PROCEEDINGS OF THE

2019 WAFWA

13th BIENNIAL DEER & ELK WORKSHOP

Sanctioned by the Western Association of Fish and Wildlife Agencies

Hotel Saint George, Marfa, Texas

May 28 – 31, 2019

Hosted by

Life's better outside.®

Editors

Shawn S. Gray

Carlos Gonzalez-Gonzalez

Published by

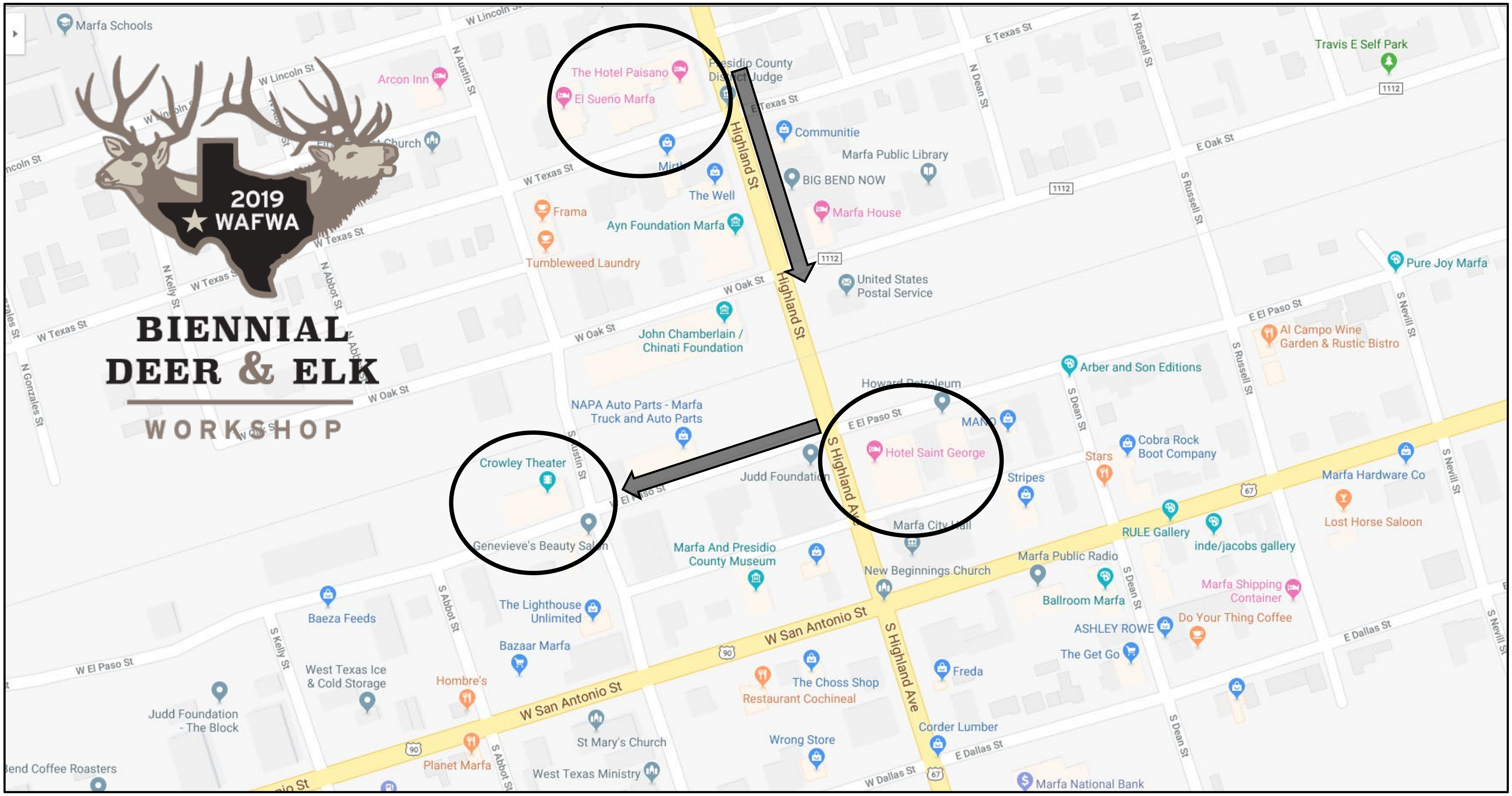
Texas Parks & Wildlife Department and Borderlands Research Institute

Suggested Citation

Gray, S. S. and Gonzalez-Gonzalez C, editors. 2019. Proceedings of the Thirteenth Biennial Deer and Elk Workshop. Texas Parks & Wildlife Department and Borderlands Research Institute, Alpine, Texas.

TABLE OF CONTENTS

2019 DEER AND ELK WORKSHOP MAP



SPONSORS

TEXAS PARKS & WILDLIFE
Life's better outside.®

NINE POINT MESA RANCH

MULE DEER FOUNDATION

DAN CRAINE

DSC

RMEF

LUBBOCK SPORTSMAN'S CLUB INC. DSC CHAPTER

WEST TEXAS CHAPTER SCI FIRST FOR HUNTERS®

Lotek

TEXAS WILDLIFE ASSOCIATION

TEXAS PARKS & WILDLIFE FOUNDATION

T. DAN FRIEDKIN

TEXAS TECH UNIVERSITY
Department *of* Natural Resources Management™

DUTCH CATTLE COMPANY

ARIZONA GAME & FISH

HOUSTON SAFARI ⋆ CLUB FOUNDATION™

CAESAR KLEBERG
WILDLIFE
RESEARCH INSTITUTE
TEXAS A&M UNIVERSITY-KINGSVILLE

NEW MEXICO GAME & FISH

SPONSORS

VECTRONIC Aerospace

FIRST LITE

SPEED GOAT

NDA NATIONAL DEER ALLIANCE

Texas Chapter The Wildlife Society www.tctws.org

Southwest Section of The Wildlife Society
Excellence in Wildlife Stewardship through Science and Education

East FOUNDATION

AppGeo

YETI®

VORTEX®

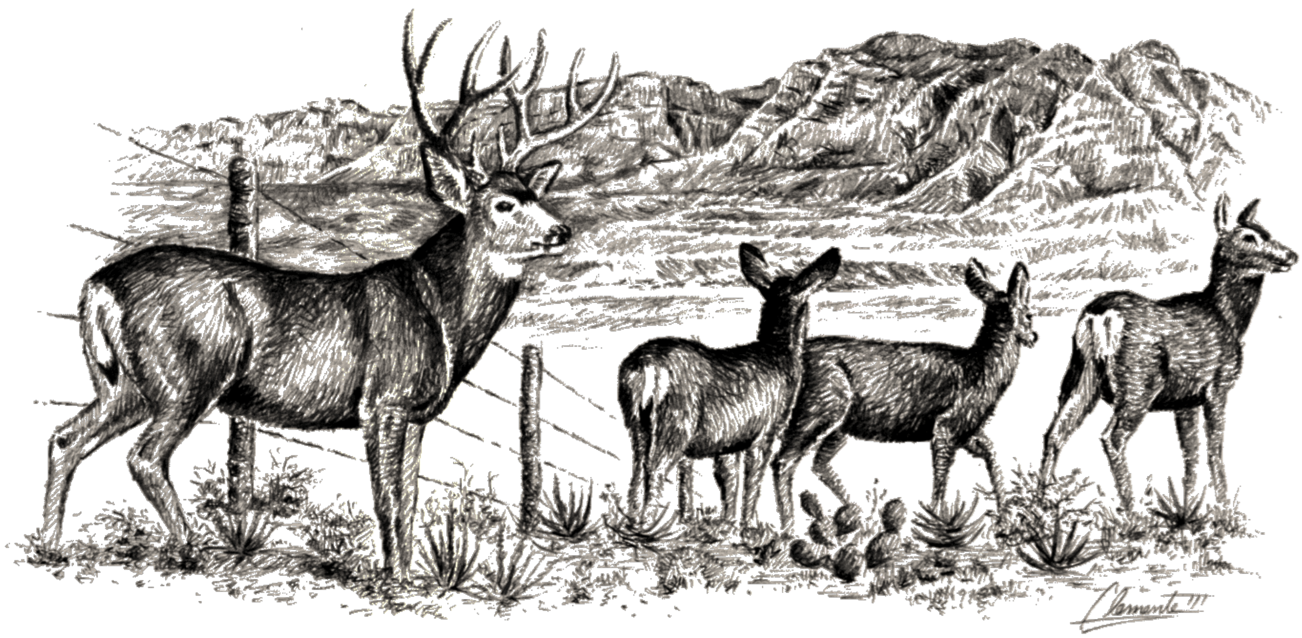
PLEASE THANK AND SUPPORT ALL OUR SPONSORS

PROGRAM AT A GLANCE

TIME	EVENT	INFO
	Tuesday, May 28	
1:00–5:00 PM	Mule Deer Working Group Meeting	Compana Room
6:00–10:00	On-site Registration, Social, and BBQ (Beer, Wine, and Refreshments Provided)	Hotel Saint George Pool Bar
9:00–9:45	Any Attendees Interested will be Bused to the Marfa Lights Viewing Station and Back to the Hotel (10 miles from Hotel)	
	Wednesday, May 29 – Saint George Hall and Crowley Theatre	
8:00–9:00 AM	On-Site Registration and Breakfast (Muffins, Granola, Yogurt, Fruit, Coffee, Water, Juice)	
9:00	Welcome	
9:15–10:30	Plenary Session – Deer Management on Private Land Discussion Panel	
10:30	Break (Refreshments)	
10:45	Status Report/Presentations	
12:00 PM	Lunch Provided (Fried Chicken)	
1:00–2:30	Elk Management on Private Land Discussion Panel	
2:30	Break (Refreshments and Snacks)	
2:45–4:15	Point Creep in the West Discussion Panel	
4:45	Leave Hotel in Buses for the H. E. Sproul Ranch in the Davis Mountains	

TIME	EVENT	INFO
5:30–8:00	Steak Dinner and Social at H. E. Sproul Ranch (Beer, Wine, and Refreshments Provided)	
8:30–10:00	Star Party at McDonald Observatory (For Those Who Signed Up to Go); Separate Buses Will Go to the Observatory or Back to Hotel After Dinner	
	Thursday, May 30 – Saint George Hall and Crowley Theatre	
8:00–9:00 AM	Breakfast (Muffins, Granola, Yogurt, Fruit, Coffee, Water, Juice)	
9:00–10:30	Presentations	
10:30	Break (Refreshments)	
11:00–12:00 PM	Presentations	
12:00	Lunch (Chicken/Beef Fajitas)	
1:00–2:30	Presentations	
2:30	Break (Refreshments and Snacks)	
3:00–4:30	CWD Research/Management Discussion Panel	
5:00–5:30	O. C. Wallmo and RMEF's Excellence in Elk Country – Wildlife Research Awards Presentation	
5:30	Leave Hotel in Buses for the Cibolo Creek Ranch in the Chinati Mountains	
6:30–9:00	Chile Relleno Dinner and Social (Beer, Wine, Refreshments Provided; Cocktail Bar is cash only)	
	Friday, May 31 – Saint George Hall and Crowley Theatre	
8:00–9:00 AM	Breakfast (Muffins, Granola, Yogurt, Fruit, Coffee, Water, Juice)	

TIME	EVENT	INFO
8:15–9:00	Business Meeting	Compana Room
9:00–12:00 PM	State and Provincial Elk Management Meeting	Compana Room
9:00–10:30	Presentations	
10:30–10:45	Adjournment	



AGENDA

Tuesday, May 28

TIME	EVENT	INFO
1:00-5:00 PM	Mule Deer Working Group Meeting	Compana Room
6:00-10:00	On-site Registration, Social, and BBQ (Beer, Wine, and Refreshments Provided)	Hotel Saint George Pool Bar
9:00-9:45	Any Attendees Interested will be Bused to the Marfa Lights Viewing Station and Back to the Hotel (10 miles from Hotel)	

Wednesday, May 29

TIME	PRESENTATIONS	PRESENTER
	SAINT GEORGE HALL	
8:00-9:00 AM	On-Site Registration and Breakfast (Muffins, Granola, Yogurt, Fruit, Coffee, Water, Juice)	
9:00	Welcome	Shawn Gray

9:15–10:30	Plenary Session – Deer Management on Private Land Discussion Panel (Moderator – Clayton Wolf)	Carter Smith, David Yeates, Bobby McKnight, Louis Harveson, and Michael Wardle
10:30	Break (Refreshments)	
10:45	State and Provincial Status Report	Michael Janis

SAINT GEORGE HALL – SESSION 1 – POLICY

Moderator – Dana Wright

11:15	The Mule Deer Foundation's Banner Year for Mule Deer Conservation: Updates from 2018 and Preview of 2019	Steve Belinda
11:35	Western Wildlife Agency Collaboration to Identify and Conserve Migration Corridors	James Heffelfinger
12:00 PM	Lunch Provided (Fried Chicken)	
1:00–2:30	Elk Management on Private Land Discussion Panel (Moderator – James Pitman)	Cody McKee, Andy Holland, Gabe Jenkins, Michael Wardle, and Brock Hoenes

2:30	Break (Refreshments and Snacks)	
2:45–4:15	Point Creep in the West Discussion Panel (Moderator – Justin Shannon)	Derrick Ewell, Andy Holland, Cody Schroeder, Trail Kreitzer
4:45	Leave Hotel in Buses for the H. E. Sproul Ranch in the Davis Mountains	
5:30–8:00	Steak Dinner and Social at H. E. Sproul Ranch (Beer, Wine, and Refreshments Provided)	
8:30–10:00	Star Party at McDonald Observatory (For Those Who Signed Up to Go); Separate Buses Will Go to the Observatory or Back to Hotel After Dinner	

Thursday, May 30

TIME	PRESENTATIONS	PRESENTER
8:00–9:00 AM	Breakfast (Muffins, Granola, Yogurt, Fruit, Coffee, Water, Juice)	

SAINT GEORGE HALL – SESSION 2 – POPULATION TECHNIQUES

Moderator – James Hoskins

TIME	PRESENTATIONS	PRESENTER
9:00	More Bang for Your Buck: Optimal Use of Monitoring Resources	Charles Henderson
9:20	Interpreting Survival Analyses for Ungulates in Context: Sample Size, Process Variance, and Model Selection	Paul Lukacs
9:40	Weaponized Research: Towards Shareable and Adaptable Solutions to Common Problems	Joshua Nowak
10:00	Using Remotely-Sensed Cameras to Classify Migrating Mule Deer Populations	Eric Freeman

CROWLEY THEATER – SESSION 2 – RESTORATION AND TRANSLOCATION

Moderator – Jeff Bonner

9:00	Release-Site Fidelity, Home Range, and Resource Selection Patterns of a Reintroduced Elk Herd: Jackson County, Wisconsin	Travis Bryan
9:20	Restoring Elk to Northeast Minnesota: Landowner and General Public Attitudes	David Fulton

TIME	PRESENTATIONS	PRESENTER
9:40	Survival and Site Fidelity Evaluation of Translocated Desert Mule Deer in the Chihuahuan Desert, Mexico	Carlos Gonzalez-Gonzalez
10:00	Waffling Over Wapiti: Virginia's Controversial and Continued Effort to Restore Elk for Over a Century	David Kalb
10:30	Break (Refreshments)	

SAINT GEORGE HALL – SESSION 3 – MONITORING TECHNIQUES

Moderator – Sam Harryman

11:00	A Non-invasive Automated Device for Remotely Collaring and Weighing Mule Deer	Chad Bishop
11:20	Linking Plant Phenology and Nutrition to Mule Deer Vital Rates	Mark Hurley
11:40	Nutritional-Landscape Models to Predict Pregnancy Rates of Elk at Broad Spatial Scales	Sierra Robatcek

CROWLEY THEATRE – SESSION 3 – GENETICS AND DISEASE

Moderator – Calvin Richardson

TIME	PRESENTATIONS	PRESENTER
11:00	Landscape-Genetic Analysis of Texas Mule Deer: Implications for the Management of Chronic Wasting Disease	Randy DeYoung
11:20	Estimating Prevalence and Potential Population Impacts of Treponeme-Associated Hoof Disease of Elk in Washington	Kyle Garrison
11:40	Evidence of Ancient and Contemporary Hybridization in Deer in the United States	Emily Wright
12:00 PM	**Lunch Provided (Chicken/Beef Fajitas)**	

SAINT GEORGE HALL – SESSION 4 – MONITORING TECHNIQUES AND PREDATOR MANAGEMENT

Moderator – Froylan Hernandez

1:00	Distance Surveys for Axis Deer and White-tailed Deer on the Edwards Plateau of Central Texas	Matthew Buchholz
1:20	An Improved Understanding of Ungulate Population Dynamics Using Count Data	Terrill Paterson

TIME	PRESENTATIONS	PRESENTER
1:40	Spatiotemporal Covariates, Individual Characteristics, and Mountain Lion Harvest as Potential Sources of Variation in Elk Calf Survival	Michael Forzley
2:00	Integrated Carnivore-Ungulate Management: A Case Study in West-Central Montana	Kelly Proffitt

CROWLEY THEATRE – SESSION 4 – ELK MANAGEMENT

Moderator – James Weaver

1:00	Managing Elk on Private Land in Kentucky, a Real Pain in the Access	Gabriel Jenkins
1:20	Integrating Forage Estimates and Public Opinion into Elk Habitat Suitability Index Maps	Nicholas McCann
1:40	Elk Management in Saskatchewan	Tom Perry
2:00	Elk Management in Utah: Balancing Quality and Opportunity	Justin Shannon
2:30	Break (Refreshments and Snacks)	
3:00–4:30	CWD Research/Management Discussion Panel	

TIME	PRESENTATIONS	PRESENTER
	(Moderator – Nick Pinizzotto)	Matt Dunfee, Jason Sumners, Andy Holland, James Kelly
5:00–5:30	O. C. Wallmo and RMEF's Excellence in Elk Country – Wildlife Research Awards Presentation	Andy Lindbloom and Tom Toman
5:30	Leave Hotel in Buses for the Cibolo Creek Ranch in the Chinati Mountains	
6:30–9:00	Chile Relleno Dinner and Social (Beer, Wine, Refreshments Provided; Cocktail Bar is cash only)	

Friday, May 31

TIME	PRESENTATIONS	PRESENTER
8:00–9:00 AM	Breakfast (Muffins, Granola, Yogurt, Fruit, Coffee, Water, Juice)	
	COMPANA ROOM	
8:15–9:00	Business Meeting	
9:00–12:00 PM	State and Provincial Elk Management Meeting	

TIME	PRESENTATIONS	PRESENTER

SAINT GEORGE HALL – SESSION 5 – MULE DEER HABITAT USE

Moderator – Austin Stolte

9:00	Are Center Pivots Pivotal to Landscape Use? Mule Deer Movement Patterns and Habitat Use in an Agricultural Landscape	Levi Heffelfinger
9:20	Mule Deer Diets and Nutrition in an Agriculturally Abundant Region of the Texas Panhandle	Jacob Lampman
9:40	From Fallow to Fat: Effects of Agriculture on Mule Deer Morphology in a Fragmented Landscape	Levi Heffelfinger
10:00	The Influence of Wildfire and Juniper Phase on Winter Habitat Selection Patterns of Mule Deer	Elizabeth Schuyler

CROWLEY THEATER – SESSION 5 – HUNTER AVOIDANCE AND HABITAT MANAGEMENT

Moderator – Jose Etchart

9:00	Risk and Reward: Personality and Age of Adult Male White-tailed Deer Dictate Exposure to Hunters During the Breeding Season	Ashley Jones

TIME	PRESENTATIONS	PRESENTER
9:20	Habitat Use and Harvest Vulnerability of Elk (Cervus Canadensis): Do Elk Learn to Avoid Hunters as They Age?	Makism Sergeyev
9:40	Ungulate Forage Biomass and Quality During 6 Years of Landscape Restoration	Sharon Smythe
10:30–10:45	Adjournment	

DISCUSSION PANELS

PLENARY SESSION – DEER MANAGEMENT ON PRIVATE LAND

PANELISTS	AFFILIATION
Clayton Wolf – Wildlife Division Director Moderator	Texas Parks and Wildlife Department
Carter Smith – Executive Director	Texas Parks and Wildlife Department
David Yeates – Executive Director	Texas Wildlife Association

Bobby McKnight – Landowner and President	Texas and Southwestern Cattle Raisers Association
Michael Wardle – Private Lands/Public Wildlife Coordinator	Utah Division of Wildlife Resources
Louis Harveson – Executive Director	Borderlands Research Institute at Sul Ross State University

ELK MANAGEMENT ON PRIVATE LAND

PANELISTS	AFFILIATION
James Pitman – Elk Program Manager **Moderator**	New Mexico Game and Fish Department
Cody McKee – Big Game Staff Biologist	Nevada Department of Wildlife
Andy Holland – Big Game Manager	Colorado Parks and Wildlife
Gabe Jenkins – Deer and Elk Program Coordinator	Kentucky Department of Fish and Wildlife
Michael Wardle – Private Lands/Public Wildlife Coordinator	Utah Division of Wildlife Resources

Brock Hoenes – Deer and Elk Section Manager	Washington Department of Fish and Wildlife

POINT CREEP IN THE WEST

PANELISTS	AFFILIATION
Justin Shannon – Wildlife Division Director **Moderator**	Utah Division of Wildlife Resources
Derrick Ewell – District Wildlife Biologist	Utah Division of Wildlife Resources
Andy Holland – Big Game Manager	Colorado Parks and Wildlife
Cody Schroeder – Mule Deer Biologist	Nevada Department of Wildlife
Trail Kreitzer – Research Manager	goHUNT

CWD RESEARCH AND MANAGEMENT

PANELISTS	AFFILIATION
Nick Pinizzotto – President/CEO **Moderator**	National Deer Alliance
Matt Dunfee – Director of Special Programs	Wildlife Management Institute
Jason Sumners – Resource Science Division Chief	Missouri Department of Conservation
Andy Holland – Big Game Manager	Colorado Parks and Wildlife
James Kelly – Deer Program Coordinator	Tennessee Wildlife Resources Agency

ORAL PRESENTATION ABSTRACTS

(In Order of Presentation)

THE MULE DEER FOUNDATIONS' BANNER YEAR FOR MULE DEER CONSERVATION: UPDATES FROM 2018 AND PREVIEW OF 2019

STEVE BELINDA, *Beartooth Strategies, LLC, 11 Beavertail Rd, Red Lodge, MT, 59068, USA*

MILES MORETTI, *Mule Deer Foundation, 1939 S 4130 W, Salt Lake City, UT, 84104, USA*

The Mule Deer Foundation (MDF) creates numerous partnership opportunities for state and federal agencies and landowners to improve mule deer conservation. The MDF provides assistance to these groups by identifying priority needs for mule deer, raising funds for mule deer projects, promoting public policy that advances mule deer conservation, stewardship contracting, and cultivating the grassroots network of MDF members. Nationally, MDF has over 150 local chapters in over 20 states including every state that mule deer and black-tail deer inhabit. In 2018, over $3.5 million dollars were used for on-the-ground projects to benefit deer and other wildlife. In addition, MDF worked to ensure mule deer were included in key pieces of legislation such as the 2018 Farm Bill as well as other federal appropriation bills. The MDF will be formally launching a "Migration Initiative" to coordinate implementation of the Department of Interior Secretarial Order 3362 with state and federal agencies and other conservation partners in 2019. Also, during 2019 MDF will be expanding its Stewardship Program to get millions of dollars to fund Forest Service and Bureau of Land Management projects. These efforts by MDF are an additive benefit for mule deer conservation by amplifying state and federal agencies' efforts and bolstering partnerships with many other organizations.

Presenter and email: Steve Belinda; sbelinda@beartoothstrategies.com

WESTERN WILDLIFE AGENCY COLLABORATION TO IDENTIFY AND CONSERVE MIGRATION CORRIDORS

JAMES R. HEFFELFINGER, *Arizona Game and Fish Department, 5000 W. Carefree Highway, Phoenix, Arizona, 85086, USA*

MULE DEER WORKING GROUP

The Western Association of Fish and Wildlife Agencies' Mule Deer Working Group, in collaboration with Wyoming Migration Initiative, Pew Charitable Trusts, Mule Deer Foundation, Bureau of Land Management, U.S. Forest Service, U.S. Geological Survey, U.S. Fish and Wildlife Service and the Crucial Habitat Assessment Tool conducted workshops throughout the West to provide guidance, resources, analysis tools and examples to states in an effort to better identify and document movement and migration corridors. Four workshops were attended by 262 attendees (110 of whom completed the migration mapper training) from 13 states. In addition to the workshops, state agencies developed State Action Plans to prioritize corridors and create

focus, allow partnership development, and ultimately serve as the tool to accomplish conservation. Secretarial Order 3362 (SO3362) directed Department of Interior (DOI) Bureaus to work closely with states to identify and conserve corridors and winter range. Funds were made available to the states so that each state listed in the SO3362 received an average of $300,000 to implement their highest priority research needs. Through the implementation of this Order, DOI has provided almost $3 million to the states in this process. The Wyoming Cooperative Fish and Wildlife Research Unit and Wyoming Migration Initiative is coordinating a Corridor Mapping Team that will be made up of state agency staff or positions that will work directly with state agencies to help identify and analyze migration and winter habitats.

Presenter and email: James Heffelfinger; jheffelfinger@azgfd.gov

SESSION 2

MORE BANG FOR YOUR BUCK: OPTIMAL USE OF MONITORING RESOURCES

CHARLES R. HENDERSON JR., *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA*

PAUL M. LUKACS, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA*

MARK A. HURLEY, *Idaho Department of Fish and Game, Boise, ID, 83707, USA*

Resources for monitoring wildlife populations are limited and their availability changes over time. The data collected using these resources is critical for making good conservation and management decisions. Determining the optimal way to allocate monitoring resources for data collection based on the amount of information the data provides for conservation and management is a responsible and efficient use of public resources. We developed a method for determining the most optimal scenarios for data collection which simultaneously minimizes cost and maximizes the precision of the abundance estimate. To accomplish this, we developed a new metric which describes the relationship between data collection cost and estimate precision in a single value, the information gain ratio. We used data collected by the Idaho Department of Fish and Game on the statewide mule deer (*Odocoileus hemionus*) population of Idaho to develop our method for determining the optimal allocation of monitoring resources. Using the information gain ratio, we characterize the relationship between cost and precision relative to the specific attributes of each mule deer population management unit. Our method allows us to generate a set of data collection scenarios that are adapted to the specific characteristics of each population management unit, change with the availability of monitoring resources, and are easily comparable via the predicted values of the information gain ratio. The collection scenarios detail the type and amount of each data type to collect for the optimal use of monitoring resources. Our optimization method is adaptable across species, scales, data types, and population models.

Presenter and email: Charles Henderson; charles1.henderson@umconnect.umt.edu

INTERPRETING SURVIVAL ANALYSES FOR UNGULATES IN CONTEXT: SAMPLE SIZE, PROCESS VARIANCE, AND MODEL SELECTION

PAUL M. LUKACS, *Wildlife Biology Program, Department of Ecosystem and Conservation Sciences, W. A. Franke College of Forestry and Conservation, University of Montana*, *Missoula, MT, 59812, USA*

J. JOSHUA NOWAK, *Wildlife Biology Program, University of Montana*, *Missoula, MT, 59812, USA* and *Speedgoat Wildlife Solutions, LLC, 408 Parkside Ln., Missoula, MT, 59802, USA.*

MARK A. HURLEY, *Idaho Department of Fish and Game, 600 South Walnut Street, Boise, ID, 83712, USA*

ANDREW J. LINDBLOOM, *South Dakota Game, Fish and Parks, 20641 SD Highway 1806, Ft. Pierre, SD, 57532, USA*

Understanding variation in survival probabilities of deer and elk represents an important component of interpreting population dynamics. Adult female survival is known to be the most sensitive demographic parameter for deer and elk population growth. Moreover, juvenile survival is often the parameter that drives population growth due to its high annual variation. Several decades of telemetry-based survival analyses provide a wealth of information about the magnitude of variation in survival. We use this information to understand how variation in survival shapes our inference about population dynamics. We provide an example of the process distribution of adult female survival from Idaho and South Dakota along with published estimates of survival to demonstrate that the shape of the distribution is consistent across space and time. We then demonstrate that the sampling distribution of estimated survival from sample sizes <100 radio collars is wider than the process distribution of adult female survival. We show how model selection results from studies focusing on a few study sites or a few years can incorrectly highlight sampling variation as spatial or temporal differences in survival. Finally, we provide guidance on sample sizes for studies aimed at short- and long-term understanding of population processes.

Presenter and email: Paul Lukacs; paul.lukacs@umontana.edu

WEAPONIZED RESEARCH: TOWARDS SHAREABLE AND ADAPTABLE SOLUTIONS TO COMMON PROBLEMS

J. JOSHUA NOWAK, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA and Speedgoat Wildlife Solutions, LLC, 408 Parkside Ln., Missoula, MT, 59802, USA.*

ANNA MOELLER, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA.*

JONATHAN WEISSMAN, *California Department of Fish and Wildlife, Bishop, CA, 93514, USA.*

T.J. CLARK, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA.*

FORREST HAYES, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA.*

KENNETH LOONAM, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA.*

HANS MARTIN, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA.*

Wildlife agencies share many problems across jurisdictions and species, yet shared solutions appear less often. Inherent complexities in university and government structures contribute to the lack of sharing. Moreover, academic projects typically culminate in publications that lack the longevity of the problems they intend to solve. The open source community of software development offers a viable alternative to problem solving that promises to meet our collective needs over the long term. We recently embarked on several projects, which produced freely available solutions that are adaptable. In addition, we built the tools with input from multiple potential end-users and sought to be general in our approach to a solution. Open source solutions permit use without licensing fees or permissions. Anyone with an internet connection can download these tools and modify them to suit their needs. We will discuss three case studies that demonstrate solutions to satisfy the needs of multiple stakeholders. First, we created software that automates the process of downloading and standardizing collar data. Second, we highlight a package that implements methods to estimate abundance from camera traps. Third, we offer a way to download remotely sensed data and builds predictive covariates for mule deer survival. Generalizing research projects and sharing the fruits of those labors with the world is a value-added approach to contributing to the wildlife community that ensures solutions can be repeated, reused and tested in novel situations.

Presenter and email: Joshua Nowak; josh.nowak@speedgoat.io

USING REMOTELY-SENSED CAMERAS TO CLASSIFY MIGRATING MULE DEER POPULATIONS

ERIC FREEMAN, *Idaho Department of Fish and Game, 1345 Barton Rd., Pocatello, ID, 83204*

ZACH LOCKYER, *Idaho Department of Fish and Game, 1345 Barton Rd., Pocatello, ID, 83204*

Wildlife management agencies closely monitor mule deer populations to enable informed decision making (e.g., harvest management, habitat improvement, etc.). Common metrics of population performance include age and sex ratios, adult and fawn survival, and population size. Unfortunately, these data can be difficult or expensive to collect. We utilized remotely sensed cameras to monitor a migrating mule deer population and attempted to compile age and sex ratio data from the images. We compared these ratios to data collected from aerial herd composition surveys to evaluate the effectiveness and efficiency of this method for collecting age and sex ratio data for mule deer. We also utilized these data to improve

understanding of migration timing and develop recommendations for collecting and utilizing this type of data.

Presenter and email: Eric Freeman; eric.freeman@idfg.idaho.gov

RELEASE-SITE FIDELITY, HOME RANGE, AND RESOURCE SELECTION PATTERNS OF A REINTRODUCED ELK HERD: JACKSON COUNTY, WISCONSIN

TRAVIS S. BRYAN, *College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point, Daniel O. Trainer Natural Resources Building, WI, 54481, USA*

TIMOTHY F. GINNETT, *College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point, Daniel O. Trainer Natural Resources Building, WI, 54481, USA*

SCOTT E. HYGNSTROM, *College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point, Daniel O. Trainer Natural Resources Building, WI, 54481, USA*

JASON D. RIDDLE, *College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point, Daniel O. Trainer Natural Resources Building, WI, 54481, USA*

DANIEL J. STORM, *Department of Natural Resources, WIDNR Service Center, Rhinelander, WI, 54501, USA*

Elk (*Cervus canadensis*) once ranged throughout most of Wisconsin, but unregulated hunting and habitat loss led to their extirpation by the 1890s. The reintroduction of elk has become an important and popular practice to restore elk populations within their historic eastern ranges. We studied the post-release movements and resource selection of elk reintroduced to Wisconsin from 2015–2017. Elk were captured near Stoney Fork, Kentucky and released in Jackson County, Wisconsin. Adult elk were fit with VHF/GPS collars for mortality monitoring and to collect spatial data. Our objectives were to identify release site fidelity, home range, and resource selection patterns for one-year post-release. To evaluate release site fidelity, maximum distance from the release site was calculated for each elk over five time periods (1–30, 31–60, 61–90, 91–180, and 181–365 days post-release). Home range sizes were estimated over the same five time periods using the time scaled local convex hull (t-locoh) method. Fifteen candidate models were developed with the covariates of time post-release, sex, age, and release year. Data were analyzed using repeated measures mixed-effects models. Resource selection function (RSF) models were used to evaluate elk resource selection, and we implemented a use-availability design to evaluate post-release response over four time periods (0–90, 91–180, 181–270, and 271–365 days post-release). RSF model covariates included 12 habitat classes, manipulated habitat, road density, distance to nearest road, distance to wolf pack centers, slope and aspect. Most elk made exploratory movements during the first 90 days post-release, but overall, release site fidelity was high and home range sizes were relatively small. Throughout the remainder of the study, release-site fidelity decreased, and home range sizes increased. Elk selected for a suite of habitat types, but they consistently avoided cranberry bogs, wetlands, and open water. Use of topographic characteristics shifted throughout the study duration. Slope and aspect had little influence on elk movements during the first 90 days

post-release. Use of slope and aspect increased 91–365 days post-release as elk selected for aspects that provided thermoregulatory advantages as seasons changed. Avoidance of wolf activity centers was minimal, but to reduce predation risk, elk often selected areas closely associated with humans which wolves tend to avoid. For elk reintroductions to be successful, release site fidelity is critical for maintaining initial herd growth and continued reproductive success. Choosing the proper release site is paramount to a successful reintroduction. Release sites should be located where there is a heterogeneous vegetation composition with large amounts of edge habitat, and in locations that minimize the potential for elk-human conflict.

Presenter and email: Travis Bryan; Travis.Bryan@tpwd.texas.gov

RESTORING ELK TO NORTHEAST MINNESOTA: LANDOWNER AND GENERAL PUBLIC ATTITUDES

DAVID C. FULTON, *U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit, University of Minnesota, 1980 Folwell Ave., 200 Hodson Hall, St. Paul, MN, 55108, USA*

ERIC M. WALBERG, *Minnesota Cooperative Fish and Wildlife Research Unit, University of Minnesota, 1980 Folwell Ave., 200 Hodson Hall, St. Paul, MN, 55108, USA*

MICHAEL W. SCHRAGE, *Fond du Lac Resource Management Division, 1720 Big Lake Rd., Cloquet, MN, 55720, USA*

JAMES D. FORESTER, *Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota, 2003 Upper Buford Cir., Suite 135, St. Paul, MN, 55108, USA*

NICHOLAS MCCANN, *Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota, St. Paul, MN, 55108, USA*

Elk (*Cervus elaphus*) historically occupied most of Minnesota but were functionally extirpated in the early 1900's due to over harvest and habitat loss. Restoring an iconic wildlife species such as elk to northeast Minnesota can provide socio-economic and ecological benefits, though may also lead to negative impacts such as human-wildlife conflict. Successful restoration of elk to northeast Minnesota requires suitable habitat to support an elk population and public support for having elk on the landscape. Three potential restoration areas were selected due to abundant public land, while minimizing potential conflict from other land uses (e.g., agriculture). In 2018, we mailed survey questionnaires to 4,500 private landowners and 4,000 local residents in northeast Minnesota to understand public attitudes toward restoring elk to northeast Minnesota. We received 2,550 surveys from landowners (59.6% response rate) and 1,574 surveys from the local residents (45.8% response rate). Over three-quarters of landowners and local residents were supportive of restoring elk to the study area in northeast Minnesota (79% and 77%, respectively). A majority of landowners and local residents believed that restoring elk within the study area would potentially provide moderate to extreme benefits (67% and 65%, respectively). A majority of landowners and local residents also indicated that they would likely make a trip to view, photograph or hear elk if restored to the study area (61% and 62%, respectively). Overall, respondents indicated that there was public support for

restoring elk to northeast Minnesota. The results of this study can be used by wildlife managers in Minnesota to guide decision-making related to restoring elk to northeastern Minnesota.

Presenter and email: David Fulton; dcfulton@umn.edu

SURVIVAL AND SITE FIDELITY EVALUATION OF TRANSLOCATED DESERT MULE DEER IN THE CHIHUAHUAN DESERT, MEXICO

CARLOS E. GONZALEZ, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX, 79832, USA*

ALFONOSO ORTEGA-SANCHEZ, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX, 79832, USA*

JOSE DE LA LUZ MARTINEZ, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX, 79832, USA*

LOUIS A. HARVESON, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX, 79832, USA*

ROEL R. LOPEZ, *Texas A&M Natural Resources Institute, 2258 TAMU, College Station, TX, 77843-2258, USA*

Historic distribution of desert mule deer (*Odocoileus hemionus*) included most of the Chihuahuan Deseret in Mexico and the United States. Economically, mule deer are one of the most important wild animals in southwestern North America. However, populations and their distribution ranges have been on a decline for the past 150 years. A combination of factors such as drought, habitat degradation, and predation have been attributed to their decline. As an effort to reintroduce desert mule deer across the Chihuahuan Desert, translocations have taken place in both Mexico and the United States. Our objective is to report mule deer doe survival and site fidelity following soft-release and hard-release methods. To compare 2 post-release methods, 55 mule deer were translocated to Mexico in 2007 with 40 of those individuals having VHF radio-transmitters. In 2008, 73 mule deer were translocated from which 36 had VHF radio-transmitters allocated. We used the Kaplan-Meier survival estimate to calculate survival rate for both hard and soft-released deer. Site fidelity was expressed as the average linear distance between the release site and individual deer locations. Deer were considered "loyal" if the majority (>50%) of locations were within a 5-km radius from the liberation site. Annual survival rate increased in soft-released ($S = 0.84$), compared to hard-released 2007 ($S = 0.57$) and those that were hard-released 2008 ($S = 0.13$). Cause specific mortalities were 35 by mountain lions (*Puma concolor*). Ten deaths were capture-related mortalities, 1 died in a coyote trap, and 4 unknown causes. Mule deer being hard- released showed a home range with an average area of 3,565.8 ha ± 882 ha. Soft-released mule deer displayed a home range with an average area of 2,908.5 ha ± 1,124 ha. Even though the average home range for mule deer decreased by 657 ha when soft-released, no significant difference ($P = 0.245$) in home range sizes was found when comparing soft release vs. hard release.

Presenter and email: Carlos Gonzalez-Gonzalez; carlos.gonzalez-gonzalez@sulross.edu

WAFFLING OVER WAPITI: VIRGINIA'S CONTROVERSIAL AND CONTINUED EFFORT TO RESTORE ELK FOR OVER A CENTURY

DAVID M. KALB, *Virginia Elk Project Leader, 1796 Highway 16, Marion, VA 24354 USA*

Virginia has a storied history with elk, including loss of the species after European colonization and the species' disappearance once again by 1970 following unsuccessful restoration efforts during previous decades. Virginian citizens were part of the initial restoration effort, and elk have always been a high-profile topic. By the late 1990s, immigrant elk from Kentucky's restoration once again brought elk to Southwest Virginia (SWVA). Assessment of social and biological feasibility regarding a second restoration attempt left the Department of Game and Inland Fisheries (DGIF) with a reserved opinion regarding elk. Restoration was delayed 10 years, then quickly planned and moved forward (2012-14) with little stakeholder evaluation. Cooperation with private land holders resulted in a 3-year, 75 animal restoration by DGIF that has been highly controversial. Reactions from constituents resulted in legislative changes and official county statements in opposition.

This restoration has been supported by the local community after a decline in coal mining created a social and fiscal gap that had been filled successfully, in similar situations, in other states with elk related tourism. Tourism and visitation to the elk areas have been increasing and brought some economic support. Virginia currently manages elk in a three-county elk management zone (EMZ) neighboring several prominent cattle dominated counties. Support for elk is relatively high (85% support in SWVA); however, a vocal minority strongly opposed the restoration citing disease and conflict concerns. Several proposed and retracted changes in the size of the EMZ eroded trust between the DGIF and the public. DGIF has recently completed a three-year process to find balance with an Elk Management Plan involving 17 different stakeholder groups that will focus on public access and rebuilding trust.

Presenter and email: David M. Kalb; david.kalb@dgif.virginia.gov

SESSION 3

A NON-INVASIVE AUTOMATED DEVICE FOR REMOTELY COLLARING AND WEIGHING MULE DEER

CHAD J. BISHOP, *Colorado Parks and Wildlife, 317 W Prospect Road, Fort Collins, CO, 80526, USA*

MATHEW W. ALLDREDGE, *Colorado Parks and Wildlife, 317 W Prospect Road, Fort Collins, CO, 80526, USA*

DANIEL P. WALSH, *Colorado Parks and Wildlife, 317 W Prospect Road, Fort Collins, CO, 80526, USA*

ERIC J. BERGMAN, *Colorado Parks and Wildlife, 317 W Prospect Road, Fort Collins, CO, 80526, USA*

CHARLES R. ANDERSON, JR., *Colorado Parks and Wildlife, 317 W Prospect Road, Fort Collins, CO, 80526, USA*

DARLENE KILPATRICK, *Colorado Parks and Wildlife, 317 W Prospect Road, Fort Collins, CO, 80526, USA*

JOE BAKEL, *Dynamic Group Circuit Design, Inc., 2629 Redwing Rd, Suite 360, Fort Collins, CO 80525, USA*

CHRISTOPHE FEBVRE, *Dynamic Group Circuit Design, Inc., 2629 Redwing Rd, Suite 360, Fort Collins, CO 80525, USA*

Wildlife biologists capture deer (*Odocoileus* spp.) annually to attach transmitters and collect basic information (e.g., animal mass and sex) as part of ongoing research and monitoring activities. Traditional capture techniques induce stress in animals and can be expensive, inefficient, and dangerous. They are also impractical for some urbanized settings. We designed and evaluated a device for mule deer (*O. hemionus*) that automatically attached an expandable radio-collar to a ≥6-month-old fawn and recorded the fawn's mass and sex, without physically restraining the animal. The device did not require on-site human presence to operate. Students and faculty in the Mechanical Engineering Department at Colorado State University produced a conceptual model and early prototype. Professional engineers at Dynamic Group Circuit Design, Inc. in Fort Collins, CO, USA produced a fully-functional prototype of the device. Using the device, we remotely collared, weighed, and identified sex of 8 free-ranging mule deer fawns during winters 2010–11 and 2011–12. Collars were modified to shed from deer 1–2 months after the collaring event. Two fawns were successfully re-collared after they shed the first collars they received. Thus, we observed 10 successful collaring events involving 8 unique fawns. Fawns demonstrated minimal response to collaring events, either remaining in the device or calmly exiting. A fawn typically required one or more weeks of daily exposure before fully entering the device and extending its head through the outstretched collar, which was necessary for a collaring event to occur. This slow acclimation period limited utility of the device when compared to traditional capture techniques. Future work should focus on device modifications and altered baiting strategies that decrease fawn acclimation period, and in turn, increase collaring rates, providing a non-invasive and perhaps cost-effective alternative for monitoring mid to large-sized mammal species.

Presenter and email: Chad Bishop; chad.bishop@mso.umt.edu

LINKING PLANT PHENOLOGY AND NUTRITION TO MULE DEER VITAL RATES

MARK HURLEY, *Idaho Department of Fish and Game, 600 S. Walnut Street, Boise, ID, 83707, USA*

JOSEPH ST. PETER, *College of Forestry and Conservation, University of Montana, Missoula, MT, 59812, USA*

MARK HEBBLEWHITE, *Wildlife Biology Program, University of Montana, Missoula, MT, 59812, USA*

SCOTT BERGEN, *Idaho Department of Fish and Game, 600 S. Walnut Street, Boise, ID, 83707, USA*

ERIN ROCHE, *Idaho Department of Fish and Game, 600 S. Walnut Street, Boise, ID, 83707, USA*

SARAH THOMPSON, *Idaho Department of Fish and Game, 600 S. Walnut Street, Boise, ID, 83707, USA*

BRENDEN OATES, *Idaho Department of Fish and Game, 600 S. Walnut Street, Boise, ID, 83707, USA*

Understanding the effect of nutritional quality of the landscape to mule deer vital rates is often compromised by the annual variation in plant phenology, especially in dry seasonal habitats. The base nutritional quality of a habitat with an identified plant composition can be vastly different depending on the phenological change in nutritional quality of individual plants. Although, many research projects use NDVI from MODIS as a surrogate for nutrition, the true nutritional quality related to plant structure is largely unknown. We used digital cameras to provide a consistent view of vegetation phenology at fine spatial and temporal scales and linked phenology data from these cameras to satellite greenness indices derived from 16-day MODIS NDVI. To estimate phenological variation in nutrition, we documented the growth cycle of plants within each MODIS window using plant composition transects and nutritional analyses of plants at varying phenological stages. We initiated 47 phenology plots within mule deer summer range in homogeneous vegetation types large enough to contain a single MODIS pixel, each were measured between 3 and 5 times per summer to facilitate linking vegetation phenology, NDVI from cameras, and NDVI from MODIS for that area. We mapped detailed forage species within GPS or VHF collared adult female fawn rearing ranges using a machine learning software (eCognition) to segment each NAIP image into polygons based on spectral values of red, green, blue, and near infrared (NIR) from the image. Five to 12 composition and ground cover plots were completed using 100m point intercept transects in each adult female's home range to produce plant composition estimates for each adult female's home range. We used discrete-time known fates modeling to determine winter fawn survival and estimated fawn ratios from aerial surveys conducted in December. We evaluated the relationship between satellite based NDVI, cameras, and vegetation plots on nutritional quality of maternal home ranges. We then linked the estimate of nutritional quality on summer range to fawn ratios and winter fawn survival to test the influence of summer nutritional quality to population performance.

