sufficiently **satisfied** with these methods to rely on them for future decisions on whether to open hunting specific units to hunting.

South Dakota – An **aerial spring** breeding population census is conducted using **line transect** methodology. Approximately 33% of the population is observed per survey. **Random ground counts** during the **summer and early fall** provide fawn and doe ratio data. Staff are **satisfied** with these methods given the current funding available for the program.

Texas – Annual **aerial strip transect** surveys are conducted with **fixed-wing** aircraft and **helicopters** in the **post-fawning period June-August**. **Ground** counts are also conducted during the same period in **targeted concentration areas**. Buck, doe, and fawn ratio data are obtained. The pronghorn's entire range in the state has not been surveyed to date (2001). Staff are **not satisfied** with these methods and are testing line transect survey methods.

Utah – **Aerial transect** surveys are conducted in **March-April** with **fixed-wing** aircraft. As estimated 60-70% of the population is observed per survey. Survey data are used primarily to detect trends rather than make precise population estimates.

Wyoming – Annual **aerial line transect** surveys are conducted with **fixed-wing** aircraft in the **pre-fawning period of May-June**. Specific units are surveyed every 2-3 years, providing observation of 50-70% of the population in these units. Surveyed units are rotated each year so that the entire range in the state is covered every 2-3 years. Buck, doe, and fawn ratio data are obtained annually by **fixed-wing aerial** surveying along **strip transects** and **ground** surveys along **fixed routes** during the **late summer and early fall**. Approximately 15-20% of the population is surveyed per classification survey. Modeling with POP II and DISTANCE assist in developing population estimates. Staff are **satisfied** with these methods.

Current population research efforts

Several states/provinces are currently conducting research on pronghorns.

- Alberta: update and better define winter ranges
- Arizona: nutritional and disease status of herds movements in response to barrier modifications
- Nebraska: habitat use, fawn survival, natal dispersal, adult movements
- North Dakota: fawn survival rates
- Oregon: evaluating genetic variability in Great Basin pronghorn herds
- South Dakota: review of current survey procedures and accuracy determination
- Texas: movement study involving fences and habitat components
- Wyoming: fawn survival in two areas of the state
  - fecundity rates, fetal sex ratios and adult doe health in 3 areas
  - movements and migrations north of the Green River (GPS collars)
  - behavior related to electric fencing

Population estimates per state or province as of 2001

Numbers given should be treated with caution since very few states or provinces census their pronghorn populations to produce accurate statewide total population estimates (see above). In some cases, numbers given are extrapolations from only limited surveying or educated guesses. Nevertheless, there is clearly a core population range (shaded) through the states of New Mexico, Colorado, Wyoming, South Dakota, and Montana. The population in this region accounts for 85% of the world's wild pronghorns. Wyoming alone accounts for 57% of the global pronghorn population.

Hunting season structure

The tables below generally illustrate the time window each year for hunting seasons in each state or province, by weapon type. This is meant as a rough guide since states and provinces are remarkably variable in how they structure their respective seasons. Shaded cells indicate when the season occurs but may be a poor indicator of the actual days open to hunting since, for example, a whole month may be shaded even though four individual management units open consecutively for only seven days each. Also, a cell may be shaded even if only one day that week was open to hunting.

All states and provinces with firearm seasons limit the number of licenses available.

Firearm 2001

State/Province	August	September	October	November	December	January	Total Days
Alberta							3 or 6*
Arizona							4 or 6*
Baja California del Sur			(no season)				
California							9
Colorado							7
Idaho							30
Kansas							4
Montana							29
Nebraska							16 and 62
Nevada							10
New Mexico							10
North Dakota							16.5
Oklahoma							8
Oregon							9
Saskatchewan			(no season)				
South Dakota							9
Texas							9
Utah							18
Wyoming							15 to 30

Note: cells refer to dates 1-7, 8-14, 15-21, 22-31 of each month, respectively

* 3 days for Trophy License, 6 days for Non-trophy License

Special firearm seasons:

Arizona has a 6-day junior season for bucks only, 9/27-10/2
California has a 4-day junior season, 8/24-27
Colorado has a "Ranching for Wildlife" 5-day season, dates variable
Nevada has a special 9-day season in some areas, 9/1-9
New Mexico has a "Mobility Impaired" 3-day season, 8/4-6
Oregon has a youth only 9-day season, 8/17-25
Utah has private land hunts in Cooperative Wildlife Management Units during a 61-day period in September and October

All states and provinces with muzzleloader seasons limit the number of licenses available.

Muzzleloader 2001

State/Province	August	September	October	November	December	January	Total Days
Alberta			(no season)				
Arizona							4 or 6*
Baja California del Sur			(no season)				
California			(no season)				
Colorado							9
Idaho							30
Kansas							8
Montana			(no season)				
Nebraska							16
Nevada			(no season)				
New Mexico							3
North Dakota			(no season)				
Oklahoma			(no season)				
Oregon							9
Saskatchewan			(no season)				
South Dakota			(no season)				
Texas			(no season)				
Utah			(no season)				
Wyoming			(no season)				

Note: cells refer to dates 1-7, 8-14, 15-21, 22-31 of each month, respectively

* 3 days for Trophy License, 6 days for Non-trophy License

All states and provinces with archery seasons limit available licenses, except for South Dakota, North Dakota, Nebraska, Kansas, and Idaho. Licenses are limited in only some management units in Colorado.

Archery 2001

Note: cells refer to dates 1-7, 8-14, 15-21, 22-31 of each month, respectively

* Closed in firearm units during firearm season

Special archery seasons:

Nevada has a 14-day season in one hunt area, 9/1-14

Hunting opportunity for nonresidents

Only North Dakota and Kansas prohibit nonresidents from pronghorn hunting with a firearm (rifle), but limited permit availability means that nonresidents constitute less than 10% of the firearm hunters in most states/provinces. Specific limitations on nonresidents take various forms. In Alberta, nonresident Canadians must hunt with a resident or commercial outfitter, while nonresident, non-Canadians can only hunt with an outfitter. California requires nonresidents to purchase special fund-raising or private land management permits, of which there are very few available; they cannot participate in the regular public hunt program. Several states limit the percent of regular permits available to nonresidents, including Idaho (10%), Montana (10%), Nevada (5%), New Mexico (22%), Oregon (3%), South Dakota (8%) provided population level exceeds a specified threshold, and Utah (10%). Nebraska allows residents to draw for permits prior to nonresidents, and there are rarely any permits left for nonresidents. Oklahoma requires nonresidents to have written landowner permission prior to registering for the hunt. Only Wyoming actively promotes firearm hunting by nonresidents – 49% of firearm

hunters were nonresidents in 2001 – through additional drawing periods, reduced price doe/fawn permits, and out-of-state advertising. Most states/provinces do not limit archery hunting opportunities for nonresidents.

Criteria used to set annual hunting seasons

Most states and provinces with hunting seasons cited, as expected, criteria relating to population viability, hunter opportunity, social tolerance of pronghorn-caused property damage, and social tolerance of pronghorn hunting as important in setting annual hunting season parameters. Differences arise among states/provinces in where the balance is struck between these often competing criteria. Although all states/provinces presumably solicit input from their publics, only three states (Colorado, Kansas, Nevada) specifically cited local advisory committees or constituent surveys to set pronghorn hunting season parameters.

One of the more apparent differences among states/provinces involves the trade-off between hunt or trophy quality and the number of people provided an opportunity to hunt. The map two sections below of sex bias in the annual firearm kill reflects this trade-off in part; buck-only hunting seasons limit hunter numbers, hunting opportunity, achieve no population control but can maximize trophy or hunt quality, while seasons that allow does and fawns to be hunted achieve the opposite ends. Some states/provinces reported that they specifically manage for trophies – Alberta, Arizona, California, Colorado, Texas, and Utah – while others specifically manage to maximize hunter opportunity – North Dakota, New Mexico, Nebraska, Oklahoma, Oregon, and South Dakota.

States/provinces may use specific buck population objectives to gauge annual hunting season parameters, particularly if they are managing for trophy quality.

Post-hunting season buck-to-doe ratio objectives:

Alberta	30:100 (9% of pre-season population)
California	24:100 (5-6% of post-season population)
Colorado	>30:100
Oregon	>25:100

Percent of pre-hunting season buck population targeted for kill:

Alberta	40%
Utah	15-20%
Wyoming (regular)	40-55%
Wyoming (trophy)	60%

Collection of hunting season data

States use a variety of means to quantify annual kill levels. Only three states indicated on their surveys that they have mandatory reporting, either through tag return (California) or carcass check-in (Nebraska, Oklahoma). Most states estimate hunting season parameters from mailed reporting cards, either sent with issued permits (Idaho, Kansas, Nevada, New Mexico, Texas) or mailed post-season (Arizona, North Dakota). Wyoming mails a survey to hunters after the season, but also follows this with a phone survey. Alberta and Colorado conduct post-season phone surveys only.

Relative annual kill and sex bias across states and provinces, 2001

Total annual kill (all weapons) is depicted as a percentage of estimated pre-hunting season population size. Four categories of shading are also used to compare the percentage of firearm kill composed of adult males: white 96-100%, light gray 81-95%, gray 65-80%, dark gray <65%. North Dakota, South Dakota, and Colorado achieved more population control through firearm hunting than most other states since they killed 14% or more of their total population in 2001 and approximately half of this kill was composed of does and fawns. Alberta, Arizona, California, and Texas achieved no population control through firearm hunting since they killed only bucks in 2001.

Annual kill comparisons: 1991 versus 2001

The three tables below compare hunting season parameters for firearm, archery, and muzzleloader seasons, respectively. In most cases, 2001 data are compared with 1991 data, although some states did not have 2001 data to report and consequently used the next closest year. Care must be taken in interpretation of these comparisons since examining two distinct periods 10 years apart is not the same as examining the trend over the same 10 years. For example, weather conditions rangewide or per state may cause a single year to deviate significantly from the 10-year trendline. For this reason, we have tried to highlight only large differences between the two sample years, reasoning that they likely indicate the true trend direction and not the results of a fluke year.

Firearm Season

Rangewide, total annual firearm kill has decreased substantially since 1991. Hunter numbers and hunter-days were down 37.9% and 50.6%, respectively, resulting in 61.9% fewer animals killed. Buck kill decreased by slightly less (50%) suggesting that relatively increased doe and fawn kill has compensated in part as total annual kill has declined. Hunter success rates have remained consistent, decreasing from a mean of 84% to 77%.

	Hunters		Bucks Killed		Total Kill		Hunter Days		Kill/100 Hunters	
State/Province	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
Alberta*	1,759	891	641	679	1,109	679	2,400	1,670	63	76
Arizona	574	465	442	369	442	369	1,225	920	77	79
California	905	184	475	146	725	146	na	na	80	79
Colorado*	10,114	11,911	4,113	3,702	7,073	7,156	14,871	19,420	70	60
Idaho*	3,510	1,300	1,610	750	2,790	1,025	9,600	8,200	79	79
Kansas	152	144	119	93	137	108	196	233	90	75
Montana**	71,693	34,851	21,463	na	42,732	na	130,447	na	60	na
Nebraska	366	894	326	470	326	603	1,800	1,800	89	67
Nevada	1,657	1,331	1,192	932	1,260	1,048	3,650	2,766	76	79
New Mexico **	4,288	3,483	na	2,847	3,787	3,106	na	5,200	88	89
N Dakota	3,173	1,030	1,602	400	2,812	880	6,092	2,163	89	85
Oklahoma*	33	67	25	36	30	52	na	na	91	78
Oregon	2,864	1,556	1,693	977	1,820	1,044	6,778	4,546	64	67
Saskatchewan	9,359	ns	3,060	ns	7,513	ns	27,910	ns	80	ns
S Dakota	7,138	6,634	4,895	2,661	7,542	4,656	12,100	12,075	106	70
Texas*	583	720	519	565	534	565	na	na	92	78
Utah*	1,574	750	610	453	1,383	591	2,402	1,624	88	79
Wyoming*	46,619	37,152	34,501	23,536	65,102	33,977	126,743	110,395	140	91
Totals	**166,361**	**103,363**	**77,286**	**38,616**	**147,117**	**56,005**	**346,214**	**171,012**	**88**	**84**

* Data for 2000

** Data for 1999

na: not available; ns: no season

Archery Season

Rangewide, total annual archery kill has not changed much since 1991. Hunter numbers decreased slightly by 7.6% but total hunter-days, total kill, and total buck kill all increased by 11.1%, 9.3%, and 17.6%, respectively. Archery hunting results in a total kill that is only 4% of the annual firearm kill, yet it provides 20% of the recreational opportunity that the firearm season provides. Success rates for archery hunters averages 26% rangewide.

	Hunters		Bucks		Total Kill		Hunter Days		Kill/ 100 Hunters	
State/Province	**1991**	**2001**	**1991**	**2001**	**1991**	**2001**	**1991**	**2001**	**1991**	**2001**
Alberta*	138	165	55	64	57	64	636	730	41	39
Arizona	678	536	46	82	46	82	3,000	3,156	7	15
California	105	8	25	3	31	3	na	na	30	38
Colorado*	1,085	2,351	197	304	242	333	5,232	2,351	22	14
Idaho*	175	772	36	150	47	180	880	3,790	27	23
Kansas	89	96	11	8	16	12	341	341	18	13
Montana	1,287	na	251	na	301	na	6,576	na	23	na
Nebraska	261	414	45	40	45	46	1,100	1,700	17	11
Nevada	252	192	51	41	51	41	1,032	589	20	21
New Mexico **	908	540	na	148	219	148	na	1,712	24	27
N Dakota	1,585	945	na	na	na	na	na	na	na	na
Oregon	427	458	36	76	36	86	1,961	1,918	8	19
Saskatchewan	373	ns	95	ns	107	ns	2,006	ns	29	ns
S Dakota	480	817	92	176	110	193	2,370	3,900	23	24
Utah*	107	87	30	49	30	49	448	430	28	56
Wyoming*	2,752	2,503	na	na	1,187	1,054	12,600	13,343	43	42
Totals	**10,702**	**9,884**	**970**	**1,141**	**2,525**	**2,291**	**38,182**	**33,960**	**28**	**26**

Muzzleloader Season

Ten-year comparisons of muzzleloader seasons are difficult given only a few states had seasons in both 1991 and 2001. Also, the number of hunters participating is low and thus more sensitive to the random factors affecting hunter participation.

	Hunters		Bucks		Total Kill		Hunter Days		Kill/ 100 Hunters	
State/Province	**1991**	**2001**	**1991**	**2001**	**1991**	**2001**	**1991**	**2001**	**1991**	**2001**
Arizona	608	93	55	61	55	61	441	214	9	66
Colorado*	ns	161	na	53	na	75	na	522	na	47
Idaho*	200	150	57	55	76	75	525	580	38	50
Kansas	ns	38	na	21	na	22	na	89	na	58
Nebraska	ns	154	na	87	na	87	na	450	na	56
New Mexico **	368	220	na	131	169	131	na	555	46	60
Oregon	48	113	4	27	5	31	261	462	10	27
Totals	**1,224**	**929**	**116**	**445**	**305**	**482**	**1,227**	**2,872**	**25**	**52**

* Data for 2000

** Data for 1999

na: not available; ns: no season

Predator control and recent translocations

Predator control (i.e. coyote removal) specifically for pronghorn populations occurs in several states/provinces (shaded), either directly by the state or through contracted services (e.g. USDA Wildlife Services. Predator control activities clearly occur in many other states/provinces but may not be specifically targeted for the benefit of pronghorns. Nevada notes that their limited coyote control has had no discernible benefit for pronghorn fawn ratios.

Recent translocations have been conducted between several states (arrows below), and three states have translocated animals from one region to another within state boundaries (Utah, Arizona, New Mexico).

Section III.
Technical Session

PRONGHORN HORN SHEATH GROWTH, AGE, AND PRECIPITATION ON A RANCH IN SOUTHERN NEW MEXICO

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Abstract: Pronghorn (*Antilocapra americana*) horn sheath length and mass decreased with age for a population in a semiarid area of southern New Mexico. Horns of bucks 7 > years were significantly smaller than younger animals ($P < 0.03$). Considering the effects of pronghorn age alone, sheaths of hunted animals decreased by an average of 0.28 cm (0.11 in) of length and 0.53 Boone and Crockett (B&C) points for every year of age. Winter rain (October through March) during the year prior to a hunt exerted a significant negative effect on B&C scores but not on sheath length. For B&C scores, age remained a significant predictor after the negative effects of increased winter rainfall had been accounted for statistically.

Key words: pronghorn, horn size, pronghorn age, precipitation and horn development.

The Southwest, especially Arizona, is well known for the trophy quality of its pronghorn. Conventional wisdom has been that horn growth and development is a function of age, nutrition, genetics, and possibly the length of the growing season. Biologists have generally assumed that maximum horn growth occurs during the first 4 or 5 years, after which the size of the deciduous sheaths increases at a slower rate (e.g., Kitchen and O'Gara 1982). This view was questioned, however, in 1985 when a new record book pronghorn was taken in Arizona. The cementum annuli of this buck's incisors indicated him to be only 3-4 years of age, even though the buck measured 94.6 B&C points (Lewis 2000).

Only 3 studies of pronghorn horn growth have been conducted, the most recent being on the Fort Belknap Indian Reservation in Montana, in which 85 animals were aged over an 8-year period (Mitchell and Maher 2001). Those authors found that pronghorn attained adult-sized horns when 2 or 3 years old, and that these two age classes contained the largest horn measurements. To gain a better understanding of the relationship between pronghorn age and horn growth in the Southwest, we measured and aged a series of bucks taken in southern New Mexico between 1994 and 2002.

STUDY AREA

Our study area was the privately owned Armendaris Ranch, a former land grant, now managed by the Turner Corporation. Most of the ranch resides at elevations between 1375 and 1525 m, and the mean annual precipitation is < 25 cm. Approximately 74,600 ha (ca. 52%) of the ranch are classified as pronghorn habitat, in which the primary vegetation is semidesert grassland populated by such grasses and shrubs as black grama (*Bouteloua eriopoda*) and palmilla (*Yucca elata*) (Brown 1994). Most of the remaining vegetation is Chihuahuan desert scrub and the climate is warm-temperate with an average of 213 frost-free days per year (Truth or Consequences, NM). Bison (*Bison bison*) are the only permitted grazing animals, other large herbivores being restricted to free-roaming gemsbok (*Oryx gazella*), mule deer (*Odocoileus hemionus*), and desert bighorn sheep (*Ovis canadensis*). Most wildfires are allowed to burn.

The pronghorn population is subject to climate-induced variation but was estimated to number more than 1,000 animals in 2000. Pronghorn hunting on the Armendaris Ranch since 1994 has been extremely conservative with the combined harvest of archers in late August and rifle hunters in September never exceeding 20 bucks in any given year (Table 1). Hunters are guided to the best areas and hunt success is usually 100% with hunters allowed to take as large an animal as desired.

METHODS

Hunter-killed pronghorn were measured in inches by 2 outfitter-guides according to Boone and Crockett record book scoring procedures (Lewis 2000). Of the measurements taken, we only used the length of the longest horn sheath and the total Boone and Crockett score, the latter to provide a measurement of horn sheath mass. Incisors were taken from each pronghorn harvested and sent in a labeled manila envelope to Matson's Laboratory in Milltown, Montana, where the teeth were sectioned and aged according to the number of cementum annuli (McCutchen 1969). Although the animals selected and the horn measurements were biased in that hunters usually took the largest animal available to them, this bias tended to be the same each year. Also, because the number of animals harvested was highly conservative, we assumed that the harvest of individual bucks in any given year had little impact on either the selection or size of animals taken in subsequent years.

We quantified horn sheath growth in 2 ways, "Horn Length" and "Boone and Crockett Score" (BCS), and conducted all of the analyses described below independently for each measure of horn size. We considered two periods of rainfall that might conceivably influence horn sheath growth: 1) "Summer Rain" (April-September) immediately prior to the hunting season in which the animals were killed, and 2) "Winter Rain" (October-March) prior to the hunting season (Brown et al. 2002). We also built a composite variable by summing the 2 rain variables (yielding total rain in the full year prior to hunting season) for use in other analyses.

Initially, we treated pronghorn age as a continuous variable and used an analysis of variance or ANOVA to determine mean horn length and BCS differences between years and age classes at a significance level of $P < 0.05$. However, a parallel effort in which we treated pronghorn age as a series of binary categorical variables, aggregating individuals at or below a particular age threshold, and contrasting their horn growth patterns with those of all older individuals, yielded entirely comparable results.

Relationships between rainfall and pronghorn horn growth were assessed using multiple regression (using GLM, Systat). Our starting point in all analyses was a fully saturated model with both seasonal rain variables and pronghorn age as predictor variables. If any predictor variables were not significant, we then used backward stepwise elimination to reduce the GLM model (1 variable at a time) to 1 in which all of the remaining predictor variables were significant. We also tested for the effects of pronghorn age ignoring any contributions from rainfall and for any systematic change over time (i.e., effects of year sequence independent of age or rainfall).

RESULTS

Data were obtained on 100 pronghorn over a 9-year period (Table 1). Annual sample sizes varied from one in 1996 to 20 in 2000. Ages ranged from 2 to 14 with all year-classes being represented except 13 year-olds. Horn lengths varied from 33.02 to 42.81 cm (13.00 to 17.13 inches; horn length data were not kept in 1994) and BCS ranged from 63.75 to 89.63 points with a mean of 78.12. Twenty-three of the animals had a BCS of 80 points or more; only 4 of these bucks were >6 years old.

As was expected, pronghorn horn sizes and BCS varied by year and by age. Both measurements tracked closely together and showed that bucks 7 years and older were significantly smaller than animals between the ages of 2 and 6 ($P < 0.001$ for sheath length, $P = 0.023$ for BCS; Fig. 1).

Table 1. Pronghorn age and horn measurements in inches for Armendaris Ranch, 1994-2002

Year	No. of Bucks	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9yrs	10 yrs	11 yrs	12 yrs	13 yrs	14 yrs	Mean Horn Length	Mean B&C[1] Score
1994	6		2	4												74.75
1995	8			6	2										15.11	76.15
1996	1					1									15.13	77.77
1997	10			1	3	2	1		1	1				1	15.75	81.93
1998	12		2	2		3	1		2	1		1			15.34	78.2
1999	9	1		1	3	2		1		1					15.56	80.42
2000	20	1	3	5	6		2	1			1	1			15.39	81.56
2001	17		1	5	1	3		2	1	2	2				15.02	74.17
2002	17	2		4	6	2	1	1		1					14.93	76.7
Total	100	4	8	28	21	13	5	5	4	6	3	2		1		
Mean B&C Score		76.7	79.9	77.3	79.7	78.5	77.6	78.1	74.2	74.3	72.3	70.9		76.7		
Mean Horn Length[2]		15.9	16.2	15.3	15.6	15.7	14.6	15.0	14.7	14.6	14.4	14.0		16.4		

[1]B&C: Boone and Crockett Score
[2]Excludes individuals from 1994

Ignoring any effects of rainfall, pronghorn age was a significant predictor of both sheath length and BCS in regression analyses ($P = 0.005$ and $P = 0.009$, respectively). On average,

pronghorn sheaths from harvested bucks decreased by 0.11 in of length and 0.53 B&C points for every year of age (Fig. 2).

Fig. 1. Mean (+/- SE) maximum horn sheath length and BCS by age class for pronghorns taken on the Armendaris Ranch in southern New Mexico 1994-2002.

Fig. 2. Pronghorn BCS as a function of age for bucks taken on the Armendaris Ranch in southern New Mexico 1994-2002.

When the effects of rainfall (see Brown et al. 2002) were examined, multiple regression analyses using backward stepwise elimination resulted in a model for BCS that included both winter rainfall and age as significant predictors ($P < 0.02$ and $P < 0.03$, respectively). On average, every inch of winter rain decreased pronghorn BCS by 0.63 points whereas every year of age >2 corresponded to a 0.44 decrease in BCS. For horn sheath lengths, we detected no significant effect of any rainfall pattern and only age was a significant predictor ($P < 0.006$). On

average, every year of age corresponded to a 0.28 cm (0.11 inches) decrease in horn sheath length. We found no significant effects of year sequence in any analysis.

DISCUSSION

Based upon BCS from hunter samples, the mean size of pronghorn horn sheaths decreased with age. Horn sheaths of animals at least 7 years old were significantly smaller than those of animals aged 2 to 6. At least some animals attained large horn sheaths at an early age (2 to 3 yrs). This decline in horn sheath length and mass in older animals is in sharp contrast to such bovids as bison and bighorn sheep that do not shed their horn sheaths (Kitchen and O"Gara 1982).

A possible concern with the methodology of this study is that the animals used to determine the dependence of horn size on age were not a random sample. Instead they were harvested, at least in part, because they possessed large horns. Theoretically, this kind of repeated harvesting bias in favor of pronghorn with large horns could generate a relationship where horn size decreased with age. In other words, if animals within a population kept the same relative horn sizes from 1 year to the next, and if the largest animals were killed each year, then the animals that reached old age would tend to be those with smaller horns. Such selectivity may contribute to the patterns we document, but, for several reasons, we do not believe they account for the entire relationship. First, the Armendaris Ranch population is hunted conservatively, with only a small fraction of the animals killed in a given year. Second, due to herd dispersion and variable encounters with hunters, size selectivity will be imperfect, with many large-horned individuals of a given age surviving to the next season. Third, we believe that horn size is likely to vary within individuals across years due to the vagaries of resource acquisition; and fourth, there is no evidence of declining horn length or BC scores over time (Lewis 2000, this study).

Because maximum horn size can be attained at an early age, and if bucks > 6 years of age exhibit declining horn sheath measurements, there would be little incentive to manage for older age animals if trophy bucks are a primary management goal. Nonetheless, it remains to be seen if a population consisting primarily of young pronghorn bucks is a desirable management goal from the standpoint of population growth or behavior in that the influence of pronghorn age on social status and reproductive function is not yet fully known (Lee et al. 1998).

Horn sizes also varied as a function of rainfall, as they did in Montana (Mitchell and Maher 2001). In particular, there was also a significant negative dependence on precipitation over the preceding October through March, but only for horn sheath length, not the BCS, which is an indicator of mass. The reasons for these relationships are unclear, and appear contradictory. Horn growth presumably takes place from before the time that the old horn sheaths are shed in November until some time the following summer, perhaps even up until the time that the buck is harvested. Hence, the preceding winter rainfall and the preceding summer precipitation should both have a positive effect on the production of nutritious forage with a corresponding increase in horn growth and size. The negative effect of rainfall on horn growth is therefore something of an enigma, because winter rainfall has been shown to have a positive effect on fawn survival on the Armendaris Ranch and elsewhere (Brown et al. 2002). We will continue this study in future years to determine if this negative relationship is true or merely an artifact.

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FETAL RATES AND SEX RATIOS IN THREE PRONGHORN POPULATIONS IN WYOMING

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Abstract: It is generally assumed when modeling pronghorn (*Antilocapra americana*) populations that females > 1 year produce 2 fawns and that the fawn sex ratio at birth is parity. Data to support these assumptions are limited, however. We examined 120 pronghorn collected in mid-May of 2000 and 2001 to estimate fetal rates and fawn sex ratios at birth. Twenty female pronghorn were collected each year near Cheyenne (CH), Gillette (GT), and Shirley Basin (SB), Wyoming. Collected pronghorn were weighed and their age estimated by counting cementum annuli. We counted, sexed, measured, and weighed each fetus. Fetal rates (number of fetuses per female > 1 year) were 1.93, 1.84, and 1.83 in CH, GT, and SB, respectively, in 2000. Mean fetus weights were 1.8, 3.0, and 1.8 kg, respectively, in these populations. Fetal sex ratios (male fetuses: female fetuses) were 42:50, 73:50, and 59:50 in the 3 populations. Mean age of females collected in the 3 populations in 2000 was 5.6, 6.0, and 4.6 years. Fetal rates in 2001 were 1.92, 1.69, and 1.73, and mean fetus weights were 1.9, 2.5, and 2.2 kg, respectively. Fetal sex ratios were 73:50, 57:50, and 45:50 in 2001. Mean age of females collected in 2001 from the 3 populations was 6.4, 5.4, and 5.4 years. Although sample sizes were small, fetal rates varied among populations and between years and averaged 1.84 when all collected females were combined. Assuming 2 fawns are born for each female > 1 year of age may lead to an overestimate of fawns produced in many populations. Sex ratio of combined fetuses (57:50, n=212) did not differ from parity.

Key words: pronghorn, *Antilocapra Americana*, sex ratio, fetus weight, fetal rates, fawn production, twinning.

REINTRODUCTION AND STATUS OF PRONGHORN ON THE CARRIZO PLAIN NATIONAL MONUMENT AND SURROUNDING AREAS IN SOUTHERN CALIFORNIA

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Abstract: Pronghorn were re-established on the Carrizo Plain National Monument and surrounding rangelands in southern California during 1987, 1988 and 1990. Population surveys for the last 15 years indicate certain herds have increased while others have decreased. Various ecological factors have been identified as affecting herd numbers, e.g., agricultural plantings, livestock foraging, wire fences, nutritious forage, drinking water, predation, collision with vehicles and others. A comparison of herd numbers for different ecological sites is provided. Recommendations for management strategies and needed research are listed with a goal of increasing healthy pronghorn populations.

Key words: *Antilocapra americana*, California Department of Fish and Game, Carrizo Plain National Monument, climate, endangered species, ecological factors, Fort Tejon Ranch, livestock foraging, mortality factors, nutrition, predation, pronghorn, The Nature Conservancy, U.S. Bureau of Land Management, vegetation status.

Pronghorn (see Appendix A for scientific names) are native to southern California, including the Carrizo Plain region (McLean 1944). Herds were abundant and widespread prior to the 1700s, however, they were extirpated during the early twentieth century. Translocations were conducted from 1987 to 1990 by the California Department of Fish and Game (CDF&G) to federal, state and private lands in San Luis Obispo, Kern, and Los Angeles counties in southern California. Estimated numbers for 2002 indicated certain habitats produced low pronghorn densities. These conditions prompted field investigations to ascertain reasons for current low numbers.

Few reports were available regarding pronghorn in southern California. Food habit studies have not been accomplished; consequently, diet composition or preference ratios, as well as forage competition with native and domestic herbivores remain unknown. The foraging interactions between pronghorn and endangered small herbivores (e.g., giant kangaroo rat, San Joaquin antelope squirrel) are of particular interest and warrant investigation. Delineation of crucial habitats for pronghorn is incomplete. Mortality factors appear numerous, but their relative influence on pronghorn numbers has not been quantified. The effects of climatic patterns influencing vegetation production important to pronghorn are unclear.

The objectives of this report are: 1) to provide a comprehensive review of the present status of pronghorn populations on the Carrizo Plain National Monument (CPNM) and surrounding rangelands in southern California, 2) to assess current habitat conditions and document environmental factors influencing pronghorn production and survival, and 3) to recommend

management practices, including basic research, to enhance pronghorn habitat conditions on private, state and federal lands.

DESCRIPTION OF PRONGHORN HABITATS

Small, isolated herds presently occupy habitats in the California Valley and the CPNM on the Carrizo Plain, Camatta and Jack Ranches near Cholame, and the Fort Tejon Ranch, Tehachapi (Fig. 1). Most populations inhabit private land except for herds on federal and state land on the CPNM.

The CPNM was originally named the Carrizo Plain Natural Area (CPNA), and was established through purchases of private ranches by The Nature Conservancy (TNC), U.S. Bureau of Land Management (USBLM) and CDF&G. Some private land holdings still exist within the CPNM, which encompasses approximately 250,000 acres (101,175 ha). The area was designated the CPNM by president William Jefferson Clinton on 17 January 2001 (Clinton 2001). One of the Monument's primary objectives is the protection and restoration of native flora and fauna, including pronghorn.

The Monument is located in south central California between Bakersfield and San Luis Obispo (Fig. 1). Elevations on the Plain range from 2,000 to 2,500 feet (610 to 762 m), and it stretches for some 50 miles (80 km). It is bordered on the northeast by the Temblor Mountains rising over 4,000 feet (1,219 m), and on the southwest by the Caliente Mountains towering over 5,000 feet (1,524 m). Plant communities include valley saltbush scrub, valley sink scrub, iodine bush scrub, non-native grasses and forbs, upper Sonoran subshrub scrub, interior coast range saltbush scrub, juniper/oak woodlands (U.S. Bureau of Land Management, California Department of Fish and Game and The Nature Conservancy 1996--hereafter cited as USBLM, CDF&G, and TNC 1996). The indigenous common reedgrass, for which early Spaniards named the "Carrizo" Plain, apparently has not been observed on the Plain recently.

Endangered, threatened or potential candidate animals for federal and state listings living on the Plain include the blunt-nosed leopard lizard, San Joaquin kit fox, giant kangaroo rat, San Joaquin antelope squirrel, California condor and 11 other animals. The rare California condor has used the Plain as a foraging site for centuries. Tule elk and pronghorn were recently reintroduced. Winter brings hundreds of sandhill cranes, shore- and marshbirds to Soda Lake. Many raptors and songbirds are found throughout the area.

Climatic characteristics include annual precipitation averages of 8 to 10 inches (20 to 25 cm) obtained primarily from December to February (Fig. 2). Winters are cold, often below freezing. Hot, dry summers experience temperatures exceeding 100 degrees F (37 degrees C). Summer rains are unusual.