Presenter and email: Mark Hurley; mark.hurley@idfg.idaho.gov

USING NUTRITIONAL-LANDSCAPE MODELS TO PREDICT PREGNANCY RATES OF ELK AT BROAD SPATIAL SCALES

ROBATCEK, SIERRA, *University of Idaho, Moscow, ID, 83844, USA*

C. WHITE, *Idaho Department of Fish and Game, Jerome, ID, 83338, USA*

E.K. STRAND, *University of Idaho, Moscow, ID, 83844, USA*

R.A. LONG, *University of Idaho, Moscow, ID, 83844, USA*

Over the last two decades, some elk populations in Idaho have begun to display uncharacteristic variability in population performance. One hypothesis for explaining this variability is that inadequate quality and abundance of forage resources on summer-autumn ranges is negatively affecting the nutritional condition of female elk, leading to cascading effects on population vital rates and performance. We intensively sampled forage quality and biomass for elk in three different populations in Idaho that spanned a wide range of habitat types and pregnancy rates. We then used those data in combination with remotely sensed data on vegetation greenness, forest structure, precipitation patterns, and other variables to: 1) develop spatiotemporally dynamic models for predicting variation in the nutritional landscape available to elk in each study population; and 2) model variation in pregnancy rates of elk as a function of variation in the nutritional landscape. Both the maximum and the coefficient of variation of usable forage biomass (a measure of the amount of available forage that is of sufficiently high quality to support reproduction) in summer and fall were positively related to pregnancy rates of elk (adjusted R^2 of the best model = 0.64). Additionally, our top model for relating pregnancy of elk to how they used the nutritional landscape explained 75% of the variation in pregnancy rates among 10 population-years. In contrast, mean usable biomass in either season was unrelated to pregnancy rates. This suggests that landscapes that are both heterogeneous and contain at least some patches of high-quality forage are important for maximizing reproductive performance of elk populations. Our results can be used to predict pregnancy rates of elk across much of Idaho as a function of remotely sensed data, and provide insight into why some elk populations have been experiencing depressed pregnancy rates and overall performance.

Presenter and email: Sierra Robatcek; sierra.robatcek@idfg.idaho.gov

LANDSCAPE-GENETIC ANALYSIS OF TEXAS MULE DEER: IMPLICATIONS FOR THE MANAGEMENT OF CHRONIC WASTING DISEASE

GAEL A. SANCHEZ, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

RANDY W. DEYOUNG, *Caesar Kleberg Wildlife Research Institute Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

DAVID G. HEWITT, *Caesar Kleberg Wildlife Research Institute Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

TIMOTHY E. FULBRIGHT, *Caesar Kleberg Wildlife Research Institute Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

HUMBERTO PEROTTO-BALDIVIESO, *Caesar Kleberg Wildlife Research Institute Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

LOUIS A. HARVESON, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79830, USA*

SHAWN S. GRAY, *Texas Parks and Wildlife Department, Alpine, TX, 79830, USA*

Chronic wasting disease (CWD) was discovered in free-ranging North American cervids in 1981 and has become a major management concern. The disease was detected in Texas mule deer in 2012, most likely spread to the Trans-Pecos region via natural movements of mule deer from New Mexico. Chronic wasting disease was detected in free-ranging Panhandle mule and white-tailed deer in 2015 and 2017, respectively. Patterns of genetic similarity can reveal how animals use the landscape, and how landscape features influence animal movements. We analyzed genetic data from mule deer harvested throughout their range in Texas to understand how deer movements may lead to future spread of the disease. Preliminary analyses revealed evidence of hybridization with white-tailed deer throughout the Trans-Pecos and Panhandle regions. Five percent of mule deer had evidence of recent hybrid ancestry, but most were back-crosses vs. F1 crosses. We removed all detectable hybrids from the data set and focused on analyses of mule deer in relation to landscape features. Genetic differentiation was low and mostly due to geographic distance among samples. We detected few barriers to mule deer movements in the Trans-Pecos, but found evidence of restricted gene flow in the more fragmented Panhandle region, and in regions of unsuitable habitat where the High Plains and Edwards Plateau meet the Trans-Pecos. The results of this study support the use of geographically extensive monitoring and management units for CWD. Based on this genetic analysis, there appear to be few barriers to mule deer movement and the spread of CWD in western Texas.

Presenter and email: Randy DeYoung; Randall.DeYoung@tamuk.edu

ESTIMATING PREVALENCE AND POTENTIAL POPULATION IMPACTS OF TREPONEME-ASSOCIATED HOOF DISEASE OF ELK IN WASHINGTON

BROCK HOENES, *Washington Department of Fish and Wildlife*

KRISTIN MANSFIELD, *Washington Department of Fish and Wildlife*

RACHEL COOK, *National Council for Air and Stream Improvement*

ERIC HOLMAN, *Washington Department of Fish and Wildlife*

NICHOLLE STEPHENS, *Washington Department of Fish and Wildlife*

KYLE GARRISON, *Washington Department of Fish and Wildlife*

Treponeme-associated hoof disease (TAHD) is an infectious, bacterial disease that causes severe hoof abnormalities and lameness in elk. It is unknown when TAHD first emerged, but the number and geographical extent of affected elk increased dramatically in southwest Washington in 2008. In response to growing concerns about population impacts of TAHD, the Washington Department of Fish and Wildlife initiated efforts to estimate the disease's prevalence and impacts on elk vital rates. Our objectives are to identify a cost-effective and reliable method to index disease prevalence, and to compare adult female survival, pregnancy rates, productivity, and nutritional condition by disease status in the Mount St. Helens (MSH) elk herd. We used the proportion of animals reported by hunters as having abnormal hooves to the total number of harvested elk within a unit as an index of disease prevalence for the 2016-2017 license years. During 2015-2017, we captured and radio-collared 148 unique female elk in 211 capture events (*n* = 63 recaptures). We assessed each elk for disease, pregnancy, lactation, and body condition (ingesta-free body fat [IFBF]). Our index of prevalence in the core MSH area was 0.40 (0.36-0.45) in 2016 and 0.32 (0.27-0.38) in 2017. Pregnancy rates of adult female elk were lower for diseased elk (0.32-0.59) than uninfected elk (0.69-0.84), as was December lactation status (0.42-0.45, diseased: 0.63-0.69, uninfected). Regardless of lactation status, mean IFBF was lower for diseased adult female elk (5.3% lactating, 5.8% non-lactating) than uninfected elk (6.3% lactating, 8.5% non-lactating). Annual survival rates ranged from 0.58-0.68 for diseased elk and 0.67-0.79 for uninfected elk. The primary cause of mortality was general debilitation for diseased elk (0.44, *n* = 24) and harvest for uninfected elk (0.50, *n* = 6).

Presenter and email: Kyle Garrison; Kyle.Garrison@dfw.wa.gov

EVIDENCE OF ANCIENT AND CONTEMPORARY HYBRIDIZATION IN DEER IN THE UNITED STATES

EMILY A. WRIGHT, *Department of Biological Sciences, Texas Tech University, Lubbock, TX, 79409, USA*

EMMA K. ROBERTS, *Department of Biological Sciences, Texas Tech University, Lubbock, TX, 79409, USA*

WARREN C. CONWAY, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

ROBERT D. BRADLEY, *Department of Biological Sciences, Texas Tech University. Natural Science Research Laboratory, Museum of TTU, Lubbock, TX, 79409, USA*

Mule deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*) are known to hybridize across a large portion of the United States and Canada, including much of West Texas (Trans-Pecos and Panhandle Regions of Texas, specifically along the eastern edge of the Llano Estacado). To further investigate introgression between these species, we investigated

maternal sources of deer by examining a cytochrome-*b* (*Cytb*) dataset that includes samples from a broader, geographic region. Collectively, the aforementioned molecular marker was used to characterize molecular history of both species, and determine hybridization frequency, genetic lineages, and geographical relationships between mule and white-tailed deer. To date, *Cytb* sequence data obtained from 150 individuals across North America were analyzed via Bayesian phylogenetic methods. This analysis revealed three clades: black-tailed (west of Cascades), white-tailed (Latin America and east coast of U.S.), and a clade containing samples of mule and white-tailed deer (middle of U.S.). We interpreted these data to indicate that introgression between mule and white-tailed deer led to the capture and elimination of the ancestral mule deer (exclusion of black-tailed) mitochondrial DNA haplotype. Subsequently, deer west of the Mississippi River and east of the Cascades have the mtDNA haplotype of white-tailed deer whereas deer west of the Cascades and east of the Mississippi River are 'pure' mule and white-tailed deer, respectively. Genetic distance and divergence rates indicated that mule (as depicted by the black-tailed deer haplotype) and white-tailed deer diverged 2.24 million years ago (mya), followed by an initial major hybridization event approximately 1 mya. That event led to the capture of mule deer mtDNA (in the western U.S.) by white-tailed deer as evidenced by the third clade containing most of the samples examined in this study. Following this hybridization event, the mule/white-tailed deer haplotype diverged from each other producing 1.6% divergence seen in contemporary samples. Detection of contemporary hybrid individuals in the white-tailed/mule deer clade may be due to large scale habitat changes, movements, and intentional translocations of both species during the last century. A nuclear marker that is potentially involved in post-mating isolation barrier in mammals will be incorporated to complete assessment of hybridization levels.

Presenter and email: Emily Wright; Emily.A.Wright@ttu.edu

SESSION 4

DISTANCE SURVEYS FOR AXIS DEER AND WHITE-TAILED DEER ON THE EDWARDS PLATEAU OF CENTRAL TEXAS

MATTHEW J BUCHHOLZ, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

WARREN C CONWAY, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

THOMAS L ARSUFFI, *Llano River Field Station, Texas Tech University, Junction, TX, 76849, USA*

BLAKE A GRISHAM, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

Axis deer (*Axis axis*) have become well established within the Edwards Plateau region of Texas, and are considered to be the most widespread and abundant exotic cervid in Texas. However, population estimates or information relative to local or regional densities are rare within the state. Therefore, our goals were to (1) estimate the density of free-ranging axis deer within the Edwards Plateau, and (2) compare regional axis and white-tailed deer (*Odocoileus virginianus*) densities. We used distance sampling protocols during nocturnal spotlight surveys in Kimble County, TX during June (77.3 km), July (77.3 km), November 2018 (59.9 km), and March 2019 (71.7 km). We recorded total herd size, herd composition, and perpendicular distance from the transect for both axis and white-tailed deer. Detection probability was consistent between both species (0.37 for axis deer vs. 0.34 for white-tailed deer) and detection probabilities declined rapidly beyond 70 m for both species. Average axis deer group size was 6.1 deer/group, while average group size for white-tailed deer was 1.78 deer/group. Average density of axis deer was 2.38 (95% CI = 1.71–3.32; seasonal = 1.10–2.81) deer/ha versus 2.20 (95% CI = 1.51–3.13; seasonal = 1.66–3.12) deer/ha for white-tailed deer. Our results suggest that the density of axis and white-tailed deer are similar within the study area. However, additional analyses are ongoing to assess if social behaviors, seasonality, and habitat use influence the densities of both axis and white-tailed deer in the study area.

Presenter and email: Matthew Buchholz; Matthew.Buchholz@ttu.edu

AN IMPROVED UNDERSTANDING OF UNGULATE POPULATION DYNAMICS USING COUNT DATA

J. TERRILL PATERSON, *Department of Ecology, Montana State University, 310 Lewis Hall, Bozeman, MT, 59718, USA*

KELLY M. PROFFITT, *Montana Department of Fish, Wildlife and Parks, 1400 South 19th Street, Bozeman, MT, 59718, USA*

ROBERT GARROTT, *Department of Ecology, Montana State University, 310 Lewis Hall, Bozeman, MT, 59718, USA*

JAY ROTELLA, *Department of Ecology, Montana State University, 310 Lewis Hall, Bozeman, MT, 59718, USA*

Understanding the dynamics of ungulate populations is a crucial goal for managers given their ecological and economic importance. In particular, the ability to evaluate the evidence for potential drivers of variation in population trajectories is important for informed management. However, the routine use of age ratio data (e.g., juveniles:adult females) to evaluate variation in population dynamics is hindered by a lack of statistical power and difficult interpretation. Here, we show that the use of a population model fueled by count, classification and harvest data can dramatically improve the understanding of population dynamics by: 1) increasing the power to assess potential sources of variation in key vital rates, and 2) providing easily interpretable vital rates (e.g., per capita recruitment and population growth) that are useful to managers. Using a time series of spring count data (2004 to 2016) and fall harvest data from hunting districts in western Montana, we constructed a population model to assess the effects of a series of environmental covariates and indices of predator abundance on the per capita recruitment rates of elk calves. Results from this modeling approach suggest per capita recruitment rates decline in association with wet springs, dry summers and severe winters, and in interactions between predator communities and the environment. In contrast, the analysis of age ratio data failed to detect these relationships. We recommend using count data and a population modeling approach rather than interpreting estimated age ratio data as a substantial improvement in understanding population dynamics.

Presenter and email: Terrill Paterson; terrillpaterson@gmail.com

SPATIOTEMPORAL COVARIATES, INDIVIDUAL CHARACTERISTICS, AND MOUNTAIN LION HARVEST AS POTENTIAL SOURCES OF VARIATION IN ELK CALF SURVIVAL

MICHAEL J. FORZLEY, *Department of Ecology, Montana State University, Bozeman, MT, 59715, USA*

JAY J. ROTELLA, *Department of Ecology, Montana State University, Bozeman, MT, 59715, USA*

KELLY M. PROFFITT, *Montana Fish, Wildlife and Parks, 1400 South 19th Avenue, Bozeman, MT, 59718, USA*

ROBERT A. GARROTT, *Department of Ecology, Montana State University, Bozeman, MT, 59715, USA*

BENJAMIN S. JIMENEZ, *Montana Fish, Wildlife and Parks, 3201 Spurgin Road, Missoula, MT, 59804*

DANIEL R. EACKER, *Alaska Department of Fish and Game,1225 West 8th Street, Juneau, AK, 99802*

MARK HEBBLEWHITE, *Wildlife Biology Program, Department of Forestry and Conservation, University of Montana, Missoula, MT, 59812, USA*

To understand the efficacy of increasing the harvest of large carnivores for increasing elk calf survival, we compared calf survival data collected from two elk herds before, during, and after a mountain lion harvest treatment which was implemented to moderately reduce mountain lion population abundances. We also estimated possible relationships between elk calf survival and several spatial, temporal, and individual attribute covariates. We collected survival data from 534 radio-tagged elk calves in both the East Fork and West Fork herds of the upper Bitterroot Valley of west-central Montana. We used these data and time-to-event analyses to estimate the annual rates of survival and cause-specific mortality for elk calves in the study, as well as to evaluate relationships between elk calf survival and a suite of covariates potentially explaining variation in annual elk calf survival. Average annual rates of survival for female calves before the mountain lion harvest treatment (pre-treatment era) were 0.38 (95% CI = 0.00-0.54) in the West Fork herd and 0.37 (95% CI = 0.09-0.65) in the East Fork herd. Annual rates of survival for

female calves during the harvest treatment (during-treatment era) were 0.65 (95% CI = 0.47-0.83) in the West Fork herd and 0.65 (95% CI = 0.46-0.87) in the East Fork herd. Annual rates of survival for female calves 4-5 years post-harvest treatment (post-treatment era) were 0.46 (95% CI = 0.31-0.61) in the West Fork herd and 0.47 (95% CI = 0.32-0.62) in the East Fork herd. Survival of male calves followed a similar pattern, but male calves survived at lower rates than female calves. Rates of mountain lion predation were highest in the pre-treatment era, moderate during-treatment era, and lowest in the post-treatment era. However, decreased rates of mountain lion predation following mountain lion harvest treatment coincided with increased probability of non-predation related mortality, and short-term changes in annual elk calf survival. We also found that a mountain lion RSF covariate, estimated using a mountain lion resource selection function, was negatively related to calf survival in both summer and winter, suggesting that calves that spend more time in areas of higher predicted mountain lion activity were more susceptible to predation. We found no predicted relationships between elk calf survival and several indices of productivity and winter severity. Our results suggest that mountain lion harvest management prescriptions designed to achieve moderate, short-term reductions in mountain lion population abundance may be effective in allowing for short-term increases in elk calf recruitment and may be an effective management tool to increase calf recruitment.

Presenter and email: Michael J. Forzley; mjforz@gmail.com

INTEGRATED CARNIVORE-UNGULATE MANAGEMENT: A CASE STUDY IN WEST-CENTRAL MONTANA

KELLY M. PROFFITT, *Montana Department of Fish, Wildlife and Parks, 1400 South 19th Street, Bozeman, MT, 59718, USA*

J. TERRILL PATERSON, *Department of Ecology, Montana State University, 310 Lewis Hall, Bozeman, MT, 59718, USA*

ROBERT GARROTT, *Department of Ecology, Montana State University, 310 Lewis Hall, Bozeman, MT, 59718, USA*

JAY ROTELLA, *Department of Ecology, Montana State University, 310 Lewis Hall, Bozeman, MT, 59718, USA*

BENJAMIN JIMENEZ, *Montana Department of Fish, Wildlife and Parks, 3201 Spurgin Road, Missoula, MT, 59804, USA*

MARK HEBBLEWHITE, *Wildlife Biology Program, Department of Ecosystem and Conservation Sciences, College of Forestry and Conservation, University of Montana, Missoula, MT, 59812, USA*

JUSTIN GUDE, *Montana Department of Fish, Wildlife and Parks,1420 East 6th Avenue, Helena, MT, 59620*

MIKE THOMPSON, *Montana Department of Fish, Wildlife and Parks, 3201 Spurgin*

Road, Missoula, MT, 59804, USA

REBECCA MOWRY, *Montana Department of Fish, Wildlife and Parks, 3201 Spurgin Road, Missoula, MT, 59804, USA*

CRAIG JOURDONNAIS, *(retired), Montana Department of Fish, Wildlife and Parks, 3201 Spurgin Road, Missoula, MT, 59804, USA*

In response to poor recruitment and declining ungulate population trends in west-central Montana, wildlife managers implemented integrated carnivore-ungulate management designed to reduce carnivore densities via harvest prescriptions in efforts to increase elk recruitment and abundance. However, the potential success of using carnivore harvest regulations as a tool to reduce carnivore population densities and increase ungulate recruitment is unknown. The management objective in this case was a moderate reduction in carnivore densities that sustained carnivore populations and associated recreational opportunities, while also reducing predation pressure on ungulate populations. We assessed the efficacy of this integrated carnivore-ungulate management using a before-after-control-treatment study design and evaluating the effects of a harvest management prescription on 1) mountain lion population density, and 2) patterns in elk juvenile recruitment. We found that 4-years after the management program was implemented, mountain lion population abundance declined by 26% (90% CI = [0.60, -0.05]) within the harvest treatment area and remained stable within the control area. The per-capita recruitment rate of elk was low and stable in the treatment area prior to the mountain lion harvest prescription (e.g., mean = 0.18, [0.14, 0.22]), increased substantially in the year following the implementation of the harvest prescription (mean = 0.32, [0.24, 0.41]) prior to declining to 0.23 ([0.16, 0.29]) at present, which contrasted with a moderate increase in per capita recruitment rates in the control area. Together these results suggest that the mountain lion harvest treatment moderately reduced mountain lion abundance within the treatment area, as intended, although the effect on elk population dynamics was short-lived. Broadly, the harvest regulations achieved carnivore and ungulate population objectives. We recommend that wildlife managers applying an integrated carnivore-ungulate management program develop a monitoring strategy to assess the program's efficacy, and provide information regarding future management prescriptions designed to achieve carnivore and ungulate population objectives.

Presenter and email: Kelly Proffitt; KProffitt@mt.gov

MANAGING ELK ON PRIVATE LAND IN KENTUCKY, A REAL PAIN IN THE ACCESS

GABRIEL S.W. JENKINS, *Kentucky Department of Fish and Wildlife Resources, #1 Sportsman's Lane, Frankfort, KY, 40601*

JOSEPH R. MCDERMOTT, *Kentucky Department of Fish and Wildlife Resources, #1 Sportsman's Lane, Frankfort, KY, 40601*

ROBERT D. CRANK, *Kentucky Department of Fish and Wildlife Resources, #1 Sportsman's Lane, Frankfort, KY, 40601*

JOHN T. HAST, *Kentucky Department of Fish and Wildlife Resources, #1 Sportsman's Lane, Frankfort, KY, 40601*

The Kentucky Elk Zone encompasses 4.1 million acres over a 16-county area in southeastern Kentucky. Although better than much of the state, the Elk Zone is predominantly privately owned with only 9% of the land area available to public hunting on state or federally owned lands. This poses issues for elk managers seeking to develop biologically relevant hunting units, set permit numbers, and provide a quality hunting experience. The need for additional quality public hunting areas spurred the development of two land access programs in eastern Kentucky, the Landowner-Cooperator and Voucher-Cooperator Permit Programs. The Landowner-Cooperator Program is geared toward large corporate landowners or lessees, many of whom control tens of thousands of acres devoted to surface mining, oil and gas production, or largescale timber operations with little other land use. Landowners receive one fully transferrable either-sex elk permit for every 5,000 acres they enroll in full public hunting access, or two antlerless-only permits for elk hunting access alone. The Voucher-Cooperator Program is different in that it is predominantly aimed at smaller, family owned properties (100 acres) and is dependent upon elk harvest. Landowners and lessees are awarded one point for each elk that is harvested from the property through regulated hunting and they receive a fully transferrable either-sex elk permit upon the accrual of ten points. Since their inception, the Voucher-Cooperator Program has opened up an additional 143,329 acres to limited elk hunting, and the Landowner-Cooperator Program has opened 199,337 acres for full public hunting access. These two programs have effectively doubled the total acreage for public hunting in eastern Kentucky, and we're now approaching 20% (18.38) of the total available land inside the Elk Zone. A thorough discussion of each program is found herein.

Presenter and email: Gabriel S. W. Jenkins; Gabriel.Jenkins@ky.gov

INTEGRATING FORAGE ESTIMATES AND PUBLIC OPINION INTO ELK HABITAT SUITABILITY INDEX MAPS

NICHOLAS MCCANN, *Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota, St. Paul, MN, 55108, USA*

JAMES FORESTER, *Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota, St. Paul, MN, 55108, USA*

MIKE SCHRAGE, *Fond du Lac Resource Management Division, Fond du Lac Band of Lake Superior Chippewa, Cloquet, MN, 55720, USA*

DAVID FULTON, *U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit, University of Minnesota, St. Paul, MN, 55108, USA*

ERIC WALBERG, *Minnesota Cooperative Fish and Wildlife Research Unit, University of Minnesota, St. Paul, MN, 55108, USA*

Elk occupied most of Minnesota prior to the early 1900s, but now only occur in northwestern Minnesota where two reestablished populations are maintained at small numbers to minimize human-wildlife conflict. Forested areas of the state with abundant public land might be suitable for reestablishing additional elk populations, as the likelihood for human-wildlife conflict is less in these areas. We quantified and mapped above ground biomass (AGB) to provide information about elk spring and winter forage in three northeastern Minnesota study areas comprised mostly of forested public land. We estimated AGB using allometric equations and vegetation measurements collected during two summers at 217 field sites located on public and private land. We then mapped AGB across the three study areas using remotely-sensed data and random forest analysis. Resulting maps were integrated with maps developed using a regional elk habitat suitability index (HSI) and results from public opinion surveys. We found that spring and winter forage is widespread across the three study areas, but with localized 'hotspots' where forage is most abundant. Habitat suitability was influenced by integrating AGB and public opinion into HSI maps. Our results provide critical information to wildlife managers and local governments for assessing potential elk restorations.

Presenter and email: Nicholas McCann; mccan062@umn.edu

ELK MANAGEMENT IN SASKATCHEWAN

TOM PERRY, *Saskatchewan Ministry of Environment, 800 Central Avenue, Prince Albert, Saskatchewan, S6V 6G1.*

In Saskatchewan, Canada, elk are subject to relatively high annual mortality from a suite of factors (e.g., climate, predators, disease), and are regularly at the forefront of the interface between landowner-wildlife conflict. To guide consistent and science informed elk management, the province of Saskatchewan has recently drafted a ten-year elk management plan. Central to the plan is the classification of data sources predicted to reflect elk population size and population trends. Indicator data includes modeled population estimates, recruitment estimates, hunter harvest rates, hunter effort and landowner crop damage. The integration of these data sources will allow elk managers to make defensible decisions on regional harvest regimes, which align with biologically and socioeconomically sustainable elk populations. Although the relationship between true elk population size and proxy indicator data will be imperfect, an objective decision-making approach will facilitate consistent elk management strategies.

Presenter and email: Tom Perry; tom.perry@gov.sk.ca

ELK MANAGEMENT IN UTAH: BALANCING QUALITY AND OPPORTUNITY

JUSTIN SHANNON, *Utah Division of Wildlife Resources, Salt Lake City, UT, 84116*

BROCK MCMILLAN, *Brigham Young University, Provo, UT, 84602*

RANDY LARSEN, *Brigham Young University, Provo, UT, 84602*

DERRICK EWELL, *Utah Division of Wildlife Resources, Salt Lake City, UT, 84116*

HEATHER BERNALES, *Utah Division of Wildlife Resources, Salt Lake City, UT, 84116*

Rocky Mountain elk (*Cervus elaphus nelsoni*) are an important component of Utah's wildlife and were designated as Utah's state animal in 1971. Elk were historically one of the most common game animals found in Utah, but unrestricted hunting eliminated most populations by the end of the nineteenth century. Elk translocations began as early as 1893 to re-establish elk into historical ranges. In 1925, after numerous elk translocations, only 1,500 elk resided in Utah. More recently, elk populations have grown from an estimated 18,000 animals in 1975 to 80,000 animals in 2018. As a result, elk management has continued to evolve to meet public expectations. On one end of the pendulum are hunters that want to pursue elk every year; on the other end of that pendulum are hunters that want to harvest a mature bull, even if that means waiting many years for that opportunity. Utah attempts to provide a diversity of elk hunting opportunities including several over-the-counter options such as spike-only hunts on limited entry (quality) units, any-bull permits on all other units, statewide archery-only permits for bulls or cows, and private-lands-only cow hunts. On limited entry units managed for quality hunting opportunities, Utah manages elk to an average age objective that ranges from 4.5-5.0 to 7.5-8.0 years old for bulls harvested. This strategy provides relative consistency in the quality of bulls harvested for a given management unit, and serves as an alternative for managing strictly on a bull:cow ratio. Data on antler characteristics collected by hunters from harvested elk in Utah show antler width and main beam lengths increasing rapidly from 2 years of age until 7 and 8 years of age, respectively, at which point an asymptote is evident. The pattern we observed between age and antler width or main beam length is consistent with the relationship between age and Boone and Crockett scores. We also present information on point creep (permit applications outpacing the number of available bull elk permits) and discuss the trade-offs and benefits of balancing quality and opportunity on elk units throughout Utah.

Presenter and email: Justin Shannon; justinshannon@utah.gov

SESSION 5

ARE CENTER PIVOTS PIVOTAL TO LANDSCAPE USE? MULE DEER MOVEMENT PATTERNS AND HABITAT USE IN AN AGRICULTURAL LANDSCAPE

LEVI J. HEFFELFINGER, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

LAURA S. WARNER, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

DAVID G. HEWITT, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

SHAWN S. GRAY, *Texas Parks and Wildlife Department, Alpine, TX, 79830, USA*

WARREN C. CONWAY, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

TIMOTHY E. FULBRIGHT, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

RANDY W. DEYOUNG, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

LOUIS A. HARVESON, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79830, USA*

Conversion of native rangeland to row crop farming is one of the largest forms of habitat fragmentation. One such area in which agricultural expansion is expected to increase is the Texas Panhandle. Historically, Texas mule deer (*Odocoileus hemionus*) were most common in the Trans-Pecos, but population numbers have dramatically increased in the Panhandle. Little is known about mule deer habitat use and movement in this area of extensive fragmentation. We delineated 3 study sites throughout the Texas Panhandle of varying agriculture densities and placed GPS collars on 55 male and 76 adult female deer. The Western Rolling Plains (WRP) represented our high prevalence of agriculture, Canadian River Breaks (CRB) represented low prevalence, and Southwest Panhandle (SWP) represented moderate prevalence. We sought to understand baseline metrics of home range sizes, proportion of individuals using agriculture, and whether mule deer exhibited long distance, seasonal shifts towards cropland. Male home range size was large and variable regardless of study site (WRP: 3107ha SD=2838, CRB: 3352ha SD=6437, SWP: 4279ha SD=4177). Female home range size was smaller and less variable regardless of study site (WRP: 1254ha SD=1942, CRB: 987ha SD=706, SWP: 1133ha SD=689). Few marked deer exhibited seasonal shifts (greater than 5km between core areas) towards cropland (WRP=10%, CRB=4%, SWP=4%). Moreover, the proportion of marked deer that used agriculture appeared dependent on accessibility of crops nearby (WRP=86%, CRB=15%, SWP=85%). Though agriculture use was high in areas with more crops, the low proportion of deer moving long distance to crops highlight that mule deer will use agriculture when nearby, but few deer expend the necessary energy stores to access crops at a further distance. These findings help define the scale of management for mule deer in the Texas Panhandle, and other regions where extensive agriculture and mule deer coexist, which is critical for managing mule deer harvest, crop damage, and population monitoring.

Presenter and email: Levi Heffelfinger; ljheffelfinger@gmail.com

MULE DEER DIETS AND NUTRITION IN AN AGRICULTURALLY ABUNDANT REGION OF THE TEXAS PANHANDLE

JACOB R. LAMPMAN, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79832, USA*

LAURA S. WARNER, *Caesar Kleberg Wildlife Research Institute, Texas A&M University – Kingsville, Kingsville, TX, 78363, USA*

LOUIS A. HARVESON, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79832, USA*

DAVID G. HEWITT, *Caesar Kleberg Wildlife Research Institute, Texas A&M University – Kingsville, Kingsville, TX, 78363, USA*

WARREN C. CONWAY, *Texas Tech University, Lubbock, TX, 79409, USA*

SHAWN S. GRAY, *Texas Parks and Wildlife Department, Alpine, TX, 79830, USA*

Mule deer (*Odocoileus hemionus*) occur in the Panhandle region of Texas. This region is characterized by extensive agriculture and large aggregations of mule deer are seen in crop fields in certain times of the year. However, seasonal food habits and nutritive value of these regional crops and rangeland in this region are largely unknown. We designed a study to 1) document seasonal forage of rangeland and agricultural crops, 2) document monthly nutritive values of forages in rangeland and agricultural crops used by and available to mule deer, and 3) determine whether protein or energy is driving selection of rangeland and cultivated forage. Forty-seven fresh fecal samples were collected over 7 seasons beginning in Spring 2016, where fecal DNA metabarcoding techniques were used to construct seasonal diets of mule deer within the study area. Composite samples of individual plant and crop species were collected monthly across the entire study area to estimate nutritive value among forage types. Fecal DNA results reported 43 genera from 20 families of plants with diets largely consisting of early successional forbs throughout most of the year. Most common crops identified were wheat (*Triticum* sp.) during fall and winter, and cotton (*Gossypium* sp.) during summer and fall. Diets comprising of only rangeland plants can provide adequate amounts of protein and energy for successful growth and reproduction ($\bar{x} = 11\%$ crude protein, 68% digestible dry matter). However, use of wheat and cotton could exceed minimum nutritional requirements during different times of the year. Mule deer use of wheat is likely for both energy and protein reasons. Wheat acts as a key supplemental forage during winter when rangeland forage diversity and nutrition is low, and when energy is greatly needed for rutting activities and post-rut recovery. Cotton use is likely due to high protein content that is easily digested during early growth stages in the summer when protein is needed for maximum body growth.

Presenter and email: Jacob Lampman; jlampman23@gmail.com

FROM FALLOW TO FAT: EFFECTS OF AGRICULTURE ON MULE DEER MORPHOLOGY IN A FRAGMENTED LANDSCAPE

LEVI J. HEFFELFINGER, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

LAURA S. WARNER, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

DAVID G. HEWITT, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

SHAWN S. GRAY, *Texas Parks and Wildlife Department, Alpine, TX, 79830, USA*

WARREN C. CONWAY, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

TIMOTHY E. FULBRIGHT, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

RANDY W. DEYOUNG, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX, 78363, USA*

LOUIS A. HARVESON, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79830, USA*

Conversion of native rangeland to row-crop farming is one of the largest forms of habitat fragmentation in the United States. Understanding how species react to such landscape alterations will prove important for conservation and management. Mule deer (*Odocoileus hemionus*) populations have been stable throughout the western United States, but have increased in the Texas Panhandle, an area of extensive row-crop agricultural production. We evaluated the influence of agriculture use by mule deer on rump fat, body mass, lactation, survival, and antler size. We collected multi-year movement (via GPS collars) and morphometric measurements from 122 unique male and 185 unique female combinations of movement and associated morphology. We found no effect of crop use on male antler size (P=0.11) or body mass (P=0.15). However, summer agriculture use had a positive effect on rump fat for both mature (β=48.82, P=0.01) and young (β =55.82, P=0.01) males demonstrating the use of crops to build nutritional reserves before rut. Agriculture use did not have an effect on rump fat (P=0.54) or body mass (P=0.20) for females. In sites with a higher prevalence of crops, agriculture use increased the probability that an adult female would be lactating the following autumn (β=3.12, P=0.001), demonstrating the importance of croplands in providing nutrition to support rearing young. In addition, fawn survival from 3 to 12 months of age was greater (66% vs. 57%) in study sites where agriculture use by adults was greater (12.4% vs. 0.0% use). Fawn production and survival are often limiting in ungulate populations, thereby highlighting the importance of cropland for mule deer in the Texas Panhandle. Our baseline population measures will aid in establishing an adaptive management plan for mule deer in the Panhandle as the rangeland-cropland juxtaposition continues to change.

Presenter and email: Levi Heffelfinger; ljheffelfinger@gmail.com

THE INFLUENCE OF WILDFIRE AND JUNIPER PHASE ON WINTER HABITAT SELECTION PATTERNS OF MULE DEER

ELIZABETH M SCHUYLER, *Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR, 97338, USA*

LISA ELLSWORTH, *Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR, 97338, USA*

DANA SANCHEZ, *Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR, 97338, USA*

DON WHITTAKER, *Oregon Department Fish and Wildlife, Salem OR, 97302, USA*

Sagebrush steppe ecosystems have been the focus of habitat improvement projects for decades due to their increasingly rapid and widespread degradation through western North America. Degradation has been attributed to livestock grazing, altered fire regimes, western juniper (*Juniperus occidentalis*) expansion, and sagebrush removal, which has impacted many wildlife populations, including mule deer (*Odocoileus hemionus*). We examined how wildfire, juniper phase, and invasive grasses with varying levels influenced habitat selection for mule deer that winter on or within 25 miles of Phillip Schneider Wildlife Area, Dayville, Oregon during 2015-2017. We used 35,446 Global Positioning System locations collected from a sample (*n*=136) of adult (>1.5-yr-old) female mule deer to determine the probability of use as a function of year since fire, juniper phase, presence of invasive grass, and other habitat variables. We treated each deer as an experimental unit and developed a population-level resource selection function for the winter season (Dec-Mar). Preliminary results suggest that deer selected areas that had been burned at least 1 to 10 years prior but avoided burned areas where the fire occurred 10+ years ago. We also found that deer selected areas that had little (<10%) or no juniper canopy cover. Understanding how mule deer respond to juniper canopy cover and wildfire can aid wildlife biologists and managers with habitat restoration efforts and decision making.

Presenter and email: Elizabeth Schuyler; Elizabeth.Mulligan@oregonstate.edu

RISK AND REWARD: PERSONALITY AND AGE OF ADULT MALE WHITE-TAILED DEER DICTATE EXPOSURE TO HUNTERS DURING THE BREEDING SEASON

ASHLEY M. JONES, *Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Mississippi State, MS, 39762, USA*

BRONSON STRICKLAND, *Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Mississippi State, MS, 39762, USA*

GARRETT M. STREET, *Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Mississippi State, MS, 39762, USA*

WILLIAM MCKINLEY, *Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Mississippi State, MS, 39762, USA*

STEVE DEMARAIS, *Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Mississippi State, MS, 39762, USA*

White-tailed deer (*Odocoileus virginianus*) must make tradeoffs between incurring risk and accessing resources. Intrinsic factors affecting these decisions are not well studied, but we expect that individuals may perceive and react to their environment differently. To address this, we examined the role of two specific intrinsic factors (age and personality type) on the level of risk white-tailed deer experienced across the breeding season in Mississippi. Bucks aged 2.5 to 6.5 years old were captured in east central Mississippi and fitted with GPS collars (n=43). Home ranges for each animal were constructed based on 15-minute relocations during 3, 2-week long temporal periods spanning the breeding season. Animals were categorized by age and personality type, and hunting intensity within their home ranges over the 3 periods evaluated. Our results indicate that age, personality, and season had no effect on whether or not bucks were exposed to risk. However, for animals that experienced risk, we found personality and age both dictated the level of that risk dependent on phase of the rut. We found that during peak rut 2.5-3.5-year-old bucks experienced an 84% increase in risk compared to older bucks. During the post rut phase, bucks that were 5.5+ years old experienced a 55% increase in risk as compared to younger bucks. The greatest effects of personality were seen in the peak rut, with “mover” personalities incurring an 81% increase in risk exposure compared to “sedentary” personalities. These differences in risk tolerance suggest that there is not a “one-size-fits-all” approach to tradeoffs between risk and access to resources for mature bucks during the breeding season. Personality and age appear to inform an animal’s decision to risk it or not.

Presenter and email: Ashley Jones; amj620@msstate.edu

HABITAT USE AND HARVEST VULNERABILITY OF ELK (*CERVUS CANADENSIS)*: DO ELK LEARN TO AVOID HUNTERS AS THEY AGE?

MAKSIM SERGEYEV, *Department of Plant and Wildlife Sciences, Brigham Young University, Provo, UT, 84602, USA*

BROCK R. MCMILLAN, *Department of Plant and Wildlife Sciences, Brigham Young University, Provo, UT, 84602, USA*

KENT R. HERSEY, *Utah Division of Wildlife Resources, Salt Lake City, UT, 84116, USA*

RANDY T. LARSEN, *Department of Plant and Wildlife Sciences, Brigham Young University, Provo, UT, 84602, USA*

Pressure from hunting alters the behavior and habitat selection of game species. During hunting periods, animals like deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*) typically select for areas further from roads and closer to tree cover, while altering the timing of their daily activities to better avoid hunters. Our objective was to determine the habitat characteristics most influential in predicting harvest risk of elk and further, to determine if elk learned to avoid hunters with age. We captured 445 elk between January 2015 and March 2017 in the Uinta-Wasatch-Cache National Forest and surrounding area of central Utah. We determined habitat selection during the hunting season using a resource selection function (RSF). Additionally, we modeled vulnerability to harvest based on habitat use within home ranges as well as based on the location of the home range on the landscape to evaluate vulnerability on a broader scale. Elk selected for areas that reduced hunter access (rugged terrain, within tree cover, on private land). Age, elevation and distance to roads were most influential in predicting harvest risk based on use within home ranges (top model accounted for 36.2% of the weight). Elevation and distance to trees were most influential in predicting risk based on centroid of home range (top model accounted for 42.1% of the weight, interaction term showed that at higher elevations, elk further from trees had a reduced risk of harvest). Vulnerability to harvest was associated with increased proximity to roads. Additionally, survival decreased with age; we found no evidence of learned hunter-avoidance by older elk.

Presenter and email: Maksim Sergeyev; ecomaksimsergeyev@gmail.com

UNGULATE FORAGE BIOMASS AND QUALITY DURING 6 YEARS OF LANDSCAPE RESTORATION

SHARON E. SMYTHE, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

JAMES W. CAIN III, *U.S. Geological Survey, New Mexico Cooperative Fish and Wildlife Research Unit, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University, Las Cruces, NM, 88003*

WARREN C CONWAY, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

Because of historic land use and fire suppression, forests in northern New Mexico are at abnormally high risk for catastrophic wildfires. In response, a coalition of agencies under a USDA Collaborative Forest Landscape Restoration Project began restoring 210,000 ha in the Jemez Mountains via forest thinning and prescribed fire. From 2013–2018, we collected data from 200 vegetation plots (60–70 monthly in summer and seasonally; 130–140 annually in summer) randomly stratified within 6 dominant stand types (aspen, grassland, oak, pinyon-juniper, ponderosa, mixed conifer). Within each plot, we established a 200 m transect and measured herbaceous biomass, shrub biomass, and collected samples for nutritional content analyses (crude protein, tannin, lignin, mineral levels). We developed regression models for estimating stand-specific herbaceous biomass using disc meters as well > 40 species-specific basal diameter regressions for shrubs. Our preliminary results suggest that herbaceous biomass increases initially for 1–4 years following treatment or wildfire before subsiding, but there is substantial variability among stand and treatment type. Similarly, changes in shrub biomass vary across stand and treatment types. Data indicate that shrub biomass within treated stands may be reduced by treatment. Overall changes in forage nutritional quality varied by stand and treatment type; however, crude protein levels consistently increased following wildfire and some treatments. In contrast, lignin and ash responses varied relative to herbaceous or woody forage types. These results are crucial to evaluating the success of the larger restoration project, while providing local and state managers with a rare long-term monitoring dataset to aid their management of ecologically and economically valuable species.

Presenter and email: Sharon Smythe; Sharon.Smythe@ttu.edu

POSTER ABSTRACTS

(Alphabetical Order of Primary Author)

DEVELOPING TOOTH REPLACEMENT AND WEAR CRITERIA FOR AGING FREE-RANGING AXIS DEER WITH COMPARISONS TO THE CRITERIA FOR AGING WHITE-TAILED DEER

MATTHEW J BUCHHOLZ, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

BLAKE A GRISHAM, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

THOMAS L ARSUFFI, *Llano River Field Station, Texas Tech University, Junction, TX, 76849, USA*

WARREN C CONWAY, *Department of Natural Resources Management, Texas Tech University, Lubbock, TX, 79409, USA*

The ability to accurately age wildlife is critical to population management and modeling. Without calibrated aging criteria for axis deer (*Axis axis*), biologists have resorted to using tooth replacement and wear criteria developed for white-tailed deer (*Odocoileus virginianus*). Our goals were to (1) develop tooth replacement and wear criteria for aging axis deer, and (2) compare these aging techniques between axis and white-tailed deer. We collected jawbones from 89 harvested or road-killed free-ranging axis deer in central Texas and submitted the primary incisor for cementum annuli analysis. We also attempted to build aging criteria for these known-age axis deer using patterns of tooth replacement and wear criteria, analogous to the method used for white-tailed deer. Cementum annuli analyses revealed ages of axis deer ranging from 0.5 to 15 years old, using an elk-validated cementum annuli model. Aging axis deer up to 36 months old can be reliably performed using premolar and molar replacement patterns, while tooth wear patterns can be used to age axis deer from 4 to > 10 years old. Applying the white-tailed deer aging technique for axis deer consistently under-estimated axis deer age ($P = 0.007$). Therefore, we are refining the axis deer tooth replacement and wear criteria, which will facilitate more accurate and precise measures of axis deer age in Texas.

Presenter and email: Matthew Buchholz; Matthew.Buchholz@ttu.edu

MULE DEER FEEDER VISITATION IN RELATION TO LUNAR PHASES IN TRANS-PECOS, TEXAS

ERICA I. DUNN, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79832, USA*

THOMAS S. JANKE, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79832, USA*

LOUIS A. HARVESON, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79832, USA*

DANA L. KARELUS, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79832, USA*

CARLOS E. GONZALEZ-GONZALEZ, *Borderlands Research Institute, Sul Ross State University, Alpine, TX, 79832, USA*

There are countless opinions and interpretations when it comes to lunar phases in relation to animal activity and behavior. Studies have been conducted on the relationship between lunar phase and deer in other regions of the world, but limited information exists on lunar phases in relation to mule deer (*Odocoileus hemionus*) feeder visitation in Texas. Objectives of this study were to 1) determine if mule deer feeder visitation differed with varying lunar phases; 2) document which lunar phases mule deer visited feeders most and least often; and 3) evaluate if there is a difference between daytime and nighttime feeder visitations in relation to lunar phase. Between October and March of 2015-2018, motion activated trail cameras collected pictures at free-choice protein feeders on a private ranch located in Brewster County, Texas. Trail cameras (n = 12) were rotated around the ranch throughout each season and collected pictures at 24 different feeders. Collected pictures were first sorted by species. Pictures containing mule deer (n = 129,806) were then sorted by lunar phase (new moon, first quarter, full moon, and last quarter), and finally sub-sorted by the number of deer in each picture. Preliminary results indicate that the deer were feeding more often at night (22:00-04:00) during the full moon and first quarter lunar phases. The results of this study will help researchers, managers, landowners, hunters, and mule deer enthusiasts better prepare management strategies, such as spotlight surveys and harvest recommendations, in relation to lunar phases.

Presenter and email: Erica Dunn; edunn25@gmail.com

ESTIMATING WHITE-TAILED DEER POPULATION SIZES USING UNMANNED AERIAL VEHICLES (UAVS)

JESSE EXUM, *Caesar Kleberg Wildlife Research Institute, Texas A&M University–Kingsville, Kingsville, TX, 78363, USA*

AARON M. FOLEY, *Caesar Kleberg Wildlife Research Institute, Texas A&M University–Kingsville, Kingsville, TX, 78363, USA*

RANDY W. DEYOUNG, *Caesar Kleberg Wildlife Research Institute, Texas A&M University – Kingsville, Kingsville, TX, 78363, USA*

DAVID G. HEWITT, *Caesar Kleberg Wildlife Research Institute, Texas A&M University–Kingsville, Kingsville, TX, 78363, USA*

JEREMY BAUMGARDT, *Caesar Kleberg Wildlife Research Institute, Texas A&M University – Kingsville, Kingsville, TX, 78363, USA*

MICKEY W. HELLICKSON, *Orion Wildlife Management Services, Corpus Christi, TX, 78426, USA*

Estimating population sizes, recruitment, and sex ratios are essential for managing wildlife populations. Helicopters are commonly used to conduct surveys of white-tailed deer; however, they are expensive, risky, and not always practical. Camera surveys and spotlight counts are also used but are labor intensive. Unmanned aerial vehicles (UAVs) are an emerging technology that has yet to be fully evaluated for wildlife surveys in Tamaulipan thornscrub. We conducted UAV surveys on 5 ranches with known numbers of deer. Surveys were conducted in November and February to assess count variation with changes in canopy coverage. Further, daytime and nighttime surveys were conducted on each ranch to evaluate variation under different conditions. The UAV was equipped with a dual thermal and optical video camera. Heat signatures were detected on the thermal imagery, then identification was confirmed, when possible, via optical imagery. Our UAV counts were compared to raw counts from September helicopter surveys. Preliminary data shows 10.5% difference in daytime vs nighttime counts on the first ranch analyzed. During the daytime survey, 51.9% of thermal heat signatures were identified in optical footage giving us a 6.2% difference between confirmed ID detections and the raw helicopter counts. Daytime and nighttime thermal-only detections were 57.8% and 48.0% higher than the raw helicopter counts, respectively. The analysis is in progress and additional results will be discussed.

Presenter and email: Jesse Exum; jxexum@gmail.com

MULE DEER FAWN SURVIVAL ON NAVAJO NATION

JESSICA FORT, *Navajo Nation Department of Fish and Wildlife, 2457 Morgan Blvd., Window Rock, AZ, 86515, USA*

JEFFREY COLE, *Navajo Nation Department of Fish and Wildlife, 2457 Morgan Blvd., Window Rock, AZ, 86515, USA*

CLAYTON NIELSEN, *Cooperative Wildlife Research Laboratory, Southern Illinois University, 1263 Lincoln Drive, Carbondale, IL, 62901, USA*

HANNAH MANNINEN, *Cooperative Wildlife Research Laboratory, Southern Illinois University, 1263 Lincoln Drive, Carbondale, IL 62901, USA*

Mule deer (*Odocoileus hemionus*) are among the most sacred and economically valuable animals to the Navajo people (Diné) of Navajo Nation, a federally-recognized Indian tribe with 18 million acres of land in Arizona, New Mexico, and Utah. Similar to much of the West, mule deer populations on the Nation have been steadily declining over the last decade. In 2018, aerial surveys conducted by the Navajo Nation Department of Fish and Wildlife (NNDFW) revealed an alarming 53% decrease in population counts in comparison to surveys conducted in 2010. Further, fawn:doe ratios are well below those estimated in areas surrounding the Navajo Nation, and thus, prolonged low recruitment is likely the primary demographic reason for populations decline. In response to depressed numbers, NNDFW initiated the Navajo Mule Deer Project by deploying 40 Global Positioning System (GPS) collars on adult does in February 2018. The study has provided valuable baseline information on seasonal movements and mortality of adult mule deer; however, the specific mechanisms driving low fawn recruitment remain unknown. For NNDFW biologists and managers, understanding how production and recruitment of Navajo mule deer populations are affected by factors of habitat, predation, and disease is vital for the recovery of the species on Tribal lands. Therefore, NNDFW has launched a fawn survival study within the most critical region for mule deer on Navajo Nation, the Chuska-Carrizo mountain chain and Defiance Plateau. In March 2019, 25 Vaginal Implant Transmitters were deployed in pregnant does to initiative the fawn survival study. Methods will include fawn capture and deployment of GPS collars, monitoring of fawn survival and causes of mortality, and habitat assessments of fawning grounds. This project will deliver quantifiable performance measures for NNDFW future deer studies on Navajo Nation, prioritized areas for protection and enhancement of deer habitats, and capacity building within NNDFW. Further, this study will help contribute to the development of NNDFW's first Mule Deer Management Plan. Rooted in applied science, this Plan will include guidance regarding management of mule deer through sustainable-use hunting, habitat management, and policy development and implementation. Ultimately, the management plan's goal is to recover mule deer populations to a sustainable level that allows for the spiritual, cultural, and material benefit of present and future generations of Diné on the Navajo Nation.

Presenter and email: Jessica Fort; jfort@nndfw.org

TIME … AND CWD…MARCHES ON – AN OVERVIEW OF CHRONIC WASTING DISEASE IN ALBERTA AND MANAGING MULE DEER TO CONTROL CWD

JUSTIN GILLIGAN, *Alberta Environment and Parks, 4901 50 Street, Athabasca, AB, T92 1E2, Canada*

MARK BALL, *Alberta Environment and Parks, 7th floor OS Longman Building, Edmonton, Alberta, T6H 4P2, Canada*

MARGO PYBUS, *Alberta Environment and Parks, 7th floor OS Longman Building, Edmonton, Alberta, T6H 4P2, Canada*

Alberta, Canada is in a unique position with regards to Chronic Wasting Disease (CWD). We have a mixed assemblage of wild cervids, including mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginanus*), elk (*Cervus canadensis*), moose (*Alces alces*), and woodland caribou (*Rangifer tarandus*), as well as a long history of CWD surveillance. Alberta Fish and Wildlife began annual CWD disease surveillance of wild cervids, primarily using hunter samples, in 1998. The first CWD positive wild deer in Alberta was detected in 2005. This ongoing proactive surveillance, coupled with a "temporary" control program, provides valuable data that highlights disease progression across the landscape, among species and cohorts, as well as its impact of various management actions attempting to control prevalence and spread. Now entering its 21st year, the CWD surveillance program has test results from over 75,000 wild cervids, with a total of 1,420 positives to date [March 13 2019], primarily, yet not exclusively, in mule deer (87% of positives). Our programs and our data formed part of the basis to develop recommendations and best practices for cross-jurisdictional management and prevention of CWD in wild cervid populations, as adopted by WAFWA (Western Association of Fish and Wildlife Agencies) and AWFA (Association of Fish and Wildlife Agencies) in 2018. These documents are at the forefront of new CWD management policy, which concentrates on mule deer management to mitigate further spread of CWD across Alberta and among other native, cervid species.

Presenter and email: Justin Gilligan; justin.gilligan@gov.ab.ca

CONTRIBUTING PAPERS

EFFECTS OF SPIKE 20P ON HABITAT USE BY MULE DEER AND OTHER WILDLIFE IN TRANS-PECOS, TEXAS

REAGAN T. GAGE, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

LOUIS A. HARVESON, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

CARLOS E. GONZALEZ, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

**Correspondent email: carlos.gonzalez-gonzalez@sulross.edu*

ABSTRACT – Brush encroachment has been a suspected culprit for population declines of many obligate wildlife species of desert grasslands throughout the southwestern United States. Recently, the use of the herbicide Spike 20P ® has increased in the southwest United States to restore grasslands. Unfortunately, little data exist on the response of wildlife to Spike 20P applications. The use of habitats by mule deer (*Odocoileus hemionus*) and other wildlife was compared across Spike 20P treated plots and controls. Treatments included three and a half, four and a half, five and a half years post-treatment; control-hilly-mountain; and control-flat. Thirty-three mule deer were captured (15 M, 18 F) in Feb 2009 and 8 more (5 M, 3 F) added in Feb 2010 were added and monitored. Habitat use of other species of wildlife, including pronghorn (*Antilocapra americana*), scaled quail (*Callipepla squamata*), and javelina (*Pecari tajacu*), were observed by road surveys. In this study, Spike 20P did not appear to affect mule deer habitat use negatively. Road survey results for other species of wildlife varied. Before applying Spike 20P, we recommend acquiring pretreatment data on vegetation and soils. Creative application patterns should be incorporated to increase landscape structure and composition heterogeneity to promote diversity for mule deer.

Introduction

The Chihuahuan Desert grasslands are a highly biologically diverse ecosystem in the United States (Parmenter and Van Devender 1995, Whitford et al. 1995). Yet, the scope and state of the Chihuahuan Desert grassland have been adversely impacted (Buffington and Herbel 1995, Saab et al. 1995). Although many factors may contribute towards the decline of grasslands, brush encroachment is one of the major causes for the loss of the desert grasslands in the southwestern United States (Van Auken 2000, Browning et al. 2008).

Mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), and scaled quail (*Callipepla squamata*) are a few obligate species of desert grasslands. These species represent a considerable economic value for many public and private landowners in Texas (Payne et al. 1987, Cantu and Richardson 1997, Harveson 2007, Conner 2007). Recent accounts suggest a general decline of mule deer throughout their range (Gill 1999, Heffelfinger 2008). Similarly, populations of grassland species such as pronghorn and scaled quail have also declined

(Brennan and Kuvlesky 2005, Bristow and Ockenfels 2006, Sauer et al. 2007, Silvy et al. 2007, Simpson et al. 2007, Cearley 2008). It is considered that broad-scale habitat change (e.g., brush encroachment) is likely to explain these population declines. However, studies that describe these species' ecology relative to long-term environmental and habitat changes in the southwestern United States are lacking.

The herbicide Spike 20P ® (Dow AgroScienes LLC, Indianapolis, Indiana, USA) with the active ingredient tebuthiuron has recently increased in use and popularity among land managers in the southwestern United States. Spike 20P herbicide is used to control various types of woody plants. It is applied to the ground to penetrate the soil, killing woody plants through the root system. The Bureau of Land Management has been active in its efforts to restore native grassland with tebuthiuron, treating approximately 163,230 ha between 1997 to 2005 (USDI 2007). However, little is known about the ecological effects of Spike 20P in the southwestern United States. A study in eastern New Mexico reported daily survival of nests of grassland birds was greater in untreated plots; however, during the nestling period, the daily survival of nests was greater in tebuthiuron-treated plots (Smythe and Haukos 2009). In the southeastern United States, a study suggested tebuthiuron's effect on browse may have sufficiently altered white-tailed deer (*Odocoileus virginianus*) habitat quality; however, negative impacts seemed to be balanced by positive impacts on forage availability (DeFazio et al. 1988). To better understand wildlife's response to Spike 20P applications, we conducted an unreplicated study by comparing mule deer, and other wildlife habitat use across Spike 20P treated plots and controls.

Study Area

The study was conducted on Boracho Peak Ranch (BPR) in Culberson and Jeff Davis counties, Texas. The ranch encompasses 40,241 hectares. Elevations in BPR range from 1,220 m to 1,717 m. BPR is predominately made up of desert grasslands with mixed prairie ecological sites at higher elevations. The ranch lies in the Trans-Pecos region of the Chihuahuan Desert. This region located in Texas is delineated by the area west of the Pecos River. Topography and elevation in the Trans-Pecos vary from 762 m to 2,667 m. Higher elevations receive more precipitation (~50 cm) than the lowlands and basins (~22 cm; Powell 1998). Topography on the study site varied from flat, to gentle rolling hills, to steep mountains with numerous canyons and washes. The helicopter survey results estimated the total population size of 440 mule deer at BPR and a 91 ha/deer density. Typical plants included creosotebush (*Larrea tridentata*), tarbush (*Flourensia cernua*), lechuguilla (*Agave lechuguilla*), sotol (*Dasylirion* spp.), yucca (*Yucca* spp.), mariola (*Parthenium incanum*), blue grama (*Bouteloua gracilis*), black grama (*Bouteloua eriopoda*), and other short native grasses.

Methods

Mule deer were captured at random with a net gun fired from a helicopter (Krausman et al. 1985). Thirty-three mule deer were captured (15 M, 18 F) in Feb 2009, and 8 more (5 M, 3 F) were added in Feb 2010. Only does ≥1.5 years and bucks ≥2.5 years old were captured and fitted with VHF radio collars.

Radio-tracking was conducted from the ground with handheld 3-element Yagi antennas for two continuous years (2009 and 2010). Mule deer relocations were based on triangulations calculated with program LOAS ® (Ecological Software Solutions LLC, Florida, version 4.0). To avoid bias concerning temporal variation, crews attempted to equally sample 6 4-hour time intervals (0500-0900, 0900-1300, 1300-1700, 1700-2100, 2100-0100, and 0100-0500) during a 24-hr day. Individual relocations were temporally spaced by >24 hours. Hawth's Tools extension for ArcView was used to calculate 95% fixed kernel home ranges. Only individuals with >30 relocations were utilized in calculating home ranges. Core areas were designated by the 50% fixed kernels (Brunjes et al. 2006). To minimize error in relocation fixes for habitat analyses, we first calculated 100% minimum convex polygon. Any relocation with a 95% confidence ellipse > 5% the 100% minimum convex polygon was excluded (Relyea et al. 2000).

Habitat selection ratios were used to determine preferences between six habitat classifications. Selection ratios followed Johnson's (1980) first, second, and third orders of selection. We used the formula S = ([observed + 0.001]/[available + 0.001]); where habitats with S >1 were used more than expected, S <1 used less than expected, and S = 1 used according to availability. We compared average selection ratios of all deer (*n* = 37) as well as differences in average selection ratios between males (*n* = 16) and females (*n* = 21). The first order of selection (point to study area) compared the ratio of the percentage of relocation points in a particular habitat type of an individual's home range to the percentage of area available. The area available (study area) was determined by the area of the cumulative 100% MCP of all individuals' relocation points. The second order of selection (range to study area) compared the ratio of the percentage of each habitat type in an individual's core area to the percentage of habitat types available. The third order of selection (point to range) compared the percentage of relocation points in each habitat type of an individual's home range to the percentage of habitat types available in an individual's home range.

Habitats included Spike 20P treated years 2.5 years post-treatment (yrs-PT), 3.5 yrs-PT, and 4.5 yrs-PT; control-hilly-mountain (C-hill-mntn), control-flat (C-flat), and control-riparian (C-rip). Spike treatments consisted of those areas previously treated by Spike 20P herbicide in November 2005, November 2006, and February 2008. Control-hilly-mountain, C-flat, and C-rip treatments were not treated with Spike. Control-hilly-mountain was hilly and mountainous habitats, while C-flat was relatively flat. Both C-hill-mntn and C-flat habitats were delineated using a hill shade layer in ArcView. Control-riparian habitats were ephemeral draws or washes delineated by buffering a flowline shapefile by 100 m in ArcView. The total area treated with Spike 20P was approximately 21,653 ha. The application rate was 0.84 kg active ingredient per ha of Spike 20P herbicide in all treatments. Spike 20P was applied aerially with a fixed-wing aircraft. Spike treatments totaled approximately 6,864 ha, 8,756 ha, and 6,032 ha for 2.5 yrs-PT, 3.5 yrs-PT, and 4.5 yrs-PT, respectively.

To help determine the effects of Spike 20P on mule deer and other wildlife in Trans-Pecos, Texas, we conducted road surveys from October 2009 to October 2010. The same six habitat classes described for radio-tracking were used for road surveys. Wildlife recorded included mule deer, pronghorn, scaled quail, and javelina (*Pecari tajacu*). Surveys were driven during periods within two hours after sunrise and before sunset. Selection ratios were created by dividing the proportion of encounters in each habitat (use) by the proportion of length driven in each habitat (available), similar to the encounter rates method used by Saiwana et al. (1998). Grazing was deferred for two years after the application of Spike 20P. Subsequently, cattle grazed BPR at equal stocking rates throughout the ranch for the duration of the study. Human-made perennial water sources were distributed throughout BPR by distances that ranged from 0.8 km to 3.2 km.

Results

We collected 1,793 radio locations on 37 desert mule deer (16 M, 21 F) between February 2009 and October 2010. Of 1,793 total relocations, 1,116 were triangulations, and 677 were biangulations. The mean size of error ellipses for triangulations was 94 ha ± 21 ha *CI*. Only 28 mule deer (10 M, 18 F) were used in calculating home ranges. The average home range size was 4,864 ha ± 148 ha *CI*. Male home ranges were larger (5,655 ha ± 222 ha *CI*) than female home ranges (4,425 ha ± 109 ha *CI*).

Habitats preferred by mule deer in the first order of selection included C-rip, C-hill-mntn, and 2.5 yrs-PT (Figure 1). Habitats avoided by mule deer were 3.5 yrs-PT and C-flat. Females preferred C-hill-mntn habitats more than males. Preferred habitats in the second order of selection for all mule deer included C-rip, C-hill-mntn, 2.5 yrs-PT, and 4.5 yrs-PT (Figure 2). Habitats avoided were C-flat, and 3.5 yrs-PT. Males preferred C-hill-mntn habitats less than females. Habitats preferred in the third order of selection were C-rip, and C-hill-mntn (Figure 3). The 2.5 yrs-PT habitats were used according to availability, while C-flat, 3.5 yrs-PT, and 4.5 yrs-PT habitats were used less than expected. Control-riparian habitats were preferred by males, while females used them proportionately to their availability. C-hilly-mountain habitats were preferred by both sexes. However, females had a stronger preference than males.

Road survey results suggested mule deer preferred C-hill-mntn habitats. Other habitats preferred by mule deer included C-rip, and 2.5 yrs-PT. Mule deer avoided C-flat, 3.5 yrs-PT, and 4.5 yrs-PT habitats. Pronghorn preferred C-rip, 3.5 yrs-PT, and 4.5 yrs-PT habitats. Pronghorn avoided C-hill-mntn, C-flat, and 2.5 yrs-PT habitats. Scaled quail preferred C-rip, and C-flat habitats. Scaled quail avoided C-hill-mntn, 2.5 yrs-PT, 3.5 yrs-PT, and 4.5 yrs-PT habitats. Javelina preferred C-hill-mntn and 2.5 yrs-PT habitats. Javelina avoided C-rip, C-flat, 3.5 yrs-PT, and 4.5 yrs-PT habitats.

Discussion

Mule deer habitat preferences were most similar between the first and second orders of selection, compared to the third order of selection. Mule deer consistently preferred C-hill-mntn and C-rip more than expected. C-hill-mountain habitats provided topography important to mule deer for escape cover. Control-riparian habitats provided brush as a source of escape cover and provided the highest diversity of forage (Gage 2011). In addition to preferences toward C-hill-mntn and C-rip habitats, the first two orders of selection suggested mule deer preferred 2.5 yrs-PT habitats. The 2.5 yrs-PT habitats provided slightly more brush than 3.5 yrs-PT and 4.5 yrs-PT habitats (Gage 2011). Gage (2011) reported 4.5 yrs-PT habitats had higher levels of forb biomass. Forbs play a vital role in mule deer diets (Cantu and Richardson 1997). The third order of selection suggested 2.5 yrs-PT habitats were used equally to their availability, while 3.5 yrs-PT and 4.5 yrs-PT habitats were avoided. In all three orders of selection, both 3.5 yrs-PT and C-flat habitats were avoided. The 3.5 yrs-PT habitats had the least amount of forb biomass and forb species richness (Gage 2011). Females preferred C-hill-mntn habitats more than males. Previous mule deer studies suggested habitats such as C-hill-mntn to be important for fawn escape cover and predator avoidance (Riley and Dood 1984, Fox and Krausman 1994). In general, results from radio collared mule deer suggested that Spike 20P did not negatively affect mule deer habitat use.

Overall results from road surveys were similar to results from radio collared mule deer suggesting the greatest preference for C-hill-mntn habitats; however, C-rip and 2.5 yrs-PT habitats were also preferred. Mule deer avoided C-flat, 3.5 yrs-PT, and 4.5 yrs-PT habitats, while 4.5 yrs-PT was used more than C-flat and 3.5 yrs-PT habitats. Mule deer road survey results were most similar to the point to range selection ratio analyses of radio-collared mule deer.

Average home ranges for mule deer were much larger than previous studies in the Trans-Pecos (Dickinson and Garner 1979, minimum area method; Wampler 1981, minimum area method; Lawrence et al. 1994, 100% harmonic mean estimator; Reylea et al. 2000, 95% harmonic mean estimator). However, relocations used to calculate home range estimates were composed of two years of data, while we compared these results to previous studies that used annual home range estimates.

Pronghorn depend on eyesight and speed as their primary modes of defense against predators (Hailey 1986). Thus, habitats with high brush densities are usually avoided. This may explain the higher encounter rates of pronghorn in the 3.5 yrs-PT and 4.5 yrs-PT habitats. C-flat habitats, which had the highest brush cover (Gage 2011), were void of pronghorn.

Scaled quail were encountered less as years post treatment Spike 20P application increased. As years post treatment Spike 20P application increased, less cover from brush was available. In the Chihuahuan Desert, scaled quail use habitats with a mixture of mid and late-seral plant communities (Saiwana et al. 1998). The lack of brush and brush diversity may have deterred scaled quail use in Spike 20P treated plots.

Control-riparian habitats appeared to be important to all species except javelina. Difficulty in detecting javelina in brushy riparian habitats may have played a factor in fewer sightings in C-rip habitats. Javelina were frequently encountered in C-hill-mntn habitats. The 2.5 yrs-PT habitats were preferred more than 3.5 yrs-PT or 4.5 yrs-PT habitats. Higher preferences for 2.5 yrs-PT was likely due to the slightly higher brush diversity and cover (Gage 2011).

Riparian habitats with higher brush diversity were important habitats for mule deer and other species such as scaled quail and pronghorn. These areas should be excluded from Spike 20P applications. Spike 20P's effective control of invasive brush may further benefit true grassland species such as pronghorn. However, the transient loss of forb diversity due to herbicide (Gage

2011) should be considered. Spike 20P applications may be harmful to scaled quail habitat if sufficient amounts of brush are not available. Creative applications such as mosaics may benefit many species of wildlife by increasing diversity and landscape heterogeneity. Future studies should focus on collecting pretreatment data of wildlife densities and vegetation to evaluate further the effects of Spike 20P on vegetation and habitat use of wildlife.

Acknowledgements – This project was funded by grants from the Buena Vista Foundation, Sul Ross State University, and other private donors. We are appreciative of S. Gray and other volunteers during this project. We would like to thank G. H. Abell for providing funding for this research and access to Boracho Peak Ranch. We thank D. Mahler, T. Bryan, and S. Jewett for their help with data collection. We also thank many Sul Ross State University students for volunteering their time and effort for help with mule deer captures and data collection.

Literature Cited

Brennan, L. A. and W. P. Kuvlesky, Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Bristow, K. D. and R. A. Ockenfels. 2006. Fall and winter habitat use by scaled quail in southeastern Arizona. Rangeland Ecology and Management 59:308–313.

Browning, D.M., S. R. Archer, G. P. Asner, M. P. Mclaran, and C. A. Wessman. 2008. Woody Plants in Grasslands: Post-Encroachment Stand Dynamics. Ecological Applications 18:928–924.

Brunjes, K. J., W. B. Ballard, M. H. Humphrey, F. Harwell, N. E. Mcintyre, P. R. Krausman, and M. C. Wallace. 2006. Habitat use by sympatric mule and white-tailed deer in Texas. Journal of Wildlife Management 70:1351–1359.

Buffington, L. C. and C. H. Herbel. 1965. Vegetation changes on a semidesert grassland range from 1958 to 1963. Ecological Monographs. 35:139–164.

Cantu, R. and C. Richardson. 1997. Mule deer management in Texas. Texas Parks and Wildlife Department print shop. Austin.

Cearley, K. A. 2008. Scaled quail management in Trans-Pecos Texas. Pages 18–29 in Proceedings of the Trans-Pecos wildlife conference (B. J. Warnock, P. H. Dickerson, and L. A. Harveson editors). Sul Ross State University, Alpine, Texas.

Conner, J. R. 2007. Economic aspects of Texas quails. Pages 313–326 in Texas quails: ecology and management (L. A. Brennan, editor). Texas A&M University Press, College Station.

DeFazio, J. T. Jr., A. E. Stone, and R. J. Warren. 1988. Effects of tebuthiuron site preparation on white-tailed deer habitat. Wildlife Society Bulletin 16:12–18.

Dickinson, T. G. and G. W. Garner. 1979. Home range use and movements of desert mule deer in southwestern Texas. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 33:267–278.

Fox, K. B. and P. R. Krausman. 1994. Fawning habitat of desert mule deer. Southwestern Naturalist 39:269–275.

Gage, R. T. 2011. Effects of Spike 20P on vegetation and habitat use of mule deer and other wildlife in Trans-Pecos, Texas. M.S. thesis Sul Ross State University, Alpine, Texas.

Gill, R. B. 1999. Declining mule deer populations in Colorado: Reasons and Responses. Special Report Number 77, Colorado Division of Wildlife, Denver.

Hailey, T. L. 1986. A handbook for pronghorn antelope management in Texas. Texas Parks and Wildlife Department. Federal Aid Rep. Serial Number 20.

Harveson, L. A. 2007. Quails on the Trans-Pecos. Pages 202–216 in Texas quails: ecology and management (L. A. Brennan, editor). Texas A&M University Press, College Station.

Heffelfinger, J. 2008 Desert mule deer ecology and hybridization with whitetails. Pages 42–54 in Proceedings of the Trans-Pecos wildlife conference (Warnock, B. J., P. H. Dickerson, and L. A. Harveson, editors). Sul Ross State University, Alpine, Texas.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Krausman, P. R., J. J. Hervert, AND L. L. Ordway. 1985. Capturing deer and mountain sheep with a net gun. Wildlife Society Bulletin 13:71–73.

Lawrence, R. K., S. Demarais, AND R. S. Lutz. 1994. Population dynamics and habitat preferences of desert mule deer in the Trans-Pecos. Final report, Federal Aid Project W-127-R, Job 94. Texas Parks and Wildlife Department, Austin.

M. A. Powell. 1998. Trees and shrubs of the Trans-Pecos and adjacent areas. University of Texas Press, Austin.

Parmenter, R. R., and T. R. Van Devender. 1995. Diversity, spatial variability, and functional roles of vertebrates in the desert grassland. Pages 196–229 *in* M. P. McClaran and T. R. Van Devender, editors. The desert grassland. University Arizona Press, Tucson, Arizona, USA.

Payne, J. M., R. D. Brown, and F. S. Guthery. 1987. Wild game in Texas. Rangelands 5:207–211.

Relyea, R. A., R. K. Lawrence, and S. Demarais. 2000. Home Range of Desert Mule Deer: Texting the Body-Size and Habitat-Productivity Hypotheses. Journal of Wildlife Management 64:146–153.

Riley, S. J. and A. R. Dood. 1984. Summer movements, home range, habitat use, and behavior of mule deer fawns. Journal of Wildlife Management 48:1302–1310.

Saab, V. A., C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. Pages 311–353 *in* Martin, T. E. and D. M. Finch, editors. Ecology and management of neotropical migratory birds. Oxford University Press, New York, USA.

Saiwana, L., J. L. Holechek, A. Tembo, R. Valdez, and M. Cardenas. 1998. Scaled quail use of different seral stages in the Chihuahuan desert. Journal of Wildlife Management 62:550–556.

Sauer, J. R., J. E. Hines, and J. Fallon. 2007. The North American breeding bird survey, results and analysis 1966–2006. Version 10.13.2007. USGS Patuxent Wildlife Research Center, Laurel, Maryland.

Silvy, N. J., D. Rollins, and S.Whisenant. 2007. Scaled quail. Pages 65–88 in Texas quails: ecology and management (L. A. Brennan, editor). Texas A&M University Press, College Station.

Simpson, D. C., L. A. Harveson, C. E. Brewer, R. E.Walser, and A. R. Sides. 2007. Influence of precipitation on pronghorn demography in Texas. Journal of Wildlife Management 71:906–910.

Smythe, L. A. and D. A. Haukos. 2009. Nesting success of grassland birds in shinnery oak communities treated with tebuthiuron and grazing in eastern New Mexico. Southwestern Naturalist 54:136–145.

U.S. Department of Interior, BLM. 2007. Final biological assessment. Vegetation treatments on Bureau of Land Management lands in 17 western states programmatic environmental impact statement. BLM Nevada State Office. Reno, Nevada.

Van Auken, O. W. 2000. Shrub invasions of North American semiarid grasslands. Annual Review of Ecology and Systematics 31:197–215.

Wampler, G. E. 1981. Seasonal changes in home range and habitat preferences of desert mule deer in Pecos County, Texas. M.S. thesis, Sul Ross State University, Alpine, Texas.

Whitford, W. G., G. S. Forbes, and G. I. Kerley. 1995. Diversity, spatial variability, and functional roles of invertebrates in desert grassland ecosystems. Pages 152–195 *in* M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University Arizona Press, Tucson, Arizona, USA.

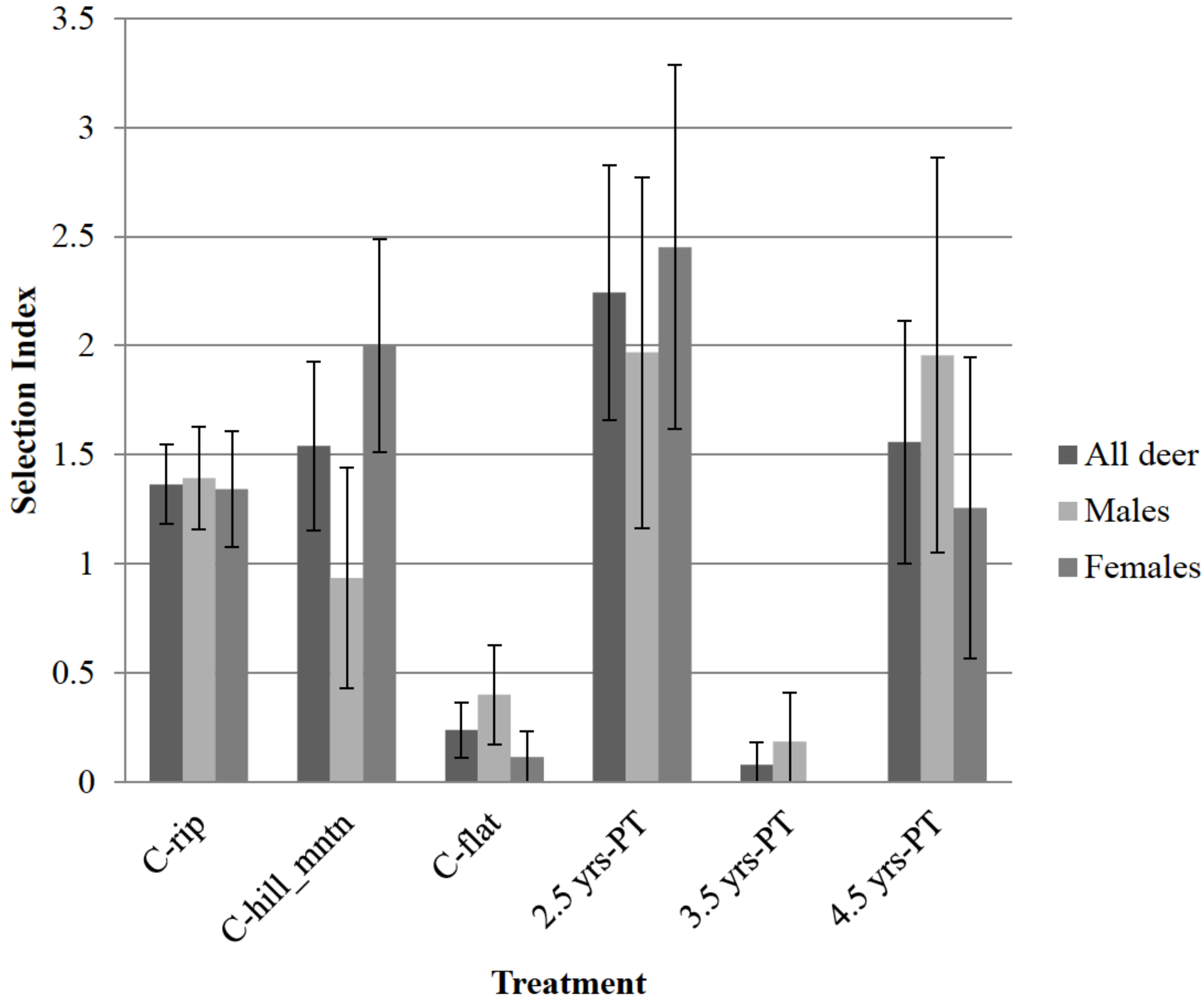


Figure 1. Point to study area habitat selection index for mule deer, Boracho Peak Ranch, Culberson and Jeff Davis counties, Texas, 2009–2010.

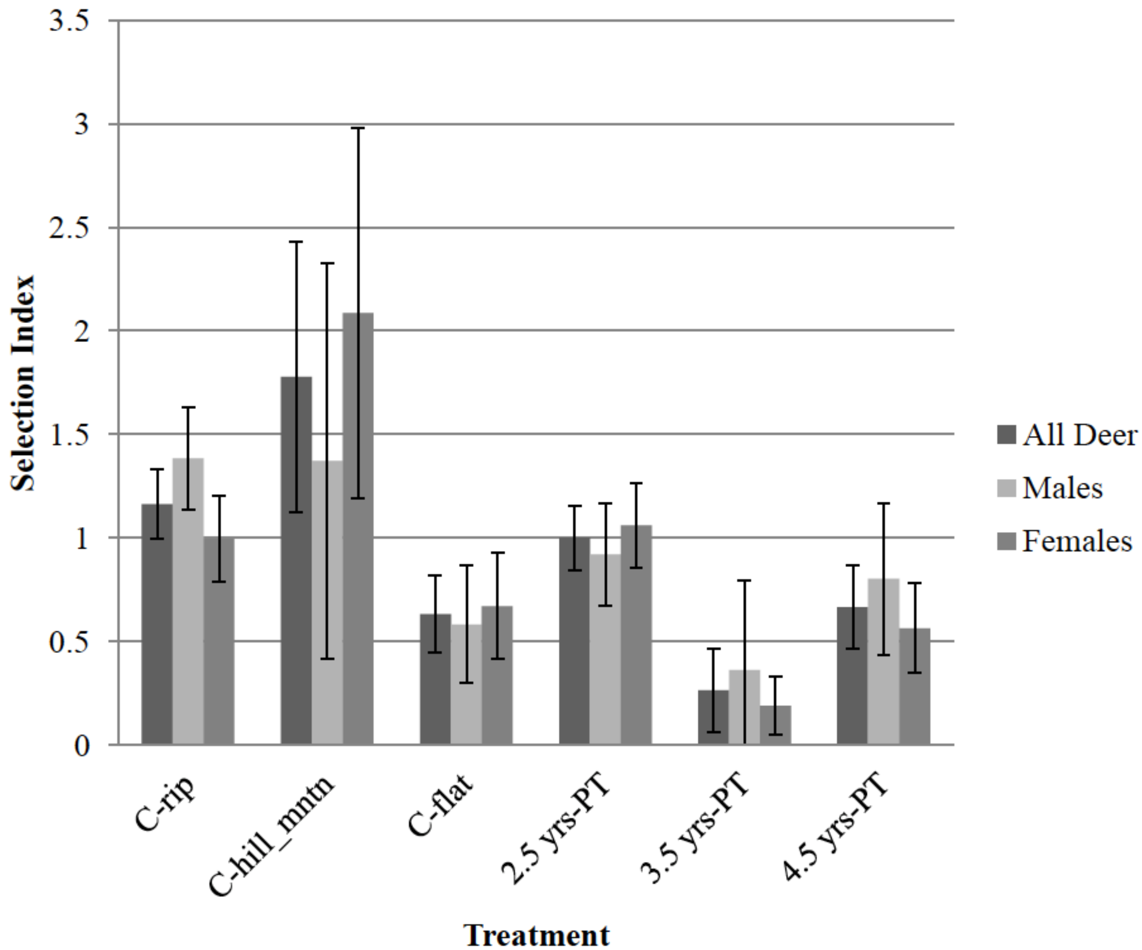


Figure 2. Range to study area habitat selection analysis for mule deer, Boracho Peak Ranch, Culberson and Jeff Davis counties, Texas, 2009–2010.

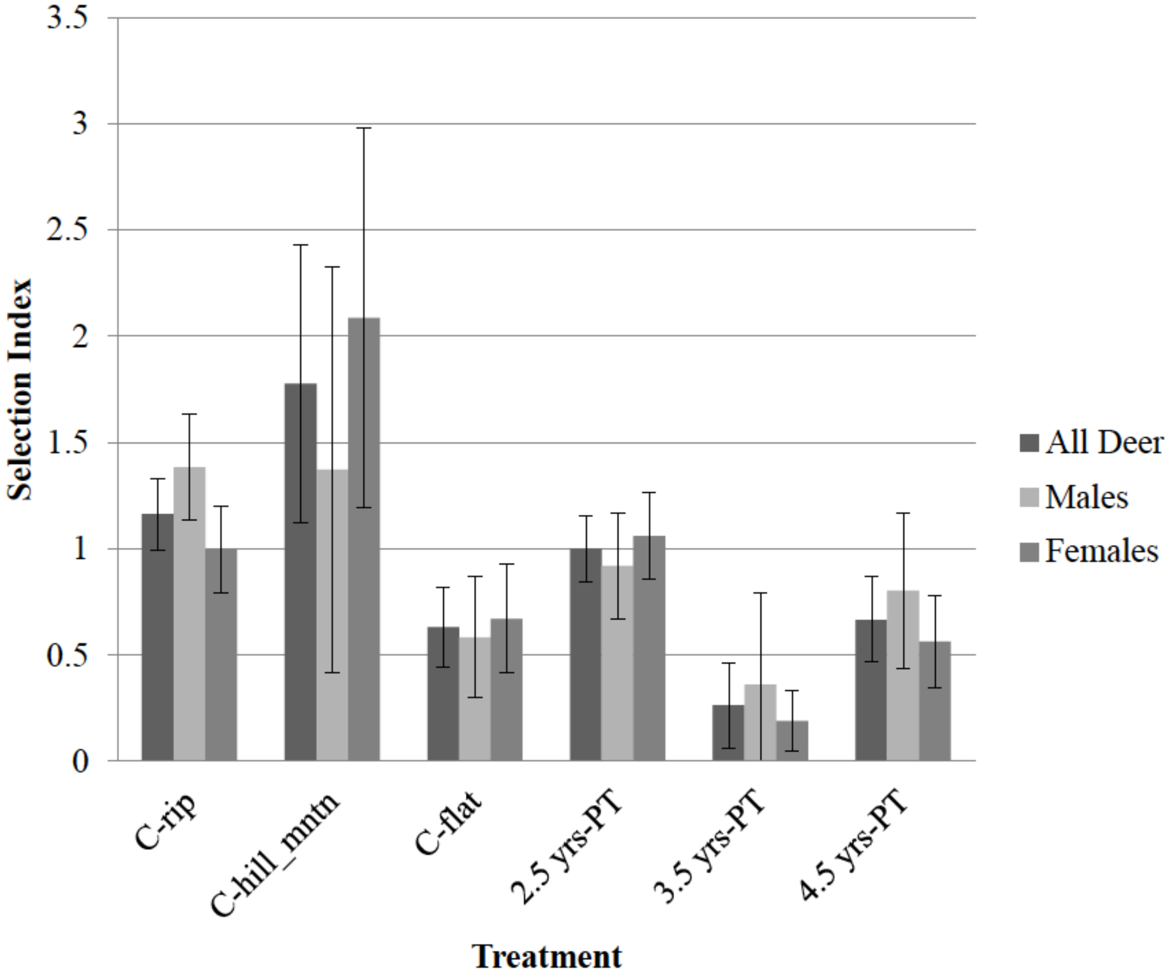


Figure 3. Point to range habitat selection analysis for mule deer, Boracho Peak Ranch, Culberson and Jeff Davis counties, Texas, 2009–2010.

AN EVALUATION OF LANDSCAPE-LEVEL CHANGES OF HABITATS ACROSS BROAD TEMPORAL SCALES AND THEIR RELATION TO DESERT MULE DEER POPULATION TRENDS IN THE TRANS-PECOS REGION OF TEXAS

DUSTIN L. HOLLOWELL, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

LOUIS A. HARVESON, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

CARLOS E. GONZALEZ, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

**Correspondent email:* carlos.gonzalez-gonzalez@sulross.edu

Abstract – Mule deer *(Odocoileus hemionus)* populations throughout the western United States have experienced unprecedented declines. Desert mule deer were once common in most mountain ranges throughout the Trans-Pecos region of Texas, but desert mule deer have shown a decline over the past 20 years. Previous research has suggested that the declines are likely an indirect result of prolonged drought. However, little information exists on the causative factors leading to the decline. Because mule deer populations have declined at the landscape level, we initiated a study to evaluate region-wide declines of desert mule deer in the Trans-Pecos region. The objective was to assess habitat changes (e.g., brush encroachment, habitat fragmentation, land-use patterns) relative to trends of desert mule deer populations. Change detection was performed on remotely sensed imagery for the 9-county region of the Trans-Pecos for periods corresponding to changes in mule deer abundance: mid-1980s, mid-1990s, and mid-2000s. The relationship between changes in landscape features and mule deer populations were evaluated at herd unit and region-wide scales. Changes observed over longer temporal intervals (10 years) were not related to mule deer populations. When observed on a 2-year time interval, negative correlations were found between change in the negative direction and population trends. The results of this project may help resource managers and landowners better understand relationships between mule deer populations and landscape-level changes in habitat.

Introduction

Monitoring and managing rangelands and habitats across a broad temporal scale at a landscape-level have previously been unreasonable due to expense, lack of available labor, and other factors (West, 2003). New approaches to using, developing, and managing rangelands may be considered with advances in remote sensing and computing technologies like Geographic Information Systems (GIS; Tueller 1989, 1983). As rangelands may make up as much as 47% of the earth's surface (Williams et al. 1968), a cost-effective method of monitoring, detecting, and quantifying change at landscape-level, region-wide, and smaller scales will be a valuable tool for resource managers.

Rangelands provide valuable habitat for many species of wildlife across the western United States, including mule deer (*Odocoileus hemionus*). The rangelands of the southwestern United States, particularly the Trans-Pecos region of Texas, provide habitat for a myriad of wildlife, including desert bighorn sheep (*Ovis canadensis*), pronghorn (*Antilocapra americana*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*), and desert mule deer (Davis and Schmidly 1994, Heffelfinger 2006).

Desert mule deer were once common in most mountain ranges throughout the Trans-Pecos region of Texas (Davis and Schmidly 1994). However, these populations have shown a declining trend from 1978 to 2004 (Figure 1) and exhibited a 55% decline from 1986 to 2000. Although the declines are likely an indirect product of long-term drought (Walser 2006), previous studies in the region (Phillips 1974, Brownlee 1981, Reylea 1992, Lawrence 1995, Cooke 1988) did not address causative factors for the declines at a landscape-level. Therefore, a landscape-level assessment of habitat changes and long-term population trends needed to be addressed.

Using remotely sensed images, GIS, and historical mule deer survey records from the Texas Parks and Wildlife Department (TPWD), I initiated a landscape-level approach to detecting and quantifying habitat changes (e.g., brush encroachment, habitat fragmentation, and changes in land-use patterns) and their correlation to periods of declining mule deer populations. Specifically, my objectives were to 1) provide a time and cost-efficient method of detecting and quantifying changes in rangeland habitats at large temporal intervals, and 2) evaluate the amount and degree of change and its relation to changes in mule deer populations.

Study Area

Trans-Pecos, Texas is a diverse region comprised of a 9-county area (El Paso, Hudspeth, Culberson, Reeves, Pecos, Terrell, Brewster, Presidio, and Jeff Davis) located at the western edge of Texas (Figure 2). Located in the Chihuahuan Desert Biotic Province, the Trans-Pecos ecoregion is approximately 7.3 million ha and is bordered to the east by the Pecos River, to the west, and south by the Rio Grande River, and to the north by New Mexico (Hatch et al. 1990). Elevations range from 762-2,667 m, with the higher elevations being mountainous terrain. Several mountain ranges, including the Barilla, Baylor, Beach, Christmas, Chinati, Chisos, Davis, Del Norte, Eagle, Franklin, Glass, Guadalupe, Santiago, Sierra Diablo, Sierra Vieja, Van Horn, and Wiley reside in the Trans-Pecos region (Powell 1998). Annual precipitation varies from 20-46 cm, mainly in monsoonal thunderstorms in July, August, and September. Higher elevations receive more rainfall (30–46 cm) than the lowlands and basins (20–30 cm). Soils in the region vary with deep sands along desert washes, gravel mulch in the desert lowlands, and shallow rocky soils on slopes of mountains. Main vegetation types include desert scrub, desert grasslands, and oak (*Quercus* spp.)-pinyon-juniper woodlands in much of the higher elevations.

Methods

In 2005, TPWD changed its survey method from fixed-wing and spotlight surveys to helicopter surveys for population density estimations. Herd unit boundaries were also redefined in 2005 (Shawn Gray, TPWD personal communication). Therefore, any data collected after 2004 was not compatible with the historical data used in this research. Until 2005, the Trans-Pecos region of Texas was divided into 20 mule deer herd units by which the mule deer were managed (Figure 3).

Twenty-six years (1978–2004) of aerial and spotlight surveys have been collected by TPWD and were organized by these herd units. These surveys recorded the number of bucks, does, and unknown deer, and distinguished between young and adult deer. Population demographics, including densities, sex ratios, and fecundity, were calculated from these data. For my analyses, 20 years of survey data were used (1984–2004) to coincide with this study.