Pronghorn habitats surrounding the CPNM have similar climatic patterns as the Monument. Wild plants and animals are also similar, however, endangered/threatened species are generally less abundant and habitats are more restricted. Land status is predominantly private ranches and farms.

Fig. 1. Location of the Carrizo Plain National Monument and adjacent rangelands in southern California.

Fig. 2. Amount of precipitation received annually, 1992-2001, for the Carrizo Plain National Monument. Data from Western Regional Climate Center, Desert Research Institute, Reno, Nevada.

PRONGHORN HISTORY AND CURRENT STATUS

According to Newberry (1855), pronghorn were possibly most numerous in the Central Valley of California when Europeans arrived in North American. For the Carrizo Plain, a rancher remembers his father telling stories about pronghorn herds numbering hundreds at the north end of the Plain. There were so many that they were often shot for recreation (Robert Lewis, personal communication). McLean (1944) noted none in southern California by the 1940s--evidently herds had been extirpated.

Pronghorn were reintroduced to the Carrizo Plain and surrounding areas in a series of releases: the first in 1987, followed by augmentation in 1988 and 1990 (Pyshora 1982). Animals were obtained from the shrub-steppes of northeastern California. Current pronghorn numbers on the CPNM are estimated to be less than originally released (Fig. 3), an indication the translocation endeavors were not particularly successful according to O'Gara and Yoakum (In Press). The CPNM apparently has not been a quality habitat for pronghorn during the past 15 years according to Yoakum (2001, 2003).

Fig. 3. Estimated pronghorn populations for the Carrizo Plain National Monument, 1990-2003.

Standard capture and transportation methods (Lee et al. 1998) were used during the reintroduction. Animals were herded by helicopter into a circular pen corral trap. Bucks were tagged, collared, vaccinated and put into transport crates, thus separating horned animals capable of injuring other animals. Does and fawns were loaded into burlap darkened stock trailers, and all animals were immediately transported approximately 600 miles (966 km) to southern California. Does and fawns were processed and placed in temporary holding pens with bucks. Following the first release, animals scattered and many did not regroup. For subsequent releases, pronghorn were held in holding pens for approximately 24 hours, thereby giving the animals an opportunity to settle down. Some animals took up to 20 minutes to leave the holding pen after the gate was opened. The

animals appeared to have been more calm and stayed grouped after release with this gentle release technique (Jim Lidberg, CDF&G wildlife biologist, personal communication).

The reintroduced herds have freely roamed southern California for more than 15 years. Population surveys were not conducted routinely during early years, however aerial counts have been accomplished annually since 1999 (Fig. 4). Fawn recruitment data also has been collected. Recent surveys indicate fawn:doe ratios are greater on private lands in California Valley than on nearby government lands. These differences may be related to greater availability of nutritious forage and/or the possibility that ground predators are hunted more intensively on private lands than on government lands.

Fig. 4. Recommended specifications for 3-strand wire fence on rangelands managed for pronghorn and livestock (Lee et al. 1998, Yoakum and O'Gara 2000).

Some of the original translocated animals on the Carrizo Plain subsequently dispersed to surrounding areas and established satellite herds. These herds occupy private lands, some of which have been plowed and seeded to dryland grain crops, and at times produce abundant forbs (filaree, morning glory, mustard, etc. relished by pronghorn). These private rangelands are foraged annually by cattle and domestic sheep. County and state roads are numerous, but towns do not exist.

Hunting of pronghorn has been permitted by the CDF&G on the Plain. Bucks only were harvested from 1996 to 2001. Allocation of tags was decreased as herds decreased. The hunting season was suspended in 2002 because of declining populations.

A group of 51 pronghorn was released on the 270,000-acre (109,269-ha), private Fort Tejon Ranch during 1985, and augmented with another 42 in 1987. The ranch is within sight of the CPNM. These pronghorn experience the unique distinction of being located as close as 50 miles (80 km) to 17 million humans in Los Angeles, which is the second largest city in the United States. The Fort Tejon (Spanish for badger) Ranch is a land grant from the days when California was under the jurisdiction of Mexico. Vegetation is generally in healthy condition on the Tejon Ranch with an abundance of native grasses, forbs, and shrubs. Vegetation transects using a modified step-point method (Evans and Love 1957) were conducted on pronghorn habitats (Table 1). Populations of wild native pronghorn, Rocky Mountain elk, mule deer, black bear and exotic wild pigs are sustained. In addition, cattle and domestic sheep forage rangelands. An attribute of the Ranch's ability to maintain healthy vegetation conditions is its effective management program of sustainable harvesting of wild and domestic ungulates. Periodic surveys of pronghorn are conducted and relatively stable populations are maintained (Don Guivet, wildlife manager Fort Tejon Ranch,

personal communication.) This is an example of private land management effectively controlling wild and domestic ungulates while maintaining vegetation in healthy condition. Unfortunately, current efforts to develop this property may change the status of natural resources over the next decade.

Table 1. Vegetation transects conducted during May 2001 for pronghorn habitat on the Carrizo Plain National Monument and the Fort Tejon Ranch in southern California.

Transect Reading	Carrizo Plain National Monument (Painted Rock)	Fort Tejon Ranch (Berrendo Flats)
Vegetation:		
Grasses	46	21
Forbs	38	44
Shrubs	0	19
Total Vegetation	84	84
Abiotic Factors:		
Bare Ground	16	15
Rock	0	1
Total Abiotic Factors	16	16
Average height of vegetation	13" (33 cm)	25" (63 cm)

ECOLOGY AND ENVIRONMENT

Vegetation Quality and Nutrition

Quality vegetation for pronghorn includes maintenance of adequate plants to provide concealment cover for neonates from predators, and sustaining quality and quantity of grasses, forbs and shrubs for forage (Yoakum 2001, 2003). Cover for neonates requires clumps or patches of vegetation at least 12 to 15 inches (30 to 38 cm) high during parturition and lactation--April through June (O'Gara and Yoakum, In Press).

Quality forage includes preferred, succulent and nutritious grasses, forbs and shrubs for all seasons. The need for nutritious forage is especially critical during the third trimester of pregnancy and lactation. It is during lactation that does have the highest nutritional requirements, for they need adequate quality forage to maintain health, and at the same time, produce sufficient milk to sustain healthy fawns. If adequate forage is not available for the does during these seasons, neonate survival decreases, thus affecting recruitment and herd numbers.

Sustaining adequate cover and forage for pronghorn is directly related to maintaining healthy and abundant herds (Yoakum et al. 1995).

Vegetation communities containing a mixture of early, mid- and late succession plants serve pronghorn the greatest. A variety of succession stages for vegetation communities provide a greater diversity of plant species allowing pronghorn to choose plants with different nutritional values and succulence to meet physical requirements during all seasons of the year. Heterogeneous communities can lack this plant diversity (Yoakum and O'Gara 2000).

Natural disturbances, such as wildfire or flood, can bring changes in vegetation favoring forage production for pronghorn (Lee et al. 1998). At the present time, USBLM has an aggressive program of suppressing wild fires as quickly as possible. This program needs to be re-evaluated to determine areas not in serious peril for loss of natural vegetation and zoned for natural plant succession. Such plant disturbance practices could be field tested on the Ecological Preserve Lands (located within the Monument) as well as on USBLM-administered lands.

Severely disturbed native vegetation communities may require restoration through rangeland seedings. Seedings have proven beneficial to pronghorn (Yoakum 1980, Kindschy et al. 1982, Aoude and Danvir, In Press). Successful seeding techniques for native and alien species are provided in Plummer et al. (1986), and Payne and Bryant (1998).

Although habitats appear to generally produce adequate forage on the Plain (Table 1), information is not available regarding the quality of vegetation. Studies in Oregon (Barnett and Crawford 1944) reveal certain forbs during the spring can have twice as much protein as grasses or shrubs. In Wyoming, Stone (2003) substantiated that pregnant and lactating deer need to obtain 17% protein from forage to produce sufficient milk to keep fawns alive. When forage is deficient in nutritional values, the female may abort her fawns or the fawns may become so weak at birth that they succumb. Also, the female can be so unhealthy that she produces milk for 2 or 3 weeks and then dries up--resulting in the fawns starving. Therefore, quality of forage can be linked to fawn:doe ratios and herd numbers (O'Gara and Yoakum, In Press).

Forage competition for herbivores, including endangered rodents and livestock, need investigation. Such data can be correlated with precipitation levels influencing forage diversity and production. Installation of permanent, large enclosure plots can help provide long-term vegetation condition and trend information as well as forage utilization by various species (Yoakum et al. 1995).

Vegetation communities in crucial habitats need to be managed to simulate natural disturbances. This would in turn provide changing forage production and species diversity that could be correlated with changes in pronghorn trends (O'Gara and Yoakum, In Press).

During the summer of 2002, severe drought conditions existed for pronghorn on the Carrizo Plain. Because drought decreases herbaceous vegetation, thus contributing to low fawn survival, the CDF&G initiated a summer supplemental feed program. A review of the literature disclosed no reports pertaining to summer supplemental feeding for wild pronghorn. Consequently, an experimental program was commenced by providing fresh, green, cultivated alfalfa hay placed in metal troughs near water troughs. Pronghorn found the alfalfa stations and

began foraging within two days. They fed on the hay daily for the duration of the drought--over 3 months. When the first autumn rains arrived, grasses and forbs commenced growth, and just as quickly, the animals switched from supplied alfalfa hay to new, green, succulent herbaceous forage. Field investigations were made for mortalities during the summer and autumn, however, none were detected (Koch and Yoakum, unpublished data).

Food Habit Studies

Information is not currently available regarding dietary studies for native or domestic ungulates on the CPNM. Such data are needed for plant restoration, soil-moisture conservation, and forage allocations. A CDF&G investigation of pronghorn has been in progress by the authors for several years. A second study of pronghorn and cattle was initiated in 2003 (Longshore 2003).

Techniques for diet studies vary greatly, with microhistological analyses of feces currently being used the most frequently (Yoakum 1990). Findings are beneficial when obtained for various herbivores competing for preferred forage during years of differing precipitation patterns - especially years of less than average rain levels. Recent investigations suggest that climate-forage-pronghorn relationships may be the most important influence on fawn survival and population density (Hervert et al. 2000, Hansen et al. 2001).

Drinking Water

Natural waters are not abundant on the Plain. A few springs occur on the west side of the Monument. The CDF&G, with financial assistance from the Rocky Mountain Elk Foundation, developed a reservoir for wildlife. The reservoir catches and retains water in a pond simulating a natural water hole. The pond is kept full with the aid of a nearby artisan well that flows to the reservoir. A nearby windmill and water tank also provides water during years of drought. Pronghorn, tule elk, mule deer, and numerous birds, amphibians and other wildlife use this source yearlong. CDF&G plans to improve other springs using similar techniques.

Livestock are watered from a series of pumps, storage tanks and pipelines to troughs descending down into the Plain. The troughs vary in distance from a quarter-mile to several miles apart. Until 1998, troughs on the Monument were filled only from October through May, but not during the hot, dry summer and autumn. This practice has been changed to provide drinking water for wildlife yearlong.

Because pronghorn and certain other wildlife often prefer drinking from natural sources rather than artificial facilities, it is recommended that water be made available at ground level rather than in raised artificial structures. This is especially important for pronghorn fawns and other wildlife that have difficulty in obtaining water from troughs (Wilson and Hanna 1977). Another recommended technique is to lower troughs into the ground as illustrated in USBLM technical note 347 (Yoakum 1980). Availability of drinking water is a constant problem for old water development systems on the Monument because they frequently break, and leaks are not always quickly found and repaired. On semi-arid rangelands in south central Wyoming, highest pronghorn densities were reported near natural and artificial drinking water sources (Sundstrom 1968).

According to Whistler (1984) and Yoakum (1994), pronghorn obtain most of their water needs from foraged vegetation and not from drinking water. This is one of the animal's adaptations to living on semi-arid rangelands and surviving long-term droughts. It is another reason why it is important to manage vegetation for the maintenance of succulent vegetation for pronghorn during spring and summer.

Because of drought conditions during 2002, breakdowns of old water systems, and a concern for low pronghorn populations on the CPNM, the USBLM hauled water to troughs. Major breakdowns of two main water systems occurred again at the end of May 2003, when approximately 85% of troughs on the floor of the Plain were dry. A local rancher was hired to bring water to the Monument and fill troughs for wildlife.

Livestock Interactions

Livestock have foraged the CPNM and surrounding rangelands for over 200 years and continue today. The CPNA Management Plan (USBLM, CDF&G and TNC 1996:27) provides guides regarding use of livestock foraging: "Livestock grazing will occur only to support the goals which serve the mission, not to establish federal grazing preferences. If research indicates that grazing is incompatible with or does not further the goals of the CPNA, livestock grazing will be eliminated. The ultimate long-term vision is to increase the role that native ungulates have in maintaining natural communities."

For other habitats in North America where pronghorn and livestock occupy rangelands in common, their interactions are well documented. One influence livestock foraging has on plants, is to change vegetation structure and composition, which in turn affects pronghorn habitat sustainability (Kindschy et al. 1982, Yoakum et al. 1995). Cattle displaced does on fawning areas, thereby affecting pronghorn recruitment (McNay and O'Gara 1982). Domestic sheep can be highly competitive for forage as both species often have similar foraging preferences (Howard et al. 1990). Livestock can be reservoirs of disease and parasites affecting pronghorn (O'Gara and Yoakum, In Press). Although studies of livestock/pronghorn interaction have been initiated on the CPNM, none have been completed to date.

Fences

Wire fences have been constructed on western rangelands to control livestock for more than a hundred years (Karsky 1988, Yoakum et al. 1995). Fences are known to injure, kill, and restrict or change pronghorn seasonal movements. Wire fences designed (Fig. 4) to allow pronghorn seasonal movements and to decrease injuries have been recommended by wildlife managers for more than 40 years (Griffith 1962, Salwasser 1980, Lee et al. 1998). The USBLM has financed research and developed guides for fence configurations that allow pronghorn access (Spillett et al. 1967, Howard et al. 2000). These are currently available in the agency's operation manual (U.S. Bureau of Land Management 1989).

USBLM recognizes that building wire fences to control livestock on public lands can be deleterious to pronghorn. More than a half dozen litigation cases have been accomplished relative to pronghorn and fencing on public lands administered by USBLM. The Red Desert case in Wyoming progressed all the way to the U.S. Supreme Court, the nation's highest court, which upheld previous court decisions that wire fences were detrimental to pronghorn and needed to be removed or modified. Another case in New Mexico resulted in the decision that fences that restrict

movements of pronghorn cannot be constructed to control livestock on multiple use public lands (O'Gara and Yoakum, In Press).

Recognizing these mandates, the USBLM Manual Handbook on Fencing (U.S. Bureau of Land Management 1989) provides fence design specifications for rangelands used by pronghorn and livestock. The preferred, standard three-wire fence with bottom wire-to-ground spacing of 18 inches (46 cm) is similar to wire standards recommended by the Pronghorn Workshop (Figure 4; Lee et al. 1998).

There were approximately 250 miles (402 km) of interior wire fences on the CPNM in 1998. The fences were constructed to control livestock in numerous pastures, corrals and holding pens. Personnel of the USBLM and CDF&G removed dysfunctional fences and modified others for approximately 85 miles (137 km) to enhance pronghorn access (Marlene Braun, Monument Manager, personal communication). Several conservation organizations and public service groups assisted. Virtually all woven wire fences have been removed.

PRONGHORN MORTALITY FACTORS

One of the major issues regarding contemporary pronghorn herds in southern California is - what factors are limiting herds from reaching higher densities, and why are fawn:doe ratios low? For pronghorn studies in North America, research indicates that pronghorn populations are predominantly influenced by predation, forage nutrition and climate, and to some extent by other factors, i.e., diseases, parasites, natural accidents, man-influenced accidents, old age, hunting, and others (O'Gara and Yoakum, In Press). All mortality factors affect populations to some extent in various degrees during different years. Determining the health of a pronghorn population has similarities to diagnosing human health - intensive examinations, laboratory testing, and repeated analyses are needed. Such endeavors can be time demanding and costly. Available information for mortality factors affecting herds on the Carrizo Plain follow.

Predation

Predation of fawns possibly contributes more to pronghorn mortality than any long-term factor. This is an ecological relationship that has endured for centuries of predator/prey interactions - that is, pronghorn produce high fawn numbers to offset high predation losses (Byers 1997, Yoakum 2002). However, predation generally is not a control factor determining pronghorn density when preferred, nutritious forage is readily available (Connolly 1978, Yoakum 2003).

Predation is an issue with pronghorn on the CPNM because vegetation conditions are at times not adequate to meet pronghorn habitat requirements. Coyotes, bobcats, and golden eagles are known predators of pronghorn and are native wildlife. No government-sponsored program exists to control predators on the CPNM, nor do the managing partners support such practices on these lands. Predation is important if there is inadequate vegetative cover to conceal fawns from predators, and inadequate preferred, succulent, nutritious forage to insure healthy fawn production and survival (Yoakum and O'Gara 2000).

Recent studies of pronghorn-predator interactions on the Hart Mountain National Antelope Refuge in Oregon postulate that high pronghorn neonate losses to predation may be

related to fawn birth synchrony (Gregg et al. 2001). This phenomenon exists when prey species produce an abundance of neonates in a relatively short time, thus "swamping" the predators with a food supply beyond their capacity to severely reduce neonate numbers. Such a relationship becomes paramount when prey numbers are low and predator numbers are high - a situation that appears currently on the CPNM.

Studies are lacking for the Carrizo Plain regarding predation of fawns or adults. The subject warrants on-site research to help determine the factors currently influencing low populations.

Climatic Patterns

Severe weather conditions on the Carrizo Plain affecting pronghorn are not winters, but frequent low levels of precipitation impacting forage production during the pronghorn's fawning season (March to August). Past records indicated 90% of rains are received from November through April. Annual precipitation totals for the past 10 years ranged from a high in 1998 of 19.8 inches (50.2 cm) to a low of 5.1 inches (12.9) in 1999 (Fig. 2). Average yearly precipitation from 1992 to 2001 was 8 to 10 inches (20 to 25 cm). Drought conditions exist when precipitation ranges below average - the most current years were 1999 and 2000. A recent pronghorn study correlated fawn survival with precipitation and concluded that low levels of rain produced low levels of nutritious forage that triggered low fawn recruitment (Hervert et al. 2000). Such studies have not have been conducted on the CPNM.

Other Factors

When pronghorn populations are as low as they currently are on the CPNM, every mortality factor may be significant. Intensive mortality studies have not been accomplished, but observers have noted the following conditions affecting pronghorn.

Frequent pronghorn-vehicle collisions have been reported for the Carrizo Plain area. Although vehicular traffic was great, high-speed vehicles have killed pronghorn adults and fawns. This was greatest for highway 58 on the northern Plain and on Soda Lake Road, the main road through the west side of the Monument. Between 2000 and 2002, 13 pronghorn fatalities were reported - additional pronghorn could have been killed but not recorded. This appears to be a high number for a population of around 100 animals. All mortalities have been on paved highways. One possible reason for these fatalities is that succulent forage is at a premium during dry seasons, and roadside berms at times contain abundant herbaceous forage, thus attracting pronghorn.

To call this matter to the attention of motorists, the CDF&G installed educational signs on bulletin boards in and adjacent to the Monument, encouraging the public to drive slowly and watch for wildlife on or near roads - particularly pronghorn feeding along roadsides. The CDF&G also installed 30 x 30 inch (76 x 76 cm) yellow reflective road signs depicting pronghorn - similar to the ubiquitous signs warning of cattle on unfenced rangelands.

Another management practice that can aid in decreasing these mortalities is to remove dysfunctional fences or modify the bottom wire of existing fences to allow pronghorn ready escape from speeding vehicles. This is now a priority item for fence management to provide a more "friendly" environment for pronghorn.

Pronghorn have occasionally been observed as fatalities in water troughs installed for livestock. One case was observed on the Plain where an adult doe died in a cattle trough. The carcass was tested for possible anthrax, which is known to occur on the Plain. Results were negative.

During the past decade, observations have been made on fawns in weak condition or lacking stamina. Several carcasses were collected for necropsy but laboratory examinations have not been completed. Such cases could be indicative of disease, malnutrition or "weak fawn syndrome" (Bodie and O'Gara 1980).

MONITORING AND RESEARCH

Paramount questions regarding pronghorn translocated to southern California are: why are the small herds maintaining low fawn:doe ratios and low population densities? There appears to be abundant habitat with desirable physiographic characteristics combined with forage and water meeting pronghorn habitat needs. However, something is lacking or remains unknown that is limiting higher densities. We recommend that intensive field studies be accelerated to determine the agents affecting pronghorn populations. Some specific suggestions include the following.

Pronghorn Ecology

Delineation of crucial areas are needed, especially fawning sites for each herd, in order to correlate fawn production with site locations in different habitat conditions. Following several pronghorn fitted with GPS collars could provide this information. Aerial surveys need to be continued because they provide information on fawn:doe ratios and population trends for each herd.

The general health of herds needs to be established: are animals thrifty, are diseases a problem? Predation certainly needs attention. These issues could be studied in conjunction with a neonate tagging project as conducted in Oregon (Gregg et al. 2001).

Food Habit Studies

Food habit investigations provide data on diet preferences, forage quality, and dietary competition between wild and domestic animals. The Plain provides a site for studying interrelationships of pronghorn and endangered herbivores - an unusual, challenging, and readily available biological and management opportunity. Such investigations are costly, but the results provide information needed by managers to make effective decisions. Strategies to enhance native wildlife cannot be effectively made without information for the specific site. Study procedures for diet selection and vegetation production relations are provided in Hansen et al. (2001) and O'Gara and Yoakum (In Press).

Coordinated Ecological Research

As Calilfornia's eminent native wildlife ecologist Ray Dasmann (2002:175) reminds us: "To protect a species, however, you must protect the habitat, the biotic community of which they form a part." Such is the case for determining which ecological factors are responsible for controlling the numbers of pronghorn on the Carrizo and surrounding California rangelands. Site-specific information relative to resources, their systems, functions and interactions are needed for the CPNM

and surrounding rangelands. The bottom line is that the health of pronghorn populations is directly related to the health of the environment. Consequently, there is a need for more intensive basic research for this area.

Field investigations take years and are expensive. Because the CPNM is a collaboration of partners, the task of conducting studies appears to be one of cooperation for financial support. During the research field trip in March 2003 with some 25 scientists, state and federal agency personnel, conservationists, and interested persons attending, the paramount issue facing managers was the need to make management decisions based on little ecological information. Decisions can and will be accomplished, however, their effectiveness will be in direct proportion to the level of ecological understanding about pronghorn in the CPNM ecosystem. A more aggressive program, with all collaborators seeking funds/resources to accomplish intensive ecological field studies, is essential for effective pronghorn management.

MANAGEMENT PLANS

The managing partners produced a Management Plan for the CPNA during the 1990s (USBLM, CDF&G and TNC 1996). It is a comprehensive framework providing activity goals and objectives. It contains background information on natural resources and societal needs, and is being updated in accordance with changes resulting from the CPNA transferring to National Monument status. The updated Plan will include new information obtained during the last decade.

USBLM manuals provide procedures for producing activity plans, e.g., fire, recreation, road, communication, livestock, watershed, wildlife, and others (for wildlife, see U.S. Bureau of Land Management 1981). Activity plans adhere to general land management criteria identified in the area's framework or land-use plan. The activity plan for wildlife (termed Habitat Management Plan, hereafter HMP) provides procedures for identifying management problems and needs. Such plans provide inventories of habitat needs and enhancement projects coordinated with other activities. An example would be an inventory of all fences and whether their designs meet criteria for preferred standards for pronghorn. With these data, the manager has a listing of fences needing removal or modification, and these can be prioritized for accomplishment. Estimated cost can be calculated for budget planning. Other improvement projects also can be inventoried and analyzed: e.g., drinking water facilities, vegetation manipulation, collecting vegetation data, and others. Today such data are best maintained in a GIS.

The HMP is a comprehensive document describing present conditions, habitat enhancement needs, and coordination with other land management activities. It provides a written record of management knowledge based on years of field experience, cooperative relations with other agencies, monitoring and research. Such information becomes a permanent record, periodically updated and signed by cooperating agencies. It is of particular importance to manager positions experiencing frequent tenure changes. It also can be used to determine whether management actions are successful. Such reports are of value to the public interested in identifying and accomplishing habitat enhancement for wildlife. At times these HMPs can be accomplished with the aid of suitable volunteers. The managing partners are encouraged to

investigate the possibility of completing an HMP for the CPNM. Such an endeavor could help the currently dwindling pronghorn population.

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Appendix A. List of vernacular and scientific names for wild animals and plants used in this report, plus status of endangered/threatened species for California and federal listings. Most information obtained from USBLM, CDF&G and TNC (1996).

Scientific Name	Vernacular Name	Endangered Status*
ANIMALS:		
Gambelia sila	Blunt nosed leopard lizard	FE, CE
Ammospermophius nelsoni	San Joaquin antelope squirrel	CE
Dipodomys ingens	Giant kangaroo rat	FE, CE
Canis latrans	Coyote	
Vulpes macrotis	San Joaquin kit fox	FE, CT
Felis rufus	Bobcat	
Sus scrofa	Wild pig	
Cervus elaphus nannodes	Tule elk	
Odocoileus hemionus columbianus	Black-tailed deer	
Antilocapra americana	Pronghorn	
Gymnogyps californianus californianus	California condor	FE, CE
Grus canadensis tabida	Greater sandhill crane	CT
VEGETATION:		
Phragamites akustralis	Common reedgrass	
Brassicus nigra	Black mustard	
Allenroifea occidentalis	Iodine bush	
Atriplex canescens	Four-wing saltbrush	
Convolvulus arvensis	Morning glory	
Juniperus californicus	California juniper	
Erodium moschatus	Filaree	

* Status codes for listed species: CE - California Endangered
CT - California Threatened
FE - Federal Endangered

A PRONGHORN METAPOPULATION IN NORTHERN ARIZONA

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Abstract: Fragmentation of pronghorn (*Antilocapra americana*) habitat and resultant isolation of herds is a critical issue in Arizona. Under fragmentation, it is necessary to know which pronghorn populations continue to function as a metapopulation. To determine if pronghorn herds in 3 Game Management Units (GMUs) in north-central Arizona function as a metapopulation, we investigated movement patterns and corridors, habitat use, and survival and mortality causes of 37 radiomarked adults over a 2-year period. Sub-area use and individual home-range plots indicated that the adults still represented 1 metapopulation, but with limited interchange. One high-elevation herd migrated southwesterly in the fall to intermingle and winter with a lower elevation herd, then returned to higher elevation to fawn and summer. The major movement corridor was roughly identified. Three of 15 radiomarked pronghorn from these herds crossed a major river, indicating genetic interchange with a more populous herd to the south. One adult from another herd crossed the river to the east, suggesting interchange between 2 local herds. Most adults from the Cement Plant herd, in the southeastern corner of the study area, crossed SR 89A, the only crossings of a fenced, paved highway. More heavily traveled highways (I-40, SR 89) were not crossed, thus fragmenting enclosed habitat from nearby suitable habitat. Pronghorn selected for grassland and grassland-shrub vegetation sites, including using small openings in forest or woodland dominated areas. These small openings were used during migratory behavior to move from summer to winter use areas. Female survivorship rates for the 2-year period were 69.2% for the Garland Prairie herd, 62.5% for the Wheatfield herd, but only 33.3% for the Cement Plant herd. Mountain lion (*Felis concolor*) predation was the primary source of mortality for females and males, with 10 identified kills. Local extirpation of the Cement Plant herd is likely and recolonization unsure without management intervention.

Key words: *Antilocapra americana*, corridors, fragmentation, habitat use, highways, metapopulation, mortality, mountain lion, movement patterns, pine forest, railroads, roads.

Previous research in Arizona (e.g., Ockenfels et al. 1994,1997; van Riper and Ockenfels 1998; Ticer et al. 1999) indicated that pronghorn populations are often isolated, their habitat fragmented by natural and human-related barriers. Primary barriers have been fenced, paved highways and fenced railroad rights-of-way, but natural barriers such as dense vegetation, steep-walled canyons, and rivers also restricted interchange among herds. Defining metapopulations (i.e., a group of nonspecific populations that exist at the same time, but in different places; Allaby 1998) is a primary concern of resource managers in Arizona, so appropriate management

actions can be undertaken to ensure continuity of genetic interchange and lessen chances of local extirpation.

Metapopulations are local populations that interchange through dispersing individuals (Hanski and Gilpin 1991). Such local populations exhibit extinction and recolonization over time, but the metapopulation normally persists. Conservation managers are concerned with metapopulation dynamics because human activities can bring about environmental changes (i.e., highway barriers, increased woody invasion, etc.) that may increase extinction rates or decrease probability of recolonization, resulting in loss of the metapopulation. If isolated herds are identified and do not act within metapopulation dynamics, then treatments can be designed to reduce habitat fragmentation, thereby possibly restoring interchange among herds and restoring metapopulation function.

In the mid-1990s, Arizona Game and Fish Department (AGFD) undertook a statewide assessment of pronghorn habitat (Ockenfels et al. 1996) to evaluate quality and quantity of habitat within each GMU, within historic (pre-1970) pronghorn range, except for any area occupied by the Sonoran (*A. a. sonoriensis*) subspecies. Results of this assessment indicated that habitat within north-central GMUs 6B, 8, and 19A was not continuous, being fragmented to an extent that herds were possibly isolated. If the herds are isolated and no longer act as a metapopulation, increased probability of local extirpation is likely.

Pronghorn are most often found in grassland and shrub-steppe habitats (Yoakum 1978), with some populations using open woodland (Alexander and Ockenfels 1994) and open desert habitats (Anonymous 1981). Seldom is it mentioned that pronghorn also occur in other major vegetative communities. Hoffmeister (1986) noted that pronghorn in Arizona formerly ranged throughout the state in meadows and fields (i.e., grassland) to the pinyon-juniper (*Pinus spp.-Juniperus spp.*) zone, and sometimes occurred in ponderosa pine (*P. ponderosa*) forest. Woodlands and coniferous forests are generally not considered suitable pronghorn habitat, particularly when high tree density provides substantial visual obstruction.

In Arizona, pronghorn have been intensively studied in grassland or shrub-steppe habitats (Ockenfels et al. 1994, 997; Ticer et al. 1999). Some juniper woodland use occurred during those studies, but trees were generally sparse in frequented areas (Alexander and Ockenfels 1994). Coniferous forest use was so infrequent, mainly being used as movement corridors between grassland islands, that Ockenfels et al. (1997) did not mention this vegetation type as used by pronghorn in northern Arizona. In GMUs 6B and 8, ponderosa pine forest dominates the higher elevation northern half. Since coniferous forests typically receive substantial snowfall, existence of migration corridors to allow pronghorn to move to lower elevation winter range is critical to survival. Identification of corridors ensures that management treatments can be designed to maintain or improve corridors, thereby retaining interchange among herds and availability of critical seasonal use areas.

Furthermore, estimating survival rates for populations is essential. Identifying causes of mortality, particularly for isolated herds, and undertaking management actions to lessen mortality is critical for long-term survival of isolated herds. For some inhabited areas in GMUs 6B, 8, and 19A, vegetation and terrain ruggedness favor mountain lions (Ockenfels 1994*a*), which could substantially reduce adult survivorship in isolated herds.

We undertook this study to document if habitat fragmentation in GMUs 6B, 8, and 19A was severe enough to isolate pronghorn into individual herds or if herds still acted as a metapopulation. We investigated such specific characteristics as home-range shape and size, migratory behavior, habitat use, and adult survivorship to determine needs for management treatments.

STUDY AREA

The study area was bounded on the north by I-40, to the east by SR 89A, and to the west by SR 89 (Fig. 1). These major highways were fenced for public safety reasons to restrict access by large ungulates. This triangle of highways encompassed areas above and below the Mogollon Rim, a major escarpment separating higher elevation Colorado Plateau habitat from rugged Central Highlands of Arizona. The escarpment becomes prominent south of the community of Williams (2,040 m), deepens along Sycamore Canyon, and continues eastward until the community of Sedona (1,366 m), below the rim, is encountered along SR 89A. The area included GMUs 6B and 8, and portions of 19A. GMUs are areas in which survey and harvest data are maintained, as elements of the management decision process.

The Colorado Plateau portion is relatively flat, with several old volcanic peaks rising above exposures of the Kaibab Limestone Formation. This plateau accounts for roughly the northern third of the study area. The highest point is Bill Williams Mountain (2,824 m), just south of Williams, whereas Volunteer Mountain (2,452 m) is to the east along I-40. The middle third is dominated by a series of rugged canyons where the perennial Verde River (1,000 m) flows southeasterly, bisecting the Central Highlands. Flats typically occur on ridges and between some ridges. South of the Verde River, along the southern boundary, the northernmost end of the Black Hills (i.e., Woodchute Mountain; 2,388 m) protrudes across SR89A, rising above the undulating hills of Lonesome and Chino valleys (1,676 m), which predominate the southern third in the west. Duff Flat and Wheatfield Draw, relatively flat areas, dominate the southeastern portion of the area, near the communities of Clarkdale (1,014 m) and Cottonwood (1,082 m).