Landsat TM scenes (p30r39, p31r39, and p32r39) were acquired for years 1985, 1995, and 2005 covering the Trans-Pecos region from the Earth Resources and Observation Science (EROS) Center. Scenes were selected during photosynthetic activity near the end of the growing season so that vegetation was most mature (August-October). Scenes selected during this period allow for clearer atmospheric conditions and ease of using vegetation indices (Washington-Allen et al. 2006). Images were standardized according to the manual for ATCOR3® for ERDAS Imagine 9.2 (Leica Geosystems Geospatial Imaging, LLC, Atlanta, Georgia, USA). This software was used to help achieve haze reduction and atmospheric correction of all raw Landsat images.

In arid regions such as the Chihuahuan Desert, factors other than vegetation tend to dominate reflectance values (Franklin et al. 1993, Allnutt et al. 2002). Therefore, only the red (band 3) and near infrared (NIR; band 4) bands from each standardized image were used to calculate a single–band soil-adjusted vegetation index (SAVI) for each scene by year (Huete 1988). The SAVI is similar to the commonly used normalized-difference vegetation index (NDVI; Tucker, 1979), which is correlated with ecological indicators commonly collected in the field, such as plant cover and phytomass (Colwell 1974, Hatfield et al. 1984, Asrar et al. 1984, Sellers 1985). However, SAVI is used because the vegetation signal-to-noise ratio is reduced by soil background reflectance in other vegetation indices, and SAVI was specifically developed to increase the vegetation signal in arid rangelands (Huete 1988). The SAVI is calculated with the equation: $SAVI = [(NIR - red)/(NIR + red + L)] * (1 + L)$ where $L = 0.5$. The SAVI scenes were mosaicked by year using the mosaic tool under the DataPrep tab in ERDAS Imagine® 9.2 (Leica Geosystems Geospatial Imaging, LLC, Atlanta, Georgia, USA) and clipped to the boundary of the Trans-Pecos region of Texas using the extract by mask tool in ArcGIS 9.2 (ESRI, Redlands, California, USA). Coverage included the majority of the Trans-Pecos region and encompassed 17 of the herd units. The change was calculated and detected from 1985 to 1995, and 1995 to 2005, respectively, using the temporal image differencing method (Lillesand et al. 2004) with the raster calculator tool in the Spatial Analyst Extension of ArcGIS 9.2. Image differencing is simply subtracting the digital numbers (DN) of the latter year observed from the earlier year. The DN from the product image was divided by the DN of the earlier year to get a percent change (e.g., Percent Change = [(1985-1995)/1985]). Values of the DN with SAVI generally range from –1.5 to 1.5. As with NDVI, a positive value with SAVI is indicative of increased moisture and vegetation; hence, a change in the positive direction is a sign of more lush, greener, or denser vegetation on the landscape. Conversely, a negative value or change in a negative direction indicates a more arid landscape and less dense vegetation. The pixels of the resulting change detection images were reclassified into categories of direction of change (positive or negative) and degree of change depending on the DN values. Categories used for degree of change included: no change (-10% to +10%), slight change (10.01-50%; +, -), moderate change (50.01-100%; +, -), and extreme change (>100%; +, -; Table 1) for each herd unit as well as region wide.

Based on general population trends displayed by mule deer, I organized herd units into 3 categories: increasing, stabilizing, and decreasing. I evaluated the potential impacts of habitat change of herd units by comparing population trends to trends in landscape changes from 1985 to 1995 and from 1995 to 2005. Comparisons were made in each herd unit. Data from all herd units were then combined and evaluated as region-wide. Statistical analysis was not incorporated due to small sample sizes. Landscape change was evaluated for each herd unit and region-wide by 10-year time intervals leaving only two samples: 1985 to 1995 and 1995 to 2005.

Results

Herd Units

Changes were classified first by herd unit. All herd units selected exhibited overwhelmingly positive change (86.6% to 96.6%) from 1985 to 1995. The mean positive change displayed in the herd units was 96.6%. The mean negative change for all herd units was -1%. In all herd units, nearly all change occurred in the slight positive change (10 to 50%), and moderate positive change (51 to 100%) categories, with the majority (66%) of this change experienced being moderate positive change.

From 1995 to 2005, the herd units experienced change mainly negatively (-56.9% to -96.7%). The mean negative change for herd units was -83.8%. Virtually all change encountered in this time frame occurred in the slight negative change (-10 to -50%), moderate negative change (-51 to -100%), and extreme negative change (>-100%) categories with no distribution pattern between categories. The no change categories were also examined for each time period. The average amount of each herd unit exhibiting no change from 1985–1995 was 2.1%, and 8.5% from 1995 to 2005. In the latter time period, herd units experienced less change than those from 1985 to 1995. Seventeen herd units were contained within the Landsat coverage. However, only 9 of the herd units (HU07, HU08, HU14, HU17, HU18, HU19, HU23, HU26, HU31) had complete survey data for the 21 years selected (1984-2004) and were included in figure representation (Table 2). Herd units with mostly complete data sets are discussed. Herd units in southern Culberson County (HU09), south-central Brewster County (HU18), and east-central Brewster County (HU19) revealed increasing populations from the beginning inferential time frame. Twelve herd units, including those in northern Hudspeth County (HU01), split by Hudspeth and Culberson counties (HU07, HU08), divided by Culberson and Jeff Davis counties (HU10, HU11), Culberson County (HU12), Jeff Davis County (HU14), Brewster County (HU15), Presidio County (HU17), southern Terrell County (HU23), and Pecos County (HU26; HU31) had populations with an initial declining trend and begin stabilizing or increasing trends after 1995 and were classified as stabilizing populations. Population trends in northern Culberson County

(HU13) and northern Brewster/southwestern Pecos counties (HU20) continued to decline during this frame.

Trans-Pecos Region

Changes were classified for the entire region (Table 4). From 1985 to 1995, 95.9% of all change in the Trans-Pecos occurred in the positive direction, with only 1.7% of all change in the negative direction. Conversely, from 1995 to 2005 change experienced in the region occurred primarily in the negative direction with 82.0%, and only 9.3% of the change in this time frame was in the positive direction. From 1985 to 1995, 2.35% of the Trans-Pecos region experienced no change, and 8.67% of the region went without change from 1995 to 2005. Hence, the Trans-Pecos region habitats were more stable in the second time period. The mule deer population for the Trans-Pecos region showed declining trends in the first time period but began to increase after 1995.

Discussion

Thirteen of the 17 herd units evaluated observed an increasing or stabilizing trend from 1995 to 2005. Herd units in southern Terrell County (HU23) and eastern Pecos County (HU31) showed the most dramatic positive population changes in the second time frame. The insight provided by TPWD (Calvin Richardson, personal communication) suggests that until the early to mid-1990s, rangelands in the Trans-Pecos region, mainly the eastern portion was primarily used for livestock grazing. Since then, many landowners and land managers have decreased livestock numbers in the Trans-Pecos region (USDA National Agricultural Statistics Service) and have incorporated wildlife into their operations, leading to less competition between mule deer and livestock. This could contribute to the impressive population increases displayed in Terrell and Pecos counties and may also explain stabilizing and increasing populations in all herd units and across the region.

Habitat stability (lack of change) may also influence desert mule deer population trends. Nearly 4-times (1995 – 2005 = 8.7%, 1985 – 1995 = 2.4%) more of the Trans-Pecos rangelands experienced no change 1995 to 2005 than from 1985 to 1995. All herd units experienced a similar outcome with slightly more than 4-times (1995 – 2005 = 8.5%, 1985 – 1995 = 2.1%) more pixels in the no change category in the second time frame. This suggests that mule deer populations may be sensitive to landscape-level disturbances.

Numerous factors have been identified that influence mule deer populations and habitats. Young and Evans (1973) found that fire suppression could increase invasive species such as downy brome (*Bromus tectorum*). Miller and Rose (1999) found similar results involving western juniper (*Juniperus occidentalis*) encroachment. Depending on frequency, intensity, and timing, livestock grazing may be detrimental or beneficial to wildlife habitat (Anderson et al., 1990; Severson, 1990; Urness, 1990). Comer (1982) reported that oil-gas-mineral exploration and extraction impacts mule deer habitats directly and indirectly. Urban areas are expanding, resulting in losses of farmland, forests, and rangeland. Across the U.S., nearly 6.5 million ha of land were converted by development (Natural Resource Conservation Service 1999).

Walser (2006) was able to correlate mule deer demographics in west Texas with precipitation and drought. Similar results were recorded for pronghorn in western Texas (Simpson et al., 2006). Precipitation determines plant growth in the Trans-Pecos region of Texas and other desert environments (Schmidly 1977). In turn, plant growth directly affects the quality and quantity of habitat through adequate cover and forage. Habitat quality and quantity are also directly related to anthropogenic disturbances such as fire suppression, livestock grazing, urban sprawl, and oil-gas-mineral exploration and extraction, as well as natural factors (e.g., precipitation, brush encroachment). Consequently, any alteration of habitat quality and quantity may affect mule deer populations. However, being able to track these changes and directly transmit their relationship to mule deer populations has proven difficult.

The image differencing method of change detection is the most often used change detection method in practice and has been shown to accurately reveal habitat change when used with a single band vegetation index such as NDVI or SAVI (Lyon et al. 1998, Ridd and Liu 1998). The SAVI is documented as the preferred vegetation index to use in arid rangelands similar to the Trans-Pecos region of Texas. Hence, this study incorporated the best tools possible for accurately portraying landscape-level habitat changes. However, I was unable to directly link mule deer population trends to trends in landscape-level changes in habitat in this study, as illustrated by image differencing with SAVI due to a large temporal and spatial scale and variability in population surveys.

Ten-year time intervals may have been too large for comparison to mule deer population spikes and crashes. Population densities may rise and fall several times within the 10 years, regulated by factors other than habitat change. Contrarily, the 20-year inferential frame may not be sufficient for evaluating long-term population trends and their relationship to habitat. More extended periods of time may be necessary for mule deer populations to react to habitat change as there may be a lag in the populations' response to the habitat change.

Assessing habitat changes on such a large spatial scale may also limit the ability to detect a relationship between these changes and population trends. SAVI has been sufficient for monitoring rangelands on smaller spatial scales (Washington-Allen et al. 2006), but has yet to be linked to herbivores. This indicates that the index may not be sensitive enough to identify specific habitat changes that affect ungulate populations. Thirty-meter resolution was required to have adequate coverage of such a large study area and limited our ability to assess changes in mule deer-specific habitat requirements. Finer resolution and a smaller study area would likely produce more accurate findings.

Density estimates can be expensive, labor intensive, and limited to habitat with high visibility (Lancia et al. 1994). These factors may influence data at large temporal scales as well as annually. Lack of funding, unattainable workloads for local agencies, and various surveyors may prohibit consistent surveys and complete long-term datasets. Variable climates may also be a culprit in the variability of survey data. Erratic weather may alter mule deer behavior patterns and make surveys difficult or impossible to conduct, leading to an inaccurate representation of density. Sampling designs may be altered to lower the cost, effort, or both required in obtaining density estimates (Roberts et al. 2006). Anderson (2001) states that sampling this sort is criticized widely due to the probability of bias.

Management Implications

Future research should focus not only on detecting and quantifying change on smaller spatial and temporal scales, but also on identifying types of habitat change (e.g., brush encroachment, urban development). The relationships between types of change and how they relate to population demographics, including densities, sex ratios, fecundity, and recruitment, should be prioritized. If given a chance to design similar research, I would create spectral signatures for each habitat type encountered with the finest resolution available. These signatures could, in turn, apply to small or larger resolution such as Landsat TM imagery, and habitats could be mapped by supervised classification. User accuracy should be assessed through ground truthing the signatures for the most current time series. Spectral signatures could be developed for each time interval, and habitats could be mapped by time period throughout the temporal frame. This would allow the user to identify changes in specific habitats, quantify the changes, and evaluate the effects of the changes on wildlife populations. However, advances in these processes are needed to recognize ways to make this less expensive and applicable at a smaller spatial scale and reduced temporal intervals.

Acknowledgements – We thank the Rob and Bessie Welder Wildlife Foundation for funding and Texas Parks and Wildlife Department for providing data and their knowledge of the region.

Literature Cited

Allnutt, T. F., W. W. Wettengel, J. V. Reyna, R. C. De Leon Garcia, E. E. Ińigo Elias, and D. M. Olson. 2002. The efficacy of TM satellite imagery for rapid assessment of Chihuahuan xeric habitat intactness for ecoregion-scale conservation planning. Journal of Arid Environments 52:135–153.

Anderson, W. E., D. L. Franzen, and J. E. Melland. 1990. Rx grazing to benefit watershed-wildlife-livestock. Rangelands 12:105–111.

Anderson, D. R. 2001. The need to get the basics right in the wildlife field studies. Wildlife Society Bulletin 29:1294–1297.

Asrar, G., M. Fuchs, E. T. Kanemasu, J. L. Hatfield. 1984. Estimating absorbed photosynthetic radiation and leaf area index from spectral reflectance in wheat. Agronomy Journal 76:300–306.

Brownlee, S. 1981. Mule deer productivity. Federal aid in wildlife restoration act final report No. 31. Texas Parks and Wildlife Department, Austin, Texas.

Colwell, J. E. 1974. Vegetation canopy reflectance. Remote Sensing Environment 3:175-183.

Comer, R. D. 1982. Understanding secondary effects of development on wildlife resources. Pages 16-35 *in* R. D. Comer, J. M. Merino, J. W. Monarch, C. Pustmueller, M. Stalmaster, R. Stoecker, J. Todd, and W. Wright, editors. Proceedings of the symposium on issues and technology in the management of impacted western wildlife. Thorne Ecological Institute. Boulder, Colorado. Figure 1. Population estimates of desert mule deer in the Trans-Pecos region of West Texas from 1978 to 2004.

Cooke, J. L. 1988. Predictability of change in density distribution of desert mule deer (*Odocoileus hemionus crooki*) in the Black Gap Wildlife Management Area of Brewster County, Texas. Thesis, Sul Ross State University, Alpine, Texas.

Davis, W. B., and d. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife Press, Austin, Texas.

ESRI. 2005. Version 9.0 ESRI, Redlands, California, USA.

Franklin, J., J. Duncan, and d. L. Turner. 1993. Reflectance of vegetation and soil in Chihuahuan Desert plant communities from ground radiometry using SPOT wavebands. Remote Sensing of Environment 46:291–304.

Hatch, S. L., K. N. Gandhi, and L. E. Brown. 1990. Checklist to the vascular plants of Texas. Publication MP-1655, Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas.

Hatfield, J. L., G. Asrar, and E. T. Kanemasu. 1984. Intercepted photosynthetically active radiation estimated by spectral reflectance. Remote Sensing Environment 14:65–75.

Heffelfinger, J. 2006. Deer of the southwest: a complete guide to the natural history, biology, and management of mule deer and white-tailed deer. Texas A&M University Press, College Station, Texas.

Huete, A. R. 1988. A soil-adjusted vegetation index (SAVI*).* Remote Sensing of Environment. 25:295–309.

Lancia, R. A., J. D. Nichols, and K. H. Pollock. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T. A. Bookhout, editor. Research and management techniques for wildlife habitats. Fifth edition. The Wildlife Society, Bethesda, Maryland.

Lawrence, R. K. 1995. Population dynamics and habitat use of desert mule deer in Trans-Pecos region of Texas. Dissertation, Texas Tech University, Lubbock, Texas.

Leica Geosystems Geospatial Imaging. 2005. Erdas Imagine version 9.2, Atlanta, Georgia.

Lillesand, T. M., R.W. Kiefer, and J. W. Chipman. 2004. Digital image processing. Pages 491-637 *in* Remote Sensing and Image Interpretation: Fifth Edition. Leigh Press, New Jersey.

Lyon, J. G., D. Yuan, R. S. Lunetta, and C. D. Elvidge. 1998. A change detection experiment using vegetation indices. Photogrammetric Engineering and Remote Sensing 64:143-150.

Miller, R. F., and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management 52:550–559.

Natural Resource Conservation Service. 1999. 1997 National Resources Inventory. Washington, DC, and Statistical Laboratory, Iowa State University, Ames, Iowa, 89 pages.

Phillips, J. L. 1974. The annual cycle of desert mule deer *(Odocoileus hemionus crooki)* in relation to vegetation use. Thesis, Sul Ross State University, Alpine, Texas.

Powell, A. M. 1998. Trees and shrubs of the Trans-Pecos and adjacent areas. University of Texas Press, Austin, Texas.

Reylea, R. A. 1992. Desert mule deer movement and behavior in Southwest Texas. Thesis, Texas Tech University, Lubbock, Texas.

Ridd, M. K., and J. Liu. 1998. A comparison of four algorithms for change detection in an urban environment. Remote Sensing of Environment 63:95–100.

Roberts, C. W., B. L. Pierce, A. W. Braden, R. R. Lopez, N. J. Silvy, P. A. Frank, and D. Ransom, JR. 2006. Comparison of camera and road survey estimates for white-tailed deer. Journal of Wildlife Management 70:263–267.

Schmidly, D. J. 1977. The mammals of Trans-Pecos Texas. Texas A&M University Press, College Station, Texas.

Sellers, P. J. 1985. Canopy reflectance, photosynthesis, and transpiration. International Journal of Remote Sensing 6:1335–1372.

Severson, K. E. 1990. Can livestock be used as a tool to enhance wildlife habitat? USDA Forest Service General Technical Report. FM-194, Ft. Collins, Colorado.

Simpson, D. C., L. A. Harveson, C. E. Brewer, R. E. Walser, and A. R. Sides. 2006. Influence of precipitation on pronghorn demography in Texas. Journal of Wildlife Management 71:906–910.

Tucker, C. J. 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing Environment 8:127–150.

Tueller, P. T. 1983. Rangeland remote sensing: an approach. Proceedings of the RNRF Symposium on the Application of Remote Sensing to Resource Management. American Society for Photogrammetry. Seattle, Washington. p. 42–45.

Tueller, P. T. 1989. Remote sensing technology for rangeland management applications. Journal of Range Management 42:442–453.

United States Department of Agriculture. National Agricultural Statistics Services. www.nass.usda.gov

Urness, P. J. 1990. Livestock as manipulators of mule deer winter habitats in northern Utah. Pages 25-40 *in* E. Severson editor. Can livestock be used as a tool to enhance wildlife habitat? Society of Range Management, Symposium, USDA Forest Service General Technical Report RM-194, Ft. Collins, Colorado.

Walser, R. E. 2006. Influence of precipitation and the effects of season change on desert mule deer populations in Trans-Pecos, Texas. Thesis, Sul Ross State University, Alpine, Texas.

Washington-Allen, R. A., N. E. West, R. D. Ramsey, and R. A. Efroymson. 2006. A protocol for retrospective remote sensing-based ecological monitoring of rangelands. Rangeland Ecology and Management 59:19–29.

West, n. E. 2003. History of rangeland monitoring in the U.S.A. Arid Land Research and Management 17:495–545.

Williams, R. E., B.E. Allred, R.M. Denio, and H.A. Poulsen Jr. 1968. Conservation, development, and use of the world's rangelands. Journal of Range Management 21:355–360.

Young, J. A., and R. A. Evans. 1973. Downy brome – intruder in the plant succession of big sagebrush communities in the Great Basin. Journal of Range Management 26: 410–415.

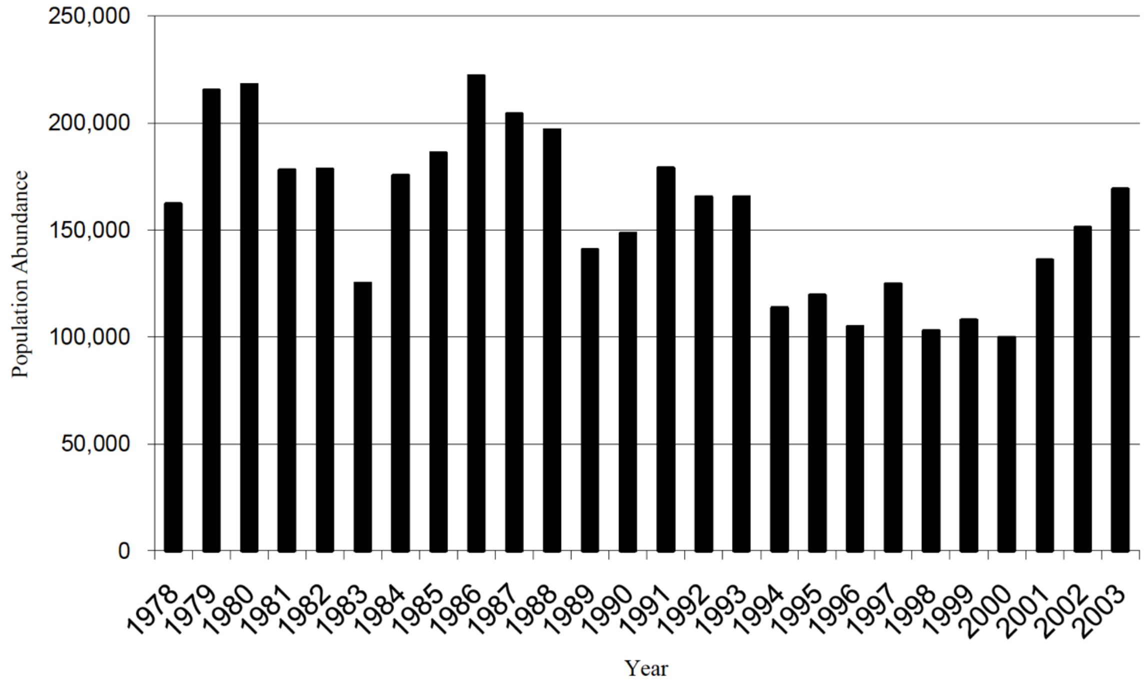


Figure 1. Population estimates of desert mule deer in the Trans-Pecos region of west Texas from 1978 to 2004.

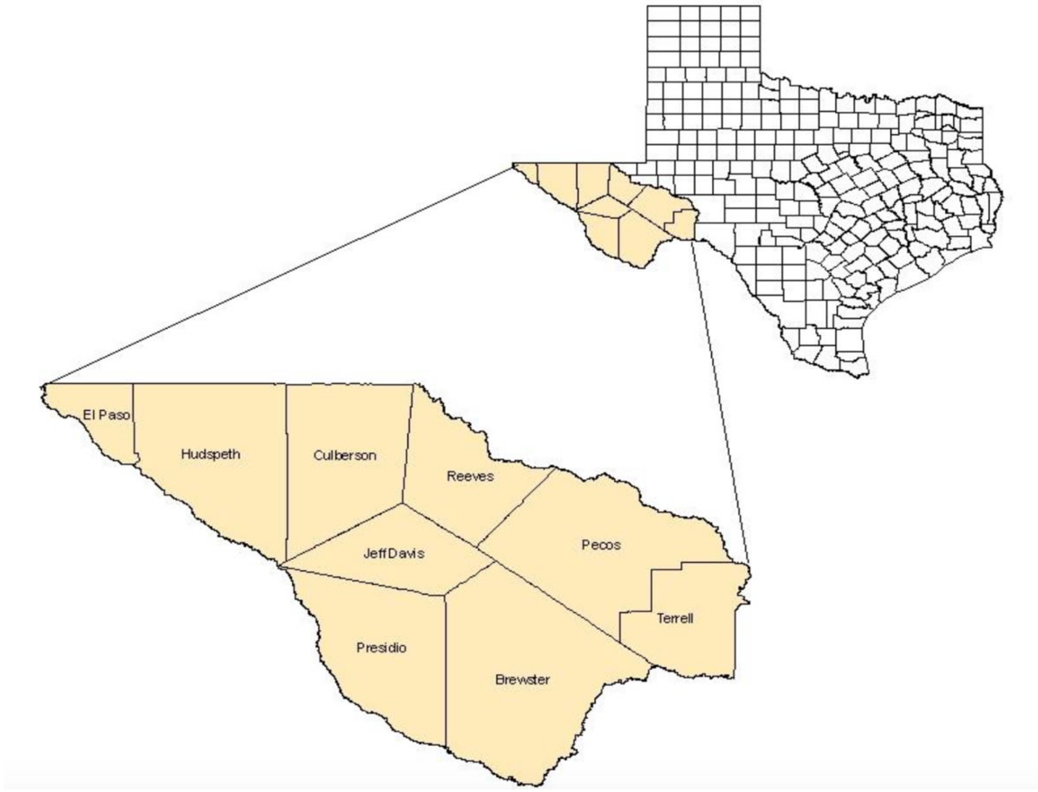


Figure 2. The 9-county region referred to as the Trans-Pecos region of Texas.

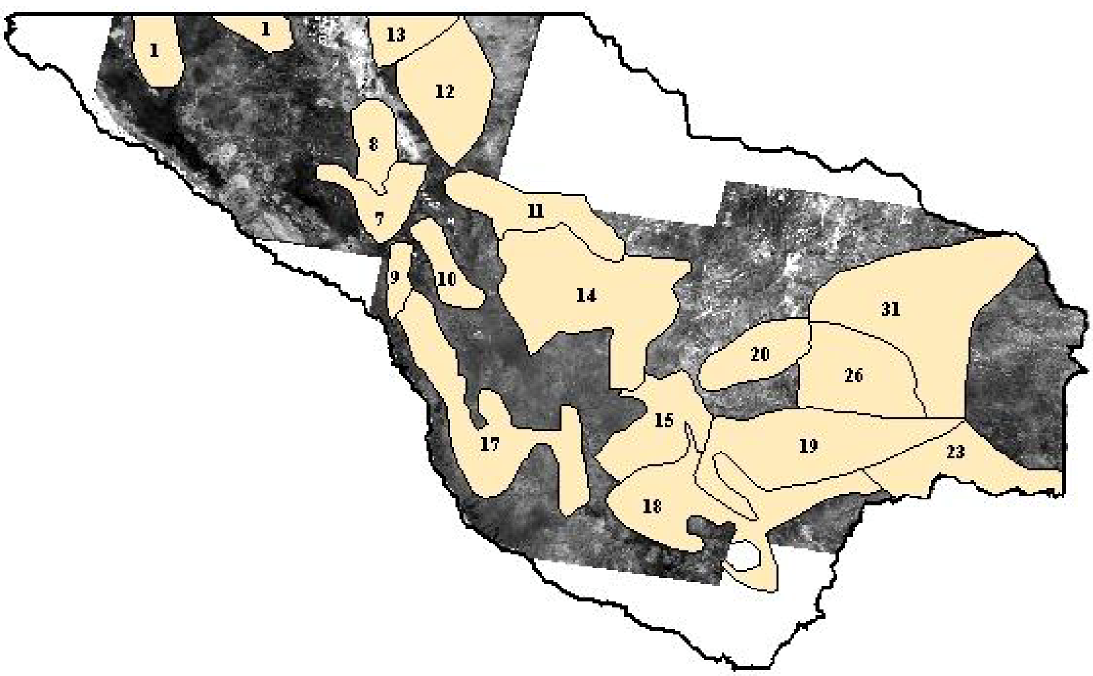


Figure 3. The Trans-Pecos region of Texas and the 20 herd units by which desert mule deer in the region were managed from 1984 to 2004.

Table 1. Categories used for classification of change including the degree of change (%) and the direction of change.

Degree of Change (%)	Category	Direction
>100.0	extreme change	positive
50.01 ≥ 100.0	moderate change	positive
10.01 ≥ 50.0	slight change	positive
10.0 to –10.0	no change	--
-10.01 ≤ 50.0	slight change	negative
-50.01 ≤100.0	moderate change	negative
<-100.0	extreme change	negative

Table 2. Herd units of the Trans-Pecos region of Texas and the corresponding years of mule deer population survey data available from 1984 to 2004.

Herd Unit	Years of Data	Number of Years	Trend
HU01	1984-1990, 1992,1994, 1998-2001	13	stabilizing
HU07	1984-2004	21	stabilizing
HU08	1984-2004	21	stabilizing
HU09	1984-1986, 1988-2002	18	increasing
HU10	1984-1999, 2004	17	stabilizing
HU11	1984-1994, 1998-2001, 2003-2004	17	stabilizing
HU12	1984-1994, 1998-2001, 2003-2004	17	stabilizing
HU13	1984-1995, 1998-2001	16	decreasing
HU14	1984-2004	21	stabilizing
HU15	1984-1999, 2001, 2003-2004	19	stabilizing
HU17	1984-2004	21	stabilizing
HU18	1984-2004	21	increasing
HU19	1984-2004	21	increasing
HU20	1994-2004	11	decreasing
HU23	1984-2004	21	stabilizing
HU26	1984-2004	21	stabilizing
HU31	1984-2004	21	stabilizing

EFFECTS OF SUPPLEMENTAL FEED ON ANNUAL AND SEASONAL HOME RANGES OF MATURE MULE DEER BUCKS IN TRANS-PECOS, TEXAS

ANDREW S. JAMES, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

LOUIS A. HARVESON, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

CARLOS E. GONZALEZ, *Department of Natural Resource Management/Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

**Correspondent email: carlos.gonzalez-gonzalez@sulross.edu*

Abstract – Understanding mule deer (Odocoileus hemionus) ranges could give insight into the necessary resource requirements to meet each animal's needs on a seasonal or annual basis. However, limited research has been conducted on home ranges in the Trans Pecos region of Texas. To better understand the movements of mule deer, our objectives were to estimate annual and seasonal home ranges and note the possible effects of supplemental feed on home ranges. Approximately 40 mature bucks (>4.5 yr old) were captured using a helicopter and net gun from 2 study areas over a 5-yr period (2006 – 2010). Supplemental feeders were available to mule deer on one site but not on the other. Upon capture, mule deer were aged and fitted with a global positioning system (GPS) radio collar programmed to record locations every 5 hours. Mule deer were then recaptured annually to retrieve the GPS collars and take the additional body and antler measurements. Home ranges were found to be much larger than estimated in previous studies, with 95% kernel home range estimates of 35.3 km2 and 45.0 km2 for supplemental-fed and non-fed mule deer, respectively. Home range size varied between ages, seasons, and study areas with a range of 20.5 km2 – 96.2 km2. Data suggest that supplemental feed may improve distribution and allow mule deer to utilize marginal habitat. Knowledge gained from this study about home ranges and habitat use will allow biologists and landowners to make more informed management decisions.

Introduction

Assessing home ranges and movements of mature mule deer (*Odocoileus hemionus*) in the Trans-Pecos has been an emerging topic of discussion in recent years. However, few studies have been conducted within the region on the issue. Recent advancements in technology, including the use of global positioning system (GPS) collars, computer programs such as ArcGIS and Hawths Tools, and Kernel Density Estimation methods, may allow for more accurate assessments analyzing home ranges and movements. Dickinson and Garner (1979) and Relyea (2000) did not have the luxury of using the computer software tools available today when they conducted several studies on home range size and movements of mule deer in west Texas.

Home range is defined as the area used by an animal as it meets its needs for food, water, cover, and social interactions. (Burt 1943). Home range may be considered within various periods, including daily, annual, and seasonal, breeding, and fawning seasons (Powell 2000). Several methods have been used to determine home range sizes during specific time periods producing varying results. The use of radio collar technology has vastly improved the accuracy of determining home ranges for many different animals. One standard method in determining an individual's home range is simply drawing a line around the outermost locations to create what is known as a Minimum Convex Polygon (MCP) (Mohr 1947). In recent years, an advance in technology uses the Kernel Density Estimation (KDE) method of determining a home range (Silverman 1986).

The knowledge gained from this study will aid biologists and landowners in the Trans-Pecos, Chihuahuan Desert, and the Southwestern United States to manage mule deer populations for hunting and recreational purposes as identify the potential risk to spread disease among individuals. Understanding an individual's home ranges will give insight into the necessary resource requirements to meet the needs of each animal on a seasonal or annual basis. Management decisions for mule deer populations require that accurate information be collected and analyzed (Heffelfinger 2006). Mule deer populations throughout the western United States respond differently to various regional environmental and habitat conditions. Objectives were to estimate annual and seasonal home ranges on supplemental and non-fed sites of mature mule deer bucks in the Apache Mountains of the Trans-Pecos region of Texas.

Study Area

The Trans-Pecos is delineated by the Rio Grande River and Mexico to the south and west, the 32nd parallel and New Mexico to the north, and the Pecos River to the east (Martin 2002). The Apache Mountains are north of Interstate Highway 10 and approximately 35 km east northeast of Van Horn, Texas, in Culberson County (Figure 1). The Apache Mountains are privately owned by 2 landowners, with the main ridgeline serving as the boundary between the 2 properties. Supplemental feed was made available south of the ridgeline but not to the north (Figure 2).

The Apache Mountains feature limestone-based geology with soils ranging from gravelly along hillsides and flats to silt alluvium in draw areas (NRCS 2013). The mountains are oriented primarily east to west with elevations ranging from 1,000 m to 1,700 m with slopes rarely exceeding 70%. There are various water sources throughout the study sites, including ephemeral streams and manmade dirt tanks that hold surface water during and following the monsoonal rains during the summer and early fall. Water troughs originally intended for livestock provide a stable, perennial water supply throughout the study area. There is approximately 1 water trough per 4 km^2. Annual rainfall ranges from 28–38 cm across the study site, with more precipitation occurring as you move east and increase in elevation across the study sites.

The Apache Mountains are located within the Southern Desert Basins, Plains, Mountains major land resource area (MLRA 42) and include several different ecological habitat types (NRCS 2006). Ecological sites include gravelly, limestone hill and mountains, limestone hill dry mixed prairies, loamy, sandy loam, draws, sandy, and gyp outcrops (NRCS 2011).

Vegetation within the Apache Mountains varies greatly with elevation change and geographically from east to west. Grass species include black grama (*Bouteloua eriopoda*), blue grama (*Bouteloua gracilis*), sideoaots grama (*Bouteloua curtipendula*), threeawn (*Aristida* spp.), tobosa (*Hilaria mutica*), and alkali sacaton (*Sporobolus airoides*) (Hatch 2007). Forbs, shrubs, and trees include fourwing saltbush (*Atriplex canescens*), creosotebush (*Larrea tridentata*), tarbush (*Flourensia cernua*), Apache plume (*Fallugia paradoxa*), skeleton-leaf goldeneye (*Viguiera stenoloba*), and broom snakeweed (*Gutierrezia sarothrae*). Lechugilla (*Agave lechuguilla*), ocotillo (*Fourquieria splendens*), yucca (*Yucca* spp.*),* and sotols (*Dasylirion* spp.) are also found frequently throughout the study area.

Methods

Capture

From 2006 to 2010, mature mule deer bucks were captured on the Apache (supplemental-fed) and Jobe (non-fed) ranches. Captures were conducted each year between February 1 and March 15. Mule deer were captured using the helicopter and net-gun method (Barrett et al. 1982). In 2006, 20 mature (estimated ≥4.5 years of age) mule deer bucks were initially captured (10 from within the supplemental-fed area and 10 from the non-fed area). In 2007, 5 mule deer (3 supplemental-fed, 2 non-fed) were recaptured while 12 new animals were captured (8 supplemental-fed, 4 non-fed). During 2008 and 2009, 9 and 8 (5, 4 supplemental-fed, 4, 4 non-fed) and 9 and 10 deer (5, 5 supplemental-fed, 4, 5 non-fed) were recaptured, respectively. In 2010, 10 deer were recaptured (7 supplemental-fed, 3 non-fed) while 8 from the supplemental-fed area were new. There were no collars placed on new mule deer within the non-fed area in 2010. In March of 2011, all animals were recaptured, and collars were retrieved.

Once each mule deer was captured, they were hobbled, blindfolded, and transported to a processing station, where they were aged using the tooth wear and replacement method (Robinette et al. 1957). Only mule deer that were ≥4.5 yrs of age were restrained by 2 or 3 people, while each mule deer was ear-tagged and fitted with an Advanced Telemetry Systems (ATS) global positioning system (GPS) collar. Collars were fitted to allow for neck swelling during the rut. Animals were pursued by the helicopter for no more than 8 min (Webb et al. 2008). Handling times at the processing location were ≤10 min to reduce stress and minimize the potential for capture myopathy. All capture and handling procedures were consistent with Sul Ross State University Institutional Animal Care and Use Committee (IACUC) procedures and Texas Parks and Wildlife Department Scientific Permit for Research (SPR) number 0592-525.

Data Collection

ATS GPS 2000 collars (Advanced Telemetry Systems Inc., Isanti, MN) were programmed to attempt a fix every 5 hrs for 1-2 yrs. A fix included recording the GPS coordinates, date, time, temperature, number of satellites available to calculate the coordinate data, and an elevation whenever 3-dimensional fixes were available. A fix was successful if at least 3 satellites could be detected by the device within 5 minutes of the collar activating, while a fix was not successful if sufficient satellites were not available. The latter occurred only rarely and was likely attributed to the location of the mule deer in rugged terrain at the time (D'Eon et al. 2002).

Once an animal was recaptured, the collar was removed and brought back to the lab where the data was analyzed (Table 1). ATS software was used to download the data from the collar into a comma-separated value (.csv) text file. Those files were then imported into Microsoft Excel and then into ArcGIS ArcView 9.3 mapping software.

Data Analysis

The fixed-kernel method was used to estimate annual and seasonal home ranges of mature mule deer bucks using the Hawths Tools extension kernel density estimator in ArcGIS® ArcView 9.3. A 95% home range value and a 50% core use area value were determined for each season and year. A Gaussian bivariate normal distribution was assumed, and a least squares cross validation smoothing parameter was used to develop kernel density estimations (Skrobarczyk 2011).

Home ranges were determined for 4 seasons: spring (1 Mar–31 May), summer (1 Jun–31 Aug), fall (1 Sep–30 Nov), and winter (1 Dec–28 Feb). The year was divided into these particular reasons, including various climatic conditions and biological needs of mule deer throughout the year. The spring is usually the driest time of year in the Trans-Pecos, while mule deer may be coming out of a hard winter and searching for the limited but lush new forb and browse growth that is high in nutrition. The summer is usually associated with monsoonal rains, and the majority of plant growth occurs during this time and the fall. During the fall, mule deer are trying to build reserves and store fat for the upcoming winter (Dietz and Nagy 1976). The winter includes the breeding season and a time when there is little or no new vegetation growth. An annual home range was calculated if locations were recorded for 3 seasons beginning on March 1 of a given year. Differences between seasons, years, ages, and supplemental-fed vs. non-fed deer were analyzed using IBM SPSS statistical software (SPSS, Inc., Chicago, IL). The Shapiro-Wilks and Levine's test for equality of variance were used to determine if the data were normally distributed to decide if parametric or non-parametric tests would be used to evaluate the results further. The Mann-Whitney test of independent samples was used to determine differences between annual and seasonal home ranges between sites. The Kruskal-Wallis, independent samples test, was used to determine differences between seasons, years, and ages for each ranch.

Results

Collar Data

A total of 31 individual mule deer collared on the supplemental-fed site and a total of 54 collar years. Only 39 collar years were used for analysis, while the remaining 15 collar years were lost due to data storage difficulties or collar malfunctions and were never recovered from the field (Figure 3). There were 60576 ($\bar{x}$ = 1553) locations with 57859 (95%) 3-D locations. Fix rate was ≥ 98% on 36 of 39 collars. Three collars had fix rates of 81%, 90%, and 96%, respectively. A total of 23 different mule deer were captured on the non-fed site and included 37 collar years. 23 collar years were used for analysis, while the remaining 14 collars were never recovered or incurred data malfunctions. Of the collars used for analysis, there were 37992 ($\bar{x}$ = 1652) total locations, of which 36065 (95%) were 3-D locations. Fix rate was ≥98% on all collars.

Range Size

Annual 95% fixed kernel home ranges were determined for each mature mule deer buck (n = 34 supplemental-fed, n = 22 non-fed). Average annual home range size for mule deer on the supplemental-fed site (35.3 km^2, SE = 1.9 km^2) and non-fed site (45.0 km^2, SE = 4.2 km^2) was different (P = 0.048) (Figure 4). Seasonal home range differences between sites varied depending on the season. Spring home ranges for the supplemental-fed site (n = 39, 27.7 km^2, SE = 1.3 km^2) and non-fed site (n = 23, 31.8 km^2, SE = 3.0 km^2) were not different (P = 0.427). Summer and winter home range sizes between sites were also not different (summer, P = 0.127 winter, P = 0.190) although home ranges on the supplemental-fed site for summer (n = 35, 24.3 km2, SE = 1.1 km^2) and winter (n = 30, 36.3 km2, SE = 3.2 km^2) were smaller than the non-fed site for summer (n = 22, 28.1 km^2, SE = 1.9 km2) and winter (n = 21, 41.1 km^2, SE = 3.58 km^2). There was a significant difference (P = 0.003) between ranches during the fall with home ranges of (n = 34) 20.6 km^2 ± SE = 1.02 km^2 and (n = 22) 25.7 km^2 ± SE = 1.74 km^2 for the supplemental-fed and non-fed sites, respectively.

A Kruskal-Wallis test was used to identify any significant differences between home range sizes for different years on each site. The non-parametric independent samples test identified differences (P = 0.014) between years on the supplemental-fed site. Adjusted significance values post-hoc tests revealed that the primary differences (P = 0.023) occurred between the years 2006 (31.3 km^2, SE = 2.0 km^2) and 2008 (23.3 km^2, SE = 1.3 km^2). Differences between other years at the supplemental-fed location and on the non-fed site (P = 0.782) were not different There were seasonal differences in home range size within both the supplemental-fed (P < 0.001) and non-fed (P = 0.003) sites. Further tests revealed that differences on the supplemental-fed site were between spring (27.7 km^2, SE = 1.3 km^2) and fall (20.6 km^2, SE = 1.0 km^2, P < 0.001), summer (24.3 km^2, SE = 1.1 km^2) and winter (36.3 km^2, SE = 3.2 km^2, P = 0.006), and fall (20.6 km^2, SE = 1.0 km^2) and winter (36.3 km^2, SE = 3.2 km^2, P < 0.001). For the non-fed site, differences occurred between summer (28.1 km^2, SE = 1.89 km^2) and winter (41.1 km^2, SE = 3.22 km^2, P = 0.034), and fall (25.7 km^2, SE = 1.74 km^2) and winter (41.1 km^2, SE = 3.22 km^2, P = 0.002).

Differences between age classes were reviewed on both the supplemental-fed and non-fed sites, but no disparity was observed. Significance levels were P = 0.667 and P = 0.546 for supplemental-fed and non-fed sites, respectively.

50% Kernel Core Use Areas

Significant differences in core use area size between sites were observed during the summer, fall, winter, and annual time periods (Figure 5). Core use areas during the summer (P = 0.046) were 5.4 km^2 ± SE = 0.26 km^2 for the supplemental-fed site and 6.7 km^2 ± SE = 0.53 km^2 for the non-fed site. During the fall ($P = 0.004$), core use areas were 4.6 km^2 ± SE = 0.22 km^2 and 5.9 km^2 ± SE = 0.35 km^2 for supplemental-fed and non-fed sites, respectively. Core use areas during the winter ($P = 0.017$) were 7.0 km^2 ± SE = 0.46 km^2 for the supplemental-fed site and 9.1 km^2 ± SE = 0.74 km^2 for the non-fed site. Annual core use areas ($P = 0.007$) were 6.9 km^2 ± SE = 0.42 km^2 and 9.75 km^2 ± SE = 0.96 km^2 for the supplemental-fed and non-fed sites respectively. Average core use area size for mule deer during the spring on the supplemental-fed site (6.0 km^2, SE = 0.32 km^2) and non-fed site (7.1 km^2, SE = 0.63 km^2) was not significantly different (P = 0.218).

The size of core use areas between years for each site was also evaluated for significance. There was a difference between years on the supplemental-fed site ($P = 0.018$), while no differences were detected for the non-fed location ($P = 0.467$). Adjusted significance values of post-hoc tests showed that differences between years occurred between 2006 (6.7 km^2, SE = 0.41 km^2) and 2008 (5.1 km^2, SE = 0.32 km^2) ($P = 0.029$).

Differences between core use areas between seasons for each ranch were also assessed. There were differences on both the supplemental-fed ($P < 0.001$) and non-fed sites ($P = 0.010$). Adjusted significance values showed that differences in the supplemental-fed site occurred between the spring (6.0 km^2, SE = 0.32 km^2) vs. fall (4.6 km^2, SE = 0.22 km^2) ($P = 0.009$), and fall (4.6 km^2, SE = 0.22 km^2) vs. winter (7.0 km^2, SE = 0.46 km^2) ($P = 0.006$) seasons. Differences in the non-fed site only occurred between fall (5.9 km^2, SE = 0.36 km^2) and winter (9.1 km^2, SE = 0.96 km^2) ($P = 0.029$) seasons (Figure 6).

Differences between age classes were reviewed on both the supplemental-fed and non-fed sites, but no disparity was observed. Significance levels were $P = 0.759$ and $p = 0.760$ for supplemental and non-fed sites respectively.

Discussion

Home Ranges

Mule deer home ranges have been examined across the western United States for several decades. Still, only a few studies have included the desert subspecies found in the Trans-Pecos region of Texas. Research conducted in the Trans-Pecos many years ago used obsolete technology to question the quality of the data. Wampler (1981) conducted a study in Pecos County that concluded that home range sizes for male mule deer were 6–9 km^2. Two studies conducted in Brewster county reported that home range sizes were 10–12 km^2 (Lawrence et al., 1994) and 13-14 km2 (Relyea et al., 2000). The results of these studies were much smaller average home range sizes than those for the supplemental-fed (35.3 km^2) and non-fed (45.0 km^2) sites in our study. Our results for core use areas for supplemental-fed (6.9 km^2) and non-fed (9.8 km^2) are similar to annual home range sizes reported in previous studies. These differences could be attributed to the acquisition of higher quality data enabled by advances in technology, such as replacing traditional VHF collars with GPS collars. Krausman (1985) found that average home range sizes of male desert mule deer were 71–160 km^2 with a range of 20–389 km^2 across 3 study sites in Arizona. Although our results indicated smaller home range sizes than those of Krausman, they fall within the range of home range sizes that he observed. Forage and other resource availability might explain the differences between the 2 studies.