Seasonal climatic conditions on the Colorado Plateau are characterized by low winter temperatures with heavy snowfall in typical years; moderate summer temperatures are normal and abundant precipitation falls during thunderstorms (Sellers and Hill 1974). At the northern edge of the study area, Williams has a daily minimum temperature of –6° C in January and receives approximately 200 cm of snow annually. The daily maximum in June is 28.4° C. Precipitation peaks in July-August at 7.1 and 9.3 cm of rainfall, with annual precipitation at 53.9 cm. At Sedona Ranger Station, below the rim of the Plateau, temperatures are more moderate and snowfall is low. Daily minimum temperature in January is –1.3° C, whereas the highest daily maximum is July at 35.1° C. Annual snowfall is 22.3 cm, with approximately 43.2 cm of precipitation. In Chino Valley, along the western boundary, the climate is relatively dry, with less than 30.5 cm annual precipitation. Over half falls during summer thunderstorms. Winter

Fig. 1. Study area and sub-areas delineated to investigate movements, habitat use, and mortality factors of adult pronghorn in 3 north-central game management units, Arizona, 1999-2001. Area is bounded by I-40 to the north, SR 89 to the west, and SR89A on the east and south.

temperatures dip low in the valleys, with January's daily minimum at –6.5° C, but rarely do daytime temperatures fail to reach 0° C

Vegetation is predominately ponderosa pine forest on the Colorado Plateau, ranging from dense thickets to open park-like sites. Major forest openings occur near Dogtown Reservoir, Davenport Lake, Sunflower Flat, Garland Prairie, Bellemont, Camp Navajo, Rogers Lake, and Fry Park. At mid-elevations, the pine forest is slowly replaced by pinyon-juniper woodland, which ranges from savanna to closed canopy. In Lonesome and Chino valleys, areas are predominately Great Plains Grassland (Brown 1994), with the dominant species blue grama (*Bouteloua gracilis*). At the lowest elevation, in the Duff Flat-Wheatfield Draw area, more xeric species such as mesquite (*Prosopis juliflora*), catclaw acacia (*Acacia greggi*), yucca (*Yucca* spp.), snakeweed (*Gutierrezia sarothrae*), and creosote (*Larrea tridentata*) provide vertical structure to the blue grama-threeawn (*Stipa* spp.) dominated understory. At some sites, woody species attain dominance, resulting in a sparse understory. Chaparral (Brown 1994) occurs on the slopes of the Black Hills and the Mogollon Rim. At these sites, plant density and height typically preclude regular pronghorn use (Ockenfels et al. 1994). The Verde River and Sycamore Creek are lined by typical Southwestern riparian habitat. Hell's Canyon, another steep-walled canyon, runs from near Bill Williams Mountain westward to SR 89. It too has stretches of riparian vegetation.

Other key mammal species within the study area were mule deer (*Odocoileus hemionus*), Coues white-tailed deer (*O. virginianus couesi*), elk (*Cervus elaphus*), collared peccary (*Tayassu tajacu*), mountain lions, black bear (*Ursus americanus*), and coyotes (*Canis latrans*). Common land-use practices included livestock grazing, predominately cattle, but with domestic sheep allotments on summer pastures in Garland Prairie. High elevation pastures are used in summer, with cattle moved to lower elevation pastures for winter.

METHODS

Captures and Locations

Pronghorn were captured using net-guns fired from a helicopter (Firchow et al. 1986). Early attempts to capture study animals from the ground with capture guns-drugs (Amstrup et al. 1980) from blinds, vehicles, and stalking were unsuccessful. Captured animals were fitted with VHF radiocollars, eartagged, and released on site.

Radiomarked pronghorn were aerially located biweekly during periods in which few major movements were anticipated (mid-June to August, November-March), then either weekly or biweekly during likely movement periods (September-October, April to mid-June), based on aircraft availability. Based on previous studies in Arizona (Ockenfels et al. 1994, 1997; Ticer et al. 1999) and information on local climatic conditions, movements were anticipated to coincide with snowfall events and spring green-up and fawning. Ground locations were sporadic and mainly used for investigating likely mortalities. For aerial locations, latitude-longitude were recorded from a Global Positioning System (GPS) receiver via a datalogger and associated with date, time, animal identification number, and group size when seen. Locations were downloaded into a Geographical Information System (GIS), converted into Universal Transverse Mercator

(UTM) coordinates, plotted by individual flight, checked for accuracy, and added to the database.

Delineation of Sub-areas

To determine metapopulation status, we compared aerial locations to several levels of sub-areas. The first level of delineating sub-areas was at the GMU level. The boundaries of GMUs are typically paved highways, major rivers, or canyons. The study boundary of paved highways, fenced along virtually their entire lengths, separated these 3 GMUs from nearby pronghorn habitat in other GMUs. A single area, approximately 100 m in length near the community of Jerome, on SR 89A was not fenced directly along the west side, near MP347. The fence was off the highway >100 m, up on a ridge. GMU 6B is mainly separated from GMU 8 by Volunteer and Sycamore canyons, with the boundary fence of Camp Navajo, a military post, an artificial boundary along the northern end of each unit. GMU 19A is separated from GMUs 6B and 8 by the Verde River drainage. All locations were overlaid with a GIS cover of GMU boundaries. Frequency distributions of locations by GMU for each radiomarked animal were compiled.

Our second level of delineating sub-areas was done by identifying and adding a GIS overlay of possible barriers to the GMU cover (Fig. 1). This created smaller areas. We subdivided GMUs 6B and 8 into high and low elevation ranges, separated by the Mogollon Rim. We also demarcated the unfenced, paved Perkinsville Road and the fenced Burlington Northern Santa Fe Railroad right-of-way. We added to this sub-area cover the national forest boundary to separate Chino and Lonesome valleys, a large grassland expanse, from the more rugged Little Black Mesa area, which was mostly woodland. We also added Little Hells Canyon, a small steep-walled canyon in the northwestern portion of GMU 8, because it separated dense woodland and rugged terrain from more open country to the north. All locations were overlaid with the GIS cover and frequency distributions compiled for each radiomarked pronghorn.

Habitat Use Analysis

Locations of radiomarked pronghorn were overlaid on a vegetation type GIS cover. GMUs were type mapped in the late 1970s and updated in the 1980s, and we combined vegetation types to the biotic community level (Brown 1994). Frequency of locations within each biotic community were compiled and compared against percentage area of biotic communities within the study area by Bonferroni simultaneous confidence intervals to determine selection or avoidance (Neu et al. 1974, Byers et al. 1984). If selection or avoidance was detected for a biotic community, then Jacobs' *D* was calculated to indicate direction and magnitude (-1 to 1) of habitat selectivity (Jacobs 1974). We minimized number of categories accounting for <5% of the study area by combining small, localized communities into a single category.

Migration Timing and Corridors

To determine whether pronghorn used separate winter and summer areas, we visually examined home-range plots of individual animals for any clustering of locations. Those pronghorn that showed separate clusters of locations within their home range and substantial locations in separated sub-areas, we classified as migratory. We were mostly concerned with altitudinal migrations. Others were deemed non-migratory. To verify our classification, we

plotted locations by season (fall = September-October; winter = November-March; spring = April-May; summer = June-August) to assess differences.

For pronghorn classified as migratory, we used GIS to calculate an elevation for each location using 30-m Digital Elevation Model data. We calculated mean (±SE) monthly elevation and mean (±SD) elevation by animal by month and plotted these means by month. Timing of migration was estimated by changes in angle of an overall mean line and by assessing width of the monthly SE.

Survival

We estimated survival of isolated herds by procedure Kaplan-Meier Survival Analysis (SPSS ver. 9.0; SPSS, Inc., Chicago, IL). When telemetry signals indicated a possible mortality, we ground located the collar and investigated the site for evidence of likely cause of mortality. Cause of death was categorized into 6 sources: 1) coyote predation, 2) mountain lion predation, 3) legal harvest, 4) road kill, 5) accidental death, and 6) unknown. Causes of mortality were grouped by month to determine if seasonal mortality was indicated. Annual survivorship, by gender, was calculated for herds in which our analysis of sub-areas indicated limited or no interchange.

RESULTS

Captures and Locations

Four capture events occurred. In October 1999, 5 (5F, 0M) were captured in Garland Prairie (GMU 8). In November-December 1999, 18 (15F, 3M) were captured. The 3rd capture, in October 2000, resulted in 3 (2F, 1M) new animals. The last capture, in November 2000, added 11 (9F, 2M) more adults to our sample. This resulted in a total of 37 study animals. Additionally, 1 capture related mortality occurred during the December 1999 capture event and another mortality occurred during the December 2000 event. Three (2F, 1M) of these animals were captured outside the main study area, just east of SR 89A, near the town of Jerome.

During the 2-yr study, we completed 67 aerial telemetry flights, with flights occurring in all 24 months. Overall, we located radiomarked pronghorn 1,206 times from the air. In winter, we completed 30 flights (554 locations) and during summer 14 flights (258 locations). For the spring migration period, we completed 14 flights (298 locations). During the fall migration, we only completed 8 flights (96). Most animals were not captured until the first winter and airplanes were grounded for most of the 2nd fall season, thereby substantially reducing our sampling effort for this season.

Use of Sub-areas

Only 1 of 6 males was located in >1 GMU (Table 1). M2333 split his time between GMUs 6B and 8, using Garland Prairie and the Wagon Tire Flat areas of GMU 8, and the Rogers Lake area of GMU 6B. M2314 never crossed into the study area, spending 100% of his time east of SR 89A, but still in GMU 19A.

Two females (F2315, F2327) were located 100% off the study area, east of SR 89A in GMU 19A, never crossing into Sub-area 11. Six of 31 radiomarked females were located in >1

GMU (Table 2). However, only F2321, F2334, and F2335 spent considerable time in >1 GMU. The other 3 (F2307, F2316, F2319) spent >90% of their time in a single GMU.

Table 1. Number (percentage) of locations by Game Management Unit (GMU) for radiomarked male pronghorn in northern Arizona, 1999-2001.

Animal	GMU			Animal	GMU		
Number	6B	8	19A	Number	6B	8	19A
2313			58 (100[a])	2326		28 (100)	
2314			20 (100[a])	2331			24 (100)
2317	51 (100)			2333	14 (56)	11 (44)	

[a] Some or all locations outside of study area boundary, east side of SR 89A.

Table 2. Number (percentage) of locations by Game Management Unit (GMU) for radiomarked female pronghorn in northern Arizona, 1999-2001.

Animal	GMU			Animal	GMU	GMU
Number	6B	8	19A	Number	6B	8	19A
2301		64 (100)		2320	57 (100)		
2302		18 (100)		2321		19 (34)	37 (66)
2303		7 (100)		2322			3 (100)
2304		68 (100)		2323			11 (100)
2305		65 (100)		2324		26 (100)	
2306	37 (100)			2325		1 (100)	
2307	56 (98)	1 (2)		2327			25 (100[a])
2308	57 (100)			2328			17 (100)
2309			3 (100)	2329			9 (100[a])
2310			58 (100[a])	2330			25 (100)
2311			58 (100[a])	2332			2 (100)
2312			8 (100)	2334		9 (38)	15 (63)
2315			14 (100[a])	2335		16 (64)	9 (36)
2316	50 (94)		3 (6)	2336		25 (100)	
2318	58 (100)			2337		25 (100)	
2319	43 (98)	1 (2)					

[a] Some or all locations outside of study area boundary, east side of SR 89A.

Three of 6 males used >1 sub-area (Table 3). M2333 split his time among 3 sub-areas, 2 in the higher country and 1 in lower elevation. M2331 (captured at Little Black Mesa, Sub-area 10) spent most of his time in the Chino Valley-Lonesome Valley grasslands, but once crossed the forest boundary fence back into Sub-area 10, near his capture site. M2326 was located twice in Sub-area 2, during movements between winter and summer use areas.

Table 3. Number (percentage) of locations by sub-area[a] for radiomarked male pronghorn in northern Arizona, 1999-2001.

	Sub-area											
Animal Number	1	2	3	4	5	6	7	8	9	10	11	12
2313[b]											55 (95)	
2314[c]												
2317								51(100)				
2326		2 (7)		17 (61)		9 (32)						
2331									22 (92)	2 (8)		
2333				3 (12)	14 (56)	8 (32)						

[a] 1 = Davenport Lake, 2 = Putney Flat, 3 = Hat Ranch, 4 = Garland Prairie, 5 = Rogers Lake/Fry Park, 6 = Drake/Wagon Tire Flat, 7 = Railroad Draw, 8 = Wheatfield/Duff Flat, 9 = Chino Valley, 10 = Little Black Mesa, 11 = Clarkdale Cement Plant, 12 = Woodchute Mtn.

[b] Some locations outside of study area boundary, east side of SR 89A.

[c] All locations outside of study area boundary, east side of SR 89A.

Thirteen (41.9%) of 31 females were located in >1 sub-area (Table 4). Most of these were located in Sub-areas 4, in higher elevation summer range at Garland Prairie, and in Sub-area 6, lower elevation winter range at Wagon Tire Flat.

Most pronghorn captured in Sub-area 8, Wheatfield, were located 100% in that sub-area, with the exceptions of F2307 and F2319, who were located west of Sycamore Creek during 1 flight. However, these locations are suspect, possibly being errors due to electronic device problems. It is very likely that these 2 also spend 100% of their time in Sub-area 8. F2316 was observed 3 times south of the Verde River, into Sub-area 11. Pronghorn captured in Sub-area 11, the Clarkdale Cement Plant herd, did not cross into other sub-areas, but 4 did cross SR 89A off the study area to mix with animals captured east of the road.

Habitat Use

Adult pronghorn in the study area used biotic communities in a non-random manner (Table 5). As expected, pronghorn selected for the mixed grass and mixed grass/shrub communities, and avoided forest, woodland, and chaparral communities. Upland desert shrub was also used by the Wheatfield herd, as that biotic community was localized to Sub-area 8. Avoidance of forest and chaparral was quite substantial, whereas the woodland avoidance was somewhat less. Visual inspection of the GIS overlay map indicated that pronghorn used relatively small openings in the forest and woodland, even if openings were remote from substantial meadows.

Migration Timing and Corridors

Only those animals that occurred in the Garland Prairie area of GMU 8 and Rogers Lake area of GMU 6B showed altitudinal migratory behavior. Ten pronghorn used higher and lower elevation sub-areas. All animals using Garland Prairie in summer migrated to the western portion of GMU 8, and wintered at Wagon Tire Flat/Drake. Pronghorn in the Chino Valley herd,

Table 4. Number (percentage) of locations by sub-area[a] for radiomarked female pronghorn in northern Arizona, 1999-2001.

	Sub-area											
Anim No.	1	2	3	4	5	6	7	8	9	10	11	12
2301		8 (13)	1 (2)	36 (56)		19 (30)						
2302				7 (39)		11 (61)						
2303				3 (43)		4 (57)						
2304		5 (7)	2 (3)	41 (60)		20 (29)						
2305		20 (31)	2 (3)	31 (48)		12 (18)						
2306								37 (100)				
2307							1 (2)	56 (98)				
2308								57 (100)				
2309											3 (100)	
2310[b]											38 (66)	
2311											57 (98)	
2312											8 (100)	
2315[c]												
2316								50 (94)			3 (6)	
2318								58 (100)				
2319							1 (3)	43 (98)				
2320								57 (100)				
2321						19 (34)			6 (11)	31 (55)		
2322											3 (100)	
2323											11 (100)	
2324		11 (42)	2 (8)	8 (31)		5 (19)						
2325		1 (100)										
2327[c]												
2328[b]											16 (94)	
2329[b]											2 (22)	
2330										25 (100)		
2332									2 (100)			
2334						9 (38)			15 (63)			
2335		8 (32)				8 (32)				4 (16)	5 (20)	
2336		2 (8)		15 (60)		8 (32)						
2337	9 (36)		1 (4)					8 (32)				7 (28)

[a] Sub-areas denoted in Table 3.

[b] Some locations outside of study area boundary, east side of SR 89A.

[c] All locations outside of study area boundary, east side of SR 89A.

Table 5. Use of biotic communities by adult pronghorn in 3 north-central game management units[a] compared to availability, Arizona, 1999-2001.

Biotic community	No. of locations	Bonferroni 90% CI	No. of locations expected	Percent area	Jacobs[b] *D*
Mixed conifer	57	39.7 – 74.0	349.0	31.3	-0.56
P-J woodland	249	216.3 – 281.0	355.7	31.9	-0.24
Interior chaparral	47	31.2 - 62.4	131.6	11.8	-0.51
Mixed grass/shrub	671	633.1 - 709.3	239.7	21.5	+0.84
Others	91	70.1 – 112.8	39.0	3.5	+0.42
	1,115		1,115.0		

[a] Only locations within study area boundary.
[b] + denotes selection for
- denotes avoidance or used less than expected
= denotes use consistent with expected.

Little Black Mesa, Clarkdale Cement Plant, and Wheatfield herds did not migrate. These were resident herds. Some of the Wagon Tire Flat/Drake animals were also resident in the lower elevations.

Due to capture dates and availability of aircraft for telemetry flights, limited data were available to precisely determine fall migration. However, fall migration seemed to occur in late October and early November (Fig. 2). Not all animals migrated to lower elevation at the same time. Variability in mean elevation was greatest in November, indicating that was the month of migration for most of the 10 animals. Most were at lower elevations by mid-November. Some were already at lower elevations in October. Animals remained at lower elevation until March. Again, variability in mean elevation was greater in March than for previous months (Fig.2). In March, pronghorn started returning to higher elevation habitat. Most were in higher elevation by April, however, some migratory animals remained at mid-elevation sites near Putney Flat until summer. By July, all 10 pronghorn were in the higher elevation Garland Prairie area.

F2321 used 3 separate use areas in GMUs 8 and 19A. She used Wagon Tire Flat (1,400 m) in GMU 8, and Little Black Mesa (1,400 m) and Chino Valley (1,500 m) in GMU 19A. However, these were not seasonal use areas, just separate pockets of habitat separated by unsuitable or poor quality habitat, mostly dense woodland. F2334 used 2 distinct areas, Wagon Tire Flat and Chino Valley. F2335 used mid-elevation Putney Flat (1,500 m) and Wagon Tire Flat in GMU 8, and Little Black Mesa in GMU 19A. She did not migrate to Garland Prairie to summer.

Fig. 2. Mean (±SE) elevation (m) by month of 10 adult migratory pronghorn in 3 north-central game management units, Arizona, 1999-2001.

We roughly identified the migration corridor from Garland Prairie to Wagon Tire Flat/Drake. From Garland Prairie, animals seemingly moved westward from meadow to meadow, using meadows at the southern edge of Dogtown Reservoir area, then apparently moving across Perkinsville Road where it junctions with FR 122. Animals seemingly moved between Bill Williams Mountain and Coleman Knoll by roughly following FR 122 to Hat Ranch Meadow. From Hat Ranch, they moved west to Putney Flat along the northern edge of Meath Wash. Putney Wash area (Sub-area 2) was a staging area before further movement south. Pronghorn moved from clearing to clearing southward along SR 89, then followed a line just east of the El Paso Corporation natural gas pipeline southeasterly to Wagon Tire Flat/Drake. For spring migration, they reversed the pattern, again with some using Putney Flat as a holdover/staging area.

Only M2333 moved between GMUs 6B and 8. He was located once on the Camp Navajo Army Depot, however, we had insufficient locations to determine whether he moved into 6B through or south of the Depot.

To move between GMUs 8 and 19A, pronghorn followed a high-voltage powerline south from Wagon Tire Flat along the ridge on the west side of Grindstone Wash across the Verde River to Little Black Mesa in GMU 19A. Little Black Mesa and openings on the eastern side of the mesa were high use areas. From Little Black Mesa, some animals moved southwesterly to Chino Valley and 1 moved easterly towards the Clarkdale Cement Plant.

F2316 crossed the Verde River from GMU 6B into 19A in an area close to the Clarkdale Cement Plant. The crossing area was near the Flagstaff-Clarkdale powerline, just south of SOB Canyon. Just south of SOB Canyon, locations along both sides of the Verde River indicated that was likely a crossing area. Most individuals of the Wheatfield herd were located in close proximity to the Verde River on a number of occasions. Exact crossings, if they exist, were not identified. The general crossing area was verified by identifying pronghorn hair samples snagged on barbed-wire fences along the river.

For the Clarkdale Cement Plant, crossings of SR 89A occurred near and south of MP347. This area was unfenced for approximately 100 m along the western side of the drainage, but crossings also occurred just south where both sides were fenced. Females F2310, F2328, and F2329 crossed numerous times during the 2-yr study. M2313 also crossed SR 89A and overlapped his home range with 3 radiomarked pronghorn, M2314, F2315, and F2327, captured in and using sites east of SR 89A.

Mortality

Ten (9F, 1M) adult pronghorn died from mountain lion predation during the 2-yr study. Five (4F, 1M) died from unknown causes, as our investigations could not accurately classify cause of death. Another (1F) likely died as the result of a vehicle collision. Of the 10 cases of mountain lion predation, 7 occurred at the Clarkdale Cement Plant. None were harvested during a hunt. Mortalities occurred across seasons, in 7 of the 12 months. Most occurred during winter and spring.

Based on analyses of the movement data, we calculated annual female survivorship rates for 3 populations: 1) the complex Garland Prairie/Drake/Chino Valley herd, 2) Clarkdale Cement Plant herd, and 3) Wheatfield herd (Table 6). We had insufficient samples of males to calculate herd or area specific rates.

Table 6. Annual survivorship (percentage) of adult female pronghorn by sub-population in 1999-2001, Arizona.

Sub-population	1999-2000	2000-2001	Overall
Garland Prairie Complex	84.62	81.82	69.23
Wheatfield Draw	100.0	62.50	62.50
Cement Plant	50.0	66.67	33.3

DISCUSSION

Metapopulation Function

Interchange among local herds serves as the basis for a metapopulation (Hanski 1991, Hanski and Gilpin 1991) and is important in maintaining viability of individual herds. Our results document that the Garland Prairie and Wagon Tire Flat/Drake pronghorn of GMU 8, the

Rogers Lake/Fry Park pronghorn in GMU 6B, and the Little Black Mesa and Chino Valley/Upper Lonesome Valley pronghorn herds of GMU 19A continue to have interchange occurring among these various herds. We believe that movements among these areas occur regularly enough to warrant metapopulation status.

It is also likely that the Clarkdale Cement Plant of GMU 19A and the Wheatfield herd of GMU 6B are herds that constitute a metapopulation, however, interchange is low, as the Verde River constitutes a considerable barrier to movement. The fact that more animals did not regularly move between the 2 areas indicates management problems that need to be addressed.

Whether interchange still occurs between animals using Rogers Lake/Fry Park (higher elevation) and the lower elevation Wheatfield herd remains unknown. It also remains unclear whether sufficient interchange occurs between the Cement Plant herd and the Little Black Mesa herd. We observed no direct interchange during the 2 years. At best, limited interchange may be occurring.

Thus, the study seemingly constitutes a single metapopulation that can be graphically illustrated with movements occurring in a "C" pattern (Fig. 3). Genetic interchange is occurring and migratory animals can use available habitat more effectively. However, interchange was low for several herds. This presents management problems for natural resource managers in the area. Designing treatments to improve interchange seem warranted.

Mortality

Most mortality of adult pronghorn was by mountain lions and most occurred in the Clarkdale Cement Plant by what was likely just 2 mountain lions. Vulnerability of this somewhat isolated herd to extirpation is high, as interchange with neighboring local herds is low at best. Close monitoring of these herd's recruitment and adult losses is warranted. Steepness of the terrain and lack of refugia (large expanses of grassland in flat terrain) for the herd increases their susceptibility to mountain lions (Ockenfels 1994*a*). Abundant favorable mountain lion habitat at nearby Woodchute Mountain suggests continual use of the Cement Plant by mountain lions. Removal of depredating mountain lions will likely be a reoccurring issue. At the morality rate observed, the pronghorn herd simply cannot persist long term.

Ockenfels (1994*b*) observed somewhat lower, but still high, cause-specific mortality for the GMU 21 pronghorn population in central Arizona, and that population declined rapidly with high adult mortality, even with moderately high recruitment. Several recent supplemental transplants (Arizona Game and Fish Department, unpublished data) into GMU 21 have stabilized and maintained the remaining low population level. Supplemental transplants into the Cement Plant site may be warranted.

MANAGEMENT IMPLICATIONS

The most critical issue for pronghorn in these 3 GMUs is maintaining corridors to ensure 2 types of movement. First, the corridor between high elevation in GMUs 6B and 8 and low elevation winter range in GMU 8 at Wagon Tire Flat must be maintained to ensure migratory behavior continues for the Garland Prairie herd. Improvements in the corridor should be undertaken. Creating additional openings can be done with well-designed, strategic timber

harvests and woodland clearing projects. Reducing tree canopy coverage to <20% should ensure use by pronghorn (Alexander and Ockenfels 1994, Ockenfels et al. 1994).

Secondly, corridors need to be improved among the various fragmented sites to maintain the integrity of the metapopulation. River crossings need to be positively identified, protected, and improved. Corridors can be cleared with fuelwood cuts. Increasing the amount of openings or savanna conditions in some areas may be critical to maintaining gene flow. By improving these corridors, metapopulation dynamics of the 3 GMUs can be improved. Metapopulation dynamics before environmental effects of Anglo-settlement are unknown, but movements were likely greater than those observed in this study.

By using standard VHF radiocollar techniques, we can only provide rough estimates of migratory or movement corridors among herds. Likely, individual movements are rapid through unsuitable habitat. Use of regular aerial or ground telemetry techniques to more precisely determine the corridor is unrealistic. However, monitoring of GPS-collared animals could be used to determine precise locations of existing corridors, if deemed necessary by the appropriate land management agencies.

The second critical issue is developing management plans that deal with mountain lion predation on isolated herds. This is particularly important for herds that inhabit rough terrain and dense vegetation. Since the terrain cannot be modified, treatments to ensure vegetation characteristic changes do not favor mountain lions (Ockenfels 1994*a*) are essential for long-term pronghorn herd persistence under such conditions.

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Fig. 3. Graphical representation of metapopulation movements among herds in various sub-areas in 3 north-central game management units, Arizona, 1999-2001.

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PRONGHORN RANGE EXPANSION IN MIDDLE PARK, COLORADO

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Abstract: Middle Park (MP), Colorado is a high mountain sagebrush/grassland park that is historic range for pronghorn (*Antilocapra americana*). MP contains 997 km^2 (385 mi^2) of pronghorn habitat that is roughly divided in half (north and south) by the Colorado River. Even with the growth of the north MP herd to >600 animals, there has been only minor summer use and no winter use of the habitat south of the river. The Colorado Division of Wildlife (CDOW) and Blue Valley Ranch (BVR, a private enterprise) entered into a Memorandum of Agreement with the intent of establishing yearlong habitation south of the Colorado River. Public benefits of pronghorn range expansion in MP include increased viewing and hunting opportunities; benefits to BVR include satisfaction of having pronghorn as seasonal or yearlong residents on the ranch. Two enclosures of approximately 2.59 km^2 (1 mi. ^{2}) each were constructed on BVR approximately 6.7 km apart and separated by a river and 2-lane highway. A total of 51 pronghorn were taken from 2 separate herds, both of which were >100 km from the enclosures. Capture was by helicopter net gunning during December 1999 and January 2000. Fifty animals (22 does and 3 bucks from each enclosure) were fitted with radio collars (does) or solar powered ear tag radios (bucks). These pronghorn were released from the enclosures 1 June 2000. Enclosure fences were 155 cm (61 in.) high built of net wire and strands of smooth wire (see methods). Mortality attributed directly or indirectly to capture, confinement, or dietary changes was 19%. Some animals remained in or near the enclosures; whereas, 1 animal ranged 58.4 km (36.2 mi.) distance from its enclosure. Survival to the first winter (2000-01) was 78% (39 animals); twenty-six (67%) of these wintered south of the Colorado River and 13 (33%) wintered with the established herd north of the river. Minimum survival to the second winter (2001-02) was 70% (35 animals) with 3 radios unaccounted for. Of the 35, 22 (63%) were south of the river and 13 (37%) were north of the river. The population south of the river is expanding. During the winters of 2000-01 and 2001-02, 43 and 50 pronghorn wintered south of the river, respectively. From the winter of 2000-01 to winter 2001-02, 2 additional radio collared animals moved from south to north of the river.

Key words: Pronghorn, movements, nutrition, fencing, capture, transporting, mortality.

Economic globalization and technology are changing ownership and use of Western ranges (Werther 1999). With expanding human population comes increased demand for space and recreation in natural areas. Advances in telecommunications, computer, and transportation technologies provide the means to stay connected with global business in relatively remote locations. Thus, many global investors are turning to Western ranches both for investments and

refuges from urban environments. As this transformation takes place, rural communities are changing from "...places where people work on the land to places where people play on the land" (Werther 1999:3).

Most of these modern era owners do not depend on the land for income or their livelihood. They have a concept different from the conventional Western ranch operation of how the land should be used; many value the historic fauna of the area and strive to re-establish it. Public resource management agencies are presented with new opportunities for assisting these landowners in establishing wildlife populations on their land while still serving the public interest in expanding wildlife populations for public use and enjoyment.

This paper reports a case study of the cooperative effort of Blue Valley Ranch (Paul Jones, owner) and the Colorado Division of Wildlife to expand the range of pronghorn in MP, Colorado. The factors of fence structure, length of confinement, supplemental feeding, and mortality encountered in this study are intended to assist others that may be presented with similar opportunities to expand pronghorn distribution. Better knowledge of these factors can maximize the probability of successful translocation given the many unknowns involved in attempting to manipulate wild populations.

BACKGROUND

Pronghorn are historic residents of MP, Colorado. During the market-hunting era of the late 1800s, pronghorn were killed in Middle Park and sold to supply mining camps. From the 1878 diary of a Middle Park market hunter, Frank H. Mayer, it was apparent that pronghorn were abundant and readily available for filling carcass tonnage contracts (Roth 1963). According to Mayer's diary "Antelope are constantly in evidence" (Roth 1963:32) and he reported seeing groups of 100 to 200 head during late summer. However, probably as the result of market hunting, by the next year (1879) there was concern that pronghorn in Middle Park were in rapid decline (Black 1969). The railroad arrived in MP in 1906 and a July celebration included barbecued pronghorn (Cairns 1975) indicating that pronghorn were still available at that time.

Pronghorn numbers were estimated to be 35 to 40 million by early explorers of the West, but by the turn of the 20th century there was grave concern that they were on the verge of extinction. This concern prompted a survey during 1922-24 to estimate numbers of pronghorn nationwide. A total of 1,233 pronghorn was counted in Colorado in 1923; only 7 were observed in MP (Nelson 1925). Nelson (1925:28) reported: "In Middle Park, northwestern Grand County, a small band of 7 still exists. This was formerly a favorite range for antelope, but they have been rapidly decreasing there and will probably be completely exterminated in the not distant future."

This ominous prediction came true almost immediately because there were no reported sightings for the next 50 years. In the early 1970s pronghorn sightings in MP were reported with increasing frequency. The largest number sighted since the report of 7 in 1923 was on 21 August 1979 when a group of 13 was seen 10 miles north of Kremmling in the Antelope Pass area (R. B. Gill, personal communication). These pronghorn most likely originated in North Park and crossed into Middle Park over Muddy Pass (Figure 1). Rare as they were, early sightings

(1970s) were always during summer and it was not until the winter of 1983-84 that pronghorn again wintered in MP.

Figure 1. Statewide distribution of pronghorn in Colorado (shaded area). Pronghorn pioneered from North Park to Middle Park over Muddy Pass during 1970s and 1980s. They wintered in Middle Park for the first time in recent history during 1983-84. Transplants for range expansion were obtained from Hayden (15 animals) and Walden (North Park) (35 animals).

The MP winter of 1983-84 was severe. Estimated mule deer mortality was 50% even with some supplemental feeding by the Division of Wildlife (Carpenter et al. 1984, Baker and Hobbs 1985). Heavy, early snows in the winter of 1983-84 may have trapped pronghorn that were using MP during summer and returning to North Park for winter forcing them to winter in MP. However, a group of 28 pronghorn survived on a wind-swept ridge northeast of Kremmling. Despite no supplemental feeding of this group, there was no observed winter mortality. This provided the first obvious reminder that there existed viable yearlong habitat for pronghorn in MP.

The following winter, pronghorn were observed again northeast of Kremmling and by fall of 1985, the MP pronghorn herd numbered close to 60 animals. Local historian, Paul Gilbert (personal communication) reported that on 23 November 1985, snowmobilers chased 61 pronghorn from their wintering area northeast of Kremmling south across the Colorado River. They successfully wintered (1985-86) south of the river providing evidence that suitable winter habitat exists south of the Colorado River.

Documentation of pronghorn habitation in MP during early settlement by Europeans is clear but there is no information on seasonal distribution. Therefore, it is unknown if pronghorn historically wintered south of the Colorado River or if their historic wintering area was the area used by the founding group northeast of Kremmling.

The Colorado Division of Wildlife began a research project in 1986 to monitor the habitat selection and population growth of pronghorn in MP (Pojar 1987). By keeping approximately 10% of the herd equipped with radio transmitters during the next 11 years, through 1997, it was possible to closely follow the seasonal movements, habitat selection, and growth of the population. During summer, pronghorn dispersed to summer ranges north toward Muddy Pass and east toward Granby (Figure 2). Less than 6% of the population crossed the Colorado River and summered south of the river. These animals then returned to the north side of the river to winter with the entire MP population on the traditional wintering area northeast of Kremmling.

The herd grew from 80 animals in 1986 to approximately 625 animals in 1997 (Pojar 1998). As the population expanded, it was expected that increasing density would result in more of the animals spending summer south of the river and eventually the wintering group fracturing and establishing a wintering area south of the river. During the 16-year period of 1984 to 1999, no pronghorn wintered south of the Colorado River with the exception of winter 1985-86 when the entire herd was forced across the river and stayed for that winter only.

Despite a 21-fold increase in numbers (28 to 600) in 16 years, the distribution of pronghorn remained essentially the same during summer and winter (Figure 2). Population growth approached zero by 1997 indicating that the range north of the river was near carrying capacity (Pojar 1998). Suitable summer range existed south of the river and it was hypothesized that suitable winter range also exists south of the river. It is possible that gregariousness of this species dictates that they re-group on a traditional wintering area. It was postulated that establishment of a "founding" group south of the river might expedite the expansion of

Figure 2. Seasonal distribution (summer, winter, and critical winter range) of pronghorn in Middle Park, Colorado. Muddy Pass is the likely route of founding migrants from North Park. East and west enclosures are where groups of 25 pronghorn each (22 does and 3 bucks) were held south of the Colorado River during winter 1999-00. They were released in June 2000.

pronghorn range to this area, providing more recreational opportunity for residents and visitors and allowing the pronghorn population to increase in size.

STUDY AREA

Middle Park, in north central Colorado (Figure 1), is a high mountain basin encompassing 5,998 km^2 (2,316 mi^2) with 997 km^2 (385 mi^2) considered winter range for mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*); (Tiedeman et al. 1987). The lower elevations, 2,200m (7,213 ft) to 2,750m (9,016 ft) are dominated by big sagebrush (*Artemisia tridentata*) communities, which are primary yearlong and winter habitats for pronghorn. At

higher elevations, aspen (*Populus tremuloides*) and conifers dominate and are used by deer and elk as summer range. Precipitation is 35 to 40 cm (13.8 to 16.3 in.) annually with mean annual air temperature of 4.6° C (40.3° F) (Tiedeman et al. 1987).

METHODS

Rather than transplanting animals from the established MP herd, we imported them from herds 100 km (60 mi) distant to reduce the probability of immediate repatriation with familiar animals and territory. Fifteen of the animals came from the Hayden area (captured on 11 December 1999) and 36 from North Park (captured on 15 January 2000) (Figure 1). Fifty-three pronghorn were net gunned from a helicopter, hobbled, and slung to the staging area for transport to enclosures in south MP. Maximum distance from capture to staging area was estimated to be $\leq$ 8 km (5 mi). Partitioned 4-horse trailers with clean straw/hay bedding were used for transport. No more than 8 animals were put in each 2-horse compartment.

Two fenced enclosures of 2.59 km^2 (1.0 mi^2) were constructed in the south half of MP. Fences were 155 cm (61 in) high constructed of smooth and net wire (Figure 3). The enclosure locations were selected based on logistics of BVR who owned the land where both enclosures were constructed. One enclosure included typical pronghorn winter range and the other was near summer range that was not currently used by pronghorn. The winter range enclosure, east of the Blue River and Highway 9, (Figure 2) provided sagebrush habitat with 2 ridges that could provide windswept areas with low snow depth. The enclosure near summer range, west of the Blue River and Highway 9, (Figure 2) was level with mostly native grass hay land and only a small area of sagebrush.

Figure 3. Fence design for pronghorn enclosures. This fence was effective in containing pronghorn that were transplanted from >100 km distance.

We held 2 groups, one of 26 animals (3 males and 23 females, 1 additional doe was only ear tagged and will be ignored henceforth) and one of 25 animals (3 males and 22 females) of various ages in these enclosures from December 1999 and January 2000 to June 2000. Twenty-five animals in each enclosure were radioed; we used solar powered ear tag radios on all males and neck collar radios on females. On 1 June 2000 the gates of both enclosures were opened and the animals were allowed free choice of leaving.

Good quality alfalfa hay and a highly digestible protein ration (16%); (Baker and Hobbs 1985) were supplied to both groups while in the enclosures. The pelleted ration was made available to the west group in a large self-feeder; it was supplied on slabs of alfalfa hay to the east group. No water source was deemed necessary during winter because of snow cover; after the spring thaw, water was available via supply tanks and irrigation ditches to both groups.

RESULTS

Mortality – Capture, Transport, and Confinement

Mortality to pronghorn during the helicopter net gun capture process was zero; one animal was injured during loading into the trailer and was euthanized. Mature bucks were captured last and placed in separate carrying crates for transport. One buck injured the soft tissue on the horn core while inside the crate and was released at the capture site. It took up to 3 hours to fill a trailer (16 animals) and no mortality occurred inside the trailers or during the 2-hour transport to the release site.

In the east enclosure, a fawn and a doe died within a week of capture and 2 other does died within a month. In the west enclosure, a fawn died within a week of capture. Mortality that could be associated with capture and handling of all animals was 10%. Within 2 weeks of release from the enclosures in June, 5 mortalities (all does) were recorded for animals from the west enclosure and none from the east. In all, there were 10 mortalities (19%) associated with capture, handling, and captivity (and immediately after release).

Subsequent mortalities included a buck killed by a vehicle in September 2000. An emaciated doe observed during fall of 2000 was found dead in February 2001, and another doe died of unknown causes during summer 2001.

Care During Captivity

Because native forage was readily available to the east group, they did not use the supplemental feed (alfalfa hay and pellets) provided. It only served to attract deer and elk so was discontinued within 2 weeks.

Lack of native forage resulted in the west group finding and beginning to use the supplemental food within 3 days of captivity. They consumed on average 510g (1.12 lb)/animal/day of pelleted feed but consumed very little of the good quality alfalfa hay provided. Toward spring they heavily used the small strip of sagebrush within the enclosure.

Winter Distribution

By late summer 2000, there were 39 of 50 radioed animals accounted for; although radio signals were not detected for 2 bucks, they were assumed to be alive giving 41 of 50 animals alive. Thirty-seven of the 39 known live animals were south of the Colorado River. By winter of 2000-01 (the first winter after release), 2 additional mortalities were recorded leaving 37 animals (not including the 2 bucks whose radio signals we did not detect). Twenty-six (67%) of these wintered south of the Colorado River and 13 (33%) wintered north of the Colorado River with groups of "native" MP pronghorn. By the winter of 2001-02, 35 animals were known to be alive with 3 unaccounted for. Of the 35, 22 (63%) were south of the river and 13 (37%) were north of the river with the established herd.

The wintering pronghorn population in south MP seems to be expanding mostly through reproduction of the introduced herd. It is possible there is some minor immigration from the north due to the attraction of introduced animals in the south. During the winters of 2000-01 and 2001-02, 43 and 50 pronghorn wintered south of the river, respectively (Figure 4). From the winter of 2000-01 to winter 2001-02, 2 additional radioed animals moved from south to north of the river indicating that introduced animals did not have complete fidelity to the new area.

Summer Distribution

During 14-22 May 2001, 30 of 39 (77%) pronghorn remained south of the Colorado River. The minimum movement was by 3 does that originated in the east enclosure and returned to summer in or near that enclosure. The maximum movement was by a doe that also originated in the east enclosure but summered northeast of Muddy Pass in North Park, which is 58.4 km (36.6 mi.) from the release site. This individual returned to Middle Park and wintered with the resident herd north of the river.

DISCUSSION

Mortality

Although possible explanations are lacking or highly speculative, there seems to have been a difference in survival between the 2 enclosures. The animals in the east enclosure suffered more capture related mortality and the animals from the west enclosure had more mortality immediately after release.

Of the original 15 animals put in the west enclosure on 11 December 1999, 1 died of capture stress. This animal was replaced during the second trapping (15 Jan 2000) and all of the remaining 26 (1 "extra" animal was captured but not radioed) survived during winter confinement. In the east enclosure, a fawn and a doe died within a week of capture and 2 adult does died within a month of capture. Capture or transport related stress or injury was definitely the cause of the first mortalities and was very likely also the cause of the other 2 although we cannot be certain. There was a coyote seen in this enclosure and the last 2 carcasses were scavenged before we found them. One possibility is that the coyote(s) chased and trapped the pronghorn against the fence before the pronghorn were aware of and accustomed to the location of the fence. Under normal conditions and with light snow cover pronghorn can easily outrun

coyotes. However, with the last mortality about 1 month after trapping and no mortalities recorded within the enclosure for the remainder of the winter the predator theory is weakened. According to Lee et al. (1998:16), "Predation is not considered a primary factor in adult survival." And, excepting snow crusting conditions that favor coyote movement and inhibit pronghorn movement, "...adult pronghorn rarely succumb to predation" (Byers 1997:48).

Figure 4. New wintering areas since range expansion . In winter 2000-01, 43 pronghorn wintered south of the Colorado River; in 2001-02, 50 wintered in this area. The larger oval represents a group of 40 animals and the smaller oval a group of 10 for winter 2001-02. Of the original 50 animals transplanted south of the river, some died and some moved north of the river to join the "native" herd. However, through reproduction and minor imigration, the wintering herd south of the river was 50 animals during winter 2001-02.

Within 2 weeks of release in June, 5 animals from the west enclosure died of undetermined causes. The animals in the west enclosure were fed a pelleted supplemental ration

and had access to good quality alfalfa hay throughout the winter. This is a sound maintenance diet but is very different from natural forage. There are 2 candidate hypotheses to explain these mortalities. Once released, they had access to prime summer range consisting of sagebrush, forbs, and grass, which may have caused "diet shock" in that the rumen microbes did not have time to adjust to the change in diet. This could have caused some degree of illness in some individuals making them susceptible to other mortality sources such as predation. However, during tests of the pelleted ration, subject mule deer were switched abruptly from pellets to a succulent green grass diet ad libitum with no apparent digestive problems other than softened feces for 2-3 days (Baker and Hobbs 1985).

A second theory also involves supplemental feeding. "Over conditioning" of pregnant females may cause a difficult delivery of larger than normal fawns (D. Baker, personal communication). Mortality from any cause during June is very uncommon for adult pronghorn (Pojar, personal data), therefore it is likely that some factor(s) associated with confinement or the supplemental diet were responsible for these mortalities. There were no June mortalities from the east herd adding credence to the hypothesis that the supplemental diet of the west group was a factor. Evidence that the pronghorn in the west enclosure were on a high nutritional plane was demonstrated by the fall fawn:doe ratio of 12 fawns to 14 does (86f:100d). Ozoga and Verme (1982) observed high fawn survival in white-tailed deer (*O. virginianus*) when does were given supplemental feed. The consumption of 510 g (1.12 lb)/animal/day of our animals is not inconsistent with the consumption of 678 g low fiber and 975 g high fiber diets of captive pronghorn kept in paddocks without any natural forage (Torbit et al. 1984).

Cost in terms of mortality from all causes associated with capture, transport, and confinement was well documented and approached 20%. Other investigators have attempted to document losses from translocations but did not have the luxury of having all the animals involved radioed. Goldsmith (1984) and Fatooh et al. (1994) reported on the introductions of groups of 43 in 1982, 24 in 1984, and 50 in 1985 into Adobe Valley, California. Of 117 animals, 22 were radioed. They also attempted to hold the transplants in a 1.3-m (51-in.) 3-strand barbed wire fence covered with burlap for up to 8 days. The first group was held for less than 1 day the second for 8 days and the third escaped the first night when high winds removed the burlap. Of the 22 radioed animals, 13 died of various causes for a mortality rate of 59%.

MANAGEMENT IMPLICATIONS

Several questions were answered for managers faced with establishing a pronghorn herd on historic range. Fences of our design, although expensive (approximately $16k/2.59 km (mile)), were effective in retaining pronghorn in a holding facility, supplemental feeding is a viable option when needed, and range expansion is apparently possible even if the expanded area is relatively close to an established herd. The group south of the river is expanding and is apparently habituated to the area for both summer and winter range.

The transplant sites meet all the requirements outlined by Lee et al. (1998) for a successful transplant with the exception that snow depth will undoubtedly exceed the designated 25cm (10 in.) in some winters. Both winters involved in our observations thus far have been mild with below average snow cover. Deep snows are possible in MP so this group will be

monitored for possible need for assistance in the form of supplemental feeding or breaking trail with snow machines to provide access to feeding areas should deep snow inhibit their movement.

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GENETIC DISTINCTION OF THE SONORAN PRONGHORN

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Abstract: *Antilocapra americana sonoriensis* is a federally listed, endangered subspecies whose distinctness has come into question repeatedly in the last few decades. Previous genetic work on the subspecific taxonomy of *A. americana* included samples from throughout North America, however, samples sizes were severely limited from the *A. a sonoriensis* range. In this study, we build a mitochondrial DNA (mtDNA) data set of approximately 500 nucleotides and 167 individuals from 3 Arizona populations (including 35 *A. a. sonoriensis* individuals), from Texas, and from New Mexico. This data set is used to explore the relationship of the *A. a. sonoriensis* population with respect to neighboring pronghorn populations. Little phylogenetic signal is recovered using maximum parsimony. Two of the 4 haplotypes found in Sonoran pronghorn are found in other populations. Only minor geographic differentiation between sampled populations is found in the statistical parsimony network. These results suggest that Sonoran pronghorn have only recently been fragmented from other southern populations. Comparison of population genetic diversity indicates that the Sonoran pronghorn have sustained a prolonged bottleneck event.

Key words: *Antilocapra americana*, conservation genetics, mitochondrial DNA, pronghorn, Sonoran pronghorn, taxonomy.

Four extant subspecies of pronghorn are generally recognized as inhabiting the open plains of western North America (Lee 1992, Lee et al. 1994). The American pronghorn (*Antilocapra americana*) occupy the largest range in North America, extending south from Canada into northern Arizona, northern New Mexico, and northern Texas. In the Southwest, the Mexican pronghorn (*A. a. mexicana*) are thought to have historically occurred throughout north-central Mexico north to southeastern Arizona, southern New Mexico, and the Big Bend region of west Texas. Peninsular pronghorn (*A. a. peninsularis*) occupy the Baja peninsula of Mexico.

The fourth subspecies, Sonoran pronghorn (*A. a. sonoriensis*), historically occurred throughout southwestern Arizona, northwestern Sonora, extreme southeastern California, and northeastern Baja, Mexico (Arizona Game and Fish Department 1981). Sonoran pronghorn declined in number and geographic range since 1940 due to overgrazing, agricultural development, human development, and poaching (Arizona Game and Fish Department 1981). Legal harvest of Sonoran pronghorn has been restricted in both the United States and Mexico for at least 80 years and has been illegal in Mexico since 1922. Currently, this subspecies occupies a

much smaller portion of Sonoran desert from southwestern Arizona southward in Sonora Mexico to the Gulf of California (USFWS 1998).

The U.S. Fish and Wildlife Service (USFWS) listed Sonoran pronghorn as an Endangered Species in 1967. A Sonoran Pronghorn Recovery Plan was adopted by USFWS in 1982, and by 1988 Cabeza Prieta National Wildlife Refuge (CPNWR) was designated as the lead office for recovery efforts. The Sonoran Pronghorn Core Working Group, created in 1991 and consisting of no fewer than 9 different state, federal, or tribal agencies, completed its most recent recovery plan revision for the subspecies in 1998 (USFWS 1998). The recovery plan goal is to pursue downlisting to "threatened" status when a stable population has been maintained for 5 years and the population has adequate protection and secure habitat. Criteria for considering them completely recovered are to "Establish an estimated population of 300 adults in 1 self-sustaining population in the U.S. for a minimum of 5 years, and establish at least 1 other self-sustaining U. S. population." (USFWS 1998). Current population survey data indicate that there are 99 Sonoran pronghorn north of the U.S.-Mexico boundary (Bright et al. 2001), however, recent drought conditions have caused high adult mortality and it is likely that little, if any, recruitment of fawns has occurred in the past year, resulting in a further reduction in the population (Jill L. Bright, Arizona Game and Fish Department, personal communication, 2002). Sonoran pronghorn in Mexico are surveyed systematically, and were estimated to number approximately 300 (USFWS 1998).

Taxonomic status of Sonoran pronghorn has always been questionable. First, peninsular pronghorn on the Baja Peninsula formerly occupied most of the northern portion of the peninsula (Nelson 1912, Cancino et al. 1994, Cancino et al. 1998) and Sonoran pronghorn ranged into northern Baja (Arizona Game and Fish Department 1981, Wright and deVos 1986). Additionally, pronghorn also occupied grassland areas adjacent to the northern (Schoeder 1961:9) and eastern (Michler 1857:121, Pumpelly 1870:17) boundary of historically described Sonoran pronghorn range. Designation of peninsular pronghorn as a separate taxon is based only on a darker coloration on the head; Nelson (1912) opined "While the differences noted are not very striking they appear sufficient to characterize a good local form." If Sonoran pronghorn and adjacent populations (including peninsular pronghorn) were a metapopulation to the early 20th century, it is unlikely they had time to differentiate into meaningful phylogeographic entities.

Secondly, designation of the Sonoran subspecies was based on only 2 specimens, both collected long before Goldman (1945) examined them. In the original subspecies description, Goldman (1945) felt that subspecific status was warranted due to smaller size; paler color; and a smaller skull that differed in detail." Unfortunately, additional morphometric examinations of skulls from the range of Sonoran pronghorn (the 2 from Goldman and 4 others) by Paradiso and Nowak (1971) and Hoffmeister (1986) failed to clarify taxonomic status of pronghorn from this region. Variations in the skulls could have been attributed to small sample size and errors in the collection locations of the original type specimens. Thus, morphological evidence underpinning designation of Sonoran pronghorn as a unique subspecies is questionable at best.

Genetic analyses have been used to improve upon or supplement morphological data for the purposes of taxonomic classifications for several decades (Avise 1989). Recent advances in genetic technologies and increasing availability of comparative genetic data from wildlife species has improved our ability to both collect and interpret genetic information for taxonomic

purposes. Although little genetic information exists for Sonoran pronghorn, a growing number of studies have collected genetic information on other North American pronghorn herds. In particular, RFLP-based analyses of a 2.3 kb fragment of the NADH dehydrogenase-2 (ND-2) mitochondrial (mtDNA) gene region have been performed on small samples of pronghorn throughout North America (Lee et al. 1994) and a large (>400) sample of pronghorn from Arizona (Reat et al. 1999). No Sonoran pronghorn were examined in these studies. Genetic variation of pronghorn throughout their geographic range (196 pronghorn in 14 populations), including a sample of 9 Sonoran pronghorn, was evaluated by Lou (1998) who sequenced a 282-basepair segment of the mtDNA control region. Two genetically differentiated groups of pronghorn populations were identified; a northern group and a southern group (comprised of Texas and *sonoriensis* samples from southwestern Arizona). Lou (1998) did not have access to pronghorn samples from New Mexico or others from Arizona, but mtDNA sequencing offered no strong genetic evidence to support recognizing a taxonomic difference between Sonoran pronghorn and those sampled from Texas.

Past morphological analyses have not demonstrated the uniqueness of this taxon to the satisfaction demanded by current taxonomic practice. Recent genetic work has not addressed the taxonomic question directly. Preliminary genetic work with mtDNA sequencing calls into question the taxonomic status of Sonoran pronghorn (Lou 1998). However, lack of diagnosable characters unique to *A. a. sonoriensis* may be due to paucity of attention directed at this question. Taxonomic status of Sonoran pronghorn can only be resolved by examining a suite of molecular markers combined with more sophisticated morphological analyses.

The objective of this research was to investigate the genetic relatedness of pronghorn from throughout Arizona. As well, we endeavored to compare the genetic diversity among a few, well sampled Arizona pronghorn populations. Using this information, we provide a preliminary evaluation of the appropriateness of maintaining distinct subspecific nomenclature for Sonoran pronghorn.

METHODS

Sample Collection

Translocation of pronghorn between distant localities (e.g. from Wyoming to Arizona) has been a common management practice and can lead to spurious results in phylogenetic and population-level analyses. Unlike other regions in Arizona, the central and eastern regions have received relatively few translocated animals. Between 1994 and 1998, blood samples and/or ear punches were collected from the Sonora, central, and eastern regions of Arizona. The Sonora population has never received translocated animals. Figure 1 illustrates the locality of the Game Management Units from which samples were taken and their respective population designations. Tissue was kept in field storage buffer at ambient temperature until it could be stored at -80°C. Additionally, liver samples of pronghorn from Texas and blood samples of pronghorn from New Mexico were obtained from the lab of John Bickham at Texas A&M University. Collection information for samples used in this study is listed in Table 1. DNA was isolated from each sample using Qiagen's Qiamp DNA extraction kit.

Fig. 1. Sampled populations within Arizona.

Table 1. Tissue sample collection information.

Location	Population	n	Collection Years	Collector
Arizona	Central	64	1995-1997	E. Reat/J. R. Heffelfinger
	East	60	1995-1997	E. Reat/J. R. Heffelfinger
	Sonoran	35	1994-1998	J. deVos
Texas		7	1989-1992	T.E. Lee
New Mexico		3	1976	T.L. Yates

Data Collection

The polymerase chain reaction (PCR) was used to amplify approximately 550 bases of the control region of the mitochondrial DNA (mtDNA). Primers used to amplify the target region were LGL283 (5' TACACTGGTCTTGTAACC 3') and LGL1115 (5' ATAGACCCTGAAGAA (A/G)GAACCAG 3') and originally used in *Antilocapra* by Lou (1998). PCR conditions used in this study are as follows: 96°C (2 min), then 35 cycles of 96°C (30 s), 52°C (20 s), 72°C (2 min 30 s) with a final 10-min extension of 72°C. PCR products were cleaned using Qiagen's QIAquick PCR purification kit. Cycle sequencing was performed in the forward and reverse direction using Applied Biosystem's (ABI) Big Dye Ready Reaction kit and PCR conditions followed the standard protocol. Sequencing products were cleaned using the recommended ABI protocol of a 3M sodium acetate precipitation followed by ethanol washes. Sequencing products were analyzed with an ABI3700 DNA sequencer, then aligned against a published pronghorn sequence (Genbank accession #AJ235314) and edited in Sequencher version 4.1 (Gene Code Corp., Ann Arbor, MI).

Phylogenetic analysis of the mtDNA sequence data utilized PAUP* version 4.0b2a (Swofford 2000). Default search parameters were used unless otherwise specified. The data set was analyzed under maximum parsimony criteria and each site was considered an unordered character with 5 possible states (1 of 4 nucleotides or a gap). The weight of all characters was set equally to 1, excepting positions 302 through 306, which were each down weighted to 1/5, as these positions involved gaps. In this way, gaps were not ignored, but the various sized insertion or deletion events (indels) were unable to outweigh a single nucleotide change at other sites in the locus, which could artificially group unrelated individuals. Sequence data from *Cervus* and *Capreolus*, obtained from Genbank (accession #AB012369 and #Z70318, respectively), were set as paraphyletic outgroups in the analyses. Parsimony trees were generated using heuristic search routines employing 1,000 random addition sequences, swapping on multiple trees (MULPARS option), and utilizing tree bisection reconnection branch swapping. Support for nodes was assessed using Felsenstein's (1985) bootstrapping method with 2,000 replicates. Consensus trees were constructed using all equally parsimonious trees under both the majority rule and strict criteria. A network of haplotypes was constructed using the statistical parsimony software package TCS Version 1.13 (Clement et al. 2000) to explore fine scale geographic associations among haplotypes.

Genetic diversity within each of 3 Arizona populations was calculated using a variety of indices. Measurements included the number of haplotypes (A), average nucleotide difference within populations (k), and population-level haplotype diversity (h). When calculating these measures, insertions or deletions were counted as 1 event, rather than a number of nucleotide insertions or deletions.

RESULTS

A total of 174 individuals were examined in this study (Table 1). Mitochondrial DNA sequencing resulted in 512 readable nucleotides in the control region. A total of 22 haplotypes were recovered within pronghorn, including 22 variable characters. Maximum parsimony analysis resulted in 93 trees of 68.6 steps. Little phylogenetic resolution is recovered at this locus. In fact, no node received bootstrap support greater than 60%. The majority rule consensus tree (Fig. 2) shows clades recovered in at least 60% of the most parsimonious trees and does not conflict with the strict consensus (not shown), which, predictably, recovered only a subset of those clades under the majority rule. Major clades resolved on both the consensus tree and the network (Fig. 3) are labeled 1-3. Internal nodes cannot be defined geographically on these topologies because many haplotypes are found in more than 1 population (Fig. 3, Table 2). For example, of the 16 haplotypes found in Arizona, 6 are found in both the East and Central populations. Two haplotypes, AE and B, are found in all 3 Arizona populations, while the latter is also found in New Mexico and Texas. The Sonoran pronghorn population contains 4 haplotypes, 2 of which are unique. The central Arizona and eastern Arizona populations contain 5 and 3 unique haplotypes, respectively.

Table 2. Haplotype frequency distribution among Arizona populations. (Cen = central AZ population, Est = east AZ population, Son = Sonora population).

	Haplotype														
Pop	B	AE1	Y	Y2	H	H1	AJ	AJ1	AC	AC1	AG	AI	AQ	E	K
Cen	0.031	0.031	0.281	0.016			0.016	0.156	0.047	0.031	0.047			0.016	
Est	0.350	0.067	0.117					0.033	0.100			0.033	0.017		0.017
Son	0.429				0.514	0.029									

The fully resolved statistical parsimony network reveals a nearly star shaped topology (Fig. 3) with the widespread B haplotype giving rise to 8 of the 21 haplotypes through a single base change or indel event. In spite of the fact that the locus used in this study is a rapidly evolving region of the mtDNA, almost every haplotype is separated from its closest relative by 1 base change or indel event. Haplotypes are marked with their respective localities on Figure 2 and the size of the oval surrounding a haplotype reflects its relative frequency within Arizona (haplotypes unique to Texas and New Mexico lack ovals in the Figure 3). As seen in the phylogenetic analysis, the parsimony network reflects the general lack of geographic structure. Three haplotypes in particular are found at high frequency in Arizona: B, AE, and Y. Interestingly, haplotype AE, found in all 3 sampled Arizona populations, appears to be derived from the unique Sonora haplotype, H.

Fig. 2. Consensus 93 most parsimonious trees generated under the majority rule criteria. Numbers at each node indicate the percentage of trees in which the respective node is recovered. Circled numbers (1-3) mark major clades recovered in both the cladistic and network analyses.

Fig. 3. Statistical parsimony network. The size of the oval or square surrounding a haplotype is relative to the frequency of the haplotype in Arizona. Haplotypes that arise through a simple insertion or deletion are indicated on the figure. U1 represents an unknown haplotype, as yet unsampled. Small letters designate localities where the haplotype was found. Population abbreviations are as follows: Central AZ (c), East AZ (e), Sonora (s), Texas (t), New Mexico (n). Circled numbers (1-3) mark major clades recovered in both the cladistic and network analyses.

Indices of genetic diversity are reported in Table 3. The large Central Arizona population has the highest amount of diversity overall, while the Sonoran population appears much less genetically diverse. The Central and East Arizona populations have over twice as many alleles as the Sonoran population, as well as a more even distribution of allele frequencies as indicated by the nucleon diversity index (e.g., h = 0.79 vs. 0.57). Additionally, when examining the average nucleotide difference within a population, it is clear that the Sonoran population is a very closely related group of individuals (k = 1.12) while the other Arizona populations are more diverse (k = 2.98 and 2.26).

Table 3. Genetic diversity in 3 Arizona pronghorn populations. Indices of diversity are the number of alleles in a population (A), average nucleotide difference within a population (k), and haplotype richness (h). N = number of individuals sampled in each population.

	N	A	k	h
Central AZ	64	11	2.98	0.79
East AZ	60	9	2.26	0.79
Sonora	35	4	1.12	0.57

DISCUSSION

Little resolution in the phylogenetic history of American pronghorn was obtained from the maximum parsimony analysis of mtDNA data. Because of the low number of nucleotide differences between haplotypes, bootstrap support was not higher than 60% for any clade. Additionally, when looking at the parsimony network it becomes clear that most of the haplotype relationships do not fit the bifurcating topology enforced in a standard cladistic analysis. This is exactly what one would expect in a recently fragmented population (Crandall and Templeton 1996). Many of the haplotypes arise in a star-like pattern from the widespread haplotype B and a second, yet unsampled haplotype (marked U1 on Fig. 3). Notably, the haplotypes found in the Sonoran population are either found in other Arizona populations or are very closely related. Our results do not lend support to the idea that the Sonoran pronghorn is an especially distinct lineage.

The mtDNA control region has been used successfully to identify highly differentiated and geographically distinct lineages (e.g. African antelope, Matthee and Robinson 1999; roe deer, Vernesi et al. 2002) and in other cases it has failed to do so (e.g. bison, Polziehn et al. 1996; red kangaroo, Clegg et al. 1998). In the present study, only minor geographic differentiation is evident between sampled pronghorn populations. For example, in spite of the extremely small sample sizes from Texas (7) and New Mexico (3), only 1 major clade, marked "3" on figures 1 and 2, contains haplotypes found exclusively in Arizona. However, gene flow is currently limited among the Arizona populations (and presumably between the Arizona and Texas populations) as is evident by divergent allele frequencies (Table 2). For example, while haplotype B is a predominant haplotype in Arizona (Fig. 3), this is primarily because of its high prevalence in the East and Sonoran populations. Other dominant Arizona haplotypes, AE and Y, are found at high

frequency in the Central and East Arizona populations, but only at low frequency or not at all in the Sonoran pronghorn. Finally, the existence of the unique, high frequency haplotype H in the Sonoran population indicates that there has been no contemporary gene flow out of this population.

The Sonoran pronghorn have a paucity of genetic diversity when estimated indices are compared to the other Arizona populations. In fact, we find less diversity in the Sonoran population than was detected in most of the pronghorn populations reported in Lou's 1998 study (tables 2.3 and 2.7). This result is surprising because, in the earlier study, only 282 nucleotides were sequenced, gaps were ignored, and sample sizes were low, ranging from 9-21 individuals per population. Conversely, the Central and East Arizona populations have average levels of diversity compared to those in Lou's 1998 study when the discrepancy in sampling and sequencing effort is considered.

Population bottlenecks and isolation act to decrease overall levels of genetic diversity within populations and to randomly shift haplotype frequencies (Nei 1975). Our data suggest this has happened in the Sonoran pronghorn population. Phenotypically plastic morphological characters can be affected by historical events like bottlenecks in much the same manner, making it difficult to judge the verity and/or depth of lineage distinctness without a comprehensive sampling effort. As well, differences in morphology at the intraspecific level are more likely to reflect ecological rather than evolutionary relationships (Zink and Avise 1990). None of the data collected in this study support the idea that the Sonoran population has accumulated a particularly unique set of genetic traits as a result of its past evolutionary history. The genetic distinctness of the Sonoran pronghorn appears to be a result of recent discontinuity within a formerly contiguous southern population. This is an issue that begs further investigation and will benefit from future studies using nuclear genetic markers and a comprehensive morphological analysis.

MANAGEMENT IMPLICATIONS

Results of the phylogenetic and population-level genetic diversity analyses reflect the recent isolation of the Sonoran pronghorn population from other southern pronghorn populations and a prolonged bottleneck event. The Sonoran population contains unique haplotypes (2), as do the Central (5) and East Arizona (3) populations. Lack of genetic distinctiveness in the Sonoran pronghorn population, relative to the other populations sampled, does not call for the cessation of current conservation efforts. It is important to preserve the genetic resources in geographically peripheral populations, particularly when populations likely have become adapted to local environmental conditions. The Sonoran pronghorn exists in marginal habitat (Arizona Game and Fish Department 1981) and its ability to do so may be a result of locally adapted gene complexes and behavioral adaptations. In the interest of conserving adaptive diversity and evolutionary potential (Crandall et al. 2000), it is clear that this population must be treated as a distinct population that warrants further conservation effort.

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AEROTRANSFER OF AMERICAN PRONGHORN FAWNS FROM WYOMING TO MEXICO: ANOTHER STEP TOWARD THE ASSISTED REPRODUCTION OF PRONGHORN

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Abstract: The application of some specific techniques for reproductive technology may assist in the recovery efforts of endangered wildlife species. The endangered peninsular pronghorn (*Antilocapra americana peninsularis*) is a particular example for Mexico. The Peninsular Pronghorn Recovery Plan (PPRP) includes the experimentation of some of those techniques. The intensive management component of the PPRP for captive management of part of the population was initiated in 1998 in the Vizcaíno Desert. This first requirement of the assisted reproduction project was to provide the source of the female donors. International cooperation between the United States and Mexico regarding pronghorn conservation was documented previously. This paper describes a new component of the assisted reproduction project involving the long-distance aerotransfer of 12 fawns (3 males and 9 females) from Wyoming to Bioparque Estrella (BE-NL), in the Mexican state of Nuevo León, as embryo receptors for this part of the PPRP project. Currently there are 1 male and 6 females at BE-NL. Originally, plans for the assisted reproduction project just involved embryo transfer (embryo recovery, estrus synchronization, and embryo transfer) using American pronghorn females as receptors and one peninsular pronghorn female as donor. Now, with just 1 male in the BE-NL, artificial insemination could be added to the project.

Key words: Captive management, embryo transfer, environmental education, American pronghorn, peninsular pronghorn, recovery plan, reproductive technology.