Unlike mule deer found in other parts of the western United States, (e. g., Colorado, Idaho, or Utah), desert mule deer in west Texas are not considered migratory (Robinette 1966, Garrott et al. 1987, Brown 1992). Before our study, seasonal home ranges of non-migratory mule deer in Texas had not been evaluated. Seasonal home ranges were categorized as spring, summer, fall, or winter. In most years, spring is the driest season in the Trans-Pecos, while monsoonal rains and rapid vegetative growth characterize the summer. Precipitation decreases once fall arrives. The winter season includes the rut or breeding season for mule deer (Cantu 1997). Differences between seasonal home ranges were observed for both the supplemental-fed and non-fed sites (Table 2). Home ranges tended to decrease regardless on both sites from March through November before drastically increasing in size during the winter. Winter home ranges tended to be similar in size to annual home ranges indicating that maximum movements to the outer edges of the annual home ranges took place during this time period. Summer and fall home ranges may have been smaller due to increased precipitation and vegetative growth during this time of the year. Deer moving in search of forage during the driest part of the year may explain why home ranges during the spring were larger than the summer and fall seasons. Similar trends were also noted for 50% kernel core use areas (Table 3).

Although statistical tests revealed no significant differences between ages of supplemental-fed and non-fed deer, a general trend was observed. Bucks were not radio-collared for this study unless they were at least 4.5 years old, so differences between yearling, immature, and mature bucks cannot be analyzed, but 95% kernel home range sizes did tend to decrease as mule deer age increased. Fifty percent of core use area sizes were less predictable and stayed relatively the same for all ages.

When seasonal home ranges were evaluated by age, few differences were found. An exception occurred during winter when there was a noticeable difference between 4.5year old deer and ≥5.5 year old deer. Winter home ranges for 4.5 year olds were more than 1.5 times larger than any other age class with an average of 54.3 km^2 and a range from 26.7–90.5 km^2. This suggests that 4.5 year old bucks may not be as dominant during the breeding season as older deer. Younger, less dominant bucks tend to “float” or wonder about in an unpredictable fashion, while dominant bucks tend to stay with doe-fawn groups during the rut (Geist 1981).

Water distribution also plays a vital role in determining an individual’s home range size, and it has been recommended that water sources be no more than 4–5 km apart to ensure that mule deer will access all available habitats rather than around limited water sources (Brownlee 1979, Dickinson and Garner 1979).

Movements

GPS locations were recorded every 5 hrs and up to 5X/day for each deer throughout the year. Although a sufficient number of data points were recorded to provide accurate estimations of home ranges and habitat use, research utilizing greater numbers of points is needed to more intensively analyze daily deer movements across the landscape, including at finer scales than analyzed herein. More intense sampling frequencies are required for accurate measurement of fine-scale movements (Mills 2006). Although only of anecdotal interest, several extreme movements were observed during the study, suggesting that mule deer can move tremendous distances over relatively short periods of time. One mule deer, in particular, moved 25.5 km over a 25-hr period and 10.9 km in 5 hrs. The same deer moved more than 35 km from the center of his core use area. There were several other deer, all 4.5 years of age, which moved >20 km at some point throughout the year. Brownlee (1963) also documented mule deer moving as much as 23 km in the Trans-Pecos, although he suggested that mule deer rarely moved further than 2.5 km. Further evaluation of male and female mule deer movements of all age classes is necessary to determine these behaviors' commonality or exceptionality.

Management Implications

Home ranges of desert mule deer bucks were much larger in the Trans-Pecos region of Texas than those defined by other studies. Distribution of food and water has been shown to impact home range sizes. Home range size tends to be inversely proportional to food resource availability. This study supports the theory that home ranges were smaller in areas where additional food resources (supplemental feed) were more available. Knowing home range sizes and identifying limiting resources such as food and water will help biologists and resource managers develop management plans to suit mule deer better. Understanding differences in seasonal home range size may assist landowners when making management decisions.

***Acknowledgements* –** Funding for this study was provide by the San Antonio Livestock Exposition, Sul Ross State University, and the D. A. Hughes Jr. family and friends. We are appreciative of M. Sumner, G. Strickhausen, L. Sumner, and many volunteers that assisted with the project.

Literature Cited

Advanced Telemetry Systems Inc., GPS Collar Quick Guide. Advanced Telemetry Systems, Isanti, Minnesota, USA.

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

Brown, C. G. 1992. Movement and migration patterns of mule deer in Southeastern Idaho. Journal of Wildlife Management 56:246–253.

Brownlee, S. L. 1963. Seasonal movement of mule deer. Texas Parks and Wildlife Dept., Fed. Aid. Proj. Texas W-57-R-11/Job 8 Job Compl. Rept., Austin, TX.

Brownlee, S. L. 1979. Water development for desert mule deer. Texas Parks and Wildlife Department, Austin, Texas, USA.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24:346–352.

Cantu, R., and C. Richardson. 1997. Mule deer management in Texas. Texas Parks and Wildlife Department PWD BK W7100–303.

D'Eon, R. G., R. Serrouya, G. Smith, and C. O. Kochanny. 2002. GPS radiotelemetry error and bias in mountainous terrain. Wildlife Society Bulletin 30:430–439.

Dickinson, T. G., and G. W. Garner. 1979. Home range and movements of desert mule deer in southwestern Texas. Proceedings of the Annual Conference of Southeastern Fish and Wildlife Agencies 33:267–268.

Dietz, D. R. and J. G. Nagy. 1976. Mule deer nutrition and plant utilization. Pp. 71–78. In: Proc., Mule Deer Decline in the West. Utah State University, Logan, Utah.

Garrott, R. A., G. C. White, R. M. Bartmann, L. H. Carpenter, and A. W. Alldredge. 1987. Movements of female mule deer in northwest Colorado. Journal of Wildlife Management 51:634–643.

Geist, V. 1981. Behavior: adaptive strategies in mule deer. Pp. 157–224 in O. C. Wallmo, ed., Mule deer and black-tailed deer of North America. Wildlife Management Institute and University of Nebraska Press, Lincoln.

Hatch, S. L. 2007. Gould's grasses of Texas. Texas A&M University, College Station, Texas, USA.

Heffelfinger, J. R. 2006. Deer of the Southwest. Texas A&M University Press. Texas A&M University, College Station, Texas, USA.

Krausman, P. R. 1985. Impacts of the Central Arizona Project on desert mule deer and desert bighorn sheep. Final report, U.S. Bureau of Reclamation, contract 9-07-30-x069, Tucson, Arizona, USA.

Lawrence, R. K., R. A. Relyea, S. Demarais, and R. S. Lutz. 1994. Population dynamics and habitat preferences of desert mule deer in the Trans-Pecos. Final Report, Federal Aid Project W-127-R, Job 94. Texas Parks and Wildlife Department, Austin, Texas, USA. 178 pp.

Martin, P. 2002. Trans-Pecos Texas Geology Resources. University of Texas Libraries. Austin, Texas, USA.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223–249.

Natural Resources Conservation Service [NRCS]. 2006. Major Land Resource Area [MLRA] Explorer. <http://apps.cei.psu.edu/mlra/>. Accessed 17 Feb 2013.

Natural Resources Conservation Service [NRCS]. 2011. Ecological site description system for rangeland and forestland. <http://esis.sc.egov.usda.gov/>. Accessed 17 Feb 2013.

Natural Resources Conservation Service [NRCS]. 2013. U.S. general soils map (STATSGO2). <http://soildatamart.nrcs.usda.gov/>. Accessed 17 Feb 2013.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. Pp 65–72 in Research techniques in animal ecology: controversies and consequences. Columbia University Press. New York, USA.

Relyea, R. A., R. K. Lawrence, and S. Demarais. 2000. Home range of desert mule deer: testing the body-size and habitat productivity hypothesis. Journal of Wildlife Management 64:146–153.

Robinette, W. L., D. A. Jones, G. Rogers, and J. S. Gashwiler. 1957. Notes on tooth development and wear for Rocky Mountain mule deer. J Wildlife Management 21:134–153.

Robinette, W. C. 1966. Mule deer home range and dispersal in Utah. Journal of Wildlife Management 30:335–349.

Silverman, B. W. 1986. Density estimation for statistics and data analysis. Chapman and Hall. New York.

Skrobarczyk, P. K. 2011. Demographic characteristics and range sizes of elk in the Glass Mountains, Texas. Thesis, Sul Ross State University, Alpine, Texas, USA. 97pp.

Wampler, G. E. 1981. Seasonal changes in home range and habitat preferences of desert mule deer in Pecos County, Texas. Thesis, Sul Ross State University, Alpine, Texas. 60pp.

Webb, S. L., J. S. Lewis, D. G. Hewitt, M. W. Hellickson, and F. C Bryant. 2008. Assessing the helicopter and net gun as a capture technique for white-tailed deer. Journal of Wildlife Management 72:310–314.

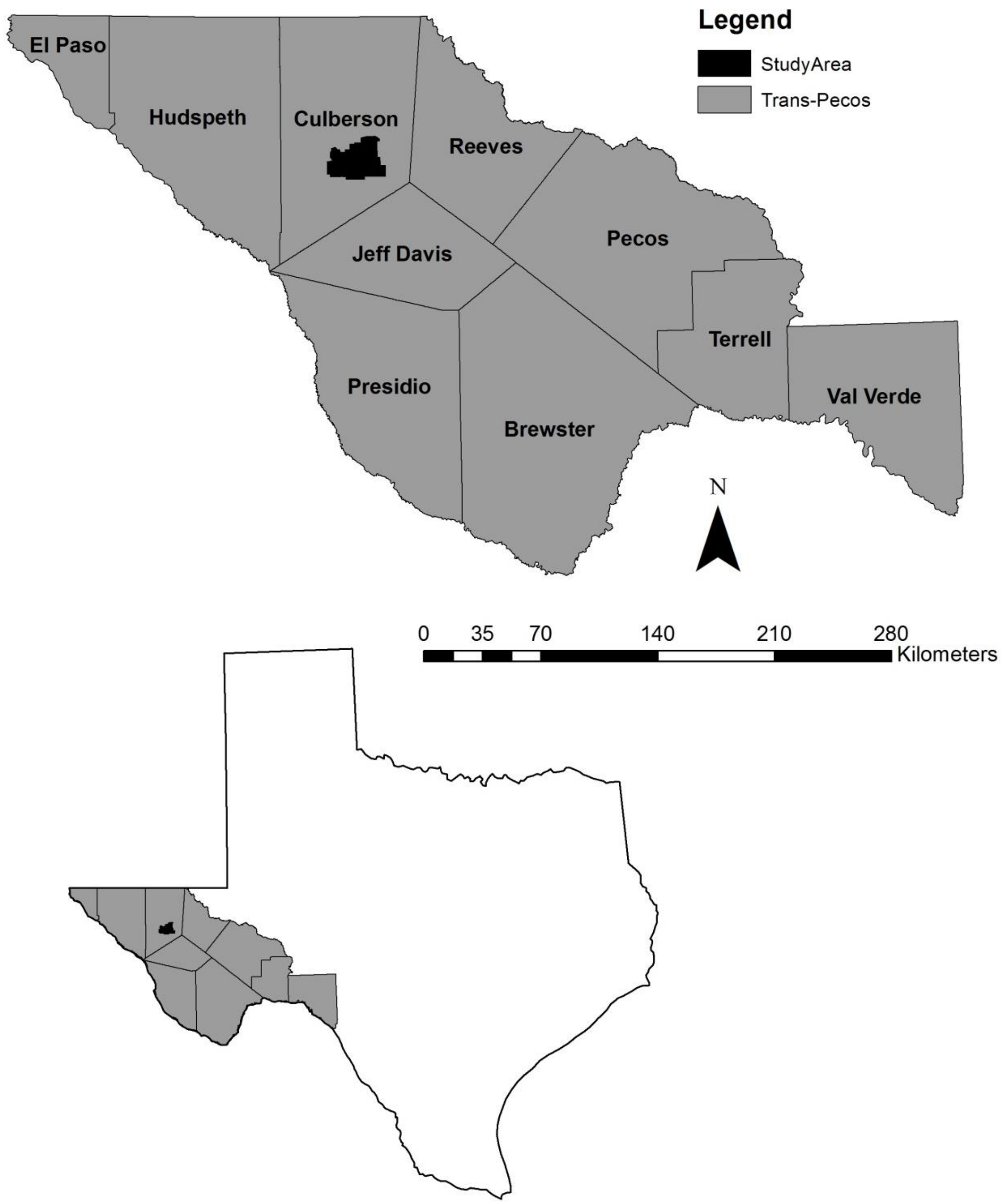


Figure 1. Location map showing general study area in relation to Trans-Pecos, Texas.

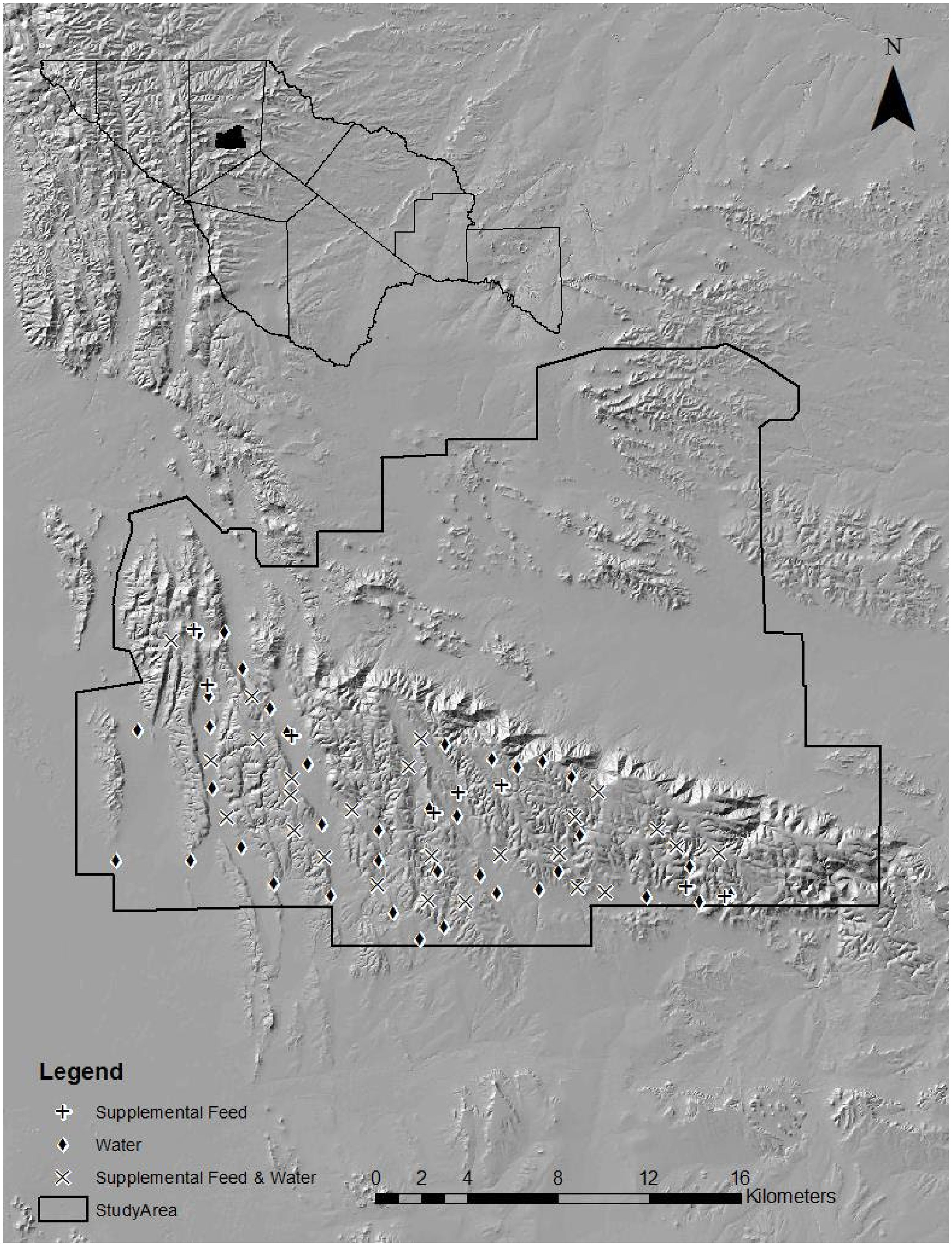


Figure 2. Location map showing the supplemental-fed and non-fed study sites in Trans-Pecos, Texas.

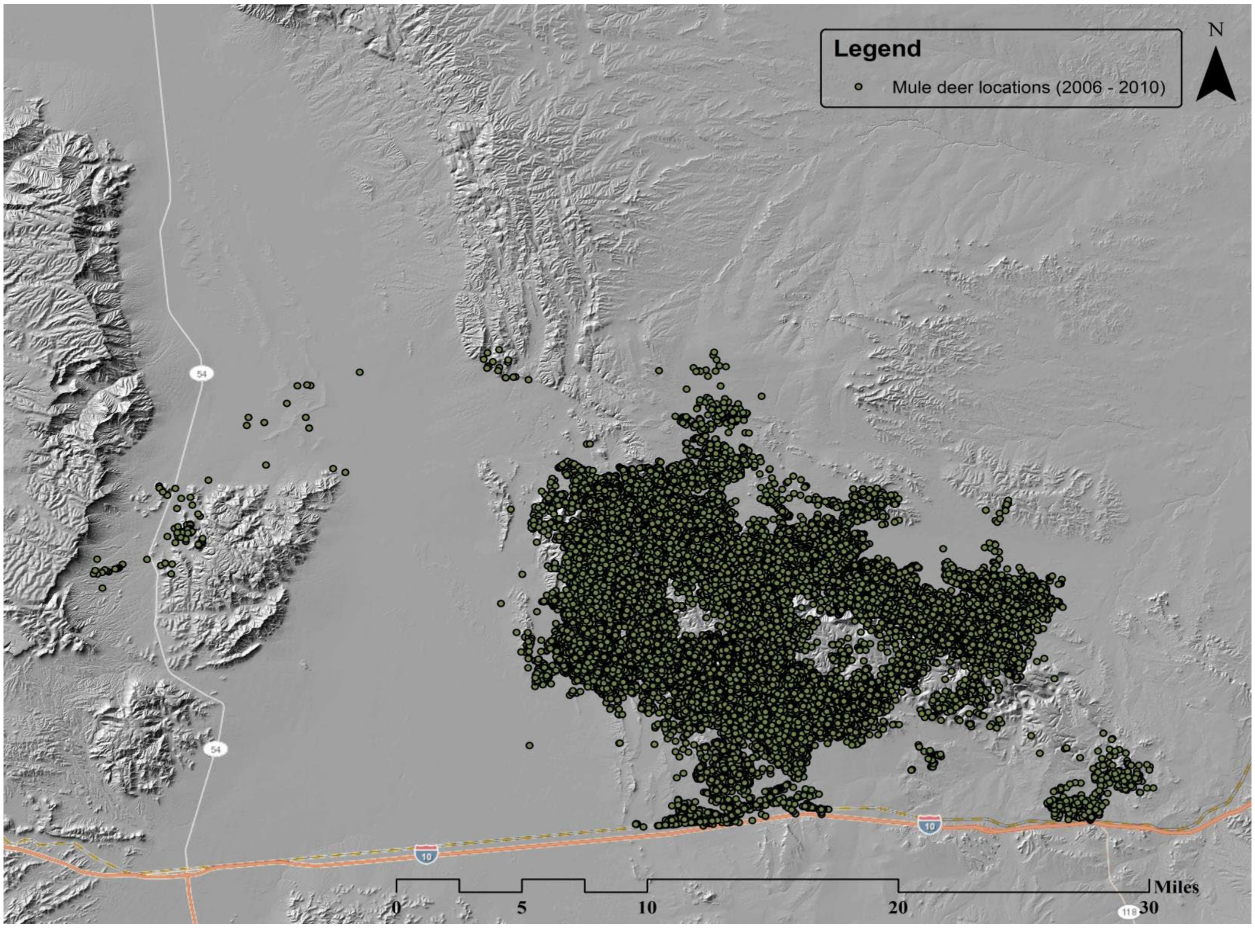


Figure 3. Total mule deer locations across both study sites from 2006–2010 in the Apache Mountains of Trans-Pecos, Texas.

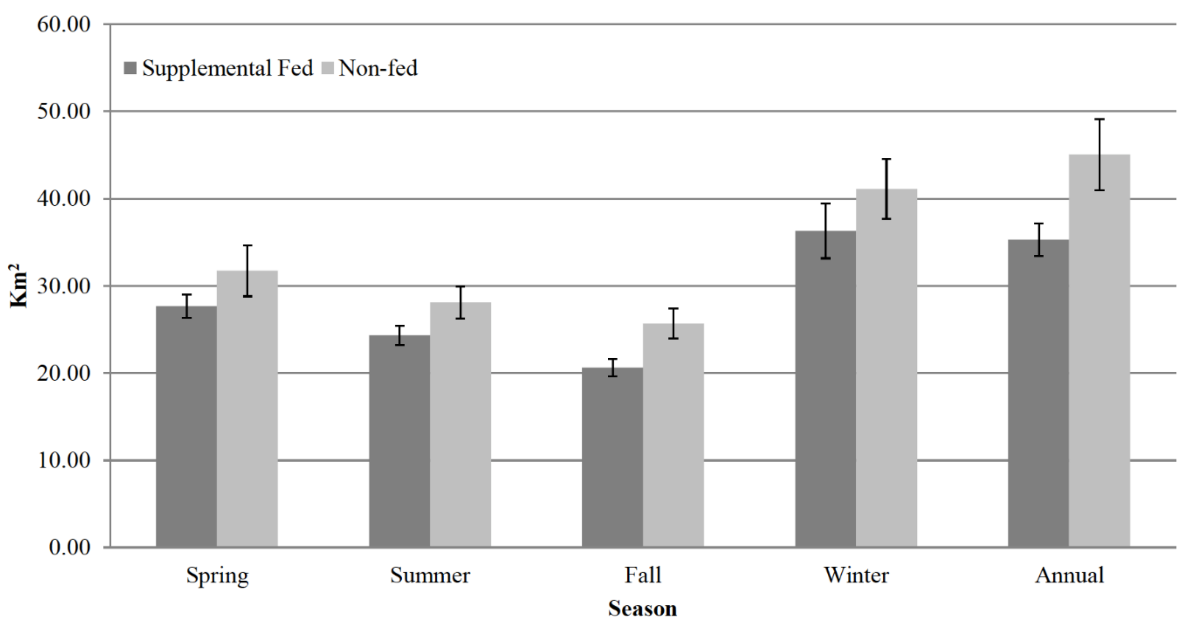


Figure 4. Mean 95% kernel seasonal home range sizes by study site for all GPS collared mule deer bucks in the Apache Mountains, Texas from 2006–2010.

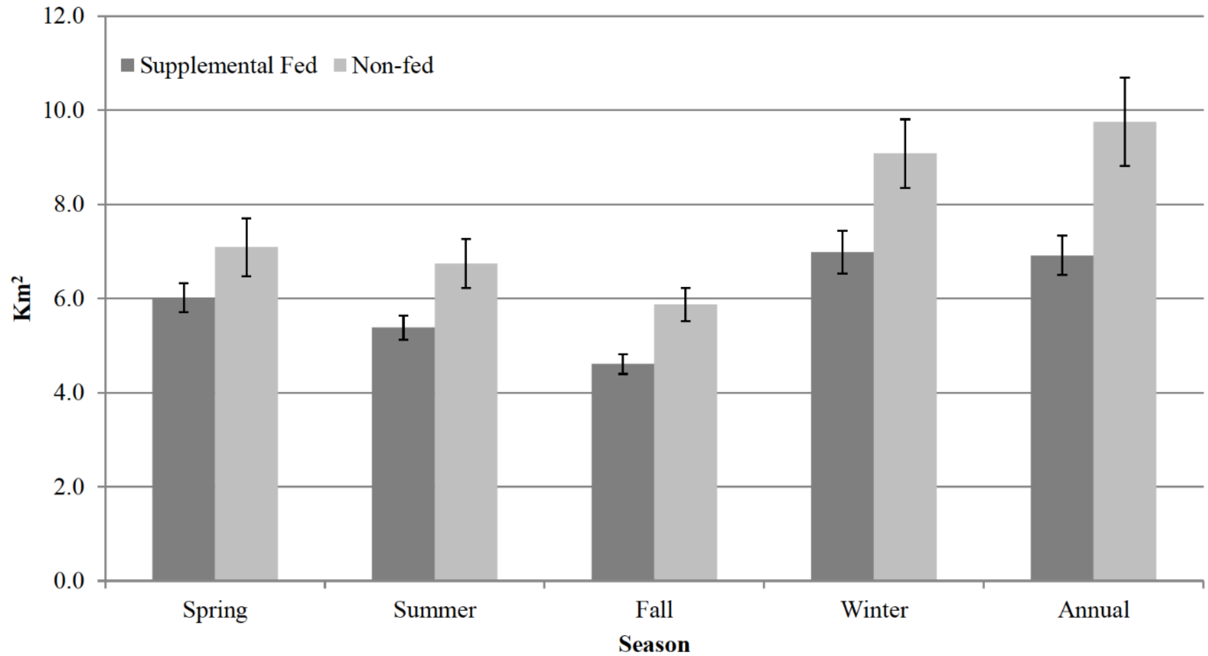


Figure 5. Mean 50% kernel seasonal core use area sizes by study site for all GPS collared mule deer bucks in the Apache Mountains, Texas from 2006–2010.

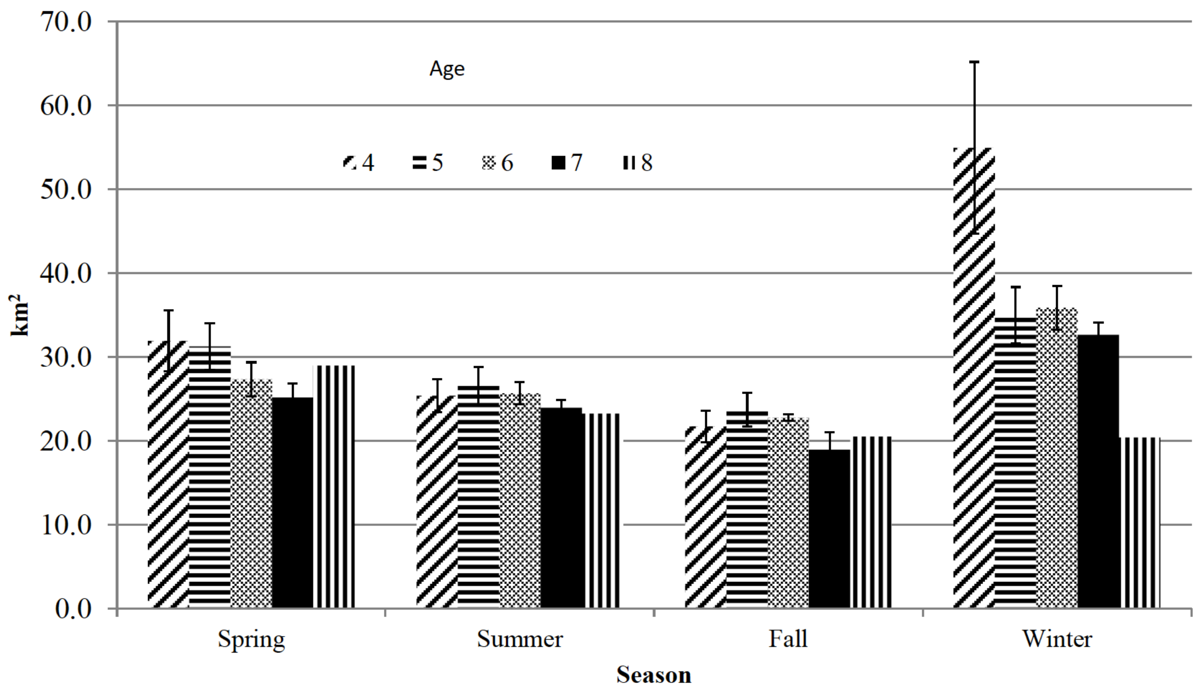


Figure 6. Mean 95% kernel annual home range size by age for each season for all GPS collared mule deer bucks in the Apache Mountains, Texas from 2006–2010.

Table 1. Number of new and recaptured mature (≥4.5 yrs) mule deer bucks from each study site from 2006–2010.

	Supplemental-fed site		Non-fed site	
Year	Recaptured	New	Recaptured	New
2006		10		10
2007	3	8	2	4
2008	5	5	4	4
2009	5	5	4	5
2010	7	8	3	

Table 2. Difference of means of 95% kernel seasonal home ranges (km^2) of mature mule deer bucks on supplemental-fed and non-fed sites in the Trans-Pecos from 2000–2010.

	Supplemental-fed site		Non-fed site		
Season	Home Range	SE	Home Range	SE	Significance
Spring	27.68	8.39	31.75	14.37	*P = 0.427*
Summer	24.34	6.76	28.09	8.85	*P = 0.127*
Fall	20.62	5.93	25.7	8.15	*P = 0.003*
Winter	36.3	17.61	41.1	16.39	*P = 0.190*
Annual	35.3	11.02	45.04	19.53	*P = 0.048*

Table 3. Difference of means of 50% kernel seasonal core use areas (km^2) of mature mule deer bucks on supplemental and non-fed sites in the Trans-Pecos from 2006–2010.
Ranch.

	Supplemental-fed site		Non-fed site		
Season	Home Range	SE	Home Range	SE	Significance
Spring	6.0	0.32	7.1	0.63	*P = 0.218*
Summer	5.4	0.26	6.7	0.53	*P = 0.046*
Fall	4.6	0.22	5.9	0.36	*P = 0.004*
Winter	7.0	0.46	9.1	0.74	*P = 0.017*
Annual	6.9	0.42	9.8	0.96	*P = 0.007*

SITE FIDELITY AND POST RELEASE MOVEMENTS OF TRANSLOCATED MULE DEER IN NORTHERN COAHUILA, MEXICO

JOSE DE LA LUZ MARTINEZ-GARCIA, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

ALFONSO ORTEGA-SANCHEZ, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

LOUIS A. HARVESON, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

CARLOS E. GONZALEZ, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

TAYLOR DAILY, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

**Correspondent email:* carlos.gonzalez-gonzalez@sulross.edu

Abstract – Historical distribution of desert mule deer (*Odocoileus hemionus*) included most of the Chihuahuan Desert in Mexico and the United States. Economically, mule deer are one of the most important wild animals in southwestern North America. In Coahuila, Mexico, populations of mule deer have been extirpated or have shown dramatic declines in the past decades. To reintroduce desert mule deer in northern Coahuila, Mexico, we initiated a study that would provide site fidelity, post-release movements, home ranges, and survival rates when comparing hard versus soft releases of radio-collared desert mule deer. From Spring 2007 to Spring 2008, 198 deer were transported from the Trans-Pecos region of Texas to the release site east of sierra del Carmen, Coahuila. Mule deer were captured using net guns and helicopters. A total of 87 deer were affixed with mortality-sensitive radio collars. Following the hard release, mule deer tended to move individually and established home ranges within 2 months of liberation. Sixty percent of the hard-released deer exhibited loyalty to the release site (>50% of locations within 5 km from the release site). Following the soft release, mule deer tended to move more in groups and established home ranges within 2 months of liberation. Seventy-five percent of the soft-released deer exhibited loyalty to the release site. Based on the data, future restoration of desert mule deer to historic habitats should use the soft release technique to increase loyalty and decrease home range sizes.

Introduction

The United Mexican States encompasses almost 2 million kmÇ with an estimated population of 109 million inhabitants. Mexico is the fourteenth most extensive country in the world but ranks third in biodiversity (McNeely et al. 1990, Ramamoorthy et al. 1993). Mexico's large size and its great diversity of climatic zones, fauna, vegetation, and zoogeographic position establish it as a crucial element in the conservation and management of North American wildlife and the world's biodiversity. Mexico is an important wintering area for temperate nesting birds, a major center for plant origins and domestication, and it has a large number of endemics (Valdez et al. 2006).

Mexico's wildlife historically has been impacted by human land use patterns influenced by socioeconomic and political factors that have resulted in mismanagement of its wildlife resources and decreased biodiversity (Valdez et al. 2006). The major direct threats are deforestation, mismanagement of livestock, unregulated agricultural enterprises, drainage of wetlands, dam construction, industrial pollution, and illegal exploitation of plant and animal resources (Challenger 1998). Biodiversity in Mexico, including wildlife, has only recently been recognized as a national priority (Valdez et al. 2006). The white-tailed (*Odocoileus virginianus*) and the mule deer (*Odocoileus hemionus*) are among the most widely distributed large mammals in Mexico. Mule deer species were an important food source for native Americans and then again for European settlers in the 1800s. Being an important food source and having no type of management, mule deer populations suffered from heavy use and declined substantially by late the 1800s.

Desert mule deer (*Odocoileus hemionus*) is the sub-species of mule deer with the second largest geographic range once covering most of the Chihuahuan Desert in Mexico, which covers the states of Coahuila, Chihuahua, Durango, Zacatecas, San Luis Potosi, and Sonora. Desert mule deer occupy arid and semi-arid environments, making them much more of a barren-ground animal, living comfortably on the most desolate desert ranges with scant vegetation (Leopold 1959). They are adapted to scarcity of free water and lower quality forage, allowing them to consume significant forage to meet their nutrient requirements. As a result of desert mule deer adaptation to arid environments, they are bigger than white-tailed deer and have larger antlers (Leopold 1959). Males increase in body mass until they are 9 to 10 yrs of age and about 90 to 115 kg (Kie and Czech 2000) with a lifespan ≤ 13 yrs (Heffelfinger 2006).

Livestock grazing is the most common economic activity in the Chihuahuan Desert region of Mexico (Martinez-Munoz et al. 2002). However, today desert mule deer play an essential role in the economy of many landowners. Because of their ability to endure the toughest environmental conditions, this animal has been designated a precious resource in many states of Mexico. Its low numbers, unique characteristics, large body, remote home ranges, and the ability to become an excellent trophy have elevated desert mule deer to a prized resource for wildlife viewers and hunters from the United States and Mexico.

Desert mule deer are one of the most economically and socially important animals in western North America (Heffelfinger et al. 2006). However, in Mexico, populations have shown declines in the past to an extent where for several decades they were considered to be in danger of extirpation (mainly due to illegal exploitation and habitat destruction; Baker 1956, Martinez-Munoz et al. 2002). This is no different in Coahuila, where desert mule deer occur in only a few areas but are abundant in local areas of the northwestern part of this state. These areas are privately owned, and hunting and livestock grazing have been carefully managed (Martinez-Munoz et al. 2002).

Several authors have mentioned factors that may be causing this decrease, including habitat loss, drought, starvation, changes in population age and sex structure, disease, predation, hunting, livestock competition, and combinations of these factors (Valdez et al. 2006, Ballard et al. 2001, Ordway and Krausman 1986, Wallmo 1981). However, few studies have been conducted on mule deer in Mexico (Mandujano 2004). With ecotourism being an actively growing enterprise in Mexico (Valdez et al. 2006), ranchers and landowners can use the information to aid in their deer restoration efforts.

The lack of fidelity to a release site is a problem that landowners often face whenever managing a big game population that has been translocated or transplanted. Translocation is the transport and release of free-ranging animals into areas where the species presently occurs or once occurred (Nielson 1988). The hard release is defined as the transport of animals from capture to release areas followed by immediate and unassisted release into the new environment (Bright and Morris 1994). Soft release refers to the release of translocated animals after an acclimatization period in a holding facility for a variable length of time (Nielson 1998). It has been suggested that soft releases can increase animal survival and fidelity to release sites by allowing translocated wildlife to acclimate to their new environment (Bright and Morris 1994, Biggins et al. 1998, Wanless et al. 2002).

Despite the apparent importance of this assumption and the proliferation of home range studies, the degree of range fidelity present in populations has rarely been evaluated (Van Dyke et al. 1995). Therefore, we initiated a study that reintroduced mule deer species to an area where they had been extirpated in the hope of establishing a viable and sustainable mule deer herd. The objective of the study was to monitor translocated mule deer populations and provide information of site fidelity, post-release movements, home ranges, and survival rate when comparing hard versus soft releases.

Study Site

This study was conducted from March 2007 to December 2008 on Rancho Guadalupe, which is a private cattle ranch located on the east side of Sierra del Carmen in Northern Coahuila, Mexico (Figure 1). With 1500 head of cattle, the study area compromised 25,000 ha of hill sand valleys between Sierra del Carmen and Serranias del Burro in the Chihuahuan Desert. Foothills and mountainous rangelands in the Chihuahuan Desert provide critical habitat for mule deer. Common herbivores in this area were white-tailed deer (*O. virginianus*), elk (*Cervus elaphus*), cattle, and domestic horses. This area comprises historic mule deer habitat with an average annual precipitation of 45 to 58 cm. Elevation on the study site ranged from 1,000 to 1,800 m.

Desert grasslands dominated the foothill rangelands, whereas matorral submontane brushlands dominated the mountain rangeland habitat. A diversity of Chihuahuan Desert plant species like agave (*Agave americana*), creosote bush (*Larrea tridentata*), tar bush (*Flourensia cernua*), lechuguilla (*Agave lechuguilla*), mesquite (*Prosopis glandulosa*), ocotillo (*Fouquieria splendens*), prickly pear (*Opuntialindheimieri*), sotol (*Dasylirion wheeleri*), yucca (*Yucca* spp.) and desert-dominant graminoids like buffalo grass (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*), and sideoats grama (*Bouteloua curtipendula*) compromise the majority of the vegetation on the ranch. Rancho Guadalupe borders to the North and south with "ejidos," which are communal lands (Valdez et al. 2006) that have undergone overgrazing for many years and the east and west with elevated mountain regions. Rancho Guadalupe is believed to have had an extinct native population of desert mule deer for ≥ 15 years before the translocation.

Methods

Translocation

During the spring of 2007 a total of 55 mule deer (7 M, 48 F) were captured using net guns and a helicopter (Schemnitz 2005) on the Nutt Ranch located east of Fort Stockton, Texas. Helicopter chase time for each animal was <10 minutes. Upon capture, mule deer were blindfolded and restrained with rope to facilitate handling and protect the animal. Captured deer were tattooed, an ear tag was attached, and each deer was given a shot of Ivermectin ®. Of the 48 females, 40 were selected for monitoring, and 2-stage VHF radio-transmitters with an 8-hour-delay mortality signal were affixed to them. Deer were chosen based on overall appearance and fitness for monitoring. Deer were transported to Sierra del Carmen in Mexico via TTT (trap, transport, and transplant) permits (SGPA/DGVS/00528) provided by Texas Parks and Wildlife Department. Mule deer were released in approximately the center of Rancho Guadalupe (UTM coordinates 0762580, 3213215) one day after capture.

During the spring of 2008, an additional 73 female mule deer were captured and transported by the same procedures outlined above from the Black Mesa and Bar Lite Ranches, located in Brewster County, Texas. Twenty-three deer were selected for the "soft release" study, and mortality sensitive radio-transmitters were affixed to them. Translocated deer were released into a 16-ha temporary holding pen located in the center of the ranch. The holding pen had 3 200 L gravity feeders with supplemental deer pellets and 3 water guzzlers available to them inside the enclosure. After a 12-week acclimation period, 38 of 71 (13 which were radioed) mule deer were released on 23 May 2008. There were 18 200L gravity-feeders with protein feed (Virginiano 18), strategically distributed throughout the ranch to decrease dispersal of translocated mule deer from the ranch.

Data Collection

Triangulated telemetry locations (Fuller et al. 2005) were collected from each deer 4 times per week. Aerial telemetry (Kenward 1987) was conducted when animals could not be found for extended periods of time or when the transmission from a collar was out of range from traveled roads. Mortalities were investigated immediately to ascertain the causes of death. Due to the increased mortality rate during the first year of the project, data could only be collected from 17 deer from the hard release treatment. During the second year of the project, data could only be collected from 13 deer in the soft release treatment.

Data Analysis

Site fidelity was expressed as the average linear distance between the release site and individual deer locations. Deer were considered "loyal" if the majority of locations(>50%) were within a 5-km radius from the liberation site. Telemetry triangulation data was input into the LOAS 4.0 program (Ecological Software Solutions LLC, Florida State) to calculate the estimated location and margin of error of each deer. Location coordinates were then uploaded into ArcGIS (Environmental Systems Research Institute, Redlands, California). We evaluated differences in elevation preference using the Mann-Whitney test for those deer that remained loyal to the release site and those who did not by recording the elevation of the locations provided by the LOAS 4.0 program for each deer. The home range was defined as the area used by an animal as it meets its needs for food, water, cover, and social interactions (Heffelfinger 2006). We estimated home ranges using the home range extension in ArcGIS at 95% minimum convex polygon (White and Garrott 1990). We also used a Mann-Whitney test to determine statistical differences of home range sizes and site fidelity between hard and soft releases. Hard-released deer were monitored from May to August of 2007, and soft-released mule deer were monitored from May to August 2008. We used the Kaplan-Meier (Pollock et al. 1988) survival estimate to calculate the late survival rate from May to November 2007 and May to November 2008 for the hard and soft-released deer, respectively.

Results

Post-Release Movements

There was no difference ($Z = -0.459$, $P = 0.668$) in elevation preference for those deer that remained loyal to the release site and those that did not (Figure 2). Even though the elevation range was greater in those who were "not loyal," the mean elevation of choice was the same (1,292 m ± 12.3 m) for both fidelity groups. Mule deer tended to disperse individually following the hard release and move through the area for 2 months before establishing a home range with an average area of 3,455.18 ha ± 882 ha (Figure 3, Figure 4, and Figure 5). Following the soft release, mule deer tended to move more in groups and move through the area for 2 months before establishing a home range with an average area of 2,880.14 ha ± 1,124 ha (Fig. 3, Fig. 4, and Fig. 5). Even though the average home range decreased by 575 ha when using a soft release, there was no significant difference ($Z = -1.196$, $P = 0.245$) of home range sizes when using a soft release compared to a hard release in this study.

The data revealed that 2 out of the 3 does that were not loyal during the soft release traveled large distances from the release site immediately before the fawning season (August) to establish a relatively small home range outside of the ranch. Only one of the soft-released deer was observed with a fawn on 8 August 2008.

Site Fidelity

Following the hard release, 10 out of 17 deer (60%) remained loyal to the release site, with overall average movements ranging from 4 to 11 km. After the soft release, 9 out of 12 deer (75%) remained loyal to the release site, with overall average movements ranging from 0.9 to 12 km (Fig. 4, and Fig. 6). Travel distances from the release site of the loyal deer averaged 3.2 to

6.6 and 1.8 to 3.7 km for deer that were hard released and soft released, respectively. Comparable values for non-loyal deer averaged 7.4 to 12.8 and 10.7 to 19.7 km, respectively. There was a difference (Z = -2.524, P = 0.011) in site fidelity when comparing a soft release versus a hard release in the study.

Survival rate also increased in those that were soft released (S = 0.84), compared to those that were hard released (S = 0.57). Of those who were hard released in 2007 and survived to January of 2008 (N = 13), there was only one mortality in 2008 compared to 20 in 2007. From a total of 130 mule deer captured, only 53 does were radio-collared in 2 years, 17 of those 53 animals at risk were preyed upon by mountain lion. Eight deaths were caused by capture myopathy, 1 doe died captured in a coyote trap, and 4 others died from unknown causes. On hard releases, translocated mule deer seemed especially vulnerable immediately after liberation, where 22 mule deer died in the first 10 weeks post-release (Figure 7).

Discussion

Soft-release was an effective tool to reduce home range sizes and increase site fidelity of translocated mule deer in the study. Although it takes many resources and is labor-intensive to maintain 71 mule deer in a 16-ha enclosure for 12 weeks (2), the use of the soft release technique decreased average home ranges by 575. It increasedsed site fidelity by 15 % compared to the hard release. There was a significant increase in loyalty in those mule deer that were soft-rel. Following their liberation, some mule deer roamed outside of the enclosure for up to 4 days before starting to disperse. Rosatte et al. (2003, unpublished report) discovered that most elk that were soft released remained within 5 km of the release site while elk that were hard-released dispersed from 20 to 50 km from the release site. Similarly, Parker et al. (2008) mention an increase in site fidelity and survival rate of translocated Florida key deer attributed to the use of soft release versus hard release. The divergence of the results when comparing the 2 release methods indicates that using soft-release will increase the loyalty of translocated mule deer and may be warranted if future releases are pursued.

Due to the increased mortality rate during the first year of the project, data could only be collected from 17 mule deer using hard-release. Non-human predation reduced the total of deer translocated for the hard-release technique to 50% of its original size, compared to only 1 occurrence of predation in our second year. On hard releases, translocated mule deer seemed especially vulnerable immediately after liberation, where 22 mule deer died in the first 10 weeks (Figure 7). Even though the 7 males translocated in 2007 were not radioed, we observed at least 3 different males on the ranch during the project.

In the first year of the project, the translocated mule deer had supplemental feed available until 2 months before the capture. It is possible that their body condition declined during this period. This, along with the stress of the capture and the travel could have influenced the high mortality that the project had in the beginning.