Reproductive technology experiments are included in the Peninsular Pronghorn Recovery Plan (PPRP), which is a unique case for Mexico (Ramírez *et al.* 1999). The first requirement of the assisted reproduction project was the establishment of a captive herd where the donor female of the endangered peninsular pronghorn would be available. That part of the project has been completed (Cancino *et al.* 2001). This note documents the capture, stabilization and aerotransfer of 12 American pronghorn fawns from Wyoming to Mexico in order to develop a captive population of receptor females for assisted reproduction. That was the main objective of the transfer.

Several early general references describe different techniques and objectives for working with fawns of pronghorn (Floyd 1924, Nelson 1925, Einarsen 1948), and other, more recent papers include Schwartz and Nagy (1974, 1976), Brinkley (1987), Wild et al. (1994), Byers (1997), Martin and Parker (1997), Baker et al. (1998) and Blunt and Myles (1998). There are many references regarding assisted reproduction for other species, both wild and domesticated animals (31 and 53 references were selected respectively, not listed in the Literature Cited). For

this line of research in pronghorn, Mitchell (1965, as cited in O'Gara 1978) stated that pronghorn may have as many as 7 embryos, which supports the concept of surplus embryos that potentially could be implanted in receptor females.

In June of 2000, American pronghorn fawns were captured, hand-raised, and stabilized at F.E. Warren Air Force Base near Cheyenne, Wyoming. Newborn fawns were captured with long-handled nets and immediately transported to Veterinary Stables on the Air Force Base. Twelve fawns were captured to be transported to Mexico. Fawns were captured 24-48 hours after birth to allow the fawns to nurse and get antibodies from their mothers. Only 1 fawn from a litter was captured because of the desired number of each sex and to reduce potential for inbreeding as the captive population increased. Two or more fawns were held in each pen to help them socialize. Hand rearing was according to Blunt and Myles (1998), with small modifications. Fawns were bottle-fed with a mixture of evaporated milk and distilled water in a 3:1 proportion. Captured fawns were allowed to adjust to captivity and hand-rearing for 10 days in Cheyenne before being flown directly to Mexico

The use of a twin engine airplane was planned to transport fawns as quickly as possible, to minimize stress. Two or more fawns were placed in each of 6 large pet carriers and loaded on the plane. Passenger seats in the plane had been removed ahead of time. The pet carriers were stacked 2 deep on one side of the plane to allow ventilation and were secured with duct tape.

The Veterinary Stables at the Air Force Base was within 5 km of the Cheyenne airport. The flight was about 3,000 km from Cheyenne, WY, located at 41° 10' N, 104° 50' W to Monterrey Nuevo Leon, Mexico at 25° 20' N, 100° 00' W, and then the fawns were transported by truck another 80 km to Bioparque Estrella, Montemorelos, Nuevo Leon, Mexico. When this flight was carried out, we thought that it would be the record for aerotransfer of pronghorns. However, we found that a couple of yearlings were flown to Japan (T. Hill, personal communication).

After 12 hours of flight, the fawns were released in a couple of 4 x 4m pens. Some modifications were made to the facilities of the BE-NL before the arrival of the fawns (*e.g.* a new door, a special fence, and structures for shade, feeding and watering).

One (male) of the 12 fawns died one month after the arrival and 4 more animals have died after weaning. Presently, one male and 6 females are still alive. With just one male in the BE-NL, artificial insemination could be included in this line of research.

This experience taught us much about the numerous permits, payments of taxes, and other different arrangements needed to transfer pronghorns from the United States to Mexico. This is especially true because the species is endangered in Mexico (SEMARNAT 2002).

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A BESTIARY OF ANCESTRAL ANTILOCAPRIDS

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Abstract: Today's pronghorn is the lone survivor of a diverse group of pronghorn-like ruminants in North America. Many people working with pronghorn today are aware that the pronghorn has extinct relatives, but few appreciate the diversity of the Miocene and Pliocene antilocaprids. More than 18 genera have been described in the family Antilocapridae, grouped into 2 subfamilies, Merycodontinae and Antilocaprinae. Merycodonts flourished in the middle Miocene and left no extant forms, but probably gave rise to the antilocaprines. Antilocaprines first appeared in the middle Miocene and reached their peak in diversity and abundance in the late Miocene, with today's *Antilocapra americana* being the only 1 to survive the dramatic environmental changes and extinctions of the late Cenozoic. Merycodonts were generally smaller than antilocaprines and also had horns that were apparently covered with skin rather than the keratin sheath of the antilocaprines. There is evidence that the skin covering the horns of merycodonts was shed periodically, leaving bony rings around the base of the horns, presumably at the point to which the skin regressed. This skin, retaining its deciduous nature, most likely evolved into the thicker keratinized horn covering that characterized the antilocaprines, including *A. americana*. Some merycodonts, such as *Ramoceros*, had horns that resembled deer antlers; others were palmated like miniature moose. Later antilocaprines sported bovine-like horns, long spiraled horns, 4 horn cores and even 6 horn cores. Fossilized keratin sheaths have not been found, but I can only imagine what an antilocaprid with 6 horn cores looked like. What follows is an illustrated "bestiary" or field guide of the ancestral antilocaprids, highlighting appearance, chronological age, and evolutionary relationships.

Key words: *Antilocapra americana*, Antilocapridae, Antilocaprinae, evolution, Merycodontinae, pronghorn antelope. .

Antilocapridae is a monotypic family endemic to North America. Pronghorn currently range from southern Alberta and Saskatchewan, south into northern Mexico and the Baja peninsula, east throughout the central plains of the United States, and west into Oregon and northern California (Yoakum 1981). The family is monotypic, however, only because extinction has robbed us of at least 17 very different forms of antilocaprids that once roamed the open western plains of North America. They appear suddenly about 19 million years ago, but their entire evolutionary development was not confined to North America because there were no

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higher ruminants on this continent prior to the early Miocene (Janis and Manning 1998). Thus, even antilocaprids have origins in the Old World.

During the mid Miocene, widespread forest was giving way to an open park savanna with a mosaic of riparian forests and open grasslands (Webb 1977). Antilocaprids diversified in the late Miocene in response to the expansion of grassland habitat. Antilocaprid teeth had a high level of hypsodonty (tall crowns), which increases through evolutionary time. The increase in hypsodonty throughout the late Miocene and Pliocene is indicative of increasing aridity and a diet containing a substantial amount of grit found in open, arid floristic environments (Wilson 1960).

The "supraorbital" cranial appendages of all antilocaprids arise from the top of the orbit as in modern pronghorn. This characteristic and the hypsodont teeth are consistently associated with this family. Antilocapridae has been divided into 2 subfamilies, the merycodontinae probably ancestral to the antilocaprinae.

The subfamily Merycodontinae appeared nearly 19 million years ago (MYA) and by the time it was fading from the fossil record (9 MYA), the subfamily Antilocaprinae was rising to prominence (14 MYA to Present). The antiquity of these antilocaprids is incredible in light of the fact that the genus *Homo* does not appear until about 2.5 MYA.

Members of Merycodontinae (merycodonts) were actually very small animals, most of the 5 recognized genera standing only about 20 inches at the shoulder and weighing 25-50 pounds (Janis 1982). Unlike later antilocaprids, many merycodonts retained the lateral second and fifth digits (dew claws) on at least the front feet and possessed upper canine teeth (Frick 1937:447, Scott 1937, Janis and Manning 1998). The most characteristic and diagnostic feature of merycodonts was their horns. Rather than a straight knife-like horn core, the horns were divergently branched or palmated. Early paleontologists were initially led astray, thinking these were ancestors of deer and that the elaborate horns were deciduous. Analysis of the horn cores, and a lack of any evidence of casting in horns or skulls, proved these to be permanent structures (Furlong 1927). The horn surfaces were smooth with some nutrient sinuses, indicating they were covered with skin and not a keratinous sheath. Additionally, a deciduous sheath could not be shed easily from a multi-branched horn. Although the horns were not deciduous, the skin apparently was (Furlong 1927). Bony rings were present around the bases of horns after the animal's second year (Voohries 1969:40). These rings are not part of the core, but are bony deposits on the surface of the horn. The skin covering was probably regulated seasonally by hormones (similar to the pronghorn sheath) and was shed and regrown annually after the animal reached adulthood. Each successive shedding cycle deposited a "psuedoburr" to mark the point at which the skin regressed (Voorhies 1969, Goss 1983). The existence of hornless merycodont skulls indicates females did not have horns (Frick 1937:266, Voorhies 1969).

Some of the earliest members of the subfamily Antilocaprinae (antilocaprines) coexisted with the latest merycodonts. Antilocaprines, however, were generally larger in body size with longer legs, and none of at least 13 genera possessed upper canine teeth or lateral digits (dew claws). The horns were not widely dichotomous as in merycodonts, but generally conical or

blade-like horn cores covered with a keratinous sheath. The surface of the horn cores was porous with grooves that carried nutrients up the shaft. Some horn cores have areas of increased porosity where there was accelerated growth in the overlying sheath, not unlike the tips of a pronghorn's core. Unfortunately no horn sheaths from ancestral antilocaprines have been preserved in the fossil record; we are left to guess what kind of elaborate sheaths past evolutionary forces fashioned. In some cases a ring of small holes (nutritive foramina) at the base of the horn cores illustrate where the base of the keratin sheath met the permanent fur of the head (Webb 1973). More than 100 skulls have been recovered from the Pleistocene antilocaprine *Stockoceros*, but none were hornless or had reduced horn cores (Skinner 1942, Furlong 1943). Because of this and other fossil evidence, it is generally thought that female antilocaprines probably had horns the same size or possibly smaller than males, similar to modern pronghorn. Webb (1973) showed clear evidence of dimorphism in a large sample of 6-horned antilocaprines from central Florida. The males and females previously had been named as separate species.

Antilocaprids were already built for speed by 18 MYA. The earliest known merycodonts had long, slender limbs and were adapted to a highly cursorial lifestyle (Furlong 1927, Frick 1937:447). It has been opined that this ability to run fast evolved as an escape mechanism in response to fast-running pursuit predators. The North American cheetah-like cat (*Miracinonyx spp.*) had a similar geographic distribution as antilocaprids and is frequently offered as the obvious evolutionary force that resulted in the speed of modern pronghorn (Byers 1997). However, the cheetah-like cat does not appear in the fossil record of North America until the end of the Pliocene when the open savanna was giving way to a more arid monoculture of steppe grasslands about 2.5 MYA (Kurten 1976, Adams 1979). The lack of *Miracinonyx* fossils prior to this time indicates the absence of this animal, since many fossil-bearing sites have yielded other Miocene and Pliocene representatives of the grassland savanna. The true Cheetah (*Acinonyx*) appeared about 3.5 MYA in Europe (Adams 1979). It is not known what felid was ancestral to *Acinonyx* and *Miracinonyx*, however, no cheetah-like cats are known prior to 3.5 MYA anywhere in the world (Van Valkenburgh et al. 1990). Certainly there were other predators preying on the great diversity of antilocaprids, however, the fossil record shows that almost all were ambush predators. Janis and Wilhelm (1993) analyzed limb morphology of fossil predator and prey taxa and showed that pursuit predators developed a capacity for running at high speeds about 20 million years after it was well-established in ungulates. The thought that a cheetah-like cat is responsible for the speed in antilocaprids is inviting, but the coevolution of speed in predators and prey in North America has no apparent scientific basis.

The purpose of this paper is not to present a taxonomic revision of Antilocapridae, nor is it to revise or describe the evolution of the various forms discussed herein. Excellent discussions of the evolution of this family are already available (Webb 1973, Janis and Manning 1998). The entire family is badly in need of taxonomic revision, but this can only be accomplished by a re-examination and reanalysis of the fossil specimens held in several key institutions. Because of the uncertainty behind some of the taxonomy, this bestiary is admittedly typological. The goal here is to highlight and discuss the different "forms" of ancestral antilocaprids to give current pronghorn enthusiasts an appreciation for the diverse assemblage of pronghorn-like ruminants that once occupied the landscape. Some forms were named and described based on only a few fragments of fossil bone. One such type specimen consisted of a partial jaw with 2 teeth (Skinner and Taylor 1967). In another case, 6 species within a genus are described with only a

single skullcap and a collection of teeth (Frick 1937:500). Only in cases of large sample sizes can the true natural variation of a species be evaluated (Furlong 1927, Voorhies 1969). To avoid the confusion at the species level, we summarize these antilocaprids by genus. The horn cores of most genera are known from fossils, however, complete fossil skulls are rare. In several genera we do not know what the entire skull looked like. In these cases our illustrations reflect a typical *Antilocapra* skull altered based on what fragmentary information is known about the animal. The names of many of the genera end in 1 of 2 Greek suffixes; "*meryx*" and "*ceros,*" the Greek words for ruminant and horn, respectively (Furlong 1941). Hopefully as more fossils come to light and more work is done on uncatalogued material, we will continue to piece together the wonderful world of the pronghorn's ancestors.

Fig. 1. Relative appearance and persistence of various Merycodontinae (gray) and Antilocaprinae (black) genera culminating in the only extant genus (*Antilocapra americana*).

Genus: **Paracosoryx**
Species: **alticornis, dawesensis, furlongi, loxoceros, nevadensis, wilsoni and minor.**
Subfamily: **Merycodontinae**

Paracosoryx is the most primitive merycodont genus yet discovered. They appear in the fossil record nearly 19 million years ago in the early Hemingfordian age (Janis and Manning 1998). The teeth were less hypsodont (high crowned) and more brachydont like those of deer. This provides evidence that it browsed on shrubs and twigs more than grass and probably lived in a shrubby or forested environment, rather than open grassland. Horns were simply forked into 2 tines on each side and set on tall, back-tilting shafts above the skull. The rear tines were frequently longer than the front. Paracosoryx had a skull that was proportionately shorter than today's pronghorn and it possessed small upper canines. The presence of upper canines was lost in almost all subsequent antilocaprids. Psuedoburrs (sometimes 2 or 3) that look like the burr at the base of deer antlers are present and believed to be the result of the seasonal regression of a skin-like covering. In Paracosoryx, these psuedoburrs appear higher on the horn shaft, meaning permanent, furred skin was present on the lower portion of the horn. This primitive form also possessed the lateral second and fifth (dew claws) on the front feet (Frick 1937:447); this feature also was lost early in the evolution of Antilocapridae.

Genus: **Merriamoceros**
Species: **coronatus**
Subfamily: **Merycodontinae**

Merriamoceros carried some of the most unusual horn cores of any early antilocaprid. The horns arose from the top of the orbits like all others, but then developed into an extremely palmated cup on the top of relatively short horn shafts (Frick 1937:318). The short horn shafts of this Merycodont also had psuedoburs, revealing that it too had seasonally skin-covered horns. Younger individuals appear to tend towards a single anterior prong and double posterior prongs (Frick 1937:332). Older animals sometimes had as many as 10 points around the palmated disk. The skull was proportionately short (Frick 1937:291) and it did not possess the upper canines of more primitive forms.

Genus: ***Ramoceros***
Species: ***osborni (=hitchcockensis, =howardae, =kansanus), ramosus (=marthae, =palmatus) , brevicornus.***
Subfamily: **Merycodontinae**

These were small ungulates, measuring about 19 inches at the shoulder. The horns of *Ramoceros* were remarkable in their similarity to deer antlers. The 2- to 4-point (usually 3) horns looked amazingly like deer antlers; the psuedoburs at the bases completed the deception. In some individuals, the horns forked dichotomously, not unlike mule deer antlers (Frick 1937:299). The horns arose not so much supraorbitally like other antilocaprids, but rather out of the back of the orbit. The beams flared outward and upward like antler beams and, oddly, all fossil horns in the American Museum collection are asymmetrical (Janis and Manning 1998; Andrea Valli, personal communication, 2002). *Ramoceros* fossils led many early paleontologists astray into considering merycodonts the ancestors of deer (Scott 1937). Others noted, however, that the teeth and body structure was too similar to present-day pronghorn to have occurred by chance. Despite the remarkable convergent evolution, these animals were most certainly primitive antilocaprids. Unlike *Antilocapra*, they possessed remnants of the second and fifth toes (dew claws). Their limbs were relatively long and thin, indicating a life of speed on the open plains (Matthew 1904:105).

Genera: ***Cosoryx***
Species: ***agilis, burgensis, cerrosensis, furcatus, ilfonensis,*** **and** ***trilateralis.***
Subfamily: **Merycodontinae**

Cosoryx has incorrectly been used as a synonym for the *Merycodus/Meryceros/Submeryceros* group (Janis and Manning 1998). This genus was very similar to the previous one, but differed in having taller horn cores, more hypsodont teeth, and appears later in the fossil record (S. David Webb, University of Florida, personal communication, 2002). *Cosoryx* horns are not easily distinguished from the *Merycodus* group, but they may have had somewhat taller shafts with elongated anterior tines that pointed inward (Frick 1937:291). The muzzle is described as short and slender. The teeth are more hypsodont with smaller premolars (Skinner and Taylor 1967), indicating life on the open plains grazing on herbaceous vegetation. Although in the subfamily Merycodontinae, Janis and Manning (1998) placed *Cosoryx* closer to the later antilocaprines than to *Merycodus* in a cladogram of evolutionary relationships.

Genera: ***Merycodus (=Meryceros, =Submeryceros)***
Species: ***crucensis, crucianus, hookwayi, joraki, major, minimus, necatus, nenzelensis, sabulonis, savaronis, prodomus, and warreni.***
Subfamily: **Merycodontinae**

This group is in need of revision to determine just how specimens assigned to these genera are related to 1 another (Webb 1969). Individuals variously published as Meryceros, Merycodus, Submeryceros are probably not taxonomically different forms. Male Merycodus are characterized by an equally forked horn with a short shaft. The front and rear tines may be as long or longer than the horn shaft, with the entire horn rising less than 6 inches above the skull. Some larger collections of this animal have juvenile individuals that sport spike-like horns (Frick 1937:362). As in other merycodonts, residual rings of bone are present on the shaft of the horn from a periodically receding skin covering. It appears that females did not have horns (Frick 1937:274) or possibly showed the variation of small or no horns exhibited by extant pronghorn. In the largest known sample, Voorhies (1969:35) found that 150 of the 273 (55%) merycodont skulls were hornless. Males still retained upper canines at this point in antilocaprid evolution, but at least 1 female skull lacks canines (Frick 1937:362). The proportions of the skeleton indicate this was a fleet-footed animal with slender legs. The lateral toes, or dew claws, are more reduced than earlier forms, but still present as small vestigial appendages (Scott 1937). This form was very abundant throughout western North America as illustrated by the recovery of 475 individuals in 1 site in Knox County, Nebraska (Voorhies 1969).

Genus: ***Hexameryx***
Species: ***simpsoni (=elmorei)***
Subfamily: **Antilocaprinae**

As 1 of the most interesting members of the subfamily Antilocaprinae, *Hexameryx* sported 6-horn cores, all separately covered with a keratinous sheath as in today's pronghorn (White 1941). Small holes, called nutritive foramina, encircle the base of each horn core, providing evidence of vessels that once carried nutrients to 6 separate horn sheaths (Webb 1973). This ring of nutritive foramina mark the location where the thick fur of the head terminated and the sheath started. What shape these sheaths took is not known since none have been found fossilized. The front horn cores were the shortest, while the rear horns were not only the longest, but also curved slightly inward near the tips. Originally 2 species were thought to be represented (White 1942). Webb (1973), however, considered these 2 forms to be male and female sexes of the same species, meaning females had horns nearly as large as males. *Hexameryx* has only been found in Florida; not as unusual as first thought when you consider that the open woodland savanna extended around the Gulf Coast in the late Miocene (Webb 1977). The upper molars were somewhat less hypsodont than other genera, so perhaps this animal was not as closely associated with the open plains.

Genus: ***Hexobelomeryx***
Species: ***fricki***
Subfamily: ***Antilocaprinae***

Hexobelomeryx was another 6-horn antilocaprine that roamed north central Chihuahua, Mexico (Furlong 1941). The uniqueness of this form lies not in the number of horns, but the placement. On each side of its head, Hexobelomeryx had 2 horn cores that were close together and a third widely divergent. Nutritive foramina showed that the 2 closely associated horn cores were enveloped in a single sheath. Some specimens had the 2 anterior horn cores joined, but in others the 2 posterior horns were joined. The teeth and skeletons of these 2 forms did not differ, leading Webb (1973) to again determine that this probably was a sex-specific trait, with males having the double sheath in the rear and females in the front. Although the horn conformation differs substantially from Hexameryx, the tooth structure is closely comparable (Webb 1973). There is no doubt Hexameryx and Hexobelomeryx are closely related and, in fact, probably should be classified as distinct species in a single genus (Hexobelomeryx; Simpson 1945, Ahearn 1988).

Genus: ***Sphenophalos (=Plioceros)***
Species: ***nevadanus, middleswarti***
Subfamily: **Antilocaprinae**

Sphenophalos was a geographically widespread animal of the open plains with relatively stout horn cores that twisted slightly as they arose from the back of the orbits. Plioceros has been described as a separate genus (Frick 1937), but differences between the 2 can be explained by age-related variation of Sphenophalos (Furlong 1932, Stirton 1938). The horn cores of this taxon angled to nearly the same degree as those of Antilocapra, but terminated in a blunt fork (Furlong 1932). Moreover, the front of the horn base is narrower than the back, reminiscent of the wedge-shaped horn core of Antilocapra. Frick (1937:266) shows a skull of this animal without horn cores, but rather small bony protuberances on top of the orbits. This may represent a female with only small vestiges of horn growth as in today's pronghorn. Sphenophalos first appeared in the middle Miocene, at a time when there were many forms of Merycodontinae coexisting on the western plains. In fact, Sphenophalos was a small animal and similar in size to the contemporaneous merycodonts. The teeth are very hypsodont, almost as much so as Antilocapra (Janis and Manning 1998). Because of the many similarities, Sphenophalos has been placed by many in the direct evolutionary line leading to the extant pronghorn (Furlong 1932, Webb 1973).

Genus: ***Ilingoceros***
Species: ***alexandrae, schizoceras***
Subfamily: **Antilocaprinae**

Ilingoceros takes the twisted horn trend to the extreme with long spiraled horn cores rising up backward and outward from the top of the orbits. Except for the spiraling grooves, the horns are round in cross section and terminate in a small fork (Frick 1937:471). The terminal fork of the horn core is made up of spongy bone tissue indicating there was considerable growth in the keratinous sheath beyond that point. Merriam (1909) originally described it as a true antelope (Bovidae), but later recanted after seeing the extreme dental hyposdonty and realizing it was an antilocaprid (Merriam 1911). The teeth of Ilingoceros are similar to Sphenophalos (Merriam 1911; Andrea Valli, personnal communication, 2002), which, along with the horn twist, indicates they may have arisen from a common ancestor. The characters of this genus were so different that it appears to be an evolutionary side branch, since no subsequent forms seemed to carry these characteristics forward. Some fossils indicate it may have reached a similar body size to the current pronghorn. Its distribution was primarily along the west coast and Great Basin, with an extension into New Mexico and northern Chihuahua.

Genus: ***Proantilocapra***
Species: ***platycornea***
Subfamily: **Antilocaprinae**

Little is known about this animal because only a single specimen consisting of a partial skull and mandible have been found in Cherry County, Nebraska (Barbour and Schultz 1934, Frick 1937:510). The horn cores are narrow, triangular blades similar to those of the extant pronghorn with a sharp leading edge. The cores, however, are exceedingly short, with bulbous and porous ends indicating an area of active sheath growth from that point (Barbour and Schultz 1934). The small horn cores actually resemble those of a pronghorn fawn. In body size it was similar to the small merycodonts that were disappearing at that time (Frick 1937:475). The high crowned teeth were used for a diet of grass and forbs rather than browse, indicating an affinity for open areas. When first discovered, it was proposed as a direct ancestor of modern pronghorn. Having only 1 specimen similar to modern pronghorn at such an early age makes it difficult to determine where, or if, it fits into the evolutionary development of Antilocapra.

Genus: ***Osbornoceros***
Species: ***osborni***
Subfamily: **Antilocaprinae**

Osbornoceros is another antilocaprid form that looks decidedly bovine. The bases of the horn cores are triangular in cross section with the edge facing forward. The flattened horns rise from the skull and curve back in a sweeping arch, with the leading edge twisting to the outside and then curling downward (Frick 1937). A complete skull has not been found, but teeth associated with these skullcaps and horn cores are unmistakably those of antilocaprines. The face was proportionately shorter than in modern pronghorn, as evidenced by the possession of shorter mandibles. Limbs were small, but larger than the largest merycodonts (Frick 1937:514). Osbornoceros had a limited distribution in the southern Great Plains of New Mexico and the panhandles of Texas and Oklahoma (Janis and Manning 1989). Proantilocapra may very well have shared an ancestor of this form; since the stubby horn cores of the former need only be lengthened and curved to take the form of Osbornoceros (Andrea Valli, personal communication, 2002, Janis and Manning 1989). No subsequent antilocaprines carry these characteristics, relegating this taxon to the category of an evolutionary side-branch.

Genus: ***Ottoceros***
Species: ***peacevalleyensis***
Subfamily: **Antilocaprinae**

This antilocaprine was discovered in the 1950s in a single locality in southern California (Peace Valley). The remains of at least 5 individuals from this location represent all the material available to describe this animal. The horn cores rise from the top of the orbit in a thick shaft similar to *Spenophalos*, but the terminal fork is much more developed (Miller and Downs 1974). In addition, each horn shaft has a prominent lateral ridge starting just above the orbit and running up the outside of the horn core giving it a triangular shape in cross section. Horn core characteristics show that a sheath was present, but how it was shed is puzzling. Perhaps, the lateral flange allowed the sheath to slide off the forked horn core. The orbits appear to be less protruding than modern *Antilocapra* and other fossil antilocaprids. One of the other 4 specimens was probably a female, since it is mature and yet has markedly smaller horns. Males and females were short, attaining only about 22 inches at the shoulder (Miller and Downs 1974).

Genus: ***Capromeryx (=Breameryx)***
Species: ***furcifer (=minimus), arizonensis, gidley, tauntonensis, minor, mexicanus***
Subfamily: **Antilocaprinae**

Capromeryx is well-known, owing to its wide geographic distribution and abundance of individual fossils in some locations. The 4 small horn cores of Capromeryx were nearly vertical and grew out of the top of the orbit; the anterior core was smaller and round in cross section, while the rear horn was flatter, larger, and bent forward. These 2 horn cores were very close to 1 another and may have been covered with a single sheath. The teeth were very hypsodont, resembling modern pronghorn (Taylor 1911) and revealing their diet consisted of grass and other herbaceous plants. Capromeryx body size seemed to decrease through time (Morgan and Morgan 1995). In the late Pliocene it was about 85% the size of Antilocapra, but only about 22 pounds and 22 inches at the shoulder by the time it became extinct at the end of the Pleistocene (Kurten and Anderson 1980). This was definitely a grassland animal, however, fossils were found among other animals that lived in an area of open plain with scattered clumps of trees. Fossils of Capromeryx were more numerous than Antilocapra in the tar pits of Rancho La Brea (Kurten and Anderson 1980).

Genus: ***Ceratomeryx***
Species: ***prenticei***
Subfamily: **Antilocaprinae**

Ceratomeryx is another 4-horned antilocaprine, but the horn cores are relatively small (larger horn cores measured 2 inches). The front, larger horn cores arose directly over the orbits and the smaller rear horn cores resemble small bumps that grew directly behind the anterior cores (Gazin 1935). Both front and back horns were flattened laterally, rather than round in cross section. The crown of the skull was flatter and not as dome shaped. This little pronghorn was about half the size of today's pronghorn antelope. Teeth were hypsodont as is typical of this family and very similar to present-day pronghorn. This early to mid Pliocene antilocaprine was much smaller than modern pronghorn, but details of the dimensions are unclear because it is known only from 2 partial skulls and a few associated bones.

Genus: ***Tetrameryx***
Species: ***shuleri, mooseri, irvingtonensis, knoxensis, tacubayensis***
Subfamily: **Antilocaprinae**

As the name implies, *Tetrameryx* had 4 horns, with the rear horn cores much longer (12 inches) than the front (4 inches; Frick 1937:531). These cores carried their own separate sheath as evidenced by the ring of nutritive foramina around the base of each (Webb 1973). The forward core is flattened slightly (longer front to back), while the rear is more nearly round in cross section (Dalquest 1974). It differs from *Stockoceros* in that the rear horns are much longer than the front (Hibbard and Dalquest 1960). This was a large, heavily built antilocaprid with molars exceeding the size of current pronghorn. Some forms had a slightly lighter build and would be mistaken for modern pronghorn if the rear horn cores were removed. Although more heavily built, the high degree of dental hypsodonty indicates it too was mostly an animal of the open country in the southwestern United States. There is a similar form (*Hayoceros*), for which little is known, relegated by Frick (1937:532) to a subgenus within the genus *Tetrameryx*. *Hayoceros* had a longer front horn core that was roughly triangular in cross section. Based on similarities in characteristics other than horns, *Tetrameryx* (including *Hayoceros*) may be congeneric with *Stockoceros* (Colbert and Chaffee 1939). A more complete analysis (and possibly more fossils) is needed to clarify these relationships.

Genus: ***Stockoceros***
Species: ***onusrosagris, conklingi***
Subfamily: **Antilocaprinae**

Stockoceros is very similar to Tetrameryx, except that both front and rear forks of each horn core were of equal length and generally circular in cross section (Skinner 1942). Females evidently had horns because after collecting well over 100 skulls, none have been hornless. The entire nose of Stockoceros was more slender than Antilocapra, and the teeth were similar but less hypsodont. There are 2 forms that have been described and given species names. The first (S. conklingi), was smaller – between the size of modern pronghorn and the diminutive Capromeryx. This species is represented by a large sample of specimens and, despite its smaller size, was built proportionately heavier than pronghorn. The other form (S. onusrosagris) is also represented by a large sample (55 skulls from 1 Arizona location alone), and was only slightly smaller than the size of Antilocapra. The latter species differs from Antilocapra in minor body proportion; difference in leg dimensions hint that it may have had a greater bounding ability but less speed (Colbert and Chaffee 1939, Skinner 1942). Like Hayoceros, Stockoceros also was designated as a subgenus within Tetrameryx (Frick 1937:521); however, subsequent authors treated this taxon as a full genus (Skinner 1942, Furlong 1943, Czaplewski et al. 1999). As mentioned, Stockoceros, Tetrameryx, and Hayoceros may be congeneric, differing only at the species level (Colbert and Chaffee 1939). A small collection of post-cranial material and a single, bifurcated horn core fragment have been referred to a new similar genus Texoceros (Frick 1937:505), but without additional material it is difficult to determine its phylogenetic affiliation or even what this form looks like.

Genus: ***Subantilocapra***
Species: ***garciae***
Subfamily: **Antilocaprinae**

Webb (1973) described a sample of 2 horn cores and a few hypsodont teeth from a unique antilocaprine from Florida. These flattened horn cores resemble extant Antilocapra, but they also have a bony "prong core" present on the leading edge of the main horn core. Because of the similarities to modern Antilocapra, Webb (1973) designated this form Subantilocapra. The presence of a bony core under the prong in the sheath of present-day pronghorn was previously suspected because of the morphology of their horn core. Extant pronghorn have 2 prominent grooves or sulci on the horn core; one runs up the back of the core to the tip and the other can be traced up the front where it ends at the location of the front prong in the sheath (formerly an anterior horn core point in Subantilocapra). With its smaller forward point, the Subantilocapra horn development was intermediate between Sphenophalos and modern pronghorn, indicating it may be a transitional step in the evolution of extant pronghorn (Webb 1973). Chronologically, the early Pliocene Subantilocapra is in the right position to derive modern pronghorn, which are found only in Pleistocene deposits dating to less than 1 million years ago. Richards and McCrossin (1991) suggested Subantilocapra was synonymous with Sphenophalos/Plioceros. New Subantilocapra material has revealed that it shares some dental characteristics with Antilocapra that are not found in Sphenophalos/Plioceros (D. Webb, Pers. Commun., 2003). This strengthens the theory that Subantilocapra represents an intermediate form leading to the evolution of today's pronghorn.

Genus: ***Antilocapra***
Species: ***americana, pacifica***
Subfamily: **Antilocaprinae**

Modern *Antilocapra* has only 2 horn cores, which are straight and unbranched. The leading surface of the horn core comes together as a sharp edge running up the front of the core. Since this animal is the sole survivor of this incredible family of ungulates, we know what the horn sheaths look like. Despite the straight cores, the horn sheathes curve inward at the top and sport a "prong" or blade on the anterior surface of the horn sheath (O'Gara 1990). The anterior prong of the horn core is absent, but its manifestation in the sheath and a noticeable anterior vascular groove to the prong attest to its former presence (Kurten and Anderson 1980:325). The prong on the leading edge of the sheath is probably a vestigial remnant suggestive of the ancestral form with a bifurcated horn core (i.e., *Subantilocapra*). Females are hornless or usually have prongless horns with sheaths less than 4 inches long. Late Pleistocene (nearly 20,000 years ago) *Antilocapra americana* fossils from Wyoming and Rancho La Brea in southern California are indistinguishable from today's pronghorn (Reynolds 1976, Chorn et al. 1988). However, Richards and McCrossin (1991) described 2 recently discovered specimens and compared them to a large sample of modern pronghorn and Pleistocene specimens from California. They found that although the skulls of the new specimens were indistinguishable from present-day and Pleistocene pronghorn, the horn cores were significantly bigger. They designated this extinct large-horned pronghorn *Antilocapra pacifica*.