Another possible reason for the differences in mortality rates from the hard-release compared to the soft-release is the area from which the mule deer were captured. Deer used for the hard-release were captured on the Nutt Ranch, bounded by an area where goat production has been one of the main economic activities. This area has had predator control for a long time, leaving virtually no predators. Deer from this area could be more susceptible to predation in a place where there has not been any predator control (B. P. McKinney, CEMEX, personal communication). On the contrary, the Black Mesa and the Bar-Lite Ranches, where mule deer for the soft-release were captured, are known to have an existent population of mountain lions, as well as other ungulate predators (B. P. McKinney, CEMEX, personal communication). Deer from this area may have familiarity with predators and avoidance strategies which could have helped the low mortality rate they exhibit in comparison of those deer that were captured in the Nutt Ranch. There were minor signs of hard-released deer using the feeders compared to the soft-released deer. Food, water, cover, elevation, and predator avoidance were considered factors that influenced the home range size in the translocated deer. The proximity of water, cover, and the use of feeders enabled soft released deer to occupy relatively smaller home ranges.

The principal predator of the mule deer in Mexico is the puma (Leopold 1959). Coyotes doubtless kill a few fawns, which may affect translocation's total success, but there was no confirmed coyote predation on fawns in this study. The high mortality caused by them reflects the local abundance of pumas in Rancho Guadalupe. The predator abundance in the area may cause high dispersal for some of the individuals.

Some authors (Beringer et al. 2002, Parker et al. 2008) mentioned translocated deer exhibit an exploration phase. This is defined as an animal that explores the area after translocation to establish a suitable home range, possibly increasing their home range size. It is also believed that there is some kind of acclimation effect (Parker et al. 2008) that will allow translocated deer to reduce home ranges over time. However, in this case, we believe that deer chose to move or not after some type of predation event(s) occurred in their home ranges. Predator risk has been shown to influence habitat selection and diet (Edwards 1983). Food, water, cover, reproduction, and safe zones are considered to influence the size of a home range (Kie and Czech 2000, Pierce et al. 2004). We think that some mule deer loyal to the release site accepted a greater risk of predation to meet forage requirements. Mountain lions in our study area were the most significant threat of mortality to mule deer. If mule deer selected habitat in response to predation risk levels, then predation by mountain lions should play an important role in site fidelity for mule deer (Pierce et al. 2004).

A mule deer has to eat from 1.5 to 1.8 kg of food daily to maintain its health, and in the desert, this good food is not easily gathered (Leopold 1959). Lack of proper food during critical seasons is the principal factor limiting deer populations almost everywhere. Food shortage is often aggravated by overgrazing caused by domestic livestock. Especially around water holes in arid regions, livestock will consume all the edible forage used by deer. This will decrease deer populations even more rapidly than overhunting (Leopold 1959).

Aside from having optimal mule deer habitat requirements, Rancho Guadalupe borders the North and south with communal lands that have undergone overgrazing for many years and to the east and west with high altitude regions. This may influence the need to travel more considerable distances for those deer that fled the ranch to encounter suitable habitat, potentially increasing their home range sizes.

Management Implications

Although the origin of the translocated mule deer may have been an important factor in the survival rate, we largely attribute the success of mule deer releases to the use of soft-release versus hard-release. We recommend soft-releases versus hard releases in future mule deer translocations, but what will ultimately determine the success of translocation is the new environment's degree to fulfill the species requirements needed to establish a suitable home range. Translocation programs should always include range evaluation as an essential requirement (Martinez-Munoz et al. 2002). We suggest that mule deer should be ≥8 weeks in holding pens before release when using the soft-release. We did not release the deer during the study until outside vegetation was favorable for them (May; after green up).

The translocation of mule deer was done in the spring when females were likely to be pregnant. Our data revealed that does that were likely to be bred were very loyal to the release site, and 2 out of the 3 does that were not loyal during the soft release traveled large distances from the release site right before fawning season to establish a relatively small home range outside of the ranch. Upon parturition, females will diminish the exploration phase because increased movements would likely prove deleterious to fawn survival, suggesting that pregnant females are good candidates for translocations (Hawkins and Montgomery 1969, Parker et al. 2008).

The proximity of water, cover, and the use of feeders mostly by soft-released deer enable them to occupy relatively small home ranges. Suitable habitat has been suggested to be a factor affecting the success of a translocation. The sustainability of ungulate populations and their foothill and mountain rangeland habitats depends, in part, on management actions that limit competitive interactions with other wild or domestic animals and encourage complementary relationships whenever possible. In this study, we think mule deer moved distances away from the ranch boundaries, not seeking to maximize forage benefits but after experiencing some predation events, suggesting that some type of predator control should occur in the area before the translocation.

After some anecdotal observations, we found that close monitoring immediately after the release should be minimal, especially during the hard release. Immediately after the release, desert mule deer are likely stressed and have had bad experiences with humans. They may be more sensitive to even minor human disturbances (Marshal et al. 2006).

Ranchers and landowners that invest in the translocation of a species are doing so with the assumption that this species will remain relatively faithful to the release site. This may not be relevant in this case since the deer of the study were released in the center of a 25,000-ha ranch. Still, it may be for future reintroductions that small ranchers have to collaborate for the reintroduction to be successful.

***Acknowledgements* –** This project was funded by Sul Ross State University, CEMEX, the Sloan Foundation, and USDA-HSI Grant program. P. Moody Harveson and B. J. Warnock provided valuable input in the development of this manuscript.

Literature Cited

Ballard W. B., D. Lutz, T. W. Keegan, L. H. Carpenter, and J. C. DeVos Jr. 2001. Deer predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:00–115.

Baker R. H. 1956. Mammals of Coahuila, Mexico. University of Kansas Publications, Museum of Natural History 9:125–335.

Beringer, J., L. P. Hansen, J. A. Demand, J. Sartwell, M. Wallendorf, and R. Mange. 2002. Efficacy of translocation to control urban deer in Missouri: costs, efficiency, and outcome. Wildlife Society Bulletin 30:767–774.

Biggins, D. E., J. L. Godbey, L. R. Hanebury, B. Luce, P. E. Marinari, M. R. Matchett, and A. Vargas. 1998. The effects of rearing methods on survival of reintroduced black-footed ferrets. Journal of Wildlife Management 62:643–654.

Bright, P. W., and P. A. Morris. 1994. Animal translocation for conservation: performance of dormice in relation to release methods, origin, and season. Journal of Applied Ecology 31:699–708.

Challenger, A. 1998. Utilizacion y conservacion de los ecosistemas terrestres de Mexico. Pasado, presente y future. Comision Nacional para el Conocimiento y Uso de la Biodiversidad, Instituto de Biologia, Universidad Nacional Auonoma de Mexico, y Agrupacion Sierra Madre, Mexico, D. F., Mexico.

Edwards, J. 1983. Diet shifts in moose due to predator avoidance. Oecologia 60:185–189.

Fuller, M. R., J.J. Millspaugh, K. E. Church, and R. E. Kenward. 2005. Wildlife Radio telemetry. Pages 377–417 in C. E. Braun, editor. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Hawkins, R. E., and G. G. Montgomery. 1969. Movements of translocated deer as determined by telemetry. Journal of Wildlife Management 33:196–203.

Heffelfinger, J. 2006. Deer of the southwest: a complete guide to the natural history, biology, and management of southwestern mule deer and white-tailed deer. Texas A&M University Press, College Station, Texas.

Heffelfinger, J. R., C. E. Brewer, C. H. Alcala´-Galvan, B. Hale, D. L. Weybright, B. F. Kenward, R. 1987. Wildlife radio tagging, equipment, equipment, field teqhniques and data analysis.

Institute of Terrestrial Ecology Furzebrook Research Station, Wareham, Dorset. Academic Press, London.

Kie, J. G., and B. Czech. 2000. Mule and black-tailed deer. Pages 629–657 in S. Demarais and P. R. Krausman, editors. Ecology and management of large mammals of North America. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Leopold, A. S., 1959. Wildlife of Mexico, the game birds and mammals. University of California Press, Berkely and Los Angeles, California.

Mandujano, S., 2004. Analisis bibliografico de los studios de venados en Mexico. Acta Zoologica Mexicana (N. S.) 20:211–251.

Marshal, J. P., V. C. Bleich, P. R. Krausman, M. L. Reed, N. G. Andrew. 2006. Factors affecting habitat use and distribution of desert mule deer in an arid environment. Wildlife Society Bulletin 34:609–619.

Martinez-Munoz, A., D. G. Hewitt., S. Valenzuela., J. I. Uvalle., A.E. Estrada., J. J. Avendano and R. Aranda. 2002. Habitat and population status of desert mule deer in Mexico. Zeitschrift für Jagdwissenschaft 49: 14–24; Maerz 2003–24.

McNeely, J. A, K. R. Miller, W. V. Reid, R. A. Mittermeier, and T. B. Werner. 1990. Conserving the world's biodiversity. International Union for the Conservation of Nature and Natural Resources, World Resources Institute, Conservation International, World Wildlife Fund-US, and World Bank, Gland, Switzerland.

Nielson, L. 1988. Definitions, considerations, and guidelines for translocation of wild animals. Pages 12-52 in L. Nielson and R. D. Brown, editors. Translocation of wild animals. Caesar Kleberg Wildlife Research Institute, Kingsville, Texas, USA.

Ordway, L. L., and P. R. Krausman. 1986. Habitat use by desert mule deer. Journal of Wildlife Management 50:677–83.

Parker, I. D., D. E. Watts, R. R. Lopez, N. J. Silvy, D. S. Davis, R. A. McCleery, P.A. Frank. 2008. Evaluation of the efficacy of Florida Key Deer translocations. Journal of Wildlife Management 72:1069–1075.

Pierce B. M., R. Terry Bowyer, Vernon C. Bleich. 2004. Habitat selection by mule deer: forage benefits or risk predation? Journal of Wildlife Management 68:533–541.

Pollock, K. H., Winterstein, S. R., and Conroy, M. J. 1988. Estimation and analysis of survival distributions for radio-tagged animals. Biometrics 44.

Ramamoorthy, T. P., R. Bye, A. Lot, and J. Fa. 1993. Biological diversity of Mexico: origins and distribution. Oxford University Press, New York, New York, USA.

Rosatte, R., J. Young, J. Hamr. 2003. Ontario elk restoration program. Elk restoration unit, Cambrian College. Unpublished internal report, 23pp.

Schemnitz, S. D. 2005. Capturing and handling wild animals, pages 239-285 in C. E. Braun, *editor*. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Valdez, R., J. C. Guzman-Aranda, F. J. Abarca, L. A. Tarango-Arambula, and F. C. Sanchez. 2006. Wildlife conservation and management in Mexico. Wildlife Society Bulletin 34:270–282.

Van Dyke, F. G., B. L. Probert and M. Van Beek. 1995. Moose home range fidelity and core area characteristics. Journal of Wildlife Management 31:21–32.

Wakeling, L. H. Carpenter, and N. L. Dodd. 2006. Habitat guidelines for mule deer: southwest deserts ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.

Wallmo, O. C. 1981. Distribution and habitats. Mule and black-tailed deer of North America. Wildlife Management Institute and University of Nebraska Press, Lincoln.

Wanless, R. M., J. Cunningham, P. A. R. Hockey, J. Wanless, R. W. White, and R. Wiseman. 2002. The success of soft release reintroduction of the flightless Aldabra rail (Dryolimnus [cuvieri] aldabranus) on Aldabra A toll, Scychelles. Biological conservation 107:207–210.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, London.

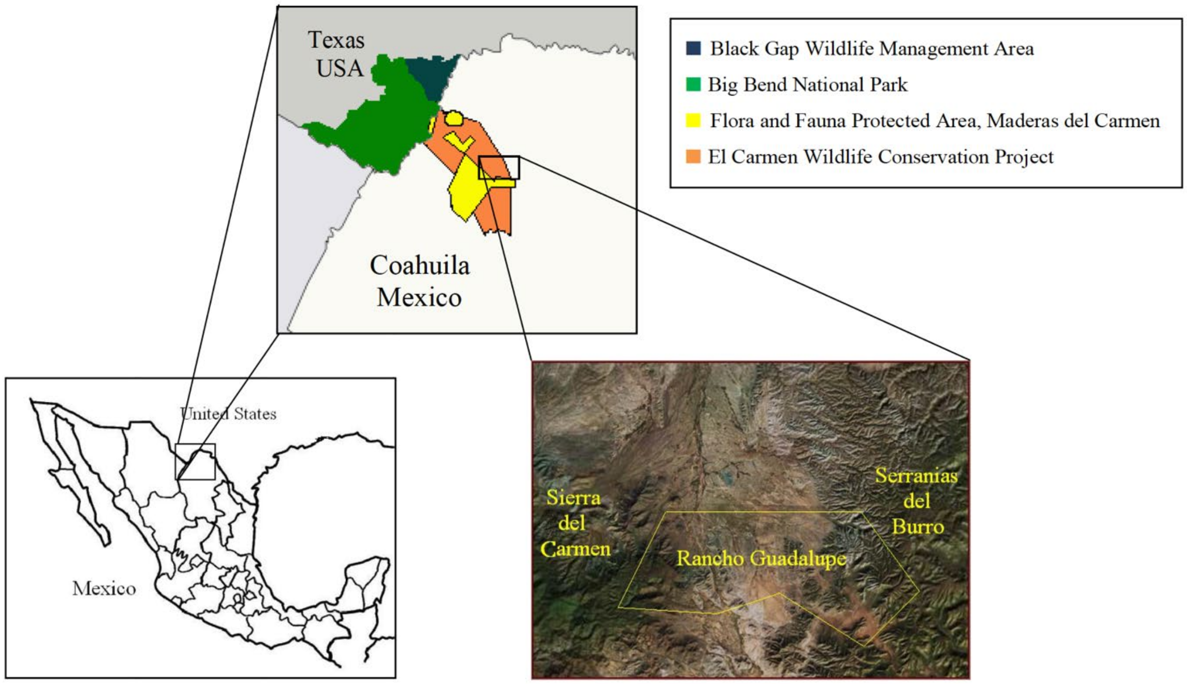


Figure 1. Location of Rancho Guadalupe in northern Coahuila, Mexico.

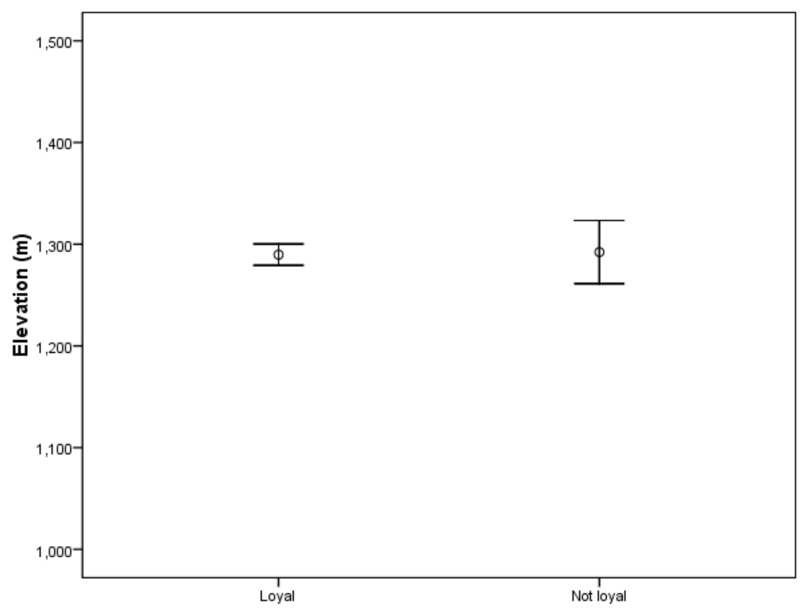
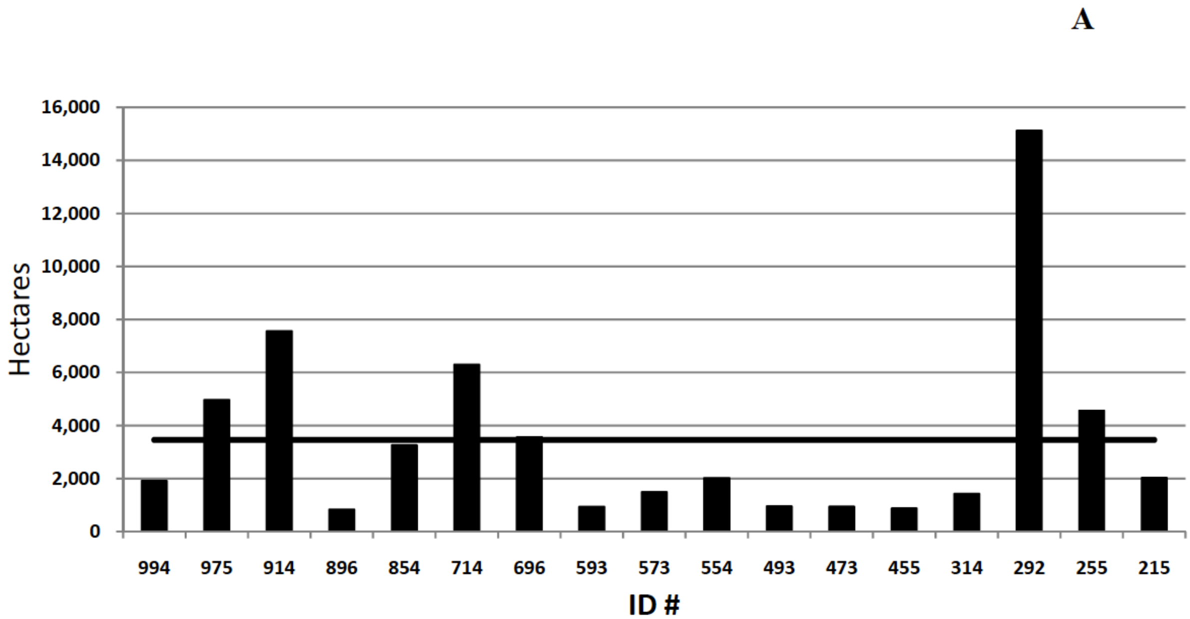


Figure 2. Average elevation (with standard error bars) and range (*) in meters of deer that were loyal (n = 19, x– = 1,292.5 m ± 10.4) and deer that were not loyal (n = 10, x– =1,292.2 m ±31) on Rancho Guadalupe, Coahuila, Mexico, 2007–2008.



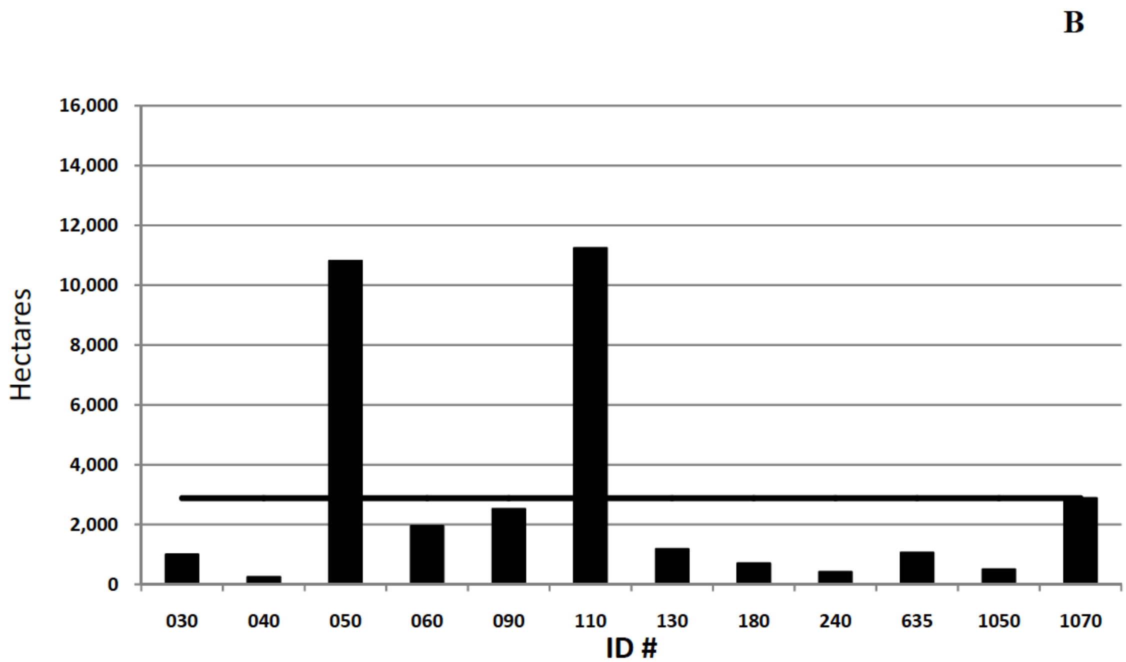


Figure 3. Home range size in hectares, estimated with the 95% minimum convex polygon, of those deer that were hard-released (A) and soft-released (B) on Rancho Guadalupe, Coahuila, Mexico, 2007-2008. Average size (horizontal line) of hard-released home ranges was 3,455.18 vs. 2,880.14 ha for soft-released deer.

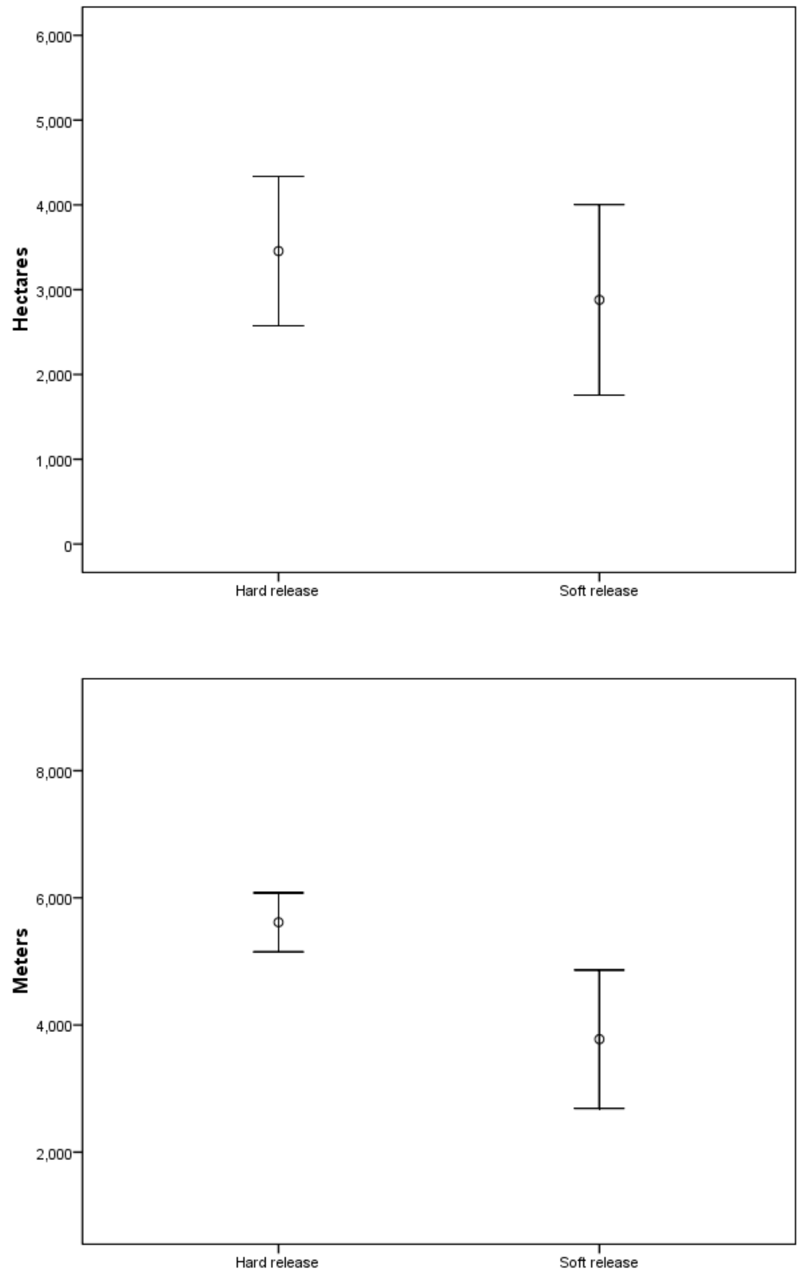


Figure 4. A comparison between home ranges (A) and distance traveled (B) for mule deer released with hard and soft releases on Rancho Guadalupe, Coahuila, Mexico, 2007-2008. Figure shows mean with standard error bars and range (*).

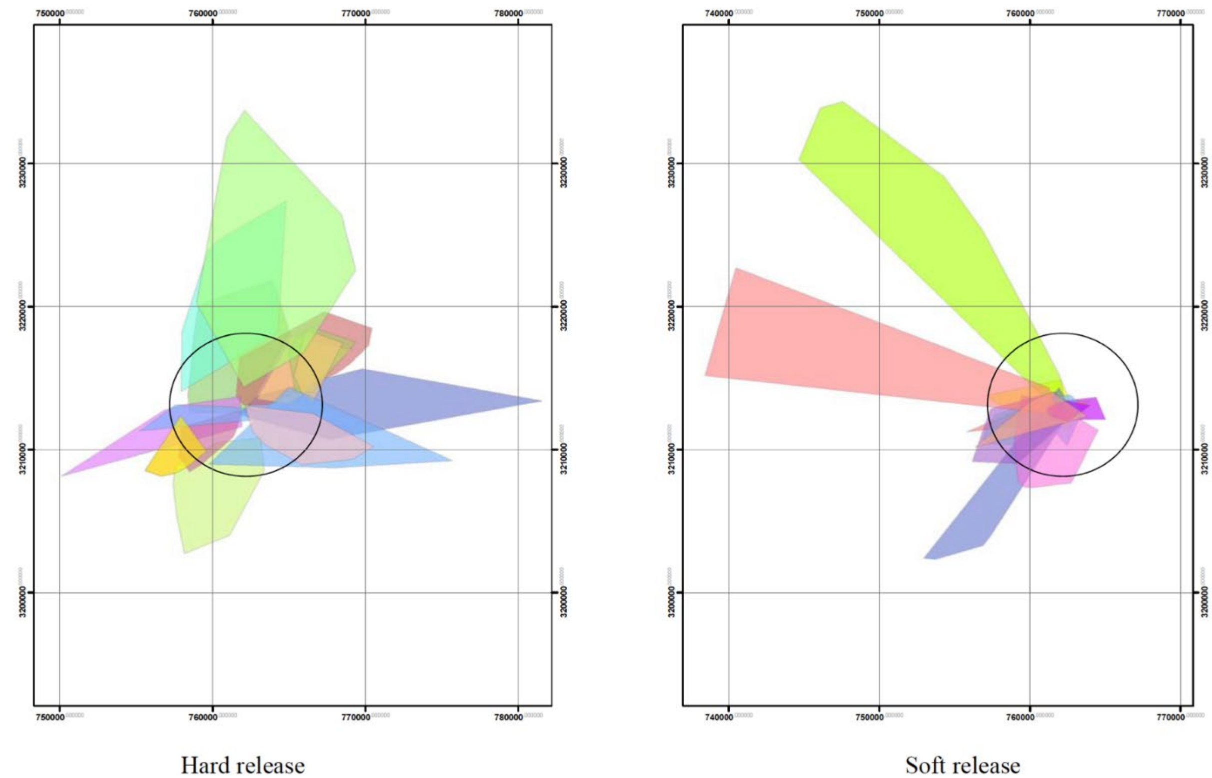
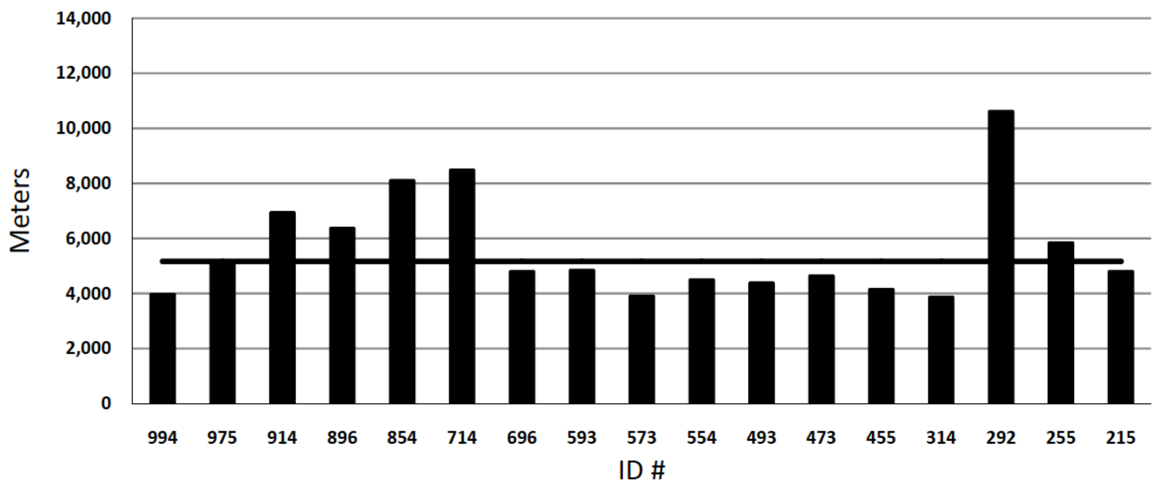


Figure 5. A comparison of desert mule deer home range sizes between hard-released and soft-released techniques referenced to the 5-km buffer (displayed as circle) from the release site on Rancho Guadalupe, Coahuila, Mexico, 2007–2008.

A



B

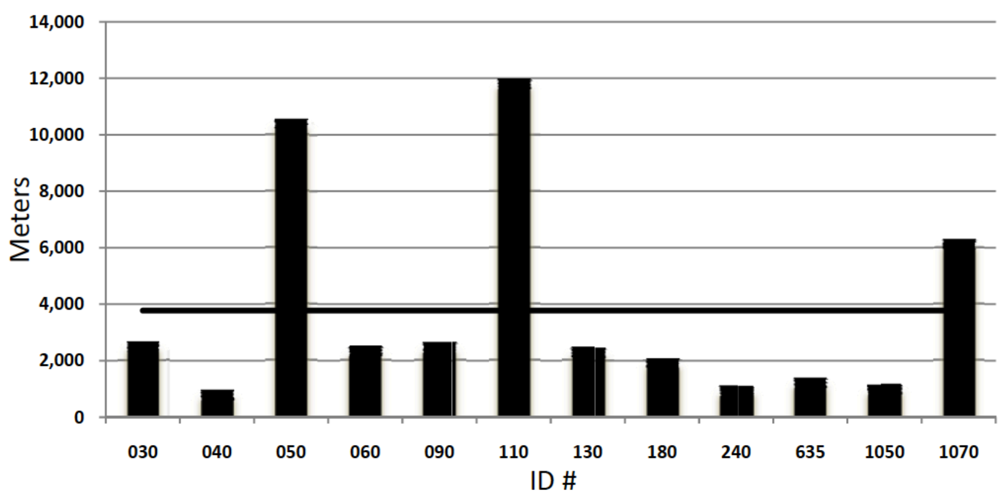


Figure 6. Site fidelity of desert mule that were hard-released (A) and soft-released (B) refrenced to their average (horizontal line), expressed as the average linear distance between the release site and the different locations for each individual, on Rancho Guadalupe, Coahuila, Mexico, 2007–2008.

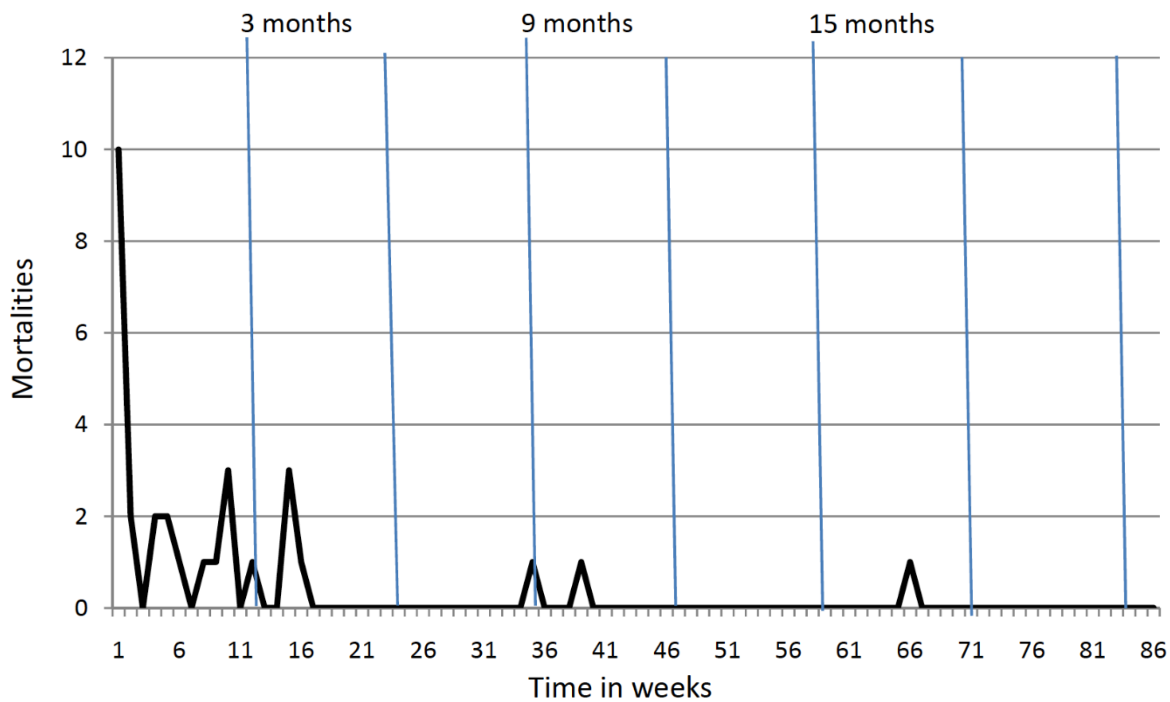


Figure 7. Mortality occurrences of translocated mule deer after release date on Rancho Guadalupe, Coahuila, Mexico, 2007–2008.

EVALUATING EFFECTS OF SEASON CHANGE ON MULE DEER HARVEST IN TRANS-PECOS, TEXAS

RYAN E. WALSER, *Borderlands Research Institute, Sul Ross State University, Box C-16, Alpine, TX 79832, USA*

LOUIS A. HARVESON, *Borderlands Research Institute,* Sul Ross State University, East Highway 90, Alpine, TX 79832, USA

CARLOS E. GONZALEZ, *Borderlands Research Institute, Sul Ross State University, East Highway 90, Alpine, TX 79832, USA*

ROEL R. LOPEZ, *Department of Wildlife and Fisheries Sciences, Texas A&M University, 314 Nagle Hall, College Station, TX 77843, USA*

CLAY E. BREWER, *Texas Parks and Wildlife Department, Alpine, TX 79830, USA*

**Correspondent email: carlos.gonzalez-gonzalez@sulross.edu*

Abstract – In 1988, Texas Parks and Wildlife Department (TPWD) changed the mule deer (*Odocoileus hemionus*) hunting season from a 9-day to a 16-day season. Subsequently, in 2005, the mule deer season was changed from a 16-day to a 60-day hunting season modeled after the Managed Lands Deer Permits (MLDP) program for white-tailed deer (*Odocoileus virginianus*). Therefore, we assessed the effects of the season change in 1988 to assess whether the 2005 season change would affect the mule deer population in Trans-Pecos, Texas. We looked for differences in harvest quality, quantity, and population abundance before (1980-1987) and after (1988-1995) the season change. We found no difference in the spread, basal circumference, or the number of points ($P \geq 0.27$). Conversely, age increased from a mean of 4.47 to 4.83 years. We found no change in the number of bucks harvested ($P = 0.19$) but, the buck:100 doe ratio increased ($P = 0.001$). There was no evidence that an extended season caused a decrease in quality and an increase in the quantity of bucks harvested. The mean age of bucks harvested and the buck:100 doe ratio increased, suggesting that hunters were more selective in the bucks they harvested.

Introduction

Management of ungulate populations by state wildlife agencies can be challenging (Collier and Krementz 2006). Agencies are constantly under pressure from the hunting and non-hunting public. Hunters may want agencies to maximize the availability of trophy bucks or hunter opportunity, yet they might not want an extended season or antler restrictions (Bender and Miller 1999, Erickson et al. 2003). To achieve mule deer (*Odocoileus hemionus*) management goals, compromises between conflicting public groups must also be managed (Biederbeck et al. 2001). Typically, the management of mule deer by agencies focuses on setting hunting seasons and harvest regulations to sustain populations and buck to doe and fawn to doe ratios (Erickson et al. 2003).

Unfortunately, most of the harvest regulations are controversial and based on culture and tradition instead of understanding biological processes and scientific experimentation (Nichols et al. 1995, Williams and Johnson 1995, Collier and Krementz 2006). Traditionally, state agencies base their deer management decisions on information sampled from harvested animals (Roseberry and Woolf 1991), even though data from harvested animals is not representative of the population (Carpenter 2000, Ditchkoff et al. 2000, Collier and Krementz 2006). Decisions by agencies about hunting seasons are often based on hunters' demands to harvest more deer, landowners to minimize deer and crop damage, or from federal land, managers to implement multiple use actions that can put livestock interests against wildlife (Erickson et al. 2003). However, most ungulate populations have high reproductive capability, and harvest regulations are usually conservative.

Few studies have evaluated the effects of a season change on ungulate populations. In Colorado, due to increased hunting pressure, buck hunting was restricted from 5 days to 3 days and resulted in a 41% decrease in license purchases. However, the shortened season did not reduce buck harvest or post-season buck:doe ratios (Erickson et al. 2003). Bishop et al. (2005) investigated limited buck harvest as a result of decreasing mule deer numbers. Although they documented a decrease in fawn:doe ratios, they concluded that factors other than harvest led to the decline. In southwestern Montana, a mule deer (buck-only) season was shortened from a 5-week to a 3-week season, and the number of deer hunters increased, but the total buck harvest decreased (Erickson et al. 2003). Bender et al. (2002) evaluated the effects of limiting the number of branched bull permits and an open-entry spike-bull harvest of elk (*Cervus elaphus*) in Washington. The regulatory change resulted in a decrease in hunter opportunity but an increase in bull:cow ratios.

Harvest data obtained from hunters have also been used to assess change in quantity and quality over time (Roseberry and Woolf 1991, Bender and Miller 1999, Bishop et al. 2005, Weckerly et al. 2005). Czaplewski et al. (1983) noted that sex ratios could be used to gauge reproductive success and the effects of harvest on wildlife. Other studies have focused on factors related to antler growth (Anderson and Medin 1969, Markwald et al. 1971, Robbins 1981), harvest strategy (Lancia et al. 1988, Lubow et al. 1996, Bishop et al. 2005), and predicting populations of cervids from harvest data (Bender and Spencer 1999, Riley et al. 2003).

Texas is different than most of the western states because it has minimal public land and is comprised primarily of private property (~97%). Currently, white-tailed deer (*Odocoileus virginianus*) are the primary hunted ungulate in the central, southern, and eastern parts of the state. In contrast, mule deer are the primary hunted ungulate in western Texas. Due to the lack of public hunting opportunities, lease-hunting has become an important and highly developed commercial system in Texas (Burger and Teer 1981, Thomas and Adams 1985, Adams et al. 1992). As a result of societal and economic changes, wildlife has become the most important economic asset to many landowners in Texas (Adams et al. 2000). Mule deer have been regarded as the most important mammal in west Texas (Davis and Schmidly 1994).

Management of mule deer in west Texas has changed considerably during the past 20 years. In 2005, Texas Parks and Wildlife Department (TPWD) adopted a season change for mule deer in west Texas that was modeled after the Managed Lands Deer Permits (MLDP) program for white-tailed deer. The proposed change extended the 16-day season to a 60-day season with various restrictions (e.g., approved management plan and population monitoring). Following a series of heated public hearings in the region, support for the proposed change was split. Many traditional landowners with large ranches were decisively opposed, and newer landowners favored the season change. Primary concerns landowners had regarding lengthening the hunting season for mule deer were the effects on (1) the quality of deer harvested, (2) the number of deer harvested, and (3) possible population impacts (sex ratios, population abundance).

Ironically, in 1988 TPWD expanded the mule deer season from a 9-day to a 16-day season. Although TPWD met with similar concerns (Mike Hobson, Texas Parks and Wildlife Department, personal communications), the effects of a season change on mule deer have not been explored. Thus, our goal was to evaluate the effects of the 1988 season change and draw on historical data to assess whether the 2005 season change will likely have detrimental effects on the quality and quantity of mule deer in the Trans-Pecos, Texas. Specifically, our objectives were to (1) determine the effects of a season change on harvest quality, (2) determine the effects of a season change on harvest quantity, and (3) evaluate the effects of a season change on population demographics (sex ratios and population numbers).

Study Area

Trans-Pecos, Texas is located within the Chihuahuan Desert Biotic Province, is approximately 7.3 million ha, and represents 11% of Texas (Hatch et al. 1990) (Figure 1). The Rio Grande and the Pecos River are the only 2 major rivers, and they represent the western, southern, and eastern border of the ecoregion. The New Mexico state line represents the border to the North. Most of the region receives ≤30 cm of annual precipitation, but precipitation varies from year to year and increases with elevation. Scattered within the ecoregion are desert islands which rise from elevations as low as 700 m and are represented by various mountain ranges, including the Chisos, Davis, Glass, and Guadalupe. The highest elevation is Guadalupe Peak, with an elevation of 2,916 m. Soils in the region are variable and are volcanic based on some mountain slopes while others are limestone based. Vegetation also varies with creosote bush (*Larrea tridentata*) and tarbush (*Flourensia cernua*) communities in the lower elevations among grasslands and a mix of juniper (*Juniperus* spp.), oak (*Quercus* spp.), and pinyon pine (*Pinus edulis*) in the higher elevations.

Methods

All data was collected by TPWD from 1980 to 1995. We analyzed data for 8 years prior (1980-1987) to and 8 years post (1988-1995) season change with equal weighted averages across years. All data were uniform over the 16 years (1980-1995). We analyzed all the data at the $\alpha = 0.05$ level.

Antler Characteristics

Biologists traveled to hunting camps and cold storage facilities throughout the hunted mule deer range (Bone et al. 2004). They took measurements of basal circumference, spread, number of points, and age. Basal circumference and spread were recorded to the nearest mm. An independent samples t-test was used to determine differences in age and antler characteristics (e.g., basal circumference, spread, number of points) before (1980-1987) and after (1988-1995) the change from a 9-day to a 16-day season. We also defined the criteria for a trophy buck to see if season change had affected the chance of harvesting a trophy buck. We defined a trophy buck as ≥4.5 years old, ≥10 points, ≥460-mm spread, and ≥120-mm basal circumference for this test. We used a Chi-square test to look for differences in mean number of trophy bucks harvested before and after season change.

Buck Harvest

Texas Parks and Wildlife uses a statewide random mail questionnaire that is sent to 25,000 purchasers (2-5%) of hunting licenses to estimate the annual harvest of mule deer. After 4 weeks, a second questionnaire was mailed out to nonrespondents (Liu et al. 2006). Response rates from mail questionnaires varied from 45-58% from 1980-1995 (Bone et al. 2004). Wildlife professionals and state agencies usually obtain harvest estimates from questionnaires after the season has closed (Geissler 1990, White 1993). Data obtained from surveying license holders might not be precise due to incomplete responses (White 1993). We used an independent samples t-test to determine differences in the numbers of bucks harvested before and after the season change. We also used a Chi-square test to look for differences in age of harvested bucks before and after season change.

Population Demographics

Spotlight surveys (1980-1995) for desert mule deer were collected from 9 counties (El Paso, Hudspeth, Culberson, Reeves, Pecos, Terrell, Brewster, Presidio, and Jeff Davis) in the Trans-Pecos region by TPWD. Five to 10 32-km spotlight surveys were used in each of the above counties. Spotlight surveys began 1 hour after sunset and were conducted between August and October (Bone et al. 2004). Spotlight surveys provide demographic characteristics on mule deer populations, including densities, sex ratios, fawn production, and buck quality (Richardson 2002). From the spotlight surveys, we analyzed fawn:100 doe and buck:100 doe ratios. Texas Parks and Wildlife Department used the spotlight surveys to estimate population numbers at the county level and finally across the Trans-Pecos. We used the estimates of the number of bucks, does, and fawns to determine change, if any, in relation to mule deer season change. A season change effect on the total number of bucks does, and fawns, fawn:100 doe, and buck:100 doe ratios were also analyzed using an independent samples t-test in SPSS 14.0.

Results

After the season was extended, no significant difference in spread (P = 0.46), basal circumference (P = 0.27), or number of points (P = 0.88) was found (Table 1). Conversely, there was a difference in the mean age of bucks ($P \leq 0.001$). Before the season change 3.5-year-old bucks ($n = 920$, $\bar{x} = 115$) were harvested the most but after the season change 5.5-year-old bucks ($n = 901$, $\bar{x} = 113$) were harvested the most (Figure 2). We also found an increase in the number of trophy bucks harvested before and after the season change (Table 2).

In addition, the season change did not influence the number of harvested bucks. Specifically, mean number of bucks harvested did not change (9-day season: $\bar{x} = 3{,}603$, SE = 274; 16-day season: $\bar{x} = 4{,}229$, SE = 362; $P = 0.19$; Figure 3). There was also no difference in number of 1.5- ($\chi^2 = 1.23$, $P = 0.27$), 2.5- ($\chi^2 = 2.34$, $P = 0.13$), or 3.5- ($\chi^2 = 0.98$, $P = 0.32$) year-old bucks harvested. However, there was a difference in 4.5- ($\chi^2 = 7.60$, $P = 0.01$), 5.5- ($\chi^2 = 40.62$, $P \leq 0.001$), 6.5- ($\chi^2 = 56.86$, $P \leq 0.001$), 7.5- ($\chi^2 = 40.71$, $P \leq 0.001$), and 8.5- ($\chi^2 = 13.55$, $P \leq 0.001$) year-old bucks harvested between seasons.
There was also no difference in number of bucks ($P = 0.72$), does ($P = 0.06$), fawns ($P = 0.07$), or the fawn:100 doe ratio ($P = 0.28$) as a result of the season change (Table 3). However, there was a difference in the average buck:100 doe ratio between seasons ($P = 0.001$).