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VEGETATION HEALTH RELATIVE TO PRONGHORN HEALTH

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Abstract: Information regarding the relationship of pronghorn herds to vegetation condition and trend is paramount in management strategies. Vegetation status has been identified as a key factor influencing pronghorn production and survival. Vegetation characteristics are related to diet selection and protection cover. Recent pronghorn/habitat assessment assignments have disclosed the need for greater understandings of these relationships. Consequently, a review of findings regarding climate/vegetation/pronghorn is provided. It appears that habitats with vegetation in healthy condition produce healthy pronghorn populations. These factors are of utmost importance in assessing environmental variables influencing pronghorn welfare.

Key words: pronghorn, *Antilocapra americana*, vegetation, vegetation condition, diet selection, cover, pronghorn production, pronghorn populations.

SONORAN PRONGHORN HABITAT USE AND AVAILABILITY ON A MILITARY RANGE

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Abstract: The Sonoran pronghorn (*Antilocapra americana sonoriensis*) population in the United States has been reduced because of habitat loss. Low population numbers coupled with unstable recruitment have raised concerns regarding this subspecies. We examined habitat use by pronghorn on the Barry M. Goldwater Range (BMGR) from 1999 to 2001. Pronghorn sightings (N=443) were overlaid on 344 1-km^2 blocks within the North and South Tactical Ranges, BMGR, with vegetation association and disturbance status (e.g., airfields, roads, targets) identified for each block. Pronghorn locations were distributed in proportion to vegetation associations. Sightings were biased toward disturbed blocks with 72% of pronghorn locations occurring in proximity to mock airfields, high explosive hills, roads and targets. Disturbed habitat on the BMGR may attract Sonoran pronghorn by creating favorable forage and viewing conditions in a vegetatively monotypic environment. Environmental manipulations simulating the effects of some military disturbances on the landscape may improve remaining Sonoran pronghorn habitat.

Key words: Antilocapra americana sonoriensis, Barry M. Goldwater Air Force Range, disturbed habitat, habitat availability, habitat use, military activity, Sonoran pronghorn.

EFFECTS OF WINTER RANGE ON A PRONGHORN POPULATION IN YELLOWSTONE NATIONAL PARK, WYOMING

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Abstract: The only population of pronghorn antelope (*Antilocapra americana*) in Yellowstone National Park (YNP) has shown a recent drop in numbers from over 500 animals in the early 1990's to < 240 animals in the past 6 years. Concern for the long-term sustainability of this herd led to an examination of the effects that the winter range has on the habitat use and demographics of this population. Radio telemetry data were collected on instrumented adult does from June 1999 through August 2001. While all pronghorn congregated on the winter range from December through March, there were 2 distinct segments to this population based on migratory strategy: a resident herd that remained on the winter range year-round and a herd that migrated to higher valleys within the Park during the summer. There was evidence of migration north of the YNP as well. The current winter range is located within the northern range of YNP, just west of Gardiner, Montana. A portion of it lies outside the Park on private, U.S. Forest Service, and conservation easement lands. Results from logistic regression showed that pronghorn selected for cover and elevation on the winter range and selected among cover types. Rabbitbrush and greasewood types were used more than grassland, while sagebrush types were avoided. Observational studies did not show any 1 cover type being used more for feeding and bedding than the other cover types. Microhistological analysis of fecal pellets showed that the majority of pronghorn winter diet was comprised of browse, with rabbitbrush (*Chrysothamnus* spp.) being the most prevalent woody species. Adult doe survival probabilities and fawn:doe ratios for non-migratory pronghorn were lower than those for migratory pronghorn. An evaluation of the relationship between adult mortality and recruitment showed that the resident herd is draining the population while the migratory herd is the source for what limited recruitment is occurring in this population.

Key words: pronghorn, *Antilocapra americana*, Yellowstone National Park, habitat selection, winter range, diet, seasonal migration.

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WINTER PRECIPITATION AND PRONGHORN FAWN SURVIVAL IN THE SOUTHWEST

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Abstract: Using consistent observer and survey procedures in an arid area of southern New Mexico, we found a significant correlation between October through March precipitation and pronghorn fawn survival the following August ($r^2 = 0.67$, $P<0.02$). Further linear regression analysis indicated less robust but still significant relationships between winter precipitation and subsequent fawn survival rates in a semidesert grassland area in central Arizona ($r^2=0.26$, $P<0.05$). Neither of the areas tested showed a significant relationship between summer precipitation and the succeeding year's fawn survival, and we postulate that forb production, as affected by winter rainfall, is more important than grass production and hiding cover in determining fawn survival in semidesert grassland habitats. Because significant relationships have also been reported for winter rainfall and pronghorn fawn survival in Arizona's Sonoran Desert ($r^2=0.51$) we consider forb production to be the most important variable limiting pronghorn fawn production in arid areas. Although both winter rainfall and April Palmer Drought Severity Indices correlated with fawn survival rates in other arid and semiarid areas, neither winter rainfall nor drought indices correlated with fawn survival rates on the more mesic Anderson Mesa in northern Arizona ($r^2 = 0.03$, n.s.). These data suggest that fawn survival rates following winters having less than 5 to 8 cm (2 to 3 inches) of precipitation are insufficient to maintain pronghorn population levels, and that other limiting factors have greater influence over fawn survival in higher elevation, more mesic situations.

Key words: Anderson Mesa, Armendaris Ranch, fawn survival, forb production, Palmer Drought Severity Index, pronghorn, semidesert grassland, Sonoran Desert, summer precipitation, winter precipitation.

That pronghorn fawn survival rates are highly variable in the arid and semiarid Southwest is well known (Arizona Game and Fish Department 2000). Biologists are uncertain, however, as to what determines this variation, some believing that the most important factor influencing fawn survival is the production of nutritious forbs, others believing that the primary cause of fawn mortality is predation by coyotes due to insufficient hiding cover (Neff and Woolsey 1979).

Because forb production has been shown to be strongly correlated with October through March rainfall and mule deer fawn survival in the Southwest (Smith and LeCount 1979, Logan and Sweanor 2001), we wanted to determine if winter rainfall had a similar influence on pronghorn fawn survival. To test the alternate hypothesis, we compared pronghorn fawn survival with the amount of rainfall during the preceding April through August as Cable (1975) showed

that these precipitation amounts determined the growth of semidesert grassland grasses. Other studies have shown summer precipitation and summer grass production to have an influence over the annual survival of grassland-adapted animals (Brown 1978, 1979).

STUDY AREAS

Armendaris Ranch

We selected the Armendaris Ranch in southern New Mexico as our primary study site, as this area has on site rain gauges and has used the same observer and pronghorn survey procedures each year since 1994. A former land grant, the privately owned Armendaris Ranch is now managed by Turner Enterprises. Elevations range between 1375 and 1525 m, and the mean annual precipitation is <250 mm. Approximately 74,600 ha of the ranch are classified as pronghorn habitat, in which the primary vegetation is semidesert grassland characterized by such grasses and forbs as black grama (*Bouteloua eriopoda*) and palmilla (*Yucca elata*) (Brown 1994). Most of the remaining vegetation is Chihuahuan desertscrub and the climate is warm-temperate with an average of 213 frost-free days per year (Truth or Consequences, NM). Bison (*Bison bison*) are the only permitted grazing animals, other large herbivores being restricted to gemsbok (*Oryx gazella)* and small populations of mule deer (*Odocoileus hemionus*) and desert bighorn sheep (*Ovis canadensis*). Most wildfires are allowed to burn.

The pronghorn population is subject to climate-induced variations but was estimated to number more than 1000 animals in 2000. Pronghorns are hunted conservatively by archers in late August and by rifle hunters in September. Relatively few permits are issued each year and the pronghorn harvest never exceeds 10% of the available bucks.

Horseshoe Ranch

The second area selected was the 26,300-ha Horseshoe Ranch within the Agua Fria National Grasslands in south-central Arizona. Although slightly lower in elevation, (1050-1250 m) than the Armendaris Ranch, this area is also semidesert grassland with tobosa (*Hilaria mutica*) and mesquite (*Prosopis velutina*) being important participants. Although the average number of 213 frost-free days is the same as on the Armendaris Ranch, the Horseshoe Ranch is generally wetter, averaging ca. 380 mm per annum. The land status of the 19,425 ha that are classified as pronghorn habitat is divided between the Tonto National Forest and Bureau of Land Management. The ranch is managed for cattle grazing with mule deer, white-tailed deer (*Odocoileus virginianus*) and javelina (*Pecari tajacu*) present in low numbers. Brush encroachment is a problem, and the ranch participates in a burning program in which approximately 2500 to 2850 ha are scheduled for burning each spring. The estimated pronghorn population in 2000 was ca. 140 animals.

Anderson Mesa

Anderson Mesa is a high elevation (2170 m), intermountain grassland located east of Flagstaff, Arizona. Annual precipitation averages just over 500 mm and the climate is cold temperate with an average of 99 frost-free days a year (Flagstaff). Anderson Mesa is under the management of the Coconino National Forest with lower elevation habitats being owned by private ranchers and the state of Arizona. Pronghorn habitat encompasses approximately 211,000 ha, which is shared with cattle, bison, and elk (*Cervus elaphus*) along with lesser numbers of mule deer. The pronghorn population, once estimated to exceed 2000 animals is now

down to less than 500 due to very low fawn survival rates, and the status and management of this "herd" is a matter of much concern.

METHODS

Pronghorn herd composition surveys have been conducted on the Armendaris Ranch each September since 1994 in accordance with procedures described by Lee et al. (1994). The same grid pattern was flown by a light aircraft and the same observer was present on all surveys. Personnel of the Arizona Game and Fish Department conducted similar surveys during the summer in the game management units containing the Horseshoe Ranch and Anderson Mesa. Those animals observed in the game management unit containing the Horseshoe Ranch were separated into northern and southern populations, the latter comprising the Horseshoe Ranch population. Surveyed pronghorn were classified as bucks, does, or fawns, and the number of fawns per 100 does was calculated.

Monthly precipitation totals were collected for all three locations. In 1994 and 1995, precipitation data for the Armendaris Ranch were taken from the adjacent Cain Ranch; after 1995, monthly precipitation totals for the Armendaris Ranch were the means of two or three gauges located on the ranch. Monthly precipitation has been collected at the Horseshoe Ranch headquarters since 1985. Rainfall and other climatic data for Anderson Mesa were taken from national weather service summaries for the Flagstaff station. Precipitation totals for each location were summarized as summer precipitation (the April through August period preceding the spring fawning season) and as winter precipitation (the October through March period prior to fawning) and compared to the succeeding year's fawn survival rate. Because drought has been shown to affect fawn recruitment in white-tailed deer and other ungulates in the Southwest, we also compared each year's fawn survival rate with the previous April's regional Palmer Drought Severity Index (PDSI) (Brown 1984).

RESULTS

Seasonal precipitation summaries are shown with annual survey results for Armendaris Ranch in Table 1. These data indicate a significant positive relationship (r^2=0.68; P<0.006) between October-March precipitation and fawn survival rates the following fall (Fig. 1). Logistic regression offered no statistical improvement over the linear fit, but predicts a slight increase (~ 3 fawns per 100 does) in fawn survival at very low precipitation levels. Comparing late summer fawn survival rates with the previous summer's rainfall showed no relationship between these two variables (Fig. 2).

Table 1. Pronghorn precipitation and survey information for Armendaris Ranch, 1994-2002.

Year	Previous Apr.-Aug. Precipitation	Previous Oct-Mar. Precipitation	Bucks	Does	Adults	Fawns	Total	B: D: F	Average Herd Size	Seen Per hour
1994		0.00	179	279	458	16	474	64:100:06	3.0	11.8
1995	1.60	3.95	111	210	321	122	443	53:100:58	3.7	4.5
1996	4.28	0.55	171	309	480	26	506	55:100:08	4.0	5.1
1997	7.73	2.10	88	158	246	88	334	56:100:56	2.5	4.7
1998	9.56	0.78	113	244	357	72	429	46:100:30	3.3	4.7
1999	5.50	2.30	136	284	420	54	474	48:100:19	3.6	4.5
2000	8.00	1.06	103	175	278	45	323	59:100:26	3.2	4.6
2001	4.40	3.69	90	209	299	107	406	43:100:51	4.4	4.4
2002	5.67	1.03	102	187	289	32	321	55:100:17	4.4	3.5

Fig.1. October-March precipitation vs. fawn survival for Armendaris Ranch, 1994-2002.

Fig. 2. Summer precipitation vs. fawn survival for Armendaris Ranch, 1995-2002.

Fawn survival rates on the Horseshoe Ranch also showed a significant positive relationship with October through March rainfall (r^2= 0.26; P<0.05; Fig. 3). And, as with the Armendaris Ranch, there was a significant positive relationship between fawn survival and the April PDSI on the Horseshoe Ranch (r^2=0.26; P<0.05) but no significant relationship between summer precipitation and fawn survival (r^2=0.03, n.s.).

Fig. 3. Winter precipitation vs. fawn survival for Horseshoe Ranch 1986-2001.

We found no relationship between any of the variables tested, winter precipitation, summer precipitation and April PDSI, with fawn survival on Anderson Mesa. October through March precipitation in this unit even showed an insignificant negative relationship with fawn survival (Fig. 4).

Fig. 4. Winter precipitation vs. fawn survival on Anderson Mesa, 1951 – 2001.

To test if aridity was a controlling factor in the relationships between winter precipitation and fawn survival, we compared winter rainfall totals from an average of four climatic stations (Ajo, Gila Bend, Organ-pipe Cactus National Monument, and Tacna) with December fawn survival data collected by John Hervert of the Arizona Game and Fish Department for pronghorn (*A. a. sonoriensis*) in southwestern Arizona. These data also indicated a positive relationship ($P < 0.07$) between October-March rainfall and fawn survival (Fig. 5). Once again, relationships between fawn survival and summer rainfall were nonsignificant ($r^2=0.21$; n.s.).

Fig. 5. Winter precipitation vs. fawn survival for Sonoran Pronghorn 1995-2001.

DISCUSSION

The above analyses indicate that winter precipitation and forb production may be more important to fawn survival in the arid and semiarid regions of the Southwest than summer precipitation and fawn survival. To further test the significance of winter precipitation in such areas we compared 1990-2001 October through March precipitation totals for a plains grassland locality (Chino Valley, Arizona), with fawn survival rates on the nearby K-4 Ranch (W. Ough, pers. com.). This relationship was highly significant (r^2 0.54; $P<0.05$). More surprising was the relationship obtained by comparing October through March rainfall totals for a semi-arid Great Basin locality (Kanab, Utah) with pronghorn fawn survival rates on the Arizona Strip to the south ($r^2=0.28$; $P<0.10$). These significant relationships suggest that fawn survival rates following winters having less than 5 to 8 cm (2-3 in) of precipitation are insufficient to maintain pronghorn population levels, and that prediction equations can be formulated for fawn survival rates in at least some areas in the Southwest. Fawn productivity was most variable (i.e., least predictable) for intermediate levels of rainfall (~5 cm) suggesting that other factors may interact with winter rainfall in such years to determine pronghorn recruitment.

Neither winter nor summer rainfall appeared to influence fawn survival rates on Anderson Mesa in northern Arizona. Linear regression analyses comparing October through March rainfall totals from other high elevation grassland areas (Springerville and Williams, Arizona) with surrounding fawn survival rates since 1990 also showed insignificant relationships ($r^2=0.22$ and $r^2=0.00$, respectively) at the 90% confidence level. These analyses indicated that variables other than annual forb production might be affecting fawn survival in these relatively mesic areas. More analyses will be conducted next year in an attempt to determine what some of these variables might be.

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CHOICE OF FAWNING AREAS AND FAWN BEDSITES WITH RESPECT TO VEGETATION STRUCTURE AND LAND USE IN NORTHWEST NEBRASKA

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Abstract: The choice of habitat by female pronghorn in the first 3-4 weeks after parturition may have important impacts on her reproductive success. Two major considerations for the female, during the hiding phase of her neonates, are likely to be quality and quantity of nearby forage, and habitats providing suitable hiding places for the fawns. Access to forage will be limited by the distance a female is willing to travel from her hidden neonates. Although fawns themselves choose their own bedsite, choice of habitat on a larger scale by the mother will determine the options available to the fawn. In this study we are addressing habitat selection by female pronghorn during the fawning season and hiding phase of fawns in the Oglala National Grasslands and interspersed private land. In summer 2001, 25 fawns of 17 radio-collared females were captured and radio-tagged; nine fawns on public land, 13 on private, and 3 on school sections. Visibility, climatic, and vegetation characteristics were measured at 17 fawn capture sites and at 10 fawn bedsites marked 7-14 days after initial capture of the fawn. We also measured percent cover of vegetation along 2 perpendicular 100-m transects centered on the bedsite and collected vegetation for analysis of N content and digestibility. Percent cover by forage class was similar for capture bedsites vs. later bedsites. Capture and later bedsites did not differ significantly in protection from wind or temperature, and visibility from the height of a bedded or standing fawn did not differ early vs. late in the hiding period. Both the height of surrounding vegetation and dry weight of live grasses were greater at capture bedsites than at later bedsites. Bedsites located on public land did not differ significantly from those on private land with respect to thermal cover or visibility. However, bedsites on public vs. private land did differ significantly with respect to vegetative composition; with a higher percent cover of live grasses on private land and higher percent cover of forbs and dead grasses on public land. Preliminary conclusions from the first year of this study are that fawns are finding similar microhabitats for bedsites on public and private land, however, public land may provide more abundant forbs to support lactation by the mother. In the second year of the study, we will include data collection at random points throughout the study area for comparison to new data collected at actual bedsites.

Key words: pronghorn, *Antilocapra americana,* fawn bedsites, thermal cover, visibility, land use, microhabitat, vegetative composition.

USING RANGE MANIPULATIONS TO INCREASE PRONGHORN PRODUCTION AND ABUNDANCE IN UTAH SAGEBRUSH STEPPE

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Abstract: Pronghorn (*Antilocapra americana*) investigations on the Deseret Land and Livestock ranch, 1985-1995, suggested density dependent fawn production limited pronghorn density (Danvir 1996). July-September, doe groups preferred habitat types with broad-leafed forbs and few shrubs (meadows and native grasslands), and used brushy or forb-poor crested wheatgrass (*Agropyron desertorum*) and dense sagebrush (*Artemesia tridentata*) habitat types less than available. Based on these observations, we hypothesized that forb-poor habitat types and tall (> 61 cm), dense sagebrush cover (>25%) reduced study area habitat quality, thereby limiting fawn production and population size. To test this hypothesis, we increased forb abundance and decreased shrub cover on 18 burned or planted treatments on the study area (totaling 4270 ha), 1995-2001. Both fawn production and population size correlated positively with cumulative ha treated (r^2=0.81, p=0.005 and r^2=0.65, p=0.03 respectively). While pre-treatment fawn production correlated negatively with population size (r^2 =0.89, p=0.0001), suggesting density dependent production, fawn production correlated positively with population size post-treatment (r^2 =0.70, p=0.04) suggesting increased habitat quality and carrying capacity. Burned or planted areas were the only habitat types used preferentially by doe groups post-treatment.

Key words: Antilocapra americana, Utah, pronghorn demographics, density dependence, habitat preference, carrying capacity, sagebrush steppe, *Artemesia tridentata*, forbs, range manipulations.

Sagebrush-steppe dominates an area of approximately 56 million ha in the western United States (Holechek et al. 1989). Fire naturally occurred on these rangelands at intervals of 20 to 80 years (Holechek et al. 1989). Changes in fire frequency, in combination with overgrazing, have likely altered the plant species composition in many sagebrush-steppe communities (West 1999).

Dense sagebrush canopy cover (>25%) generally reduces the abundance of herbaceous plants, including many early-mid seral forbs preferred by pronghorns (Yoakum 1974, O'Gara and Yoakum 1992). Consequently, fire, mechanical, and chemical methods have been used by managers to reduce brush cover and increase the abundance of herbaceous plants to benefit livestock and selected wildlife species (Nielson and Hinckley 1975, West and Hassan 1985, Patton et al. 1988, Holechek et al. 1989, Master et al. 1993).

Historically, many range plantings likely affected pronghorn negatively. Plantings were often single species, consisting solely of grazing-tolerant, introduced grasses such as crested wheatgrass (Hart et al.1983, Baker 1991). Crested wheatgrass tends to competitively exclude native grasses and forbs (Box 1986), and its seedlings are better at sequestering moisture at low temperatures (Caldwell et al. 1985, Black et al. 1994). Few native herbaceous plants repopulate

crested wheatgrass plantings (McHenry and Newell 1947, Looman and Heinrich 1973, Wilson 1989). The result of this exclusion is a near monoculture that may last for decades (Smoliak et al. 1967, Anderson and Marlette 1986, Box 1986) resulting in decreased biodiversity of grassland communities.

Sagebrush or crested wheatgrass dominated ranges lacking forbs may be marginal pronghorn summer habitat. Yoakum (1974) compared characteristics of sagebrush-steppe having relatively high pronghorn densities and production to sagebrush-steppe landscapes having relatively lower pronghorn densities and production. Preferred sagebrush-steppe landscapes generally had 50% plant canopy cover, comprised of 40-60% grasses, 10-30% forbs and 5-20% shrubs. These landscapes expressed a high diversity, both of plant species and vegetation types, with vegetation averaging 38 cm in height. Dietary studies suggested succulent forbs to be preferred summer forage (Yoakum 1974, O'Gara and Yoakum 1992). Conversely, relatively monotypic landscapes, lacking succulent forbs, and with vegetation averaging > 61 cm in height were less preferred. "Preferred" sagebrush-steppe habitats were those exhibiting higher than average pronghorn densities and fawn production (Yoakum 1974, O'Gara and Yoakum 1992).

On the Deseret Land and Livestock ranch study area (DL&L) from 1985-1995, doe-fawn pronghorn groups selected forb-rich areas (Danvir 1996). Highest fawn:doe ratios were found in habitat types having greater forb abundance. Relatively few pronghorn were observed in tall (> 61 cm), dense (> 25% cover) sagebrush stands in summer, does with fawns being particularly absent (Danvir 1996).

These findings led us to hypothesize that summer habitat condition on the study area might be limiting pronghorn carrying capacity. We tested this hypothesis by implementing a series of range treatments to a) increase forb cover and, in many cases, b) decrease shrub cover and height while monitoring pronghorn demographics and habitat use. We then contrasted pronghorn demographics and habitat use between the pretreatment (1985-1995) and treatment phases (1996-2002) of this study.

STUDY AREA

The DL&L study area includes 39,000 ha (97,000 acres) of sagebrush steppe, located in northern Utah. The study area is roughly rectangular, extending approximately 29 km north to south and 14 km east to west. Annual precipitation averages 23 cm (9 in) in the northeast part of the study area, increasing to 28 cm (11 in) in the southeast part and 38 cm (15 in) in the western foothills. The wettest months are September, May and June. Mean annual temperature at nearby Woodruff, Utah, is 4° C (40° F); summer temperatures in excess of 32° C (90° F) and winter temperatures below –29° C (-20° F) are not uncommon. Most herbaceous forage growth occurs during approximately 45 frost-free days, late May through early June. Elevations range from 1920-2100 m (6400-6900 feet).

Four major habitat types dominate the study area. The northern quarter is predominantly upland range, disked and planted to crested wheatgrass 30-40 years ago (sagebrush-crested wheatgrass habitat type). Wyoming big sagebrush (*A.t. wyomingensis*) has repopulated much of this type, and is the dominant shrub. The topography is generally flat. Cover values range from 0-25% for shrubs and 5-40% for herbaceous plants (primarily crested wheatgrass). Perennial

forbs are conspicuously absent, averaging less than 7% cover. Predominant perennial forbs include woody species such as *Phlox longifolia* and *Eriogonum spp*. Pronghorn can be found in this habitat type year-round, and nearly all pronghorn on the study area winter here.

The central quarter of the study area is predominantly native big sagebrush stands (dense native sagebrush habitat type). The topography is flat to rolling. The area is dominated by mature to decadent stands of Wyoming or Basin big sagebrush (*A.t. tridentata*). Shrub cover ranges from 10-35% for shrubs and 5-30% for herbaceous plants. Perennial forb cover and plant species richness is greater than in the crested wheatgrass type. Dominant grasses include western wheatgrass (*A. spicatum*), needlegrass (*Stipa spp.*), Sandberg's bluegrass (*Poa secunda*), Great Basin wildrye (*Elymus cinereus*) and Indian ricegrass (*Oryzopsis hymenoides*). Perennial forb genera include *Achillea, Agoseris, Allium, Antennaria, Astragalus, Castelleja, Crepis, Erigeron, Eriogonum, Lomatium, Oxytropis, Penstemon, Phlox, Senecio, Solidago, Spaeralcea, Taraxacum* and *Trifolium*. Pronghorn primarily use this type spring through fall.

The southern quarter of the study area is predominantly native grassland with occasional sagebrush stands (native grassland habitat type). The topography is a series of low ridges and moist draws. Uplands are predominantly native grasses and forbs (as listed above) interspersed with scattered patches of Wyoming or Basin big sagebrush. Draws include native meadow grasses and forbs. Upland herbaceous vegetation exceeds 50% cover, with 10-25% being perennial forbs. Shrub cover ranges from 0-25% (generally <10%). Pronghorn primarily use this type spring through fall.

The western quarter of the study area is predominantly a mountain big sagebrush community (*A. t. vaseyana*) (mountain sagebrush habitat type). The topography is hills and ridges (>20% slope). Shrub coverage is generally >30%. Herbaceous vegetation is generally 10-40%, diverse and similar in composition to the native sagebrush habitat type. Pronghorn were present but uncommon in this habitat type.

Scattered patches of low sagebrush (*A. arbuscula*) and black sagebrush (*A. nova)* occur on clay basins and gravelly ridges throughout the study area. Riparian meadows and free water are well distributed throughout the study area.

Potential predators of pronghorn on the study area include coyote (*Canis latrans*), golden eagle (*Aquila chrysaetos*), bobcat (*Lynx rufus*) and cougar (*Felis concolor*). Coyotes have been observed pursuing and killing pronghorn during the study. Study area coyote densities were 0.2 coyote per km^2 1996-2000 (Bromley 2001).

The study area is grazed by cattle annually, managed using a time-controlled grazing strategy (Savory 1988). The number of cow/calf pairs grazing the area ranged from 4300 to 5500 during the study. Annual grazing plans utilize short-duration grazing periods to minimize rebiting of plants by livestock during the growing season, and maximize the benefits of seasonal rest. Fences are numerous, interior fences are generally 4-strand barbwire, with bottom strands at least 40 cm above ground. Immigration and emigration of pronghorn is somewhat restricted, due to net-wire fences on the eastern and southern boundaries, mountains to the west and the town of Woodruff to the north. Approximately 87% of the study area is privately owned and

managed by DL&L, 13% is operated under the authority of the Bureau of Land Management (BLM).

METHODS

Pronghorn population size was estimated by winter aerial counts (most years), or ground-based counts (1985, 2000 and 2002). Attempts were made to count all the pronghorn on the study area; however occasional small wintering groups may have been missed. Fall fawn production estimates (fawns to does) were obtained by ground classifications of 25-35% of the population each August prior to hunting season.

We obtained mean April-July temperature (the season during which 90% of herbaceous growth occurs on the study area) and total April-September precipitation (entire growing season) from the NOAA reporting station in nearby Woodruff, Utah. Mean winter snow depth was estimated by recording and averaging snow depth at the north end of the study area on the 1st, 10th and 20th of each month, November-March. An index of coyote abundance was obtained by recording all coyotes observed on the study area during 100-160 hours of sage grouse (*Centrocecus urophasianus*) lek counts each spring. Cattle herd size was recorded annually. Records of all pronghorn legally harvested from the study area were obtained from hunters at a DL&L mandatory check station; no illegal killing was observed. We mapped and estimated the size of all burns and plantings. Each year we then calculated the cumulative ha treated since 1995.

The experiment involved increasing forb availability and reducing shrub cover (by burning or planting) on 18 sites (5 burns, 13 plantings) scattered throughout the study area. We treated 4270 ha from 1995-2001 (averaging 1.7% of the study area/year). Treatments occurring 1995-2001 were included in the analysis, but were compared to following year estimates of pronghorn production and population size, since post treatment plant growth did not occur until the year following treatment. Treatments included 520 ha of burns (range 20-200 ha each) and 3900 ha of plantings (range 40-630 ha). Two burns (64% of total burned area) were August wildfire burns; three (36% of area) were prescribed spring burns (April). All burns occurred in native sagebrush habitat type. August wildfire burns were aerially seeded subsequent to burning with a mixture of forbs, grasses and shrubs. Plantings involved disking and mechanically seeding a mixture of forbs, grasses and shrubs. Six plantings (600 ha) were 30-60-m wide strips in 30-40 year old, crested wheatgrass plantings. Seven plantings (3150 ha) were planted as irregularly shaped blocks (having numerous undisturbed sagebrush islands) within dense native sagebrush stands. Non-native forb species such as alfalfa (*Medicago sativa*), sainfoin (*Onobrychis viciifolia*), and small burnett (*Sanguisorba minor*) were added to all seeded treatments due to their nitrogen-fixing abilities, high protein content, digestibility and palatability to pronghorn and other wildlife, and their low cost and ease of establishment.

Percent cover of shrubs, grasses, forbs, litter and bare ground were estimated for treatments, meadows, and the four rangeland habitat types using the point-intercept method (Hays et al. 1981) on 103 randomly located transects. The amount of each habitat type on the study area was estimated using Landsat imagery and GIS methods (Hunnicutt 1992). Doe-fawn pronghorn vegetation-type preference was indexed by calculating the percent of doe-fawn groups

observed 15 July-15 September (1990-2000) in each vegetation type, divided by the percent of the study area comprised of each vegetation type (P=U/A) (Krueger 1972).

Annual production of grasses, forbs and shrubs was obtained in July of 1998 and 1999 by clipping six 3-m x 10-cm strips at random locations within 5 burns, 3 plantings and their adjacent, paired controls having similar soils, aspect, elevation and site potential (Aoude 2002). Samples were oven-dried at 60°C for 48 hours and weighed.

The purpose of this experiment was to assess the landscape-scale effects on the pronghorn population (macro-habitat scale), not to compare differential pronghorn use or vegetative composition of burns and plantings (micro-habitat scale). We used linear regression to test for density dependence and to compare fawn production and population size with cumulative ha treated. Simultaneously increasing fawn production and population size would support the hypothesis that habitat quality and carrying capacity had improved (Garshelis 2000). We also used linear regression to test whether observed variability in pronghorn abundance or fawn production correlated with the additional variables summer temperature and precipitation, prior winter mean snow depth, population size, cattle herd size, coyote abundance and annual pronghorn harvest. Pronghorn demographics and habitat use were compared 1985-1995 (pretreatment) and during the treatment phase (1996-2002).

RESULTS

Percent cover estimates of shrubs, forbs, grasses, litter and bare ground in the treatments and other habitat types are summarized in Figure 1. Estimated forb cover in the crested wheatgrass habitat type was lower (<7%) and shrub cover in the native sagebrush type was higher (>30%) than values recommended for pronghorn (O'Gara and Yoakum 1992). Forb cover increased and shrub cover decreased on burned and planted treatments (Fig. 1). Biomass estimates of forbs and grasses similarly increased, and shrub biomass decreased on burned or planted treatment areas as compared to adjacent, paired controls in dense native sagebrush (Fig. 2). Annual and perennial forb species richness also increased on planted treatments (Aoude 2002).

Estimated pronghorn herd size on the study area, 1985-2002, is presented in Figure 3. The population showed classic density dependence in the pretreatment phase (1985-1995); fawn production was negatively correlated with population size (r^2=0.89, p=0.0001; Fig. 4). Low fawn production was observed in the pretreatment phase when the population exceeded 500 animals, apparently slowing population growth. In contrast, fawn production in the treatment phase (1996-2002) correlated positively with population size, suggesting lack of density dependence and increased carrying capacity (r^2= 0.70, p=0.04; Fig. 4). Both fawn production and population size were positively correlated with cumulative ha treated (r^2= 0.81, p= 0.005 and r^2= 0.65, p=0.03 respectively).

Figure 1. Percent cover (mean and std. dev.) estimated from 103 point-transects in seven pronghorn habitat types, 1995-2001, Deseret Land & Livestock Ranch, Utah.

Fig. 2. Changes in plant biomass on 5 burns and 3 plantings compared to paired, sagebrush-dominated, untreated control areas, 1988-1999, Deseret Land & Livestock Ranch, Utah.

Fig. 3. Pronghorn population size 1985-2002, Deseret Land & Livestock Ranch, Utah.

Fig. 4. Relationship between fawn production and population size in the pre treatment (1985-95) and treatment phases (1996-2002), Deseret Land & Livestock Ranch, Utah.

Fawn production was significantly correlated with mean April-July temperature in both the pre-treatment and treatment phases. However, pre-treatment fawn production correlated positively with mean April-July temperature, while fawn production correlated negatively during the treatment phase (r^2=0.59 p=0.005 and r^2=0.39, p=0.004 respectively). A multiple linear regression using prior-year population size and same-year April-July temperature to predict fawn production explained 70% of the observed variation in fawn production in the combined pretreatment and treatment years (1985-2002) (model r^2=0.70, p=0.0002). Cumulative ha treated was auto-correlated with population size, thus was not added to the model. Fawn production and population size did not correlate significantly with summer precipitation, mean winter snow depth, prior-year pronghorn harvest, cattle herd size or coyote abundance.