Discussion

Based on our findings, the change in the hunting season of mule deer in 1988 from a 9-day to a 16-day season did not harm the quality of bucks harvested. Based on spread, base, and number of points, quality either did not change or slightly increased after the season expansion. Additionally, the age of animals harvested slightly increased, suggesting that hunters were more selective in the animals harvested. Aging mule deer is not an exact science, and therefore the results should be viewed with caution (Erickson et al., 1970).

Based on our trophy buck analysis, less trophy bucks were harvested after the season change. However, an outlier year (1986, $n = 126$) skewed our data, but we included it in the statistical analysis to keep our number of years of analysis even. Some of the possible explanations for the outlier may be data entry error, new TPWD personnel, the start of big buck contests, or a change in TPWD methods for collecting data on harvested bucks. Also, hunters may be reluctant to show biologists small or young bucks that are harvested, but they may be more willing and even seek out biologists to show them a large antlered buck. Antler development in mule deer bucks reaches its potential at 6.5-7.5 years of age (Heffelfinger 2006). If hunters are allowed to actively manage the mule deer on their ranches, then they can successfully harvest mature animals and keep a balanced age structure of bucks (Rollins 1990). Furthermore, sound management of rangeland conditions may increase the nutritional availability of forage and cover, which are essential for reaching maximum antler development in deer (Heffelfinger 2006).

The quantity of mule deer bucks harvested was not adversely affected by season change either. There was no evidence of hunters harvesting more bucks with a longer season. However, a decrease in buck harvest and a no doe harvest strategy could create an exaggeration of density-dependent factors and lead to a decrease in fawn survival (McCullough 1979, Fowler 1987, White and Bartmann 1998, Bishop et al. 2005). However, Horejsi et al. (1988) found that an increase in hunting pressure led to a decrease in the number of mature mule deer bucks and a reduction in the bucks:100 doe ratio. After the season change in Texas, hunters harvested more mature bucks (4.5-8.5 years old) and less 1.5-3.5 year old bucks than before the season change. This shift in the age composition may result from managers having more time to effectively manage and regulate harvested animals on their respective properties.

The number of fawns, does, bucks, and fawn:100 doe ratio was also not affected by season change. Conversely, the buck:100 doe ratio significantly increased after the season change. If animals harvested shift from 3.5- to 5.5-year-old bucks, then younger bucks will have the chance to mature, resulting in increased buck:doe ratios (Erickson et al. 2003, Bishop et al. 2005, Heffelfinger 2006). Buck:doe ratios are thought to be related to reproductive success. However, Horejsi et al. (1988) and McCulloch and Smith (1991) reported that low buck:doe ratios were unrelated to fawn recruitment in the following year. Increasing buck:doe ratios does not necessarily increase reproductive success but may increase the chance of harvesting an older buck. Smith and LeCount (1979) found that factors other than harvest regulations (i.e., weather and habitat change) may lead to variation in fawn:doe ratios.

Management Implications

Even though it appears that there were no negative effects of lengthening the season in 1988 from 9 days to 16 days, there may be issues in the future with the change to a 60-day season with MLDP permits. It is possible that some landowners may abuse the opportunity to hunt for a longer time because it may bring more opportunities to generate profit from lease hunting. It is important though for landowners, biologists, hunters, and state regulating agencies to work together to manage mule deer and their habitat. The MLDP permit program allows the landowner to work together with the regulating state agency for sound management at a much smaller scale than the ecoregion level. It will give them a better understanding of the general health and effects of regulation changes on the population. We encourage landowners to work with TPWD and help them with the collection of population and harvest data to make more informed decisions on regulations of mule deer. We also suggest an evaluation of the recent season change (2005) from a 16-day season to a 60-day season to assess the impacts of the change on the desert mule deer population and the reactions of landowners, hunters, biologists, and the general constituency in Trans-Pecos, Texas.

Acknowledgements – Support for this study was provided by TPWD, Boone and Crockett Club, and Sul Ross State University. We thank TPWD for collecting and providing mule deer harvest and abundance data. We thank B. J. Warnock for assistance with statistical analysis and T. L. Bone for assistance with obtaining data.

Literature Cited

Adams, C. E., J. K. Thomas, and C. W. Ramsey. 1992. A synopsis of Texas hunting leases. Wildlife Society Bulletin 20: 188–197.

Adams, C. E., N. L. Wilkins, and J. L. Cooke. 2000. A place to hunt: organizational changes in recreational hunting, using Texas as a case study. Wildlife Society Bulletin 28: 788–796.

Anderson, A. E., and D. E. Medin. 1969. Antler morphometry in a Colorado mule deer population. Journal of Wildlife Management 33: 52533.

Bender, L. C., and P. J. Miller. 1999. Effects of elk harvest strategy on bull demographics and herd composition. Wildlife Society Bulletin 27:1032-1037.

Bender, L. C., and R. D. Spencer. 1999. Estimating elk population size by reconstruction from harvest data and herd ratios. Wildlife Society Bulletin 27: 636–645.

Bender, L. C., P. E. Fowler, J. A. Bernatowicz, J. L. Musser, and L. E. Stream. 2002. Effects of open-entry spike-bull, limited-entry branched-bull harvesting on elk composition in Washington. Wildlife Society Bulletin 30:107–1084.

Biederbeck, H. H., M. C. Boulay, and D. H. Jackson. 2001. Effects of hunting regulations on bull elk survival and age structure. Journal of Wildlife Management 29:1271–1277.

Bishop, C. J., G. C. White, D. J. Freddy, and B. E. Watkins. 2005. Effect of limited antlered harvest on mule deer sex and age ratios. Wildlife Society Bulletin 33:662–668.

Bone, T. L., M. Berger, and R. Cook. 2004. Mule deer harvest recommendations. Federal Aid Project W-127-R-12, Project No. 3. Texas Parks and Wildlife Department, Austin, Texas, USA.

Burger G. V., and J. G. Teer. 1981. Economic and socioeconomic issues influencing wildlife management on private lands. Pages 252–278 *in* R. T. Dumke, G. V. Burger, and J. R. March, eds. Proc. of the symposium on wildlife management on private lands. LaCrosse Print. Co., Lacrosse, Wis.

Carpenter, L. H. 2000. Harvest management goals. Pages 192–213 *in* S. Demarais, and P. R. Krausman, editors. Ecology and management of large mammals of North America. Prentice Hall, Upper Saddle River, New Jersey, USA.

Collier, B. A., and D. G. Krementz. 2006. White-tailed deer management practices on private lands in Arkansas. Wildlife Society Bulletin 34:307–313.

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

Davis, W. B., and D. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife Press, Austin, Texas, USA.

Ditchkoff, S. S., E. R. Welch, Jr., and R. L. Lochmiller. 2000. Using cast antler characteristics to profile quality of white-tailed deer (*Odocoileus virginianus*) populations. Wildlife Biology 6:53–58.

Erickson, J. A., A. E. Anderson, D. E. Medin, and D. C. Bowden. 1970. Estimating ages of mule deer-an evaluation of technique accuracy. Journal of Wildlife Management 34:523–531.

Erickson, G. L., J. R. Heffelfinger, and J. H. Ellenberger. 2003. Potential effects of hunting and hunt structure on mule deer abundance and demographics. Pages 119–138 *in* J. C. deVos Jr, editor. Mule deer conservation: Issues and management strategies. Berryman Press, Utah State University, Logan.

Fowler, C. W. 1987. A review of density dependence in populations of large mammals. Pages 401–441 *in* H. H. Genoways, editor. Current mammalogy. Volume 1. Plenum Press, New York, New York, USA.

Geissler, P. H. 1990. Estimation of confidence intervals for federal waterfowl harvest surveys. Journal of Wildlife Management 54:201–205.

Hatch, S. L., K. N. Gandhi, and L. E. Brown. 1990. Checklist to the vascular plants of Texas. Publication MP-1655, Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas, USA.

Heffelfinger, J. 2006. Deer of the southwest: a complete guide to the natural history, biology, and management of mule deer and white-tailed deer. Texas A&M University Press, College Station, Texas, USA.

Horejsi, R. G., D. D. Haywood, and R. H. Smith. 1988. The effects of hunting on a desert mule deer population. Federal Aid Project W-78-R, WP2, Job 27. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Lancia, R. A., K. H. Pollock, J. W. Bishir, and M. C. Conner. 1988. A white-tailed deer harvesting strategy. Journal of Wildlife Management 52: 589–595.

Liu, X., M. Berger, and R. Cook. 2006. White-tailed deer harvest surveys. Federal Aid Project W-127-R-9, Project No. 4. Texas Parks and Wildlife Department, Austin, Texas, USA.

Lubow, B. C., G. C. White, and D. R. Anderson. 1996. Evaluation of a linked sex harvest strategy for cervid populations. Journal of Wildlife Management 60:787–796.

Markwald, R. R., R. W. Davis, and R. A. Kainer. 1971. Histological and histochemical periodicity of cervine leydig cells in relation to antler growth. General and Comparative Endocrinology 16:268–280.

McCulloch, C. Y., and R. H. Smith. 1991. Relationship of weather and other variables to the condition of the Kaibab deer herd. Technical Report No. 11, Arizona Game and Fish Department, Phoenix.

McCullough, D. R. 1979. The George Reserve deer herd: population ecology of a K-selected species. University of Michigan Press, Ann Arbor.

Nichols, J. D., F. A. Johnson, and B. K. Williams. 1995. Managing North American waterfowl in the face of uncertainty. Annual Review of Ecology and Systematics 26:177–199.

Richardson, C. 2002. Comparison of deer survey techniques in west Texas. Pages 62–72 *in* L. A. Harveson, P. M. Harveson, and C. Richardson, eds. Proceedings of the Trans-Pecos Wildlife Conference. Sul Ross State University, Alpine, Texas.

Riley, S. J., D. J. Decker, J. W. Enck, P. D. Curtis, T. B. Lauber, and T. L. Brown. 2003. Deer populations up, hunter populations down: Implications of interdependence of deer and hunter population dynamics on management. Ecoscience 10:455–461.

Robbins, C. T. 1981. Prevention and stimulation of antler growth by injections of calcium chloride. Journal of Wildlife Management 45:733–737.

Rollins, D. 1990. Managing desert mule deer. Texas Agricultural Extension Service. Bulletin 1636. Texas A&M University, College Station.

Roseberry, J. L., and A. Woolf. 1991. A comparative evaluation of techniques for analyzing white-tailed deer harvest data. Wildlife Monographs 117:1–59.

Smith R. H., and A. LeCount. 1979. Some factors affecting survival of mule deer fawns. Journal of Wildlife Management 43:657–665.

SPSS Incorporated 2005. Version 14.0. SPSS Incorporated, Chicago, Illinois, USA.

Thomas, J. K., and C. E. Adams. 1985. Socioeconomic factors affecting land access to hunt white-tailed deer. Wildlife Society Bulletin 13:388–394.

Weckerly, F. W., M. L. Kennedy, and S. W. Stephenson. 2005. Hunter-effort-harvest-size relationships among hunt types of white-tailed deer. Wildlife Society Bulletin 33:1303–1311.

White, G. C. 1993. Precision of harvest estimates obtained from incomplete responses. Journal of Wildlife Management 57:129–134.

White, G. C., and R. M. Bartmann. 1998. Effect of density reduction on overwinter survival of free-ranging mule deer fawns. Journal of Wildlife Management 62:214–225.

Williams B. K., and F. A. Johnson. 1995. Adaptive management and regulation of waterfowl harvests. Wildlife Society Bulletin 23:430–436.

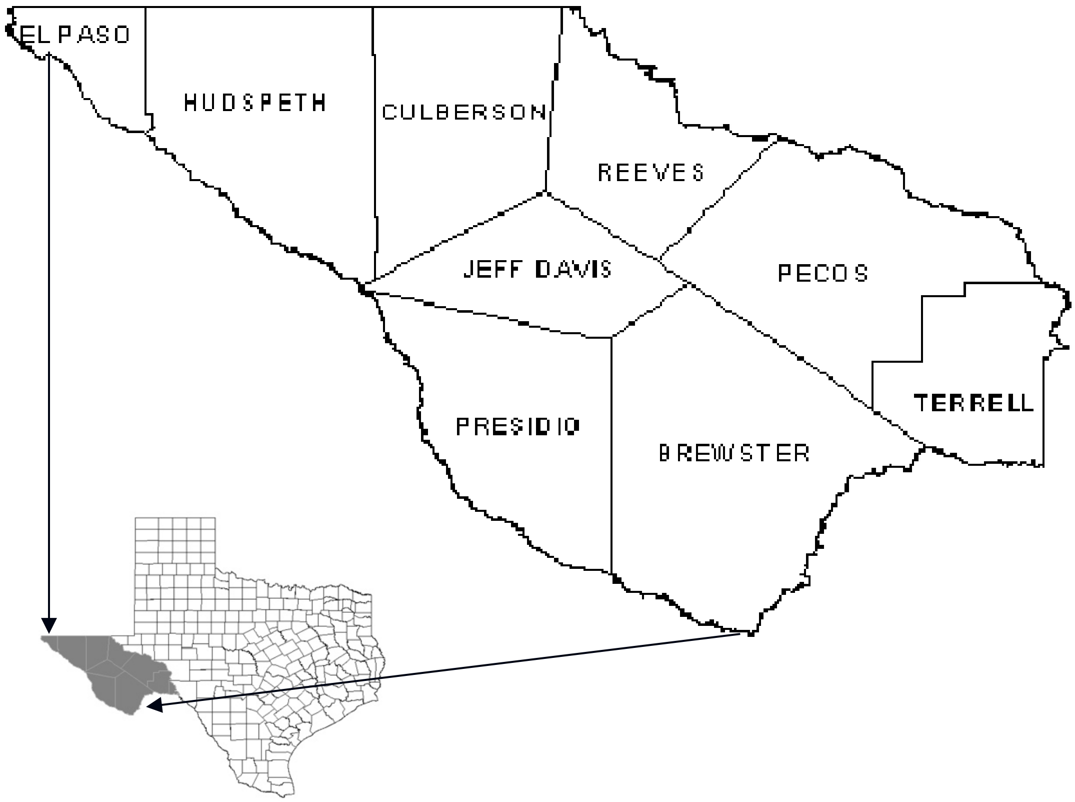


Figure 1. The Trans-Pecos includes 9 counties, is 7.3 million ha, and is located in southwest Texas.

Table 1. Means and standard errors of antler characteristics measured during the 9-day season (1980-1987) and the 16-day season (1988-1995) in Trans-Pecos, Texas.

	Trans-Pecos			
	9-day season		16-day season	
Antler Characteristic[a]	$\bar{x}$	SE	$\bar{x}$	SE
Spread	402.76	1.74	404.48	1.55
Circumference	100.91	0.40	101.47	0.33
Points	7.61	0.04	7.60	0.04
Age	4.47	0.03	4.83	0.03

[a]Spread and circumference were measured in millimeters.

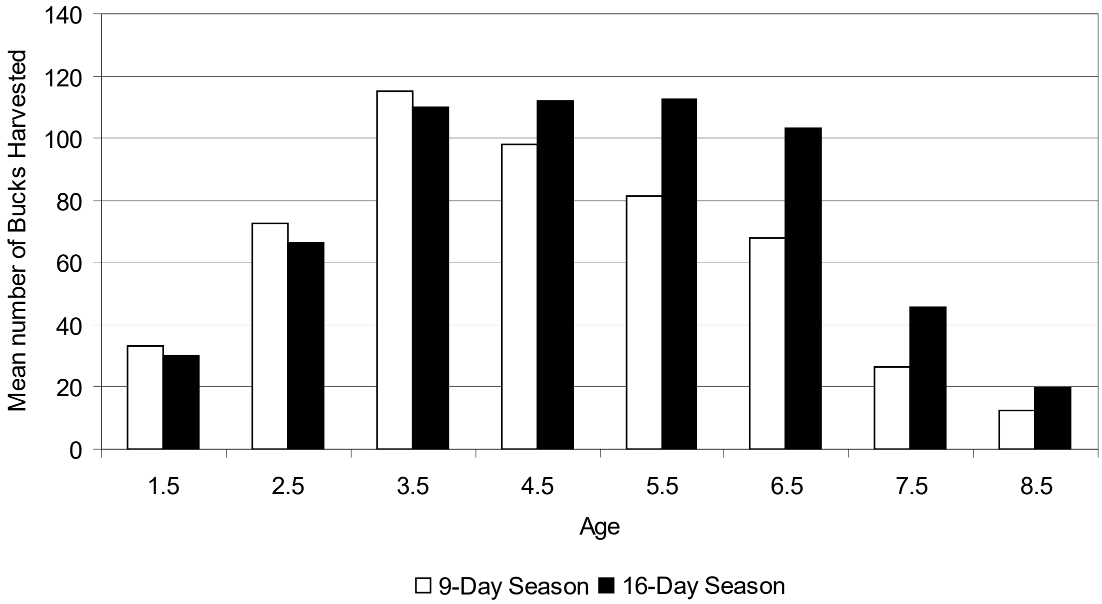


Figure 2. Comparison of the mean number of bucks harvested by age class during the 9-day (1980-1987) and 16-day (1988-1995) season in Trans-Pecos, Texas.

Table 2. Sample size and percent harvest of bucks and trophy bucks and corresponding antler characteristics (mm) during a 9-day (1980-1987) and 16-day (1988-1995) hunting season of mule deer in Trans-Pecos, Texas.

	9-day season								16-day season							
Harvest Characteristic	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Buck harvest (*n*)	3,773	4,392	3,292	2,474	2,841	3,281	4,018	4,759	4,887	4,859	3,956	5,162	4,803	4,528	3,583	2,055
Buck harvest[a] (%)	6	11	8	7	7	7	7	9	8	11	8	12	10	9	10	5
Mean # of points	6.4	7.5	7.4	7.1	8.4	8.0	7.8	8.0	7.9	7.2	7.3	8.4	7.7	7.7	7.1	7.3
Mean spread	348.0	395.5	394.3	387.0	418.4	430.2	398.9	432.7	405.2	386.6	392.0	452.2	420.1	400.0	387.8	376.8
Mean circumference	88.5	101.9	101.0	96.8	104.8	106.4	98.1	106.6	98.9	96.2	98.4	110.8	107.9	102.5	97.6	97.2
Trophy harvest[b] (*n*)	96	99	96	22	47	74	162	50	83	34	54	81	94	39	82	36
Trophy harvest[c] (%)	3	2	3	1	2	2	4	1	2	1	1	2	2	1	2	2

[a] The estimated number of bucks harvested divided by the estimated buck population for that year.

[b] A trophy buck was defined as ≥4.5 years old, ≥10 points, ≥460-mm spread, and ≥120-mm basal circumference.

[c] The number of trophy bucks harvested divided by the estimated number of bucks harvested for that year.

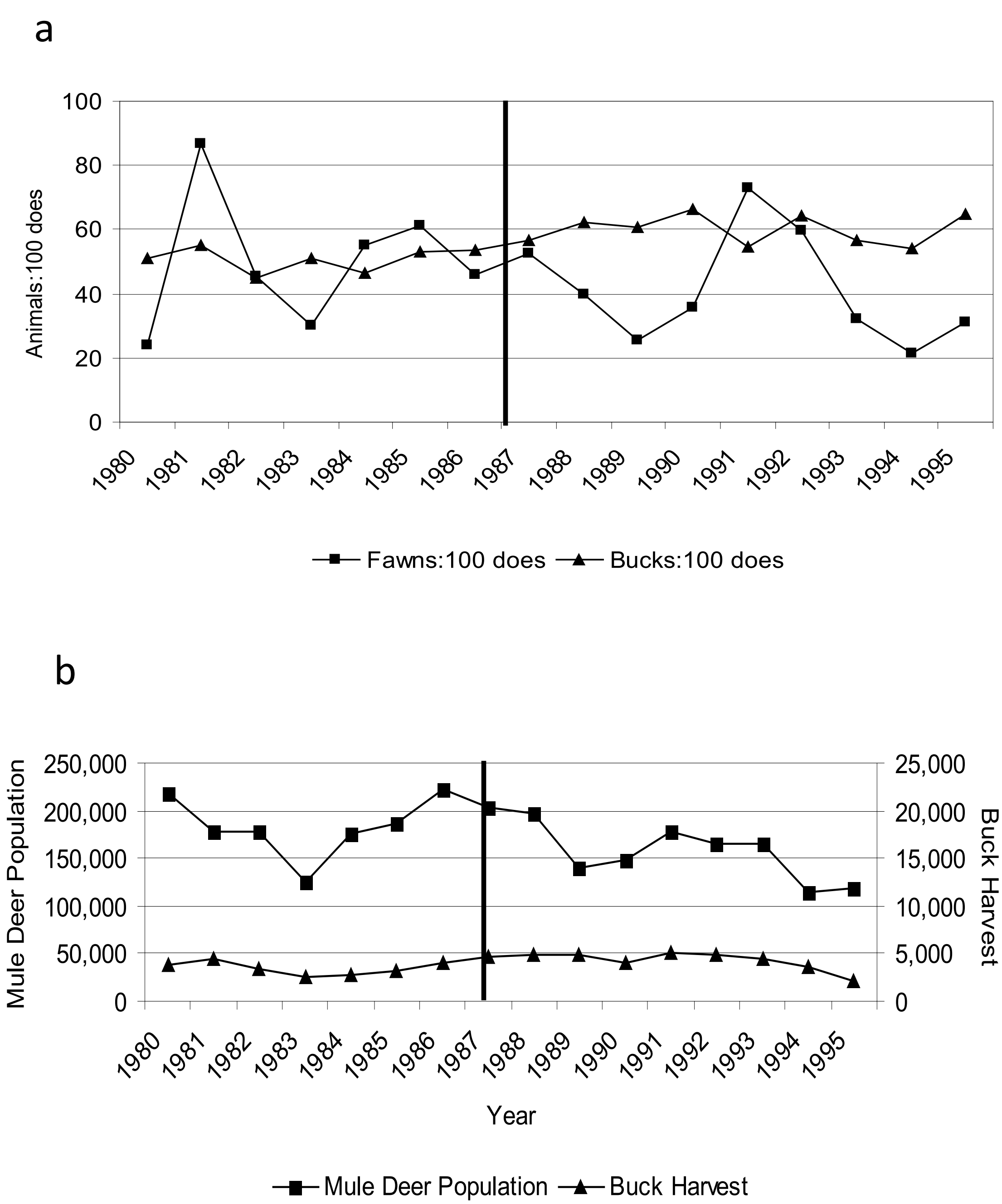


Figure 3. Comparison of fawns:100 does and bucks:100 does ratios(a) and mule deer population and total buck harvest before (1980-1987) and after (1988-1995) season change from 9-day season to a 16-day season (b).

Table 3. Means, standard errors, and sample sizes of mule deer population during the 9-day season (1980-1987) and the 16-day season (1988-1995) in Trans-Pecos, Texas.

	Trans-Pecos					
	9-day season			16-day season		
Population	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*
Bucks	47,845	3,616	382,761	46,208	2,677	369,663
Does	92,970	6,537	743,760	76,578	4,148	612,623
Fawns	45,128	4,884	361,022	30,831	5,229	246,650
Fawn:100 doe	50.21	6.87	n/a	39.75	6.23	n/a
Buck:100 doe	51.48	1.41	n/a	60.41	1.68	n/a

HOME RANGE, RELEASE SITE FIDELITY, AND RESOURCE SELECTION PATTERNS OF A REINTRODUCED ELK (*CERVUS CANADENSIS*) HERD: JACKSON COUNTY, WISCONSIN

TRAVIS S. BRYAN, *College of Natural Resources, University of Wisconsin – Stevens Points, Stevens Point, WI 54481, USA*

TIMOTHY F. GINNETT, *College of Natural Resources, University of Wisconsin – Stevens Points, Stevens Point, Wisconsin 54481, USA*

DANIEL J. STORM, *Wisconsin Department of Natural Resources, Rhinelander, Wisconsin 54501, USA*

SCOTT E. HYGNSTROM, *College of Natural Resources, University of Wisconsin – Stevens Points, Stevens Point, Wisconsin 54481, USA*

JASON D. RIDDLE, *College of Natural Resources, University of Wisconsin – Stevens Points, Stevens Point, Wisconsin 54481, USA*

**Correspondant email*: travis.bryan@tpwd.texas.gov

Abstract – Elk (*Cervus canadensis*) once ranged throughout the majority of Wisconsin, but local elk populations were extirpated by the late 1800s. The reintroduction of elk has been an mportant tool in restoring elk populations to their historical range. We studied the post-release movements and resource selection of elk reintroduced to Wisconsin from 2015-2017. Elk were captured near Stoney Fork, Kentucky and transported to Jackson County, Wisconsin, and subsequently fit with GPS collars to collect spatial data. Our objective was to identify elk resource home range, release site fidelity, and resource selection patterns for one year post-release. Release site fidelity was high over the first 90 days post-release but decreased throughout the remainder of the study. Elk made exploratory movements during the first 30 days post-release, but range sizes decreased 31-90 days post-release. Home range sizes increased and then stabilized between days 91-365 post-release. Elk selected for a suite of vegetation cover types between each post-release time period, but they consistently selected against the cranberry, shrubland, wetland, and open water habitats. Use of topographic characteristics shifted throughout the study duration. Slope had little influence during the first 90 days post-release, while use of aspect varied. The influence of slope then increased and stabilized between days 91-365. The use of aspect shifted between the post-release time periods, and elk selected for aspects that provided for thermoregulatory advantages as seasons changed. Elk mostly avoided roads for the first 90 days, but as time progressed, elk often utilized resources near major roads and human development. Elk did not particularly avoid wolf activity centers between days, but they often selected toward areas closely associated with humans, which wolves tend to avoid. For ungulate reintroductions to be successful, release site fidelity is critical for maintaining initial herd growth, continued reproductive success, and mitigating human-wildlife conflict. Future reintroduction efforts should encourage elk to remain near the release site.

Introduction

Prior to European colonization of North America, approximately 10 million elk (*Cervis canadensis*) ranged throughout North America (Popp et al. 2014). One of six subspecies, the now extinct eastern elk (*C. c. canadensis*), once inhabited substantial portions of Wisconsin. Historic records indicate that elk were once present in 50 of 72 counties (Schorger 1954). Unregulated hunting and the loss of suitable habitat extirpated local elk populations by the late 1880s (Schorger 1954).

Elk reintroductions have been commonplace in the United States since the turn of the 20th century, but early reintroductions often failed (O'Gara and Dundas 2002; Bleisch et al. 2017). In 1989, the Wisconsin Department of Natural Resources (WDNR) began assessing the feasibility of reintroducing elk to Wisconsin. In 1995, 25 elk were acquired from northern Michigan and subsequently release near Clam Lake, WI (Fawcett 2004). In May 1999, the reintroduction study was considered a success. As of May 2018, the estimated population of the Clam Lake elk herd was approximately 200 animals.

Efforts to establish a second herd near Black River Falls, WI began in 2012, and in December 2014, the Wisconsin Department of Natural Resources (WDNR) and the Kentucky Department of Fish & Wildlife Resources (KDFWR) finalized a five-year agreement to potentially provide Wisconsin with up to 150 wild elk. Twenty-three elk were released in the summer of 2015, and 50 elk were released in the summer of 2016.

As elk reintroductions to eastern North America become more prevalent, site-specific studies regarding initial movements are needed to maximize success (Bleisch et al. 2017). Post-release challenges include human conflict, predation risk, inclement weather conditions, habitat and food shortages, disease, and parasitic infections (Samuel et al. 1992; Frair et al. 2007; Seddon et al. 2007; Bleisch et al. 2017), all of which can influence habitat use, dispersal, and reproductive success. Understanding post-release movements and resource selection is crucial for optimizing management protocols to delineate areas with appropriate habitat requirements, monitor initial population growth, mitigate human disturbance, and to reduce elk-human conflict (Larkin et al. 2004; Rosatte et al. 2007; Ryckman et al. 2010; Bleisch et al. 2017).
Elk and other large mammals often leave release sites quickly and can make extensive movements *(*Armstrong & Seddon 2008; Yott et al., 2011; Ewen 2012; Le Gouar et al. 2012; Bleisch et al. 2017). Animals that disperse long distances often experience high mortality rates, higher risk of predation and lower reproductive success (Le Gouar et al. 2012; Scillitani et al., 2013; McIntosh et al. 2014). Reintroduced populations also must maintain densities that minimize inbreeding, maintain resiliency against stochastic events, and prevent temporary Allee effects (Larkin et al., 2002; Armstrong & Seddon 2008; Groombridge et al. 2012; Popp et al. 2014; Bleisch et al. 2017). Adult survival is crucial to the long-term population growth, and large mammal restorations should be developed to encourage animals to remain near the release site (Bleisch et al. 2017).

Age, sex, and reproductive status can all affect post-release elk movements. Sex and age bias tend to influence range and dispersal distances in mammalian reintroductions, with males usually dispersing farther than females (Ryckman et al. 2010; Bleisch et al. 2017), and older individuals typically dispersing farther than younger animals (Larkin et al. 2004; Ryckman et al. 2010; Le Gouar et al. 2012). Females with offspring may further restrict movements compared to those without, which may be especially true for elk post-parturition as they conceal their young (Bleisch et al. 2017). Elk typically avoid anthropogenic features such as roads and human development (Beck et al. 2013). Topographic features, seasonal differences in plant phenology and availability, and adverse weather conditions can affect elk resource selection throughout the year (Rowland et al. 2000; Fawcett 2004; Beck et al. 2013). Predation risk may also influence elk movements and resource selection, particularly where wolf populations are present, trade-offs between predation risk and forage fundamentally drive resource selection by animals (Hebblewhite & Merrill 2009).

Understanding how anthropogenic and environmental factors influence habitat selection is critical in establishing conservation objectives for wildlife populations (Beck et al. 2013). We studied the post-release movements and resource selection of elk reintroduced to Wisconsin from 2015-2017. Our objectives were to estimate elk home range sizes, assess release site fidelity, and identify resource selection patterns.

Elk were released into suitable habitat surrounding the release site, and the Wisconsin Department of Natural Resources (WDNR) planted a food plot adjacent to the quarantine facility to encourage elk to remain in the area. A soft release was used due to the quarantine requirement which allowed elk to form social bonds and acclimate to a new environment after transport.

We hypothesized that HR sizes would be highest immediately post-release and decrease over time, also varying by sex, age, time post-release, and release year (Larkin et al. 2004, Ryckman et al. 2010, Bleisch et al. 2017). We expected release site fidelity to vary by sex, age, time post-release, and release year, but to remain high overall. Elk resource selection was modelled using resources selection function models (RSF) between 4 distinct post-release time periods. We expected elk resource selection to shift over time and be influenced by habitat type, road features, distance from wolf activity centers, and the topographic attributes of slope and aspect.

Methods

The study area is centered approximately 20 km east of Black River Falls, WI which is located in the Central Sand Plains ecological zone. The mean annual temperature of the study area is 6.5°^{C}, and mean annual precipitation and snowfall are 83.3 cm and 114.3 cm respectively (WDNR 2014). Topographic relief is low, and elevations lie primarily between 259 and 275 m, with a range of 220 to 429 m. The vegetation mosaic consists primarily of pine (*Pinus spp.*), oak (*Quercus spp*.), and aspen (*Populus spp.*) forest, with intermittent plantations of red pine (*Pinus resinosa*). Agriculture is limited, but it is one of the top cranberry producing regions of Wisconsin and multiple cranberry farms are present east and southeast of the study area.

Elk Trapping and Translocation

In December 2014, WDNR and the Kentucky Department of Fish & Wildlife Resources (KDFWR) finalized a 5-year agreement to provide Wisconsin with up to 150 wild elk. Beginning in January 2015, elk were captured near Stoney Fork, Kentucky using corral traps.

As required by the United States Department of Agriculture (USDA) and the Wisconsin *Department of Agriculture, Trade and Consumer Protection* (DATCP), a quarantine period was established to reduce the risk of interstate disease transmission. Captured elk were transported to a holding facility where the age and weight of each individual was recorded. Elk also received 2 numbered ear tags for identification. The official quarantine began the day after the last elk was added to the confined cohort. After 30 days of quarantine in Kentucky, the elk were tested for tuberculosis (TB) and brucellosis. At day 45 of the quarantine, elk were transported in commercial stock trailers to a 2.85 ha holding facility in Jackson County, WI for the final quarantine period. At the end of the quarantine, a final series of health tests were performed, and elk were fitted with PIT tags and GPS collars.

In 2015, 26 elk were transported to the holding facility in BRSF. During the quarantine, 5 elk succumbed to a tick born parasite, babesiosis (*Babesia spp.*), and one adult female died from complications associated with birthing. An adult male that initially tested positive for TB had to be euthanized for additional health testing. This delayed the release date, and the remaining elk were held for a total 146 days in the Wisconsin holding facility. Four calves were born in the holding facility during the quarantine, and subsequently fit with PIT tags and expandable VHF radio collars (Advance Telemetry Systems, Insanti, MN) to monitor for mortalities. Elk (*n*=23, 2 adult males, 6 yearling males, 5 adult females, 6 yearling females, and 4 calves) were released on August 20, 2015.

Using the same capture and quarantine procedures, 39 elk were captured in 2016. During the quarantine, they were held in Kentucky for 45 days and for 112 days in Wisconsin. The elk were held until all known pregnant females had given birth, allowing WDNR biologists to fit newborn calves with PIT tags and VHF radio collars. Elk (*n*=50, 4 adult males, 4 yearling males, 9 yearling females, 22 adult females, and 11 calves) were released on July 11, 2016.

Elk Monitoring and Spatial Data Collection

To monitor yearling and adult elk movements, we fitted each individual (*n*=58) with a GPS collar manufactured by Vectronic Aerospace (Berlin, Germany). To estimate GPS accuracy, multiple collars were left in stationary locations, both under canopy and in the open. We used the 2 distance root mean squared (2 DRMS) method to estimate GPS accuracy (NRC 1995). Mean GPS accuracy was 8.39 m (12.96 m under canopy and 3.82 m in the open). All elk from the 2015 cohort (*n*=19), and most elk from the 2016 cohort (*n*=35), received collars programmed to record GPS coordinates in 13-hour intervals. Yearling males (*n*=4) of the 2016 cohort were fitted with collars that recorded locations on an hourly basis. Data from those collars was filtered to be concurrent with the data from the collars with 13 hour fix rates. Prior to analyses, we removed locations recorded as false mortalities using the method described by Lyons (2014).

For any time-period where an individual elk survived the duration, data were included in the analyses. For mortalities and collar malfunctions, data were censored so that incomplete time periods were not considered in the analyses. Collar failures on 2 adult males and the mortality of 3 adult females occurred less than 30 days post-release between both release years. Therefor, they were censored from all analyses. After filtering and censoring the GPS data, we used 24,911 locations from 53 elk for the analyses (2015 *n* = 5,235; 2016 *n* = 19,676).

Release Site Fidelity and Home Range

To assess release site fidelity, we determined maximum distances traveled for each time period, for each individual elk using the Near tool in ArcGIS 10.5.1 (ESRI 2017). We summarized and formatted data for analysis using the ddply function of the plyr package in R Studio (Wickham 2011; RStudio Team 2016).

We conducted analysis regarding HR size using time scaled local convex hull (t-locoh) in the t-locoh package in R studio (Lyons et al. 2013; RStudio Team 2016). T-locoh uses a set of nearest neighbors for each point to construct local minimum convex polygons (MCP) and incorporates the time stamp of each point in nearest neighbor selection and sorting of hulls during UD construction (Lyons et al. 2013). Nearest neighbor selection is based upon a distance metric known as time-scaled distance (TSD), which transforms the time interval between any 2 points into a third axis of Euclidean space (Lyons et al. 2013).

T-locoh requires the researcher to define the parameters for the nearest neighbor selection and TSD. Three methods for nearest neighbor selection are available. The k-method selects the k^{th} nearest neighbors around each point, the r-method includes all points within a fixed radius (r), while the adaptive a-method selects all points whose cumulative distance to the parent point is less than or equal to (a) (Lyons et al. 2013). The time and space components of TSD are weighted by defining parameter (s), which specifies the maximum amount of time at which spatially neighboring, but not necessarily sequential, GPS fixes are still considered to be temporally correlated to the parent point and considered to be a nearest neighbor (Lyons et al. 2013; Stark et al. 2017).

The a-method was used for nearest neighbor selection, as it is better suited for studies where both, high and low point densities of GPS locations can be expected (Getz and Wilmers 2004; Schweiger et al. 2015). To make comparisons between the animals possible, for each time period, data from each individual were examined to determine the cumulative distance that stabilized the isopleths' edge to area ratio, thus balancing type I (including area that is not used) and type II errors (omitting area that is used) (Lyons et al. 2013; Dürr and Ward 2014; Lyons 2014; Schweiger et al. 2015). That distance was recorded for each animal and the mean value was used for the (a) parameter for all individuals. Lyons (2014) recommends values of (s) be set so 40-80% of hulls are time selected. We used values of (s) equal 50% so both the spatial and temporal data were being considered relatively equal in the analysis (Stark et al. 2017). Fifteen candidate models (Table 1) were developed representing different hypotheses regarding post-release elk movement patterns using the covariates time (post-release), sex, age, and release year (Bleisch et al. 2017). To account for variation between maternal cows, and cow without calves, we had 3 levels for the sex covariate (Male, Female, and Maternal Female).

We used repeated measures, mixed-effects models for each movement response using the lmer function in the lme4 package in R Studio (Bates et al. 2015). We used Akaike's Information Criterion corrected for small sample sizes (AIC_C) to evaluate support for each model (Burnham and Anderson 2002, Bleisch 2017). Candidate models were fit using maximum likelihood methods to achieve AIC_C values and models with at least one-eighth support relative to the top model were included in the confidence set for each response (Bonnot et al. 2011, Bleisch 2017). Models were refit using restricted maximum likelihood to achieve unbiased estimates and standard errors, and models with at least one-eighth support relative to the top model were then model averaged using the maximum likelihood Akaike weights (Bonnot et al. 2011, Bleisch 2017). Unconditional variance estimates were used to determine confidence intervals (Burnham and Anderson 2002, Bleisch 2017)

Resource Selection

Elk resource selection was characterized 1-year post-release for both release years. Release dates differed by 7 weeks in the respective years, and to evaluate the effect of release on elk resource selection, time periods established were based on the number of days post-release, instead of biological seasons. We implemented a use-availability RSF design to evaluate post-release resource selection (Boyce et al. 2002, Johnson et al. 2006, Manly et al. 2007, Beck et al. 2013), and responses were evaluated over 4 time periods (0-90, 91-180, 181-270, and 271-365 days post-release). We identified resource use using GPS locations collected by GPS collars fitted to each elk. Locations were pooled across individual elk from both release years to assess habitat selection response at a population level (Type I design; Manly et al. 2007), and habitat selection was observed for the second order of selection (Johnson 1980). We determined the availability extent by constructing a 100% minimum convex polygon (MCP) around all elk locations. The MCP was truncated along U.S. Interstate 94 because it proved to be a significant barrier to elk movements (Figure 2). To ensure complete coverage of the availability extent, we generated random points at a 5:1 ratio of used to available locations (Lehman et al. 2016).

We identified variables for 12 habitat classes, use of manipulated habitat, road density, distance to nearest road, distance to wolf pack centers, and topographic features of slope and aspect. Habitat data were collected from the Wiscland2 land cover dataset (WDNR 2016), which is derived from satellite imagery acquired from the Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM) and Landsat 8 Operational Land Imager (OLI). Twelve habitat covariates were collected from the third level of the dataset. Habitat classes considered were developed, agricultural crops, cranberry fields, grassland, coniferous, aspen, oak, hardwoods, mixed coniferous/deciduous, shrubland, wetland, and standing water. The WDNR planted a food plot adjacent to the release site, which was classified as grassland. Spatial data regarding habitat manipulations were supplied by WDNR and JCDPF foresters and consisted of any habitat treatment that occurred between 2007 - 2017.

Spatial data were analyzed in ArcGIS 10.5.1 (ESRI 2017). We used the line density tool to create a road density map, and the Near tool to measure the distance between the nearest road and each elk location. Road data were collected from TIGER line shapefiles produced by the United States Census Bureau (USCB 2015). We digitized wolf pack centers based on the WDNR wolf pack detection map (WDNR 2017), and the distance to the nearest wolf pack center was recorded for each location. Slope and aspect were determined using the Spatial Analyst tool using a 30m resolution digital elevation model (USGS 2000). Aspect was classified into 5 categories; flat (no aspect), North (315º - 359º, 0º - 45º), East (45º - 135º), South (135º - 225º), and West (225º - 315º).

We used logistic regression with used and available locations to estimate the relative probability of use within the availability extent for each time period. Used and available locations were the dependent variables and a suite of habitat characteristics constituted our set of predictor variables (Johnson et al. 2006 and Beck et al. 2013). We implemented a Pearson's correlation matrix to test for multicollinearity among variables. Correlation coefficients (r) for all variables remained below the recommended threshold of 0.5 – 0.7 r (Doherty et al. 2010, Dormann 2013, Beck 2013). The highest coefficient was 0.412, therefore, all variables were retained for logistic regression analysis. We used Akaike's Information Criterion corrected for small sample sizes (AIC_C) to evaluate support for, and rank, all candidate models for each time-period (Burnham and Anderson 2002). Akaike weights (w_i) were computed for all candidate models to provide weights of evidence in support of each model being the most parsimonious of the candidate models for each time-period (Burnham and Anderson 2002, Beck 2013). Analyses were conducted using R Studio statistical software (RStudio Team 2016).

Goodness of fit tests were used to validate RSF models using the model validation method described by (Johnson et al. 2006). Elk locations for each time period were subset into training and testing data, with 75% of the used and available locations were randomly selected to use for training the logistic regression models. The remaining 25% were set aside for model validation. RSF values were predicted in GIS and probability maps were generated. We then reclassified pixels into ordinal bins based on natural breaks. Utilization values for each bin were calculated and the expected number of validation observations for each bin was determined. The number of used locations for the model testing data were counted for each RSF bin and compared to the number of expected number of observations using chi-squared tests.

Results

For the 23 animals of the 2015 release, 4 GPS collars were lost due to malfunction (1 adult male, 3 yearling males). Eight elk were lost to mortality. Four were killed by wolves (1 yearling male, 1 yearling female, and 2 adult females), 2 adult females were killed by vehicle collisions, 1 yearling female died of unknown causes, and 1 yearling female died of a meningeal worm infection (*Parelaphostrongylus tenuis*).

For the 50 animals of the 2016 release, 1 collar on an adult female was lost due to malfunction, and 8 were lost due to mortality. Mortalities included 1 adult male, 1 adult female and 2 yearling females killed by wolves, 2 yearling females died from meningeal worm, 1 yearling female died from a vehicle collision, and 1 adult female died from a bacterial infection.

Initial Elk Movements

Elk from both release years showed differing patterns of movement behaviors following release. As a group, in 2015, all the elk made exploratory movements immediately following the release, with the exception 1 maternal female who remained at the release site. Over the course of 12 days, the group tracked a clockwise course, leaving and returning to the release site. After 3 days, they were located approximately 7.4 km southeast of the release site, and spent days 4-9 approximately 5.2 km south of the release site. On day 10 they moved to within 2.9 km southwest of the release site, and by day 12, all elk were within 0.5 km of the release site.

At day 30, all elk were within 1 km of the release site, with the exception of 3 (2 adult females 5.85 km southwest, and 1 yearling female 6.85 km southeast).
After the 2016 release, one adult male and 1 adult female had travelled together 8.8 km south, and 1 adult female had travelled 8.3 km northeast of the release site where they remained through the first 30 days. One adult female travelled 13.6 km northwest of the release site, on day 13. On day 15 she moved approximately 16.5 km east, where she remained through day 30. The remaining elk were located within 1 km of the release site, two weeks post-release. Between days 17 – 20, several groups of elk began dispersing. At day 20, the 4 yearling males were grouped together 1.9 km southeast of the release site, and a group of 23 elk (1 adult male, 8 yearling females, and 14 adult females) had dispersed 3.7 km in the same direction. By day 30, 2 adult males and 2adult females were located within 1 km of the release site, and 2 adult females dispersed individually approximately 16 km from the release site (1 northwest, and 1 south). Aside for the aforementioned individuals, the remaining elk were loosely grouped 5 – 6 km southwest to southeast of the release site.

At the time of the 2016 release, most elk from the 2015 cohort had localized their movements to an area approximately 10.5km south-southeast of the release site. Although many elk of the 2016 cohort made exploratory movements in the first 30 days post-release, the 2 cohorts remained isolated from each other. Approximately 120 days post-release, 6 members of the 2016 cohort located and began interacting with the 2015 cohort. Those animals formed the basis of the largest group of elk observed throughout the remainder of the study.

Release Site Fidelity

Maximum distance traveled from the release site was stable over the first 3 time- periods, but increased substantially over the last 2 time-periods. Between days 1-90, mean maximum distance traveled of all elk was 10.055 km (2015 = 9.21 km, 2016 = 10.9 km; Figure 2). Between days 91-180, mean maximum distance traveled doubled to 20.135 km (2015 = 19.29 km; 2016 = 20.98 km). Mean maximum distance increased approximately 36% between time periods 90-180 and 181-365 to 27.45 km (2015 = 26.57 km; 2016 = 28.26).