Habitat preference by doe pronghorn groups differed between the pre-treatment and the treatment phase. Pre-treatment, doe groups preferred the native grassland and meadow habitat types (Table 1). During the treatment phase, however, doe groups preferred only burned or planted treatments.

Table 1. Range type availability and use preference by doe groups on the Deseret Land & Livestock Ranch, Utah.

		% Use by doe groups		Preference rating	
Range Type	% Available	1990-95	1996-2000	1990-95	1996-2000
Burns and plantings	6.4	--	39.2	--	6.1
Meadow	13.7	24.5	13.0	1.8	1.0
Native Grassland	25.0	38.7	21.0	1.5	0.8
Sage/Crested Wheat	18.3	17.7	13.8	1.0	0.8
Dense Native Sage	31.1	8.9	11.7	0.3	0.4
Low Sagebrush	5.5	1.6	1.3	0.3	0.2

DISCUSSION

Many ecologists dispute the value of density dependence in explaining long-term population regulation (Krebs 1995). However, our results suggest that at least in the short-term, the treatments increased fawn production and carrying capacity of the study area. In particular, fawn production estimates in 2001 (0.66) and 2002 (0.86) were higher than expected given the population size (> 700). Based on the density-dependent response observed 1985-1995, production was expected to be below 0.5 in 2001 and 2002. The fact that both fawn production and population size were simultaneously increasing 1996-2002, and that production and population size were each positively correlated with cumulative ha treated, further support the hypothesis.

Doe-fawn groups preferred treated habitats as summer habitat. Large doe-fawn pronghorn groups were frequently observed on burned or planted areas, particularly in the first 1-5 years following treatment. The abundant broad-leafed forbs common on treatments seemed particularly sought by lactating does and fawns, and may be the cause of the apparent increase in production and carrying capacity. Introduced forbs alfalfa, sainfoin and small burnett "greened up" earlier in the spring and remained green longer into the summer than many native forbs on the study area (Danvir 2002).

Regression analysis suggested much of the annual variability in fawn production observed 1995-2002 might be due to pronghorn density and summer temperatures. Freezing spring-summer temperatures may increase early fawn mortality (O'Gara and Yoakum 1992) and reduce forb availability to does in late gestation and early lactation.

These treatments were not implemented just to benefit pronghorn. Indeed, the initial impetus for these treatments was to increase summer cattle and winter elk forage. These two herbivores account for much of the forage eaten and much of the management activity of ranch staff. However, we attempted to design and situate treatments to enhance (or at least minimize impacts to) pronghorn, sage grouse and other species. Fortunately, pronghorn and sage grouse (Danvir 2002) have thus far shown a preference for treated areas (particularly females with young) as summer habitat, and populations are responding positively.

Our data support the hypothesis that sagebrush steppe communities dominated by dense, decadent sagebrush or crested wheatgrass lack adequate nutritional resources to maintain high pronghorn densities and fawn production. Sagebrush steppe communities lacking periodic disturbance to create early-mid seral forbs may also lack reproductive nutrition for species such as sage grouse and mule deer (*Odocoileus hemionus*). Our experience thus far suggests grazing strategies based on intermittent herbivory and rest (Augustine and McNaughton 1998) coupled with occasional shrub thinning and (if necessary) planting desirable forbs can benefit pronghorn and other species. Since mature sagebrush stands also provide cover and winter forage for pronghorn and many other sagebrush-dwelling wildlife species, the interspersion, arrangement and connectivity of sagebrush patches must be considered when manipulating landscapes. Results of this experiment suggest treating as little as 2% of the range/year increased pronghorn production and carrying capacity.

MANAGEMENT IMPLICATIONS

DL&L's management strategy in sagebrush steppe involves simply thinning sagebrush and releasing native herbaceous vegetation when the herbaceous understory appears robust (generally > 28 cm precipitation). Where the herbaceous understory is lacking biomass or diversity (generally < 28 cm), planting a diverse mix of forbs adapted to the environment may be beneficial. When selecting seed mixes for treatments, we have found that maintaining or increasing diversity is important. We plant a variety of species to maintain or increase range diversity, production and nutritional value, despite the variable, unpredictable weather patterns that define sagebrush steppe (West 1999). We suggest that managers start small, monitor results, experiment with larger-scale projects and continue monitoring to determine best management practices for each area.

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PRONGHORN USE OF SHADE

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Abstract: Rarely has shade been identified as a habitat variable for pronghorn. After reviewing more than 4,000 photographs of pronghorn, it appears these ungulates readily use shade, when available, from vertical formations, including natural sources (e.g., trees, shrubs, cacti, thistle, etc.) and man-made structures (e.g., billboards, haystacks, buildings, power poles, etc.). Pronghorn use of shade has been reported for all biomes – grasslands, shrub-steppes, and deserts. The values and needs of shade as a habitat characteristic for pronghorn during high temperatures may be greater than previously reported. This natural characteristic appears to warrant research and field investigations to provide quantitative data for future management strategies.

Key words: pronghorn, *Antilocapra americana*, habitat use, shade.

DISTRIBUTION OF PRONGHORN BEFORE AND AFTER DEVELOPMENT OF RECREATIONAL TRAILS IN ANTELOPE ISLAND STATE PARK, UTAH

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Abstract: We studied the effects of opening recreational trails on the distribution of pronghorn (*Antilocapra americana*) at Antelope Island State Park, Davis County, Utah, from May-October 1993 and April-October 1994. Pronghorn were reintroduced to the island in January 1993. In 1994, several trails that circle the north end of the island were opened to the public for recreational use. Using GIS, we measured the distance of each location of a pronghorn group in 1993 (prior to opening of the trails) and each location in 1994 (following opening) to the nearest trail. Comparisons of distance from trails before and after opening were made for all pronghorn groups, and for groups categorized by sex/age composition and number of individuals. For all groups combined, pronghorn were located significantly farther from trails after trail opening than before. Groups with fawns and male only groups were farther from trails in 1994 than in 1993. There was no significant difference between years in distance of the larger, mixed-sex groups, however, group size was not significantly related to distance from trails in either year. Our results indicate that pronghorn distribution was altered significantly in 1994 following opening of the north trails.

Key Words: pronghorn, *Antilocapra americana*, recreational use, trails, human disturbance, Antelope Island.

MOTOR VEHICLE ASSOCIATED MORTALITY IN AN URBAN PRONGHORN HERD

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Abstract: Compared with other ungulates, motor vehicle collisions involving pronghorn are relatively uncommon. However, in some situations, motor vehicle interactions can be a major mortality factor. Francis E. Warren Air Force Base, Wyoming, contains a population of pronghorn that inhabit residential and other developed areas. This close proximity contributes to a high incidence of pronghorn-motor vehicle interaction. Pronghorn road kill and related mortality and other data from the Base for 1992 to 2001 were recorded. Annual direct and indirect motor vehicle attributable mortality averaged over 6% of the installation peak pronghorn population. More female pronghorn were involved in motor vehicle collisions than males. Factors contributing to the comparatively high incidence of motor vehicle collisions, including annual pronghorn numbers, motor vehicle use, both pronghorn and driver behavior, season, and other influences are discussed.

Key words: pronghorn, *Antilocapra americana*, vehicle collision, mortality.

Pronghorns are widely distributed across central North America. While not nearly as abundant as they were originally (Einarsen 1948) pronghorn (*Antilocapra americana*) are nonetheless common throughout much of their range. Pronghorn range generally coincides with regions of relatively low human populations and activity. Partly as a consequence, pronghorn – human conflicts are comparatively infrequent and at a low level. This is in dramatic contrast to some situations involving other ungulates, notably deer (*Odocoileus* spp.). While human – wildlife conflicts are widespread (Conover et al. 1995), they are perhaps most important when they potentially involve human safety, such as is the case with ungulate – motor vehicle collisions. Public and management interest in ungulate – vehicle collision, while always present, is of relatively recent concern. As recently as 1979 little, if any, mention was made of deer – vehicle collisions during regional discussions of white-tailed deer (*Odocoileus virginianus*) populations (Hine and Nehls 1980). However, deer mortality on national highways has increased significantly since 1980 (Romin and Bissonette 1996). While the most wildlife - vehicle interactions involve deer, in some circumstances, pronghorn can be subjected to elevated motor vehicle-related mortality.

An urbanized herd of pronghorn is found on and near F. E. Warren Air Force Base adjacent to Cheyenne, Wyoming. The base consists of open, undeveloped short-grass prairie, widely dispersed industrial areas, and more densely developed residential and administrative areas. At the time of the study, a portion of the base was enclosed with a chain link fence, which effectively reduced movement onto bordering Interstate and State Highways. We report on pronghorn mortality associated with motor vehicles in that environment.

METHODS

From 1992 to 2001, pronghorn injury and mortality attributable to motor vehicle collisions occurring on and adjacent to F. E. Warren Air Force Base were recorded and examined. Pronghorn that were observed or reported hit by motor vehicles were removed and disposed of. In some instances, where the injuries did not cause immediate death, pronghorn were euthanized. Some pronghorn were known to have been hit but apparently recovered without intervention. Other pronghorn that exhibited injuries, which were deemed to be consistent with those observed in motor vehicle collisions or which were attributable to roads or vehicles in other ways, were also noted.

Sex of the pronghorn involved and the month of the accident were recorded in many instances. Age data were collected for some individuals, but since they are incomplete they are excluded from this study.

Total herd size on the base was estimated annually by conducting aerial and ground census. Pronghorn were counted by driving roads on the base and counting individuals. This ground census was conducted at a minimum of once a month. Aerial census data during May, August, September, and October were obtained from helicopter-flown transects. Indices of motor vehicle traffic volume were obtained by recording the number of vehicles passing a given point on the major base road for randomly selected daylight hours and days during January-February, May-June, and September-October.

RESULTS

During 1992 to 2001, the pronghorn mortality directly attributable to motor vehicle collisions was recorded. Data for the entire calendar year of 1992 and 2001 were incomplete and were excluded from this analysis. For 1993 through 2000, 122 pronghorn were known to have been killed as a result of being hit by motor vehicles (mean = 15.3). Not all collisions resulted in apparent injury or mortality. Some injuries and subsequent mortality were known to occur as an indirect result of motor vehicle or roadway interactions. Data were also recorded for pronghorn that were observed or recovered and determined to have injuries consistent with vehicle interactions. From 1993 through 2000, 25 pronghorn were recovered for which vehicle interaction was considered contributory or causatory. Total direct pronghorn-vehicle mortality averaged 5.5% of the peak population. Average annual mortality determined indirectly attributable to pronghorn and vehicle or roadway interactions was 1.1 %.

Although pronghorn-vehicle collisions occurred in all months, most collisions occurred in August, September, and October (60%). More females (61%) were involved in collisions than males. All known vehicle collisions occurred during daylight hours and coincided with pronghorn diurnal activity patterns.

The number of pronghorn inhabiting or frequenting the base varies seasonally and annually. Peak annual pronghorn numbers ranged from 200 to 450. Highest numbers of pronghorn were present in one or more of the last four months of the year in all years. The high number (450) recorded in 2000 was associated with a severe snow and cold temperature event

and coincided with an atypical immigration of pronghorn onto the base. There was no significant relationship between annual peak population and annual direct vehicle caused mortality ($P \geq 0.05$). Motor vehicle counts at a common point on major base streets for three of the study years ranged from 240 to 430 per hour.

DISCUSSION

Pronghorn on and around F. E. Warren Air Force Base are abundant and generally accepted as part of an urbanized landscape. Pronghorn habits and the physiography and demographics of the base are such that, while pronghorn inhabit open prairie and otherwise undeveloped portions of the installation, they have a definite tendency to congregate on, and frequent, relatively heavily developed areas, including residential lawns, golf courses, and recreational ball fields. These areas are also those most commonly frequented and densely populated with humans. A reason for this apparent selective site preference is probably related to vegetation quality and moisture (Torbit et al. 1993), and other factors. Higher numbers of pronghorn observed during the fall and winter appear to be related with annual peak abundance, off base hunting pressure, seasonal migration (Ryder and Irwin 1987), and favorable vegetation and topographic conditions (Burns 1977).

Data and information on pronghorn - vehicle collisions is sparse. In contrast, the magnitude and importance of deer - vehicle collisions is widely recognized (Cook and Daggett 1995). Factors affecting deer - vehicle collisions, including habituation, animal numbers, seasonality, traffic volume and speed, physical roadway attributes, and habitat proximity (Puglisi et al. 1974; Bashore et al.1985; Romin and Bissonette 1996, Hubbard et al. 2000) apparently are operative factors in pronghorn - vehicle collisions as well.

The high proportion of pronghorn - vehicle collisions observed in August through October coincides with the period of annual local pronghorn abundance and activity associated with mating. During these months, many instances were observed where solitary bucks were oblivious to or at least much less concerned about the presence of vehicle traffic. During this period also, several instances of bucks pursuing individual or small groups of does and fawns across heavily traveled streets were also observed. In many of these cases near misses with vehicles resulted. Three instances of pronghorn – vehicle collisions were observed. In one of these cases, a fawn was observed to run into the side of a moving automobile. In that instance the animal recovered itself and ran away apparently uninjured. In all of the observations it appeared that pre-estrous or estrous related behavior on the part of both sexes was involved.

Some pronghorn, while not actually hit, were known to be injured in the immediate vicinity of streets and the presence of vehicles. Two instances of pronghorns breaking a leg while crossing a street were observed. In one case the animal stepped into a storm serve grate causing it to fall forward and break a foreleg. In the other, the animal was seen to slip on the street concrete and fall, again breaking a foreleg. On multiple occasions other pronghorn were observed exhibiting similar broken legs. In these cases, although direct information was lacking, the supposition was that the animal had suffered the injury in a similar fashion. In another case a pronghorn was observed to run into a large cottonwood tree (*Populus* sp.) as it crossed in front of oncoming traffic. The animal got up and ran away limping, with ultimate recovery unknown. In instances where pronghorn were found dead, an effort was made to determine the cause of death

through necropsy or other investigation. In some instances massive bruising, internal hemorrhaging, and/or hair loss were noted. These conditions were consistent with those observed on known vehicle collision killed animals. In these instances the cause of death was attributed to vehicle collision even if there was not direct observation of that event.

With deer, increased densities of residential and other buildings have been related to decreased likelihood of deer-vehicle collisions (Bashore et al. 1985). However, in this study most of the pronghorn-vehicle collisions occurred near residential and administrative buildings. These are areas that generally have well-watered lawns and are in close proximity to parks, parade fields, and recreation areas. Developed and high human use areas of the base are also those areas with the greatest motor vehicle traffic. It was not uncommon for pronghorn to spend time immediately adjacent to streets and roads. In these and other instances pronghorn are generally visible to motorists. Vehicle speed on residential and other streets and roads is regulated and controlled. Vehicle speed by itself did not appear to be a major contributing factor in pronghorn-vehicle collisions. Rather motorist inattentiveness was a common factor in these collisions. This fact was established through numerous interviews with motorists involved in collisions. A common comment made by motorists was that they did not see the animals. In other cases, motorists did not take appropriate preventive measures, such as changing lanes or reducing speed.

The number of pronghorn deaths directly attributable to vehicle collisions annually was comparatively stable (12 – 19). The maximum number of pronghorn present showed greater variation and was possibly related to local and regional climatic conditions (seasonal precipitation) and population levels. The base human population varied somewhat over the study period, as did, presumably, the number of vehicles frequenting the installation. Other than daily peak installation entry and exit times (0700-0800, 1600-1700 hrs.), comparative vehicle road use was felt to be relatively constant. The levels of vehicle use that were recorded were felt to provide a representative index of major base vehicle thoroughfare use. Based on this, it appears that a more resident segment of the pronghorn population is subjected to most vehicle interaction pressures. However, more study is needed.

More female than male (75F, 47M) deaths were directly attributable to vehicle collisions. Information on the sex ratio of the base population is limited and is assumed to be similar to lightly hunted populations of the greater Iron Mountain herd, of which the base herd is considered a part. Although the age at time of death for all animals is unknown, it appears that breeding bucks are more susceptible to vehicle collision during Aug. – Oct. than at other times of the year. This is consistent with observations of adult male pronghorn breeding season behavior on the installation and throughout their range.

Environmental factors alone would not seem to account entirely for the apparent high degree of association of pronghorn with areas of higher human use. Pronghorn on F. E. Warren Air Force Base appear to be attracted to areas of higher human use because of vegetation conditions or food preference. In frequenting and utilizing developed areas, pronghorn become habituated to human disturbance and other interactions (Eibl-Eibesfeldt 1970). The ability of pronghorn to adapt to varied conditions and to co-exist with human environment-altering activities is recognized (Yoakum 1978). The ability of pronghorn to adapt and habituate to urbanized environments is worth further investigation.

The convergence of a relatively large number of human-habituated pronghorn with a large volume of vehicular traffic contributes to the relatively high levels of pronghorn-vehicle collision. However, this observed relationship is confused by population dynamics, varying traffic patterns and landscape features, limited data on populations, and intensity of study (Bruinderink and Hazebroek 1996). In this instance, while a vehicle collision-caused mortality rate of a minimum of 6.6%, as measured by a percent of the peak annual population, appears high, the local pronghorn herd appears able to sustain that level of loss without decline.

MANAGEMENT IMPLICATIONS

The visibility and close proximity of pronghorn at F. E. Warren Air Force Base tends to foster a local sense of pride and ownership. However, this close proximity also tends to result in some negative interactions and safety concerns. Management to encourage and allow widespread public appreciation and enjoyment of the species, while balancing the protection of human property and safety, should be the goal.

While pronghorn have not previously been associated with motor vehicle interactions to the degree reported here, the species apparently has the malleability and adaptability to contribute to what are more typically considered urban economic and human safety concerns. Managers need to be aware of this potentiality when managing pronghorns. In addition to traditional management focuses, emerging and increasingly important transportation, urban, and general public-pronghorn interactions and perceptions need to be considered.

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PRONGHORN AND A CALIFORNIA HIGHWAY: POTENTIAL IMPACTS AND MITIGATION

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Abstract: The California Department of Transportation plans to widen a 2-lane highway to 4 lanes. Pronghorn cross this highway. The highway expansion would prevent pronghorn from crossing the highway, isolating and potentially extirpating subpopulations. Proposed mitigation includes enhancing pronghorn habitat and either constructing a vegetated wildlife overpass or using a proposed creek bridge to maintain pronghorn migration and dispersal across the highway.

Key Words: *Antilocapra americana*, California, highways, pronghorn antelope, San Luis Obispo, transportation, wildlife overpasses, mitigation.

The California Department of Transportation (Caltrans) is proposing to widen 40 km of State Highway 46, a portion of which pronghorn cross in eastern San Luis Obispo County, California (Fig. 1). The existing highway is a standard two-lane facility with private landowner-maintained, barbed wire, right-of-way fences. The highway splits into 2, 2-lane highways (46 and 41) at the eastern end of the project, where both highways will be widened to 4 lanes for short distances east of the split. This location is known as "the Y" because of the highway intersection's shape (Fig. 2). The Y occurs within the Cholame Valley, which has proven to be valuable pronghorn range since the species was reintroduced to San Luis Obispo County.

The proposed project would expand the 2-lane highway into a divided, 4-lane highway with an 18.6-m-wide median. The Y interchange would be moved slightly east and reconstructed with one bridge that would eliminate the potential for head-on accidents at the interchange. The 5- and 6-strand right-of-way fences would remain or be replaced as needed. Another project has been proposed to continue widening Highway 41 to 4 lanes east of the Y.

History of the San Luis Obispo Pronghorn Population

The California Department of Fish and Game (CDFG) reintroduced pronghorn to a small portion of their historic range in eastern San Luis Obispo County between 1987 and 1990. The reintroduced animals were from northeast California. Approximately 280 pronghorn were released at 3 locations (Fig. 2; A. Koch, CDFG, personal communication).

This pronghorn population now consists of 3 subpopulations (Fig. 2). About 60 animals range in the Cholame Valley where there were no reintroductions, approximately 40 in the San Juan River/Shell Creek area near Shandon, and approximately 132 animals in the Carrizo Plain area.

The Cholame Valley subpopulation is of primary interest to Caltrans due to the proposed highway expansion through the Cholame Valley. State Highway 46 crosses the southern end of

the Cholame Valley and splits into Highways 41 and 46 at the Y where approximately 60 pronghorn live year-round. Of the 60 pronghorn that utilize the Cholame Valley, only about 10 are regularly seen south of the Y.

Pronghorn regularly cross Highways 41 and 46 (B. Stafford, CDFG, personal communication). Pronghorn are occasionally observed in the Y area between the two highways, indicating that the animals cross the highways in the Cholame Valley. Other evidence of pronghorn crossing the highways includes road kill (L. Bonner, Caltrans, personal communication) and the fact that the approximately 50 pronghorn north of the Y originated from the animals reintroduced far south of the Y.

No specific pronghorn crossing locations have been identified, although the animals frequently range adjacent to approximately 3 km of highway near the Y. This fact, combined with the excellent sight distance and low slope gradients (0-5%) in that area lead Caltrans and the CDFG to believe that when the pronghorn cross the highway, they cross within these 3 km. Herds of pronghorn can often be seen grazing at the right-of-way fence, which is approximately 9 m from the highway. These herds often graze on forbs that grow in a strip that is tilled by a private landowner as a firebreak. No obvious crossing points, such as high bottom fence wires, gaps in the fences, open gates, or other features have been identified.

Little is known about the exchanges between these subpopulations and their movements in relation to highways. Several aerial counts are performed every year, but individual animal movements have not been recorded. One intensive study did document seasonal foraging patterns for the south Cholame Valley pronghorn (Jones 1991). Seasonal movements were not great, although some seasonal differences in foraging patterns were documented. These animals foraged primarily in areas of 0-2.2% slopes in summer and in areas of 15.6-40% slopes in spring.

We know of 2 fawning areas in the Cholame Valley. One is just south of the Y in relatively tall grasses; the other is north of the Y in an alfalfa field. These areas are important for fawning probably because of their abundant forbs and slightly taller vegetation than surrounding areas.

The Cholame Valley is a potential source population for the pronghorn. Natural water sources are more numerous, more frequently spaced, and more dependable than on the Carrizo. The numerous springs, seeps, and sag ponds have perennial carpets of forbs that the pronghorn frequently graze through the dry summer and fall (personal observation).

The Cholame Valley receives more rainfall than the Carrizo Plain. Storms traveling southeast deliver all appreciable precipitation to the area. Three successive mountain ranges shadow the Carrizo Plain from these storms: the Santa Lucias, the La Panzas, and then the Calientes, reaching 947 m, 1238 m, and 1556 m, respectively. Only one range on the immediate coast (the Santa Lucias) shadows the Cholame Valley. The greater rain shadow effect on the Carrizo Plain is evident from the grasslands that transition to desert scrub communities; the Cholame Valley grasslands transition to chaparral and oak woodlands. The rain shadow effect was also apparent in the 2001/2002 wet season (a notably dry winter) when the Carrizo Plain received almost no rain and grew no green grass and forbs, while the Cholame Valley received

sufficient rain to remain green well into April and to grow favorable forbs such as *Delphinium* sp. through May.

Effects Analysis

The Highway 46 widening project, as proposed, would directly affect the pronghorn by permanently separating the pronghorn north of the highway from those south of the highway.

Characterizing the Effects

We believe that the proposed highway widening would negatively affect the entire San Luis Obispo County pronghorn population. This is based on the belief that a 4-lane highway would eliminate all north-south movements of pronghorn and that free north-south movement between subpopulations is essential to maintain the assemblage of subpopulations. Examples in California, Arizona, and Wyoming show that fenced, 4-lane highways prevent pronghorn movement and isolate subpopulations (Ward et al. 1980, Ockenfels 1984, J. Yoakum, Western Wildlife Consultants, personal communication). Based on these examples, it is reasonable to conclude that widening Highway 46 to four lanes would further divide subpopulations.

Metapopulation principles tell us that subpopulations may depend on immigration to sustain their numbers and remain viable (Hanski 1999). These principles applied to the San Luis Obispo pronghorn suggest that isolation would jeopardize the viability of the subpopulation north of the Y. The reverse is also true: isolating the north Cholame Valley pronghorn, in addition to preventing immigration, would prevent emigration and eliminate it as a potentially important source population for all of the San Luis Obispo subpopulations. The long-term effects are unknown but potentially substantial, considering the differing environmental conditions between the Cholame Valley and the Carrizo Plain, which may translate to different recruitment rates between the two areas. Expanding the highway and preventing pronghorn from crossing would completely isolate the population north of the Y, which is already near the proposed minimum viable population threshold of 50 breeding adults (Samson et al. 1985, Reed et al. 1986, and Scott 1990). The small herd of approximately 10 animals south of the Y is clearly below the proposed minimum threshold, and most likely depends on individuals dispersing from other herds. Should disease, drought, illegal hunting, or other events cause a decline in the north or south Cholame Valley herds, the proposed highway expansion would create a barrier that would prevent dispersal events necessary to maintain genetic exchange, to supplement subpopulations with new individuals, and to populate unoccupied habitat.

Although a highway widening has not been proven to extirpate pronghorn populations, highways have been shown to create complete barriers to pronghorn movement. The general barrier effect of roads on other species is also well documented (Oxley et al. 1974, Singer et al. 1985, Forman and Alexander 1998). Additionally, increased road width and traffic density have been shown to increase a road's barrier effect for many species (Barnett et al. 1978, Swihart and Slade 1984, Brandenburg 1995).

At least 3 major highways in western states are substantial pronghorn barriers (Ward et al. 1980, Ockenfels et al. 1994, J. Yoakum, Western Wildlife Consultants, personal communication). All 3 are divided, 4-lane highways, similar to the proposed Highway 46. California's Highway 395, a 3-lane divided interstate in Lassen and Sierra Counties, completely

blocks a traditional seasonal migration for pronghorn (Jim Yoakum, Western Wildlife Consultants, personal communication). The opening of Wyoming's Interstate 80, a divided 4-lane facility, isolated portions of one of the largest remaining populations by virtually preventing pronghorn from crossing the highway (Ward et al. 1980; Bill Rudd, Wyoming Game and Fish Department, personal communication). Arizona's Highway 17, a 4-lane divided interstate highway, isolated pronghorn into separate populations (Ockenfels et al. 1994). Highways 69 and 89A, which are two lane highways, also isolate populations in Arizona.

The 3 examples above strongly suggest that widening Highway 46 to 4 lanes and retaining right-of-way fences would prevent all pronghorn from crossing the highway. The long-term effects would include permanent habitat fragmentation, loss of range for individuals or groups that may regularly cross the highway, loss of dispersal events across the highway, loss of genetic exchange between groups of animals, reduction of subpopulation sizes to less than sustainable levels, increased inbreeding, increased susceptibility to extirpation from disease, and ultimately the loss of subpopulations and even the entire population in San Luis Obispo County.

Establishing the Significance of Effects

A "significant" impact under the National Environmental Policy Act (NEPA) can be a primary impetus for mitigation on any project that uses federal funds. The case is similar for State-funded or State-permitted projects in California that are regulated under the California Environmental Quality Act (CEQA). However, each law defines "significant" differently.

Under both definitions, the Highway 46 widening may significantly affect pronghorn. Section 15065 of the CEQA Guidelines clearly tells us that if a project will "substantially reduce the habitat of a fish and wildlife species, [or] cause a fish or wildlife population to drop below self-sustaining levels," then the project would have a significant impact. The project would substantially reduce habitat for the entire population and cause the subpopulation north of the Y (and probably other subpopulations) to drop below self-sustaining levels.

The NEPA definition and effects analysis is less clear. Resources upon which effects may be considered significant include, but are not limited to, "Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas." Assessing an impact's significance relies on identifying the balance between an impact's intensity and the affected resource's context. If the resource has a great context, then a less intense impact to that resource would constitute a significant impact under NEPA. For example, if the National Park Service built a new lodge that caused Old Faithful to gush 1 less time per day, then the impact would probably be considered significant because of the geyser's national recognition and importance. If no one knew about the geyser except for people in West Yellowstone, Montana, then the geyser's context would be considered local and probably no impact to the geyser would be considered significant.

The pronghorn population in eastern San Luis Obispo County has mostly regional and statewide context. It is valued by tourists at the Carrizo National Monument, by the locals that see pronghorn every day, by the thousands of people that drive Highway 46 between the San Joaquin Valley and the central coast (many of whom stop to photograph the animals), and by the CDFG, which has spent nearly $1,000,000 reintroducing and managing the population (B.

Stafford, CDFG, personal communication). The pronghorn also have some local historical importance. Antelope Road, Antelope Grade, and Antelope Valley are all named on maps of the Cholame area.

A species' status under the Endangered Species Act or other laws is not a mandatory premise for a "significance" determination, although listing under the Endangered Species Act automatically gives a species national importance and, therefore, makes a "significance" determination easier than for a non-listed species such as pronghorn.

Rejected Onsite Mitigation Options

After establishing the significance of the highway project impacts, the next step was to develop mitigation options. The initial strategy was to modify the right-of-way fences. The new fences would have been set far back from the highway and strung with a high bottom wire to allow the animals to pass underneath. This idea was rejected for 4 reasons. One reason was the substantial right-of-way cost. Another reason was that the adjacent property owner, who is responsible for maintaining the fences, would modify the fences because he believes that his cattle would escape and cause highway accidents and subsequent lawsuits. A third reason was that, even if the fences were maintained to allow pronghorn passage, this would still allow animals onto the highway. It was thought that there would be a greater risk of animal-vehicle collisions with the expanded highway and the projected increase in traffic volume. Because smaller populations are predisposed to extinction (Weaver et al. 1996), the loss of animals on the highway would further threaten the pronghorn in this area. The fourth reason was that, even if the pronghorn negotiated the fence crossings, they would be deterred by the elevated highway fill and 4 lanes of high-volume daytime traffic. As illustrated by the California, Wyoming, and Arizona examples, the combination of 4 lanes and 2 fences seems to comprise a complete barrier to pronghorn—so this would not achieve the goal of maintaining migration and dispersal across the highway.

Proposed Mitigation

Both onsite and offsite mitigations are proposed. Offsite mitigation would include removing or modifying fences on the Carrizo Plain National Monument to enhance pronghorn habitat. Barbed wire fences fragment the pronghorn range in the Carrizo Plain area, which harbors the largest portion of the population. These fences limit pronghorn movements, ensnare individual pronghorn, and aid coyotes in pursuit of fawns (Yoakum 1980, B. Stafford, CFG, personal communication). Some of the fences are relict ranch fences that have no use and may be removed. Many other fences periodically control cattle. These fences would all be replaced with 3-strand fences and the bottom wires would be replaced with smooth wire, placed 46-56 cm from the ground to permit easier pronghorn crossings. These fence modifications would reduce the fences' barrier effect, entanglement potential, and benefit to coyotes (Yoakum 1980, Ockenfels 1994).

Onsite mitigation is focused around promoting and maintaining pronghorn and other wildlife movement across the highway. For pronghorn, this would include either an underpass (highway bridge over land) or an overpass (a vegetated bridge over the highway). An overpass would be 30-60 m wide with a 30-45 m span (length across the highway), with soil and low

vegetation over the bridge deck. Woven-wire fences would parallel the highway but would not cross either end of the bridge. Imported fill would be used to blend the overpass approaches into the natural topography, creating very low slopes (0-5%) leading up to the crossing and to shield a pronghorn's view of the highway. One-meter earthen berms may be used next to the fences and on the bridge deck to further shield the view of the highway, but placed so as not to prevent a pronghorn's long-range views across the Cholame Valley.

Constructing an underpass specifically for pronghorn was initially rejected because dimensions for a successful pronghorn underpass are unknown (none have been built) and it was believed that a successful underpass would have to be extremely tall, wide, and expensive, and because it was unknown whether pronghorn would use any underpass. Although mountain goat (*Oreamnos americanus*), mountain lion (*Puma concolor*), mule deer (*Odocoileus hemionus*), and many other animals will readily use properly placed underpasses, few examples of pronghorn going under highways were found (Ford 1980, Ward et al. 1980, Singer et al. 1985, Evink 1990, Putman 1997, Haas 2000). We found examples of locations where multiple underpasses were available to pronghorn but which they did not use (Ward et al. 1980, J. Yoakum, Western Wildlife Consultants, personal communication). Due to the pronghorn's generally skittish nature and avoidance of features that limit sight distance and mobility, the limiting factor of underpasses for pronghorn seems to be the underpasses' limited apertures, which are directly related to length and width.

Nevertheless, an underpass is being reconsidered because of 2 parallel, 120m-long bridges that are proposed for hydraulic reasons at Cholame Creek just west of the Y. These bridges were not designed for pronghorn crossings, but may be modified to accommodate pronghorn. The creek floods rarely and flows intermittently, filling a channel that is approximately 9 m wide only during heavy rains, and rarely fills a wide floodplain that engulfs much of the Cholame Valley floor. The bridge would have only 2 bents (supports) with approximately 40 m between each bent. If the bridges are tall enough, and fences modified as described above for the overpass, then they may allow pronghorn to pass underneath except during the rare floods. The bridge location may be optimal for the pronghorn because it would be on the floor of the Cholame Valley, at a specific site that the pronghorn currently use, and in a wide expanse of flat ground with very low vegetation. Highway underpasses that have been monitored intensively for pronghorn were box culverts or equipment underpasses—structures with much smaller apertures than the proposed 120m bridges (Ward et al. 1980).

Remaining Challenges

The greatest challenge is deciding whether to construct the wildlife overpass or to only modify the proposed bridges so that pronghorn may use them as underpasses. Neither underpasses nor overpasses have been shown to successfully maintain pronghorn habitat connectivity. Another major challenge is deciding how tall the Cholame Creek bridge needs to be to promote pronghorn crossings, and whether pronghorn would use it at any height.

A third challenge is determining how to acquire baseline data before construction to facilitate a post-construction study of the proposed highway's barrier effects. We have several years before construction, but with so few pronghorn, the Department of Fish and Game considers it infeasible to radio collar the animals due to the risk of mortality during capture. The

CDFG does aerial counts of the animals and records their locations. However, these annual counts cannot document movements of individuals or small groups of animals relative to the highway. It would be impossible to measure successes or failures without knowing current movement patterns in relation to the highway. The intensity of the existing highway's pronghorn migration and dispersal barrier effects compared to the proposed highway and animal crossing structures' barrier effects would be a valuable comparison because large overpassses or underpasses have not been built specifically for pronghorn.

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Fig. 1. Historic pronghorn distribution in California and project location.

Fig. 2. Approximate current pronghorn distribution in and near San Luis Obispo County.

PRONGHORN USE OF MODIFIED FENCES IN NORTHERN ARIZONA

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Abstract: Fences obstruct pronghorn (*Antilocapra americana*) movements to water or feeding areas (Lee et al. 1998). Results of a pronghorn habitat analysis on Babbitt Ranches in northern Arizona concluded that fence structure limited pronghorn movement (Ockenfels et al. 1996*a*). At that site, Ticer et al. (1999) determined that fences restricted movement and defined some pronghorn home range boundaries. To facilitate increased pronghorn movements, we modified 37 fence segments and monitored crossing of modified and a paired unmodified fence segment. Fence segments were modified with 5-cm diameter, 1.2 – 1.8-m long PVC pipe slid over the bottom 2 raised barbed-wire fence strands. Sample segments were checked for pronghorn tracks and hair for the duration of this study (6 months). Fence crossings occurred nonrandomly, with a preference for modified fence segments. Height of modified segments used by pronghorn averaged 53 cm. We determined that this fence modification facilitated pronghorn movements across previously uncrossed fences.

Key words: *Antilocapra americana*, fences, habitat, home range, modification, movements, pronghorn.

Pronghorn are nomadic and travel great distances to water (Autenrieth 1978, Yoakum 1978), seasonal food sources (Buechner 1950, Hailey 1979, Neff et al. 1985, deVos 1990), fawning grounds (Buechner 1950), and to avoid inclement weather (Hailey and DeArment 1972). In addition to seeking fawning areas, female pronghorn probably travel great distances to meet increased nutritional requirements during breeding and gestation. Fences used to restrict livestock movements inhibit pronghorn movements (Ockenfels et al. 1994, Lee et al. 1998) and restrict their ability to locate water and forage, and to avoid predators or deep snow (Hailey 1979, Yoakum 1979).

Because pronghorn evolved in open, gentle terrain with limited tall vegetation, their survival did not necessitate jumping obstacles, such as fences (Lee et al. 1998). The fact that pronghorn have difficulties negotiating fences has been documented for more than a century (e.g., Caton 1877 and many others), and extensive mortality has occurred in some areas when pronghorn become entangled or trapped as they attempt to pass through fences (Oakley 1973). Fence structure dictates the level of impact imposed on pronghorn movements. To-the-ground woven-wire fences virtually eliminate pronghorn movements and barbed-wire fences with the bottom strand <40 cm from the ground greatly impede movements. Game-standard fencing (i.e., smooth bottom strand placed >40 cm from the ground; Lee et al. 1998) facilitates pronghorn passage, but may still impede movements. Although 2-strand electric wire fencing is considered

passable by pronghorn (McAtee 1939, Spillett et al. 1967, Yoakum 1978), research into impacts of such fencing is warranted.

Ockenfels et al. (1996*a*) developed and tested a pronghorn habitat model for Arizona, which was subsequently used to evaluate pronghorn habitats statewide (Ockenfels et al. 1996*b*). The Cataract and the Espee ranches, owned and operated by Babbitt Ranches, Inc., were evaluated using this model, and we determined that current fence structure fragmented available habitat on these ranches (Ockenfels et al. 1996*b*, Ticer et al. 1999). In response, Babbitt Ranches, Inc., agreed to undertake fence modifications to improve conditions for pronghorn using a newly developed PVC pipe fence modification that allows for rapid change of existing barbed-wire fences. The goal of this study was to determine if these modifications were effective in facilitating pronghorn movements in areas where movements were limited prior to these modifications.

STUDY AREA

The Babbitt Ranches Study Area (BRSA), located on the Colorado Plateau in north-central Arizona, is approximately 182,115 ha in size and elevation ranges from 1,675-1,830 m (Fig.1). Climate during our study was arid (<19 cm precipitation/year) and most precipitation occurred in summer (July-September) monsoons (Thybony and Thomas 1998). Terrain was flat to gently rolling hills, except where bisected by Cataract Canyon, a deep, steep-walled canyon formed by a tributary to the Colorado River.

Vegetation was predominately Shortgrass Plains Grassland integrated with Great Basin Grassland (Brown 1994). Livestock grazing was the predominant land use during our study of BRSA and fences defined 26 pastures within the study area.

METHODS

Ticer et al. (1999) showed that pronghorn home ranges were constrained at pasture fence boundaries and little movement occurred between pastures. We recommended that ranch managers raise bottom strands of fences to at least 46.0 cm, using a 5-cm diameter PVC pipe (Fig. 2). Ranch personnel implemented the recommendation by modifying a 1.2-1.8-m fence span at 0.3-km intervals on most of their fences. They cut a slit lengthwise on each PVC pipe, placed the PVC over the bottom strand, and then used wire to tie the raised strand to the next strand, or they raised the bottom-barbed strand to the second strand and slid the PVC pipe around the 2 strands. This design allowed for easy application and removal of fence modifications, based on current livestock rotation and ranch objectives in their grazing program.

Fig. 1. Location of Babbitt Ranches study area with pasture numbers and home ranges of radiomarked pronghorn. Not the northeastern boundary fences in Pasture 8 where fence modifications were made and studied, 1999-2000.

Fig. 2. Example of a typical 1.2-1.8-m, PVC-modified fence span on Pasture 8, Babbitt Ranches, Arizona.

To determine whether pronghorn used these modifications and if the modifications facilitated pronghorn movements through non-game standard fences, we monitored every third span ($n = 37$) along a 36.2-km section of Pasture 8 (Fig. 1) to determine if pronghorn crossed beneath the fence. For comparison, we randomly selected 37 unmodified spans 0.16 km from modified spans along the same fence. We measured height (cm) above ground of sample bottom strands (modified, unmodified). All spans were checked twice a month for evidence of pronghorn use.

We monitored pronghorn movements at modified fence sites using double-sided carpet tape placed on the underside of the PVC pipes to collect hairs from pronghorn as they crossed under the fence. At unmodified sites, we searched for pronghorn hair stuck to barbs on the lower fence strand. Although we were not able to quantify the efficiency of the tape or the barbed fence to collect hairs, both methods were able to capture hair from pronghorn that did cross under the fence and we assumed that the methods were equally efficient. We also placed 6 motion detector cameras at modified fence spans to monitor pronghorn crossings at select sites. We subjectively selected 6 areas by looking for spans that were >40 cm from the ground and located in gentle terrain with low (<45 cm) vegetative heights. We used Chi-square Goodness-of-fit Likelihood Ratio to test for differences in pronghorn fence crossing patterns.

RESULTS

We checked modified fence spans for pronghorn crossings 21 times between mid-October 1999 and May 2000. Number of pronghorn crossings of modified fence spans differed from unmodified spans ($X^2 = 19.6$, df = 1, $P < 0.001$), as pronghorn were never detected crossing unmodified fence spans. We detected 14 crossings at modified fence spans with 10 of 37 (27.0%) modified spans crossed by pronghorn (3 were crossed more than once).

Mean modified fence height crossed by pronghorn was 53.0 cm (SD = 3.1, $n = 10$) and ranged from 49.3 - 58.9 cm. However, mean height of all modified spans was 48.5 cm (SD = 7.6, $n = 37$) and ranged from 23.4 cm - 61.0 cm. In comparison, mean unmodified fence height was 31.2 cm (SD = 5.3, $n = 36$) and ranged from 20.1 - 44.1 cm.

There were no pronghorn crossings detected using the remote sensing cameras as livestock in the area frequently tipped the camera system over, making this technique unusable.

DISCUSSION

In our experience, many livestock operators are reluctant to modify existing fence structure because of the high cost of modifying fences, concern over losing calves that cross beneath the higher bottom strand, and in some cases, such as water sites, the need for low strands to preclude escape of calves during branding and health inspections. This presents a problem for pronghorn managers as much of the pronghorn range has been fragmented by thousands of kilometers of fences that preclude pronghorn movements (Lee et al. 1998). Personnel from Arizona Game and Fish Department and Babbitt Ranches developed the concept of modifying existing fence structure using PVC pipe to join the bottom strands of existing fences to facilitate pronghorn movement without the expense of complete removal of bottom strands. The benefit of this approach was that it was feasible to modify fencing in large areas with minimal cost and time.

We found that pronghorn used the modifications we made to existing fence structure using the PVC pipe, but we did not detect crossings at the unmodified paired sites. Although we did not document cost and time, use of PVC clearly was more effective in comparison with typical fence modification methods, such as bottom strand removal and replacement with smooth wire. PVC lengths typically cost <$1.00 each, and one person can install several per day.

Another important factor in using PVC pipe to modify fence structure was acceptance of this tool by most livestock operations, where removal of the lower strand was not accepted in some instances. Some modifications completed by Babbitt Ranches were on boundary fences and initially when we discussed fence modifications, adjacent ranches were concerned that unbranded calves would move between ranches. Once fence modifications were installed and other livestock operators were able to see the modifications, opposition to the modifications waned.

We also found that many of the waters constructed on Babbitt Ranches were surrounded by multi-strand fences designed to retain calves during branding and health inspections, which typically were used for only a few days per year, but the fences precluded pronghorn from using

the waters yearlong. With the PVC pipe modifications we tested, fences to these waters could be raised for the majority of the year and the PVC pipes removed during livestock handling periods.

We also found that pronghorn used segments of modified fences that were >49 cm high, although modified fence segments <49 cm high were available. The current pronghorn guidelines recommend that the bottom strand of "pronghorn friendly" fences be ≥ 40.6 cm from the ground (Lee et al. 1998), but we found that pronghorn favor a greater height when available. Therefore, we recommend that current guidelines should be reconsidered.

MANAGEMENT RECOMMENDATIONS

Modified fence spans (5-cm OD PVC pipes, 1.2-1.8 m) should be placed in currently occupied pronghorn ranges, adjacent to potential expansion areas, and in likely reintroduction sites where low bottom strands might preclude pronghorn movements.
Modified fence spans should be >49 cm from the ground, and placed in sites void of visual obstructions, such as tall (>45cm) vegetation or hilly (slope >10%) terrain.
Current fence construction guidelines for pronghorn should be changed to recommend that the bottom strand be >49 cm from the ground. This height did not result in problems with cattle movements between pastures, but was used by pronghorn on BRSA.

ACKNOWLEDGEMENTS

The Federal Aid in Wildlife Restoration Act, Project W-78-R, of the Arizona Game and Fish Department, and Babbitt Ranches, Inc., provided funding for this study. Babbitt Ranches' President Billy Cordasco, provided us the opportunity to conduct this study.

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Section IV.

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Section V.

BUSINESS MEETING
20TH BIENNIAL PRONGHORN ANTELOPE WORKSHOP

KEARNEY, NEBRASKA
MARCH 20, 2002

Chair Jeff Abegglen called the business meeting of the 20th Biennial Pronghorn Antelope Workshop to order at 0830 hours.

Representatives present at meeting are as follows: Richard Ockenfels and Shelli Dubay, Arizona Game and Fish Department; Jorge Cancino, Centro de Investigaciones Biologicas, Baja California Sur, Mexico; Tom Pojar, Colorado Division of Wildlife; Lloyd Fox, Kansas Department of Wildlife and Parks; Bruce Morrison, Karl Menzel, Gary Schlichtemeier, and William Vodehnal, Nebraska Game and Parks Commission; Mike Cox, Nevada Division of Wildlife; Bill Jensen and Bruce Stillings, North Dakota Game and Fish Department; Steve Griffin and Lowell Schmitz, South Dakota Game, Fish, and Parks; Rich Guenzel and Roger Bredehoft, Wyoming Game and Fish; Mike Oehler, National Park Service; Kim Brinkley, Los Angeles Zoo; Jim Yoakum, Western Wildlife Consultants; Robb Hitchcock, North American Pronghorn Foundation; David Brown, Arizona State University/Arizona Antelope Foundation; Sue Fairbanks, University of Nebraska at Omaha; Fred Lindzey, University of Wyoming Cooperative Research Unit; and Jason Zimmer, University of Wyoming.

OLD BUSINESS

• Awards Chairman Selection

Richard Ockenfels indicated that the Awards Committee chairman selected at the La Paz meeting would no longer be able to serve as chairman.

Richard volunteered to become the new chair of the Awards Committee. Tom Pojar and Rich Guenzel both volunteered to become committee members.

Jorge Cancino proposed having the workshop chairman serve as Awards Committee chairman. Through discussion, the attendees decided that if there were not a volunteer to serve as chairman, the workshop chairman would be responsible for chairman and committee member selection.

The Awards Committee will be responsible for selecting Berrendo Award recipients and also to whom and how many special recognition certificates will be awarded. The committee is also responsible for writing an awards process addition to the bylaws including information of award selection and criteria. This will be completed by the 2004 meeting.

• Management Guidelines

Jim Yoakum gave a brief history regarding the pronghorn management guides. Concern is that these guidelines are in need of periodic updating, for example, fencing and food habits information could be updated. Jim indicated that every five or so years an update is necessary. Through a show of hands the group approved the management guides update idea.

A committee and chairman were organized to handle this task. Dave Brown volunteered to chair the Management Guidelines Update Committee. Committee members will include Jorge Cancino, Jim Yoakum, Tim Pojar, Richard Ockenfels, Karl Menzel, Jeff Abegglen, and Fred Lindzey. The committee's responsibility will include correcting a pagination problem present in the current management guides, finding a publisher, and distributing guides to all necessary parties. The committee is to have objectives accomplished by the 2004 meeting.

Discussion on the topic included publishing the management guides on a website. However, it was noted that a certain amount of published copies of the guides must be available for archival purposes and for those without Internet capabilities.

• By-Law Changes for Ratification

Jeff Abegglen pointed out discrepancies in the by-laws to the group. On pg. 35, section 4B, subheading 1 of the by-laws, a formal change to remove the word "Mexico" was to take place. This discrepancy will be taken care of accordingly.

Jorge Cancino also brought about discussion regarding by-laws. His concern was whether other organizations and foundations should be added to the list in section 4B, subheadings 4 and 5. The group decided this couldn't be done without Western Association's direct approval.

• North American Pronghorn Foundation Updates (NAPF)

Robb Hitchcock provided background information regarding the status of pronghorn funding for the NAPF. The pronghorn doesn't attract as much capital as other big game species, for example, bighorn and elk, despite efforts. The group does what it can with these limited resources, including providing scholarship and research monies. The group is also pushing for more regional chapters with limited success.

One of the group's main concerns is the coal bed methane boom occurring in Wyoming. This is having detrimental affects on the pronghorn in the area and will into the future. Consequently, the group voices concerns whenever possible, however, more support is needed from other states and organizations. Robb will be making contacts in the future regarding this issue.

• Arizona Antelope Foundation Update (AAF)

David Brown provided the update on the AAF. The organization, active since 1994, meets on the second Monday of every month, and is currently about 330 members strong.

The AAF has three major events this year. They are involved in several field projects, including fence modifications, through various cooperative programs. The Foundation also holds an annual hunter clinic; all pronghorn permit holders are contacted and an informative seminar are presented to attendees. Lastly, the Foundation has thus far annually been awarded 2 pronghorn

tags to auction. The Arizona Game and Fish Department use funds from this auction for fence modification projects, water development, and other projects.

• Website

Richard Ockenfels led discussion regarding the need to keep up with changing technology. The goal is to have a centralized website with the management guides, proceedings, and upcoming workshop information available to all persons.

A Website Development Strategy Committee was organized to deal with this issue. Mike Cox agreed to chair the committee, and committee members will include Robb Hitchcock, Bill Jensen, and Richard Ockenfels. Jeff Abegglen will provide assistance when available. The committee is responsible for gaining approval from the Western Association and addressing funding and other discussed issues. The committee will take immediate action.

• Usage of Past Proceedings

Richard Ockenfels led discussion on present usage of past proceedings and how it can be improved. He is indexing the past proceedings onto a CD and it will be available for a website. He asked the group to provide help in gaining original copies of proceedings to aid in this undertaking.

Current policy includes submitting papers for presentation in an electronic format. This will alleviate the need for a future compiling. However, a scanning or typing process will have to be done for past papers. Who will perform this endeavor has yet to be determined.

Fred Lindzey will check on possibilities for the group to proceed forward with this project.

• Date and Place of Next Meetings (2004, 2006, and 2008)

Bill Jensen indicated that North Dakota is interested in hosting the 2004 workshop.

Richard Ockenfels motioned to have 2004 meeting in North Dakota at their location and date of choice. Tom Pojar seconded motion. Motion approved unanimously by show of hands.

Jeff Abegglen noted that South Dakota, New Mexico, Idaho, Montana, and several Canadian provinces might have an interest in hosting the workshop in 2006 or 2008. Representatives are to discuss this with their respective agencies.

NEW ISSUES

• International Pronghorn Population Survey

The Workshop has agreed to oversee this effort. Jim Yoakum gave background and described discrepancies with current process. Recent surveys completed have been incomplete and this information is necessary for use in determining such information as population trends.

Jeff Abegglen indicated that the current questionnaire needed some minor changes to be more comprehensive in gathering population estimates. After considerable discussion, the group decided that the responsibility should fall on the hosting state in gathering the necessary

information to be published in the proceedings. Nebraska will be first to revise the questionnaire and set precedents on sending the questionnaire and following up. The goal is to have population survey information available to be published in the proceedings.

• Improving and Maintaining a Comprehensive Mailing List
Jeff Abegglen voiced concerns regarding the broad definition of the mailing list in the bylaws. Richard Ockenfels will provide a breakdown of mailing recipients.

Bruce Morrison pointed out the need for advertising for the workshop in the Wildlife Society Bulletin. Kim Brinkley noted that an advertisement in the AAZA Communiqué (American Association of Zoos and Aquariums) would reach more members of the zoo community.

All parties interested in receiving mailings should be added to the mailing list. Advertisements in the Wildlife Society Bulletin, Listserv, and any other journals should be forwarded to the workshop chair.

• Proper Name of Pronghorn Antelope Workshop
Jeff Abegglen made note of the various common name verbiage associated with the species, including pronghorn, pronghorn antelope, and American pronghorn. Jim Yoakum provided the group with a brief history of the common name.

Jim also commented that a recent publication by the Smithsonian Institute has indicated that the proper common name is just "pronghorn."

Karl Menzel motioned to change the name in the bylaws to read "Pronghorn Workshop." Motion seconded by Rich Guenzel. Motion to change name passed 12-1.

• Fencing and Highway Issues
Rich Guenzel brought new fencing and highway issues to the groups attention. A cooperative effort through the states is needed to encourage each states roads department. Through discussion, group consensus was that the Western Association would be the most effective organization to make these recommendations.

Bruce Morrison noted the importance of specific recommendations regarding these issues. This will be the most effective means of having highway improvements made.

Rich Guenzel will draft and submit a proposal to the Western Association for their next meeting.

The Business Meeting was adjourned at 1130 hours by Chair Jeff Abegglen.

Section VI

[Amendment Version 2002]

ORGANIZATION and FUNCTION of the PRONGHORN WORKSHOP

BYLAWS

I. Designation

This organization shall be known as the Pronghorn Workshop. The official publication of the Workshop shall be known as the Pronghorn Workshop Proceedings.

II. Goal

The goal of the Workshop is to provide information relative to and encourage the perpetuation of sustainable wild stocks of pronghorn as an ecological, aesthetic, and recreational natural resource on western rangelands, both public and private, at their most productive levels consistent with other proper land uses.

III. Objectives

A. To provide an opportunity for all persons interested in pronghorn to meet and discuss current research and management of the species and its habitat.

B. To provide a vehicle for disseminating research and management findings to the various agencies and organizations concerned with pronghorn management.

C. To promote species-oriented research for development of new information on all aspects of pronghorn ecology, life history, and management on western rangelands.

D. To identify particular problems associated with pronghorn management and to formulate recommendations and resolutions directed to the appropriate agency or organization, including the Western Association of Fish and Wildlife Agencies.

E. To promote cooperation among all agencies and organizations concerned with pronghorn management and research, particularly among the various provincial, state, and federal agencies with the primary responsibilities of managing this species and its habitat.

IV. Organization

A. The Workshop shall be open to any person interested in pronghorn and its management.

B. Voting

Voting members shall consist of one representative of each of the following:

1. States, provinces, and countries.

Alberta, Arizona, Baja California Sur, California, Chihuahua, Coahuila, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, Saskatchewan, Sonora, South Dakota, Texas, Utah, Washington, Wyoming.

2. Federal Agencies.

Bureau of Land Management, Canadian Wildlife Service, Forest Service, Fish and Wildlife Service, National Park Service, Natural Resources Conservation Service, Parks Canada, and the Direccion General de Fauna Silvestre.

3. Universities and Colleges.

The chair may appoint up to three people to represent colleges and universities. This appointee shall come from any college or university actively engaged in pronghorn research.

Voting representatives for the states, provinces, and countries shall be appointed by the agency directly responsible for wildlife management within the above named states, provinces, and countries.

The chair shall request that each of the above named federal agencies appoint one voting member. This request shall be directed to one of the regional offices or service centers in the western United States, Canada, and Mexico.

Voting shall be accomplished only by those authorized representatives in attendance at the business meeting of the Workshop.

C. The Workshop will be scheduled biennially on even number years. The host state, province, or country shall select the time and place of the meeting. The host shall appoint one of its representatives who will act as chair. The duties of the chair shall be:

1. To serve as chair for the two-year period following his/her appointment.

2. To call for papers and prepare an agenda for the Workshop and assemble and distribute any recommendations or resolutions made or passed at the Workshop.

3. To prepare and distribute the proceedings of the Workshop for which he/she has been responsible.

4. To organize and conduct the meeting and business of the Workshop.

5. To appoint committees as necessary.

6. To maintain the goals and objectives of the Workshop.

7. To prepare and make a formal report to the Western Association of Fish and Wildlife Agencies.

D. The new host state, province, or country shall be selected and announced at the business meeting of the Workshop. It is the intent of the Workshop that host state, province, or country will be volunteered on a rotating basis among the actively participating member states, provinces, and countries.

E. The mailing list of the Workshop shall be:

1. The Western Association of Fish and Wildlife Agencies.

2. The Director and Game Chief of every member state, province, and country.

3. All biologists known to be conducting pronghorn research.

4. All Bureau of Land Management State Offices and Regional Service Centers in the western United States.

5. All Regional Forest Service Offices in the western United States.

6. All Fish and Wildlife Service Regional Offices in the western United States.

7. All Natural Resources Conservation Service Regional Offices in the western United States.

8. All Cooperative Wildlife Research Units in the western United States.

9. All persons attending the Workshop.

10. Any person or organization requesting a copy of the Proceedings.

F. The chair shall forward the mailing list and other pertinent material to the new Workshop chair upon completion of his/her responsibilities as chair of the current Workshop.

As amended on March 20, 2002, at Kearney, Nebraska.
20th Biennial Pronghorn Workshop
Jeffrey S. Abegglen, Chair

Awards Presented at the 20th Biennial Pronghorn Workshop
Kearney, Nebraska

James D. Yoakum, Western Wildlife, Verdi, Nevada, was presented the first ever Berrendo Award at the recently completed 20th Biennial Pronghorn Workshop. Jim was recognized for his nearly 50-year commitment to the understanding and management of pronghorn on western rangeland. He is widely recognized as the foremost authority on pronghorn habitat requirements and habitat condition.

Bill Rudd, Wyoming Game and Fish Department, was presented a special recognition award for his management of over 100,000 pronghorn in western Wyoming, including the large migratory Sublette herd. Bill has been an outspoken advocate of fence designs that allow passage of migratory herds.

Other special recognition awards went to:
Jorge Cancino, Centro de Investigaciones Biologicas del Noroestes, La Paz, Baja California Sur, Mexico, for his long-term ecological research and management of the endangered Peninsular pronghorn. Jorge also served as the chair for the 19th Biennial Pronghorn Workshop, held in March 2000.
Richard Ockenfels, Arizona Game and Fish Department, for his nearly 15 years of management-oriented research on Arizona's pronghorn, such as his statewide assessment of habitat and work on movement barriers and mortality causes. Richard was also the chair of the 18th Biennial Pronghorn Workshop, held in March 1998.
Karl Menzel, Nebraska Game and Parks Commission, was given an award for his 44-year career of managing pronghorn in Nebraska, with 40 years as the Big Game Program Manager. Karl was instrumental in the re-establishment of pronghorn in Nebraska's Sandhill Region.

2002 Workshop Attendees

Last Name	First Name	Title	Affiliation	City	State
Abegglen	Jeff	Wildlife Biologist	US Forest Service	Chadron	NE
Aoude	Anis	Wildlife Biologist	Desert Land & Livestock	Woodruff	UT
Becker	Tom	Regional Wildlife Manager	Utah Division of Wildlife Resources	Tooele	UT
Berger	Kim	Field Biologist	Wildlife Conservation Society	Victor	ID
Boccadori	Vanna	MS Candidate	Montana State University	Bozeman	MT
Bredehoft	Roger	Game Warden	Wyoming Game and Fish	Laramie	WY
Brewer	Clay	Pronghorn Antelope Program Coordinator	Texas Parks and Wildlife Dept.	Alpine	TX
Bright	Don	Forest Supervisor	US Forest Service	Chadron	NE
Brinkley	Kim	Animal Keeper	Los Angeles Zoo	Glendale	CA
Brown	David	Adjunct Prof. of Biology / AZ Antelope Foundation	Arizona State Univ. / AZ Antelope Foundation	Phoenix	AZ
Cancino	Jorge	Engineer	Centro de Investigaciones Biologicas del Noroeste	La Paz	Baja C.S. Mexico
Catanach	Michael	NE Area Wildlife Specialist	New Mexico Dept. of Game & Fish	Raton	NM
Compton	Brad	Regional Wildlife Manager	Idaho Department of Fish & Game	Idaho Falls	ID
Cornicelli	Lou	Regional Wildlife Manager	Utah Division of Wildlife Resources	Ogden	UT
Cox	Mike	Big Game Staff Biologist	Nevada Division of Wildlife	Reno	NV
Danvir	Rick	Wildlife Manager	Desert Land & Livestock	Woodruff	UT
Douglas	Jim	Wildlife Division Administrator	Nebraska Game and Parks Commission	Lincoln	NE
Dubay	Shelli	Research Biologist	Arizona Game and Fish Dept.	Phoenix	AZ
Emmerich	John	Wildlife Management Coordinator	Wyoming Game and Fish	Cody	WY
Fairbanks	Sue	Assistant Professor	University of Nebraska - Omaha	Omaha	NE
Feeney	Mark	Wildlife Biologist	Nebraska Game and Parks Commission	Loup City	NE
Figgs	Daylan	District Wildlife Manager	Nebraska Game and Parks Commission	Kearney	NE
Fox	Lloyd	Big Game Program Coordinator	Kansas Department of Wildlife & Parks	Emporia	KS
Griffin	Steve	Wildlife Biologist	South Dakota Game Fish and Parks	Rapid Ctiy	SD
Grue	Mike	Wildlife Technician	Alberta Conservation Association	Lethbridge	Alberta, Canada
Guenzel	Rich	Wildlife Biologist	Wyoming Game and Fish	Laramie	WY

Gustin	Mike	Habitat/Antelope Specialist	New Mexico Game and Fish	Albuquerque	NM
Hack	Mace	Assistant Division Administrator, Research	Nebraska Game and Parks Commission	Lincoln	NE
Hacker	Dave	Biologist	California Dept. of Transportation	San Luis Obispo	CA
Hamer	Russ	Wildlife Biologist I	Nebraska Game and Parks Commission	Norfolk	NE
Hefflefinger	Jim	Regional Game Specialist	Arizona Game and Fish Dept.	Tucson	AZ
Hitchcock	Robb	President	North American Pronghorn Foundation	Casper	WY
Jacques	Chris	Graduate Research Assistant	South Dakota State University	Brookings	SD
Jensen	Bill	Big Game Biologist	North Dakota Game and Fish Dept.	Bismarck	ND
Jones	Paul	Regional Wildlife Program Coordinator	Alberta Conservation Association	Lethbridge	Alberta, Canada
Koch	Alice	Fish & Wildlife Scientific Aid	California Dept. of Fish and Game	Templeton	CA
Krolikowski	Tom	Biologist II, Wildlife Division	Nebraska Game and Parks Commission	Valentine	NE
Landin	Pam		Harris Environmental Group, Inc	Ajo	AZ
Lemmon	Lon	Fish & Wildlife Biologist II	Nebraska Game and Parks Commission	Crawford	NE
Lindzey	Fred	Assistant Unit Leader	Wyoming Coop. Research Unit, University of Wyoming	Laramie	WY
Loecker	Cory	Conservation Tech II	Nebraska Game and Parks Commission	Alliance	NE
Loose	Steve	Wildlife Biologist	Wyoming Game and Fish	Saratoga	WY
Lucia	Duane	Natural Resource Specialist	Texas Parks and Wildlife Dept.	Lubbock	TX
Malone	Catherine	Wildlife Geneticist	Purdue University	West Lafayette	IN
Martin	Ryan	Wildlife Biologist II	Nebraska Game and Parks Commission	Cambridge	NE
Mathis	Pat	SW Area Game Manager	New Mexico Dept. of Game and Fish	Las Cruces	NM
Menzel	Karl	Big Game Program Manager	Nebraska Game and Parks Commission	Bassett	NE
Morrison	Bruce	Assistant Division Administrator	Nebraska Game and Parks Commission	Lincoln	NE
Muenchau	Barbara	Wildlife Biological Technician	Wind Cave National Park	Hot Springs	SD
Naderman	Justin	Regional Wildlife Manager	Idaho Department of Fish & Game	Idaho Falls	ID
Nelson	Ritch	District Manager/Habitat Partners Section	Nebraska Game and Parks Commission	Alliance	NE

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Ockenfels	Richard	Wildlife Program Supervisor	Arizona Game and Fish Dept.	Phoenix	AZ
Oehler	Mike	Wildlife Biologist	National Park Service	Midora	ND
O'Gara	Bart	Professor Emetitus	University of Montana	Lolo	MT
Palazzolo	Sal	District Wildlife Biologist II	Nebraska Game and Parks Commission	Lincoln	NE
Pojar	Tom	Wildlife Researcher	Colorado Division of Wildlife	Kremmling	CO
Reichle	Richard	Project Consultant / Senior Engineer	Advanced Telemetry Systems	Isanti	MN
Reichle	Elly	Graduate Student	Advanced Telemetry Systems	Cambridge	MN
Roddy	Dan	Resource Management Specialist	Wind Cave National Park	Hot Springs	SD
Rudd	Bill	Wildlife Management Coordinator	Wyoming Game and Fish	Green River	WY
Rutten	Ben	District II Supervisor, Wildlife Division	Nebraska Game and Parks Commission	Bassett	NE
Schlichtemeier	Gary	District I Wildlife Manager	Nebraska Game and Parks Commission	Alliance	NE
Schmitz	Lowell	Wildlife Biologist	South Dakota Game Fish and Parks	Rapid Ctiy	SD
Scott	Mike	Principal Wildlife Research Biologist	Idaho Department of Fish & Game	Nampa	ID
Seitz	Brad	Wildlife Biologist II	Nebraska Game and Parks Commission	Alexandria	NE
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Studnicka	Dean	Fish & Wildlife Biologist I	Nebraska Game and Parks Commission	Crawford	NE
Taylor	Chad	Wildlife Biologist I	Nebraska Game and Parks Commission	Cambridge	NE
Trindle	Bruce	District Wildlife Manager	Nebraska Game and Parks Commission	Norfolk	NE
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Walters	Rich	Wildlife Biologist	Nebraska Game and Parks Commission	Kearney	NE

Wasley	Tony	Game Biologist	Nevada Division of Wildlife	Elko	NV
Welstead	Tom	Wildlife Biologist	Nebraska Game and Parks Commission	Battle Creek	NE
Yoakum	Jim	Wildlife Biologist	Western Wildlife Consultants	Verdi	NV
Zimmer	Jason	Graduate Student	University of Wyoming	Laramie	WY
Zornes	Mark	Wildlife Biologist	Wyoming Game and Fish	Wheatland	WY