The age effect on maximum displacement show that adult elk traveled further distances from the release site than yearlings (Figure 3). Model averaging predicted that adult elk would be 3.57 km farther than yearlings for any of the 5 time-periods.

Maternal females remained closer to the release site compared to males and females without calves, but females without calves travelled farther distances from the release site than males (Figure 4). Model averaging indicated that for any time-period, females without calves were predicted to be 1.89 km and 3.01 km, farther from the release site than males and maternal females respectively.

Home Range

Home range size decreased over the first 3 time-periods, but increased substantially over the last 2 time-periods. Mean home range size for all elk 30 days post-release was 438.9 ha (Figure 5). Between days 31-90, mean home range sizes decreased 156% to 170.9 ha. Mean home range sizes were 296.6 ha between days 1-90, but between days 91-180, mean home range sizes increased approximately 230% to 986.1 ha. Home range sizes continued to increase thorough days 181-365 to 1275.8 ha, a 29% increase from range sizes between days 91-180. The effect of age on elk home range sizes was minimal between adults and yearlings (Figure 6). In each of the 5 time-periods, adult elk had home range sizes only 9.3 ha larger than yearlings. Maternal females and females without offspring had similar range sizes, with only a 7.4 ha difference between the 2 classes for any time-period. Male home range size was 129.4 ha larger than females without calves and 136.8 ha larger than maternal females (Figure 7).

Resource Selection

The global model prevailed as the top ranked model for all 4 time periods, and very little support was shown for the remaining candidate models as Akaike weights for global model in each time period were ≥ 0.963 (Tables 4-7).

Habitat Variables

In relation to coniferous forest, elk showed the strongest preference towards grassland, and positive associations also were seen with crops, oaks and mixed coniferous/deciduous forests between days 1 – 90 post-release (Table 8). Grassland and oaks were used more proportionately than their availability, and crops and mixed forest were used in proportion to availability (Figure 13). A slight negative association occurred regarding aspen, hardwoods and wetlands, and stronger negative associations occurred regarding developed, cranberry, shrubland, and water habitat classes. Positive parameter estimates indicate positive association towards areas were habitat manipulation has recently occurred. During the 91 – 180 day time period, elk showed the strongest preference towards crops and grassland, and positive associations occurred regarding developed and oak habitat classes (Table 9). Aspen, mixed coniferous/deciduous and shrubland classes were used in proportion to availability (Figure 14), and negative associations occurred regarding cranberry, hardwoods, wetland, and open water classes. Slight negative association occurred regarding areas where habitat manipulation had recently occurred (Table 6). Elk showed the strongest preference towards the crop habitat class, and had positive associations with the developed, grassland and oak classes between days 181 – 270 (Table 10). Conifer, mixed coniferous/deciduous and shrubland classes were utilized in proportion to availability (Figure 15), and there was a negative association with the cranberry, aspen, hardwoods, shrubland, wetland, and open water classes.

During this time period, elk locations were negatively associated with areas where habitat manipulation has recently occurred (Table 10). Elk showed the strongest preference towards the grassland habitat class, and had positive associations with the crop, developed, oak, hardwoods, and mixed forest classes during the 270 -365 day time period (Table 11). Crop, grassland and oak classes were used more in proportion to what was available, while mixed coniferous/deciduous, hardwoods, and developed classes were used in proportion to availability (Figure 16). Slight negative associations occurred regarding cranberry, aspen, shrubland, wetland, and open water classes, and during this time period, and elk locations were positively associated with areas where habitat treatments had recently occurred.

Topography

A slight positive association occurred with areas of sloped terrain between days 1 – 90. Elk selected for northern and eastern aspects as opposed to southern, western, and flat aspects (Table 8). A positive association with sloped terrain occurred between days 91 – 180, as well as toward northern and eastern aspects (Table 9). Flat and southern aspects were used at a similar frequency, and there was a negative association with western slopes (Figure 19). A positive association occurred regarding sloped terrain between days 181 – 270, and elk selected southern, western, and flat aspects over northern and eastern aspects (Table 10 and Figure 19). Positive association occurred regarding sloped terrain (Table 11), and parameter estimates indicate that elk selected areas with flat aspects over those of the four cardinal directions between days 270 – 365 (Table 11 and Figure 19).

Road Features

Parameter estimates for road distance and density indicate that elk used areas devoid of roads between days 1 – 90 (Table 8). Road distance and density parameter estimates indicate that elk mostly utilized areas without roads between days 91 - 180, but to a lesser extent than the previous time period (Table 9). Parameter estimates for road distance and density indicate that elk mostly did not avoid areas with roads between days 181 – 270 (Table 10). Parameter estimates were lowest between days 271 – 365, indicating that avoidance of roads by elk declined even further (Table 11).

Wolf Pack Proximity

Parameter estimates indicate that elk did not avoid areas located near wolf pack centers during the first 90 days post-release (Table 8), and parameter estimates were nearly identical between days 91 -180 (Table 9 and Figure 18.). Between days 181 -270 elk showed the most avoidance wolf pack centers, but elk locations were still closer to wolf pack locations compared to what was available (Table 10). Avoidance of wolf pack centers decreased between days 270 – 365, and parameter estimates were similar to days 1 – 180 (Table 11 and Figure 18.)

Model Validation

We created probability maps by applying model coefficients to the model variable raster datasets, from which model validation was performed (Figures 9-12). Model validation indicated that the global model was a strong predictor of elk habitat use for all 4 time periods (Days 1-90: X^2 = 3.13, df = 9, P = 0.959; Days 91-180: X^2 = 0.308, df = 9, P = 0.999; Days 181 – 270: X^2 = 0.123, df = 9, P = 0.999; Days 271 – 365: X^2 = 0.197, df = 9, P = 0.999).

Discussion

Our results indicated that there were only minor differences in maximum distance traveled and home range sizes of between the 2015 and 2016 cohorts. The amount of time post- release, and age, had the most influence on the release site fidelity. Time post-release and sex mostly influenced elk home range sizes. Site fidelity remained high over the first 90 days but decreased during the remainder of the study period. We expected home range sizes to be highest immediately post-release and to decrease over time. This was the trend between days 1-90 post-release, but home range sizes increased substantially, and then stabilized, between days 91-365 post-release. Reintroduced elk selected for a suite of vegetation cover types throughout the duration of the study. They localized their movements around a food plot planted by WDNR over the first 90 days post-release, but resource selection change relative to the seasons through the remainder of the study period.

In ungulate reintroductions, older animals often travel farther than younger animals (Larkin et al. 2004; Ryckman et al. 2010; Le Gouar et al. 2012). In our study, yearling elk were more likely to be located near the release site than adults, and Bliesch et al. (2017) reported that elk reintroduced to Missouri exhibited a similar response. Male elk typically have larger home ranges than females (Ryckman et al. 2010; Bleisch et al. 2017). Elk in our study were no different, and only slight differences in home range sizes were observed between maternal and non-maternal females. Maternal females were most likely to remain near the release site, and our results support those found by Bliesch et al. (2017) who reported that maternal elk are likely to remain near the release site after release, as the calves they are supporting are less mobile and cannot make extensive movements. Non-maternal females travelled farther from the release site than males. This is likely due to several individual adult females that made extensive movements, and the fact that most of the males were yearlings that remained with the main herd.

Following a similar pattern found in elk reintroduced to Missouri (Bliesch et al. 2017), Wisconsin elk exhibited a multiphasic movement strategy post-release. Elk initially departed the release site making exploratory movements, and then established home ranges while including previously used habitat. Most elk made short exploratory movements but returned to the release site within 45 days post-release. Elk released in 2015 immediately left the release site, but after 12 days post-release, all elk were within 0.5 km of the release site. Bliesch et al.

(2017) reported similar result, noting that elk released in Missouri were transient for 10 days before settling into a home range phase. Elk released in 2016 showed a similar pattern to the 2015 cohort, but less temporally constrained. Elk began dispersing approximately 18 days post-release. By day 30, only 4 elk remained within one km of the release site. Between days 31-90, most elk had returned to the release site. Home range sizes reflected these movement patterns, averaging 438.9 ha 30 days post-release. Between days 31-90 they decreased 156% to 170.9 ha

The primary reason that elk returned to the release site was the presence of a 2.85 ha food plot adjacent to the quarantine facility. Elk were released in mid-summer, and the food plot provided immediate access to a high-quality source of forage, which allowed them to maximize caloric intake prior to winter. Most elk made short exploratory movements between days 1-90, but most returned to the release site and localized their resource use around the food plot. Elk disproportionately used grassland and oak over the remaining habitat classes (Figure 13). The food plot was classified as grassland during the analyses, and substantial use of it during the first 90 days post-release was reflected in our results. Approximately 28% of elk locations were classified as grassland, which encompasses only 1.8% of the availability extent. When elk where not occupying the area near the release site, they showed a preference for areas that had recently received habitat treatments.

The topography near the release site is primarily of slopes < 2.5^{o}, and our results indicated that slope had the least amount of influence on elk resource selection over the first 90 days post-release. As elk were making exploratory movements, many of them encountered a ridge network (Wildcat ridge), where they selected for northern and eastern aspects over southern and western aspects (Figure 19).

Topography can be an important determinant of elk resource use. In the western United States where topographic relief can be quite drastic, elk are generally migratory in respect to elevation and is as a crucial factor influencing overall elk movements (Hebblewhite & Merrill 2009, Nelson et al. 2012, DeVore 2014). In contrast, most current elk populations inhabiting eastern states live in temperate climates with low to moderate topographic relief. Therefore, assuming an adequate supply of food is available, eastern elk should show little to no tendency to migrate and have greater fidelity to local ranges (Cox 2011). The range in elevation in our study area was only 210 m between the highest and lowest elevations. Therefore, it likely had little effect on elk resources use and movements, but our results indicate that elk still use topography that is advantageous to them.

Elk typically avoid roads (Beck et al. 2013), and parameter estimates regarding road density and distance were highest between days 1-90 post-release. This may indicate that elk of the BREH were avoiding roads, but these results may be misleading. The release site and food plot are in a restricted part of BRSF, and the closest road is 2.3 km away (Figure ##). The results are more likely a function of elk localizing their movements around the food plot, more so than specifically avoiding roads, as elk locations were often near roads when making exploratory movements over the first 90 days post-release. Anderson et al. (2005) used RSF's to study summer habitat use of elk in northern Wisconsin. They reported that areas near roads were avoided by elk when establishing a home-range, but areas near roads were selected for use within the established home range.

McIntosh et al. (2014) identified predation by wolves as the most important proximate cause of mortality on reintroduced elk in Ontario, Canada, and our results indicate the same. 50% of elk mortalities in our study were attributed to predation, all of which were perpetrated by wolves. Our data suggests that elk did not explicitly avoid wolf activity centers 90 days post-release, but many elk of the 2016 release dispersed from the release site between days 18 – 30. Trail cameras located near the release site indicated increased wolf activity (Roepke 2016). Elk likely dispersed in response to the disturbance, but many returned to the release site, and food plot, as wolf activity decreased. Kittle et al. (2008) examined predation risk of white-tailed deer (*Odocoileus virginianus*), elk, and moose (*Alces alces*), and they noted that ungulates did not select resources based on avoiding areas of direct predation risk, but instead selected areas of use that tradeoff predation risk minimization with forage and/or mobility requirements. This is likely the case for elk of the BREH. Even with evidence of wolf activity near the release site, elk returned to maximize the use of the highest quality resource available to them. While the prevalence of high quality forage resources at release sites can increase fidelity of reintroduced elk, it may also increase mortality risk, potentially setting an ecological trap for animals naïve to local risks (Frair et al. 2007).

Between days 90 – 180 post-release, and most elk began leaving the release site in search of suitable wintering habitat that the food-plot and the surrounding area could not provide. Maximum distance travelled increased approximately 200%, and home ranges sizes increased 230%. During this time-period, elk showed the strongest preference towards crops and grassland, and positive associations occurred regarding developed and oak habitat classes (Table 9). Aspen, mixed coniferous/deciduous and shrubland classes were used in proportion to availability (Figure 14), and negative associations occurred regarding cranberry, hardwoods, wetland, and open water classes. Slight negative association occurred regarding areas where habitat manipulation had recently occurred (Table 6). A positive association with sloped terrain occurred between days 91 – 180, as well as toward northern and eastern aspects (Table 9). Flat and southern aspects were used at a similar frequency, and there was a negative association with western slopes (Figure 19). Road distance and density parameter estimates indicate that elk mostly utilized areas without roads between days 91 - 180, but to a lesser extent than the previous time period (Table 9). Elk did not avoid areas located near wolf pack centers during this time-period and parameter estimates were nearly identical to the 1 - 90 day time-period (Table 9 and Figure 18).

Elk remained in established winter ranges during the first half of the 181 - 365 day time period. They began leaving their winter ranges between days 250 – 300 as winter transition to spring, and the majority of elk movements during the 181 - 365 day time period occurred during the last 75 days.

During the 181-270 day time period, elk localized their resource selection to winter ranges and they selected habitats near roads. The mean distance to the nearest road was 0.37 km. The BREH continued to use the developed, crop, and oak habitat classes at a greater proportion that what was available, but utilization of the grassland habitat declined and only 3.3% of locations were classified in grassland habitats. Thirty-six percent of elk locations were classified as coniferous, compared to 40% that were considered available (Figure 15). Lyon & Christensen (1992) define a stand of coniferous trees 40 feet tall, or taller, with average crown closure of 70 percent as thermal cover, and elk likely used coniferous habitats to alleviate the effects of winter weather. Although thermal cover is typically associated with coniferous habitats, (Skolvin et al. 2002) note that in some cases, topography and other vegetation types may meet an animal's needs for thermoregulation. The influence of slope remained similar to the previous time period. Selection of aspect shifted to southern and western slopes which receive more direct solar radiation during winter and are generally warmer than northern and eastern aspects. During this time-period, elk avoided wolf use areas more than any of the remaining 3 time periods. Parameter estimates were almost 450% higher compared to the mean parameter estimates of the other 3 time periods (Days 181 – 270 = -0.018; Days 1-180 and 271-365 μ = -0.08).

During the 271 - 365 time-period, elk continued to use crops at approximately the same rate as the previous time period. Selection of coniferous habitat declined, but use of the grassland, hardwood, and oak classes increased (Figure 16). In contrast, elk in northern Wisconsin primarily utilized coniferous forest, mixed coniferous/deciduous forest, and aspen stands in spring and summer (Fawcett 2004). Elk often prefer areas that contain open areas for feeding while having escape cover nearby, and parameter estimates indicated a positive association with areas where recent habitat manipulation created more open landscapes with increased edge habitat. Dewar (2006) identified the proximity to a forage-cover edge as the main factor driving summer resources selection in northwestern Ontario, Canada. Among the 4 time periods, the maximum parameter estimate for slope was estimated between days 271 - 365. This may indicate that slope was most influential during this time frame, but this seems to be contradicted by negative parameter estimates for the 4 cardinal directions of aspect when compared to areas with no aspect (Figure 19). These results likely are due to the distribution of elk during this time frame. Approximately 50% of elk remained in the Wildcat ridge area where the highest concentration of topographic relief occurs, and the area used by elk encompasses a varying degree of both slope and aspect. The remaining elk were distributed in smaller groups 20 – 30 km to the northwest where topographic relief is minimal. Elk displayed a minimal amount of avoidance regarding road features during this time-period (Figure 18). Most elk that had not established home ranges in the Wildcat ridge area were primarily distributed within 10 km to the east and northeast of Black River Falls, where road density is highest. Avoidance of wolf pack centers decreased between days 270 -365, and parameter estimates were similar to those of the 1 - 90 and 91 - 181 day time periods. Anderson et al. (2005) reported that at a large spatial extent, home-range establishment of the CLEH was largely explained by the spatial distribution of wolf territories, and wolves may have greater effects on elk dynamics than would be predicted based on direct predation alone (Creel et al. 2005). Elk of the BREH increased use of habitats near roads and human development throughout the duration of the study period. They most likely used these areas to reduce predation risk. Compared to migratory elk, resident elk are exposed to higher predation risk, but they reduce predation risk at fine scales by using areas close to human activity, which wolves avoided (Hebblewhite and Merrill 2009).

One year post-release, 9 Black River elk had made excursions ≥ 25 km from the release site, with 3 traveling ≥ 60 km, and 1 traveling as far as 172 km. Black River elk will likely shift their ranges, and may disperse farther distances from the release site. Yott et al. (2011) reported that of elk released in eastern Ontario, Canada, a year and a half post-release, only 16% of the elk were located within 10 km of the release site, 27% within 20 km, whereas 37% were >40 km away. Haydon et al. (2008) and Bliesch et al. (2017) reported that reintroduced elk often travel farther when solitary, and our study showed comparable results. Adult females and their calves form the most constant part of elk herds (Franklin et al. 1975), and they are structured by dominant cows (Millspaugh et al. 2004 and Bliesh et al. 2017). Franklin et al. (1975) reported that yearling females and 2 year-old females associated most strongly with the cow/calf herds, but observed too few encounters between cows 3 years and older to determine whether an absolute or partial dominance hierarchy existed. The quarantine period allowed elk to form social bonds and establish a dominance hierarchy prior to release. The 3 individuals that travelled more than 60 km from the release site were adult females, ≥ 3 years old, without offspring. They dispersed earlier than most other elk, and it is likely that they were subordinate to the dominant females and rejected from the main herds that coalesced upon release.
The accuracy assessment of elk GPS collars indicated high spatial accuracy, but a lack of temporal resolution between GPS fixes was one of the limiting factors to this study. GPS locations were record in 13-hour intervals and missed GPS fixes led to large gaps between recorded locations. This was particularly true during spring and summer as canopy cover increased, and the reduced ability of GPS collars to acquire satellites and record GPS locations. The combination of these factors led to gaps in GPS location data, and in some instances, 3.5 days elapsed between successful GPS fixes. Even without missed GPS fixes, elk can move considerable distances in 13 hours. The use of resources may be misrepresented, especially as elk were establishing home ranges.

Interstate 94 is a significant barrier to elk movements, and the t-locoh home range method was used because it is particularly robust to variations in sampling intensity, detecting barriers, and accounts for both spatial and temporal autocorrelation of GPS data (Schweiger et al. 2015; Stark et al. 2017). T-locoh does not estimate home range sizes outside of known locations and likely underestimates true home range size. This method may not be suitable for other home range studies (Stark et al. 2017), and in locations where movement barriers are less frequent, probability-based home range estimators such as kernel density estimators (Worton 1989, Seaman and Powell 1996, and Kie 2013), Brownian bridge movement models (Horne et al. 2007 and Kranstauber et al. 2012), and biased random bridge models (Benhamou 2011) likely provide more accurate home range estimates.

Accuracy limitations of the Wiscland 2 data, and misidentified habitat classes likely influenced our RSF models. We used the third level of Wiscland 2 to differentiate between class of deciduous cover. At the third level, the estimated overall accuracy is 73% (WDNR 2016). The highest accuracy classes consisted of wetland, grassland and forest subtypes. Broad-leaved deciduous scrub/shrub (87%), pasture (80%), and pine (80%) were most accurately assessed, while the lowest accuracies are generally forest subtypes, including central hardwoods (34%), red maple (30%) and lowland aspen (19%) (WDNR 2016). Low accuracy classes are confused with compositionally similar classes, with aspen being misclassified as swamp hardwoods (11%), or oak (14%) and central hardwoods is misidentified as oak (28%) and northern hardwoods (12%). In each of these examples, the commission to the oak class indicates that oak is possibly over-estimated at Level 3 (WDNR 2016).

Wolves have dynamic social structures that change frequently, and pack sizes and ranges change over time. Limited access to wolf spatial data reduced our ability to identify how wolves influenced elk resource selection. Wolf pack locations had to be digitized visually from a WDNR map, with only a single, stationary point, being used to act a reference point for each wolf pack for each time period analyzed (WDNR 2017). Therefore, inference from the data should be treated with caution, and actual wolf locations may have been drastically different from the reference points. This likely induced bias in the results regarding the distance between wolf packs and elk locations.

Overall, our results indicate that release site fidelity was high over the first 90 days post-release but decreased throughout the remainder of the study. Elk made exploratory movements during the first 30 days post-release, but range sizes decreased 31-90 days post-release. Home range sizes increased substantially between days 91-180, and then stabilized between days 91-365 post-release. Elk selected for a suite of vegetation cover types between each post-release time period, but they consistently selected against the cranberry, shrubland, wetland, and open water habitat classes. Use of topographic characteristics shifted throughout the study duration. Slope had little influence after the first 90 days post-release, while use of aspect varied. The influence of slope then increased and stabilized between days 91-365. The use of aspect shifted between the final 3 time periods, and elk selected for aspects that provided for thermoregulatory advantages as seasons changed. Elk mostly avoided roads for the first 90 days, but as time progressed, elk often utilized resources near major roads and human development. Elk avoided wolf activity centers between days 181 -270. They did not particularly avoid wolf activity centers between days 1-180 and 271-365, but they often selected toward areas closely associated with humans, which wolves tend to avoid.
Most GPS collars used in this study will potentially collect data on elk locations for up to 4 years, and further research should be conducted to identify how elk resource selection changes as the BREH expands and home ranges shift. Future reintroductions should use the highest fix rate possible for GPS collars, while taking into account the battery life needed to sustain the collars for the duration of the study period. A GPS fix rate of 3 – 8 hours will increase temporal resolution and resource selection can be examined at finer scale than those with longer with longer fix rates. When a GPS collar fails to record a location, the length of time between successful fixes is also reduced in collars with shorter fix rates. Wolves are the primary predators of the BREH and identifying how wolf activity influences elk resource selection should be studied in greater depth. Future research should incorporate wolf location data into RSF analyses to provide a more detailed description of elk resource selection and how it is influenced by wolf activity. Spatial scale of environmental variables should also be considered when using RSFs. Results from Anderson et al. (2005) show that the effects of environmental variables on habitat use by elk were scale-dependent, and they emphasize the necessity of analyzing habitat use at multiple scales that are fit to address specific research questions.

Acknowledgements

I would like to give thanks to all of the individuals and organizations that provided support and funding throughout the duration of this project. Without their time and dedication, this project would not have been possible. I want to personally thank my committee members for their time and all of the knowledge they passed on to me. Throughout this project, my graduate advisor, Dr. Tim Ginnett, provided an immense amount of support and guidance while helping me keep my expectations in line. Dr. Scott Hygnstrom provided support throughout this project, and the conversations we had forced me to be more critical of the reasoning behind the methodology's that I employed. Dr. Jason Riddle's knowledge of statistics and his ability to explain statistical concepts in a way that they are easily understood helped immensely. Dan Storm of the Wisconsin Department of Natural Resources aided in all aspect of this research, and his input on elk resource selection was particularly helpful.

I would like to thank all of the biologists, technicians, and veterinarians WDNR, KDFW the Ho-Chunk Nation who assisted in this project. They spent many hours of hard work trapping, transporting, and monitoring elk. Without them, this project would have been impossible. In particular, I'd like to thank Scott Roepke. He provided invaluable assistance in supporting me while I was in the field, and in supplying GPS and mortality data. I would also like to thank the Kentucky Department of Fish and Wildlife biologists who provided assistance throughout all aspect of the trapping and quarantine procedures in Kentucky, and without their partnership, this project could not have happened. Finally, I want to thank all of my family, friends, and fellow graduate students for their support, and for putting up with the rants about my research that I forced them to listen to.

Literature Cited

Anderson, D. P., M. G. Turner, J. D. Forester, J. Zhu, M. S. Boyce, H. Beyer. L. Stowell. 2005. Scale- dependent summer resource selection by reintroduced elk in Wisconsin, USA. Journal of Wildlife Management 69:298-310.

Armstrong, D. P., and P. J. Seddon. 2008. Directions in reintroduction biology. Trends in Ecology & Evolution 23:20-25.

Barbknecht, A. E., W. S. Fairbanks, J. D. Rogerson, E. J. Maichak, B. M. Scurlock and L. L. Meadows. 2011. Elk parturition site selection at local and landscape scales. Journal of Wildlife Management 75:646-654.

Beck, J. L., K. T. Smith, J. T. Flinders, C. L. Clyde. 2013. Seasonal habitat selection by elk in north central Utah. Western North American Naturalist 73:442-456.
Benhamou, S. 2011. Dynamic approach to space and habitat use based on biased random bridges. PloS ONE. 6.

Bleisch, A. 2014. Initial movements and disturbance response of a newly reintroduced elk herd in the Missouri Ozarks. Thesis, University of Missouri – Columbia, Columbia, USA.

Bleisch, A. D., B. J. Keller, T. W. Bonnot, L. P. Hansen, and J. J. Millspaugh. 2017. Initial movements of re-introduced elk in the Missouri Ozarks. The American Midland

Naturalist 178:1-16.

Bonnot, T. W., J. H. Schulz, and J. J. Millspaugh. 2011. Factors affecting mourning dove harvest in Missouri. Wildlife Society Bulletin 9999(xx):1—9.

Boyce, M. S., & L. L. McDonald. 1999. Relating populations to habitats using resource selection functions. Trends in Ecology & Evolution 14:268-272.

Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157:281-300.

Buchanan, C. B., J. L. Beck, T. E. Bills, S. N. Miller. 2014. Seasonal resource selection and distributional response by elk to development of a natural gas field. Rangeland Ecology & Management 67:369-379.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information – theoretic approach. 2nd edition. Springer. Verlag, New York, NY.

Buskirk, S.W. and J. J. Millspaugh. 2006. Metrics for studies of resource selection. Journal of Wildlife Management 70:358-366.

Cox, J.J., 2011. Tales of a repatriated megaherbivore: challenges and opportunities in the management of reintroduced elk in Appalachia. Proceedings of the 17th Central Hardwood Forest Conference. U.S. Department of Agriculture. Lexington, KY, USA

Creel, S., J. Winnie Jr, B. Maxwell, K. Hamlin, and M. Creel. 2005. Elk alter habitat selection as an antipredator response to wolves. Ecology 86:3387-3397.

DeVivo, M.T., W. O. Cottrell, J. M. DeBerti, J. E. Duchamp, L. M. Heffernan, J. D. Kougher, and J. L. Larkin. 2011. Survival and cause-specific mortality of elk *Cervus canadensis* calves in a predator rich environment. Wildlife Biology 17:156-165.

DeVore, R. M. 2014. Population dynamics and habitat use by elk (*Cervus elaphus*) at Bosque

Del Apache National Wildlife Refuge, New Mexico, USA. Dissertation, Texas Tech University, Lubbock, USA.

Dewar, N. E. 2006. Development and evaluation of inductive and deductive models of summer elk (*Cervus elaphus*) resource suitability in Northwestern Ontario. Dissertation. Lakehead University. Thunder Bay, Ontario, Canada.

Dickens, M. J., D. J. Delehanty, and L. M. Romero. 2010. Stress: an inevitable component of animal translocation. Biological Conservation 143:1329-1341.

Dürr, S., and M. P. Ward. 2014. Roaming behaviour and home range estimation of domestic dogs in Aboriginal and Torres Strait Islander communities in northern Australia using four different methods. Preventive Veterinary Medicine 117:340-357.

ESRI. 2017. ArcGIS Desktop: Release 10.5.1. Environmental Systems Research Institute. Redlands, CA, USA.

Fawcett, F. 2004. Resource selection and spatial relationships of elk (*Cervus elaphus nelson*) and wolves (*Canis lupis*) in Northern Wisconsin. Thesis, University of Wisconsin – Stevens Point, Stevens Point, Wisconsin, USA

Frair, J. L., E. H. Merrill, J. R. Allen, and M.S. Boyce. 2007. Know thy enemy: experience affects elk translocation success in risky landscapes. Journal of Wildlife Management 71:541-554.

Franklin, W. L., A. S. Mossman, and M. Dole. 1975. Social organization and home range of Roosevelt elk. Journal of Mammalogy 56:102–118

Fryxell, J. M., A. R. Sinclair, and G. Caughley. 2006. Wildlife ecology, conservation, and management. 2nd edition. John Wiley & Sons. Hoboken, NJ, USA.

Fuhlendorf, S.D., D. M. Engle, J.A.Y. Kerby, and R. Hamilton. 2009. Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23:588-598.

Gese, E. M. and S. Grothe. 1995. Analysis of coyote predation on deer and elk during winter in Yellowstone National Park, Wyoming. The American Midland Naturalist 133:36-43.

Getz, W. M., S. Fortmann-Roe, P. C. Cross, A. J. Lyons, S. J. Ryan, and C. C. Wilmers. 2007. LoCoH: non-parameteric kernel methods for constructing home ranges and utilization distributions. PloS ONE 207:1-11.

Getz, W., C. Wilmers. 2004. A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. Ecography 27:489–505.

Gilbert, J., J. Sausen, B. Dhuey. 2010. Wisconsin elk habitat suitability analysis. Wisconsin Department of Natural Resources, Bureau of Science Services, Madison, Wisconsin, USA.

Groombridge, J. J., C. Raisin, R. Bristol, and D. S. Richardson. 2012. Genetic consequences of reintroductions and insights from population history. Reintroduction biology: integrating science and management, 395-440. John Wiley & Sons. Hoboken, NJ, USA

Griffith, B., J. M. Scott, J. W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477-480.

Haydon, D. T., J. M. Morales, A. Yott, D. A. Jenkins, R. Rosatte, and J. M. Fryxell. 2008.

Socially informed random walks: incorporating group dynamics into models of population spread and growth. Proceedings of the Royal Society B275:1101-1109.

Hebblewhite, M., & E. H. Merrill. 2009. Trade-offs between predation risk and forage differ between migrant strategies in a migratory ungulate. Ecology 90:3445-3454.

Horne, J. S., E. O. Garton, S. M. Krone, and J. S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology 88:2354-2363.

Johnson, C. J., S. E. Nielsen, E. H. Merrill, T. L. McDonald, and M. S. Boyce. 2006. Resource selection functions based on use-availability data: theoretical motivation and evaluation methods. Journal of wildlife Management 70:347-357.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Keating, K.A. and S. Cherry. 2004. Use and interpretation of logistic regression in habitat-selection studies. Journal of Wildlife Management 68:774-789.

Kie, J. G. 2013. A rule-based ad hoc method for selecting a bandwidth in kernel home-range analyses. Animal Biotelemetry 1:1-13.

Kittle, A. M., J. M. Fryxell, G. E. Desy, and J. Hamr. 2008. The scale-dependent impact of wolf predation risk on resource selection by three sympatric ungulates. Oecologia 157:163-175.

Kranstauber, B., R. Kays, S. D. LaPoint, M. Wikelski, and K. Safi. 2012. A dynamic Brownian bridge movement model to estimate utilization distributions for heterogeneous animal movement. Journal of Animal Ecology 81:738-746.

Larkin, J. L., J. J. Cox, M. W. Wichrowski, M. R. Dzialak, and D. S. Maehr. 2004. Influences on release-site fidelity of translocated elk. Restoration Ecology 12:97-105.

Larkin, J. L., D. S. Maehr, J. J. Cox, M. W. Wicherowski, and R. D. Crank. 2002. Factors affecting reproduction and population growth in a restored elk (*Cervus elaphus nelson*) population. Wildlife Biology 8:49–54.

LeGouar, P., J. B. Mihoub, and F. Sarrazin. 2012. Dispersal and habitat selection: behavioral and spatial constraints for animal translocations. Reintroduction biology: integrating science and management. 138-164. John Wiley & Sons. Hoboken, NJ, USA

Lehman, C.P., M.A. Rumble, C.T. Rota, B.J. Bird, D.T. Fogarty, and J.J. Millspaugh. 2016. Elk resource selection at parturition sites, Black Hills, South Dakota. Journal of Wildlife Management 80:465-478.

Lele, S.R., E. H. Merrill, J. Keim, and M. S. Boyce. 2013. Selection, use, choice and occupancy: clarifying concepts in resource selection studies. Journal of Animal Ecology 82:1183-1191.

Lupardus, J. L. 2005. Seasonal forage availability and diet of reintroduced Elk in the Cumberland Mountains, Tennessee. Thesis, University of Tennessee, Knoxville, USA.

Lyons, A.J. 2014. T-LoCoH for R - Tutorial and Users Guide. http://tlocoh.r-forge.r-project.org/tlocoh_tutorial_2014-08-17.pdf

Lyon, L. J., & A. G. Christensen. 1992. A partial glossary of elk management terms. General technical report. United States Forest Service, Washington D.C., USA.

Manly, B. F. L., L. McDonald, D. Thomas, T. L. McDonald, and W. P. Erickson. 2007. Resource selection by animals: statistical design and analysis for field studies. Springer Science & Business Media. Berlin, Germany.

McDonald, T. L. 2013. The point process use-availability or presence-only likelihood and comments on analysis. Journal of animal ecology 82:1174-1182.

McGeachy, D. N. 2014. Population distribution and seasonal resource selection by elk (*Cervus elaphus*) in central Ontario. Dissertation, Laurentian University, Sudbury, Canada.

McIntosh, T. E., R. C. Rosatte, J. Hamr, and D. L. Murray. 2014. Patterns of mortality and factors influencing survival of a recently restored elk population in Ontario, Canada. Restoration Ecology 22:806-814.

Millspaugh, J. J., G. C. Brundige, R. A. Gitzen, and K. J. Raedeke. 2004. Herd organization of cow elk in Custer State Park, South Dakota, Wildlife Society Bulliten 32:506-514.

Morris, L. R., K. M. Proffitt, V. Asher, and J. K. Blackburn. 2016. Elk resource selection and implications for anthrax management in Montana. The Journal of Wildlife Management 80:235-244.

National Research Council (NRC). 1995. The global positioning system: A shared national asset. National Academies Press. Washington D.C., USA.

Nelson, A. A., M. J. Kauffman, A. D. Middleton, M. D. Jimenez, D. E. McWhirter, J. Barber, And K. Gerow. 2012. Elk migration patterns and human activity influence wolf habitat use in the Greater Yellowstone Ecosystem. Ecological Applications 22:2293-2307.

Northrup, J. M., M. B. Hooten, C. R. Anderson Jr, and G. Wittemyer. 2013. Practical guidance on characterizing availability in resource selection functions under a use-availability design. Ecology 94:1456-1463.

O'Gara, B. W., and R. G. Dundas. 2002. Distribution: past and present. Pages 121-198 *in* J. W.

Popp, J. N., T. Toman, F. F. Mallory, and J. Hamr. 2014. A century of elk restoration in eastern North America. Restoration Ecology 22:723–730.

Proffitt, K. M., J. A. Gude, K. L. Hamlin, R. A. Garrott, J. A. Cunningham, and J. L. Grigg. 2011. Elk distribution and spatial overlap with livestock during the brucellosis tr ansmission risk period. Journal of Applied Ecology 48:471-478.

R Studio Team. 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA, USA.

Ranglack, D. H., K. M. Proffitt, J. Gude, J. Canfield, J. Rotella, and R. A. Garrott. 2016. Evaluating elk summer resource selection and applications to summer range habitat management. Intermountain Journal of Sciences 22:114-115.

Roepke, S. C. 2012. Estimating genetic variation and population abundance of Wisconsin's reintroduced elk herd. M. S. Thesis, University of Wisconsin – Stevens Point, Stevens Point, Wisconsin, USA

Roepke, S. C. 2016. Personal communication.

Rosatte, R., J. Hamr, J. Young, I. Filion, and H. Smith. 2007. The restoration of elk (*Cervus elaphus*) in Ontario, Canada: 1998–2005. Restoration Ecology 15:34-43

Rowland, M. M., M. J. Wisdon, B. K. Johnson, and J. G. Kie. 2000. Elk distribution and modelling in relation to roads. Journal of Wildlife Management 64:672-684.

Ryckman, M. J., R. C. Rosatte, T. McIntosh, J. Hamr, and D. Jenkins. 2010. Postrelease dispersal of reintroduced elk (*Cervus elaphus*) in Ontario, Canada. Restoration Ecology 18:173-180.

Samuel, W. M., M. J. Pybus, D. A. Welch, D. and C. J. Wilke. 1992. Elk as a potential host for meningeal worm: implications for translocation. The Journal of Wildlife Management 56:629-639.

Schorger, A.W. 1954. The elk in early Wisconsin. Transactions of the Wisconsin Academy of

Sciences, Arts and Letters XLIII:5-23. (Reprinted in Brockman, K.M. and R.A. Dow Jr. (eds). 1982. Wildlife in Early Wisconsin, A Collection of Works by A. W. Schorger. Student Chapter of the Wildlife Society, Stevens Point, WI, USA.

Scillitani, L., G. Darmon, A. Monaco, G. Cocca, E. Sturaro, L. Rossi, & M. Ramanzin. 2013. Habitat selection in translocated gregarious ungulate species: an interplay between sociality and ecological requirements. Journal of Wildlife Management 77:761–769.

Schweiger, A. K., M. Schütz, P. Anderwald, M. E. Schaepman, M. Kneubühler, R. Haller, and A. C. Risch. 2015. Foraging ecology of three sympatric ungulate species–behavioral and resource maps indicate differences between chamois, ibex and red deer. Movement Ecology 3:1-12.

Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77:2075-2085.

Seddon, P. J., D. P. Armstrong, R. F. Maloney. 2007. Developing the science of reintroduction biology. Conservation Biology 21:303-312.

Stark, D. J., I. P. Vaughan, D. A. R. Saldivar, S.K. Nathan, and B. Goossens, B. 2017. Evaluating methods for estimating home ranges using GPS collars: A comparison using proboscis monkeys (*Nasalis larvatus*). PloS ONE 12.

Stewart, K. M., D. R. Walsh, J. G. Kie, B. L. Dick, and R. T. Bowyer. 2015. Sexual segregation in North American elk: the role of density dependence. Ecology and Evolution 5:709-721.

Skolvin, J. M., P. Zager, and B. K Johnson. 2002. Distribution: past and present. Pages 531-556 *in* J. W. Thomas and D. E. Toweill, editors. North American elk: ecology and management. Smithsonian Institution, Washington, D.C., USA.

Teixeira, C. P., C. S. de Azevedo, M. Mendl, C. F. Cipreste, and R. J. Young. 2007. Revisiting translocation and reintroduction programmes: the importance of considering stress. Animal Behaviour 73:1-13.

Thomas and D. E. Toweill, editors. North American elk: ecology and management. Smithsonian Institution, Washington, D.C., USA.

United States Geological Survey (USGS). 2000. Thirty meter national elevation data set. U.S. Geological Survey EROS data center, Souix Falls, SD, USA.

U.S. Census Bureau (USCB). 2015. TIGER/Line Shapefiles. Prepared by the U.S. Census Bureau, 2015. U.S. Department of Commerce. Washington D.C., USA.

Wisconsin Department of Natural Resources (WDNR). 2014. The ecological landscapes of Wisconsin: an assessment of ecological resources and a guide to planning sustainable management. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Wisconsin Department of Natural Resources (WDNR). 2016. Wiscland 2 User Guide. Wisconsin Department of Natural Resources. Madison, Wisconsin, USA.

Wisconsin Department of Natural Resources (WDNR). 2017. 2016-2017 Wolf detection map. Wisconsin Department of Natural Resources. Madison, Wisconsin., USA.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 164-168.

Yott, A., R. Rosatte, J. A. Schaefer, J. Hamr, and J. Fryxell. 2011. Movement and spread of a founding population of reintroduced elk (*Cervus elaphus*) in Ontario, Canada. Restoration Ecology 19:70—77.

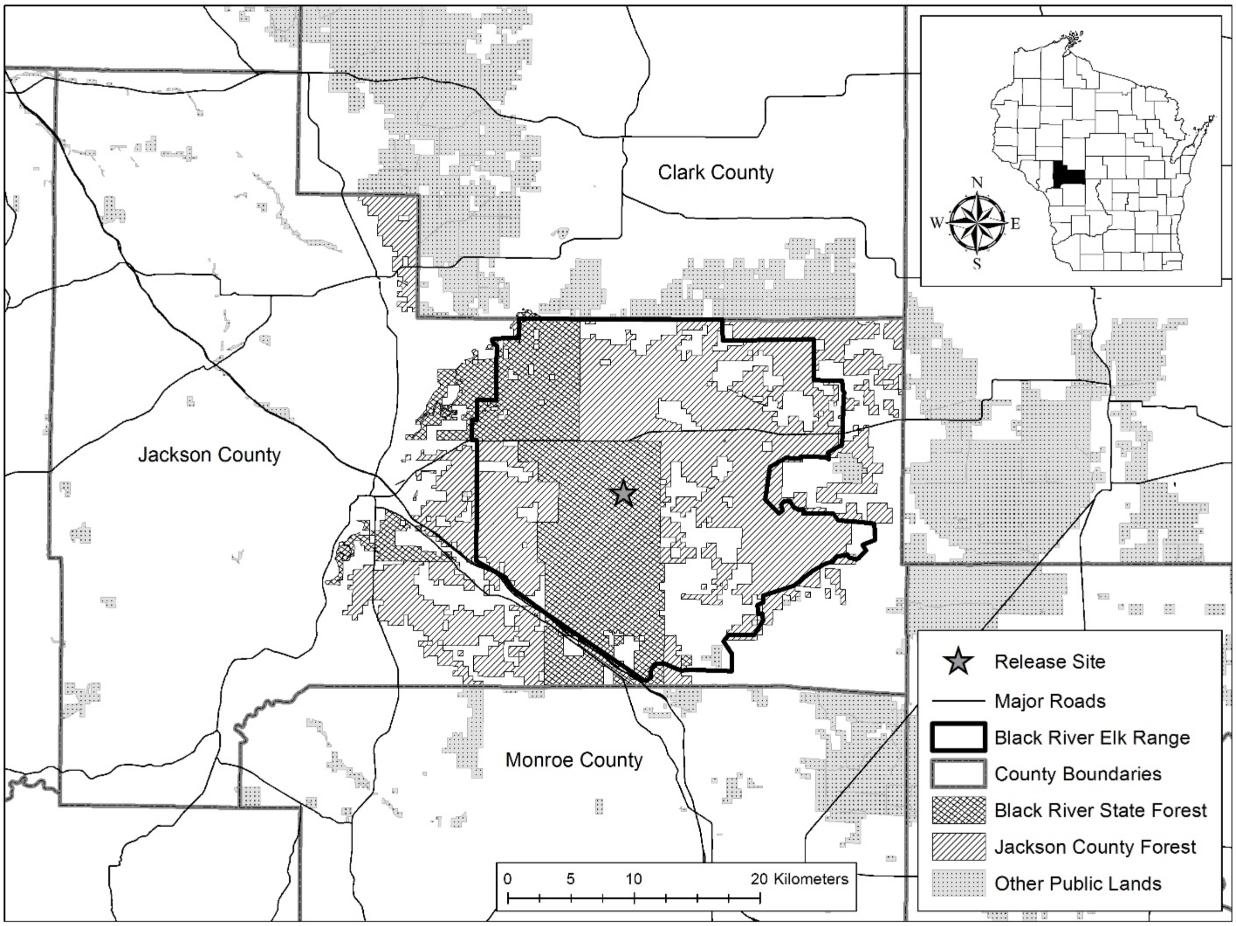


Figure 1. Black River Elk herd study area in Jackson County, WI. Primary elk range consists mostly of lands managed by Black River State Forest and Jackson County Department of Parks & Forestry. Other public lands are present in adjacent counties.

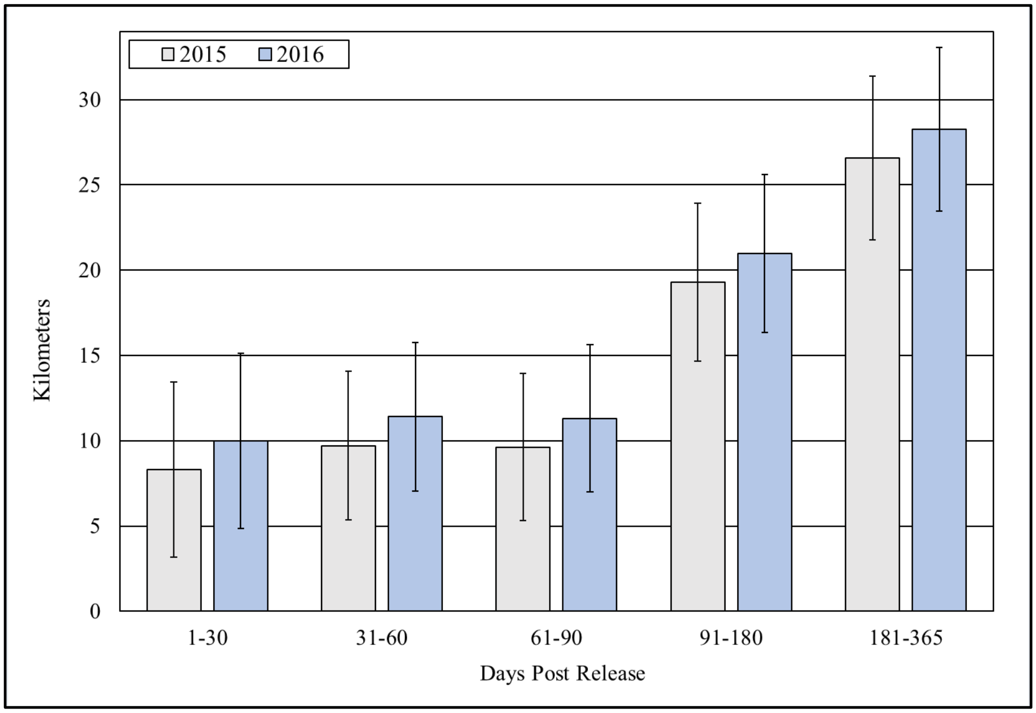


Figure 2. Model-averaged estimates for the release year effect on maximum displacement from the release site for elk reintroduced to Jackson County in 2015 and 2016. Error bars equal 95% confidence interval.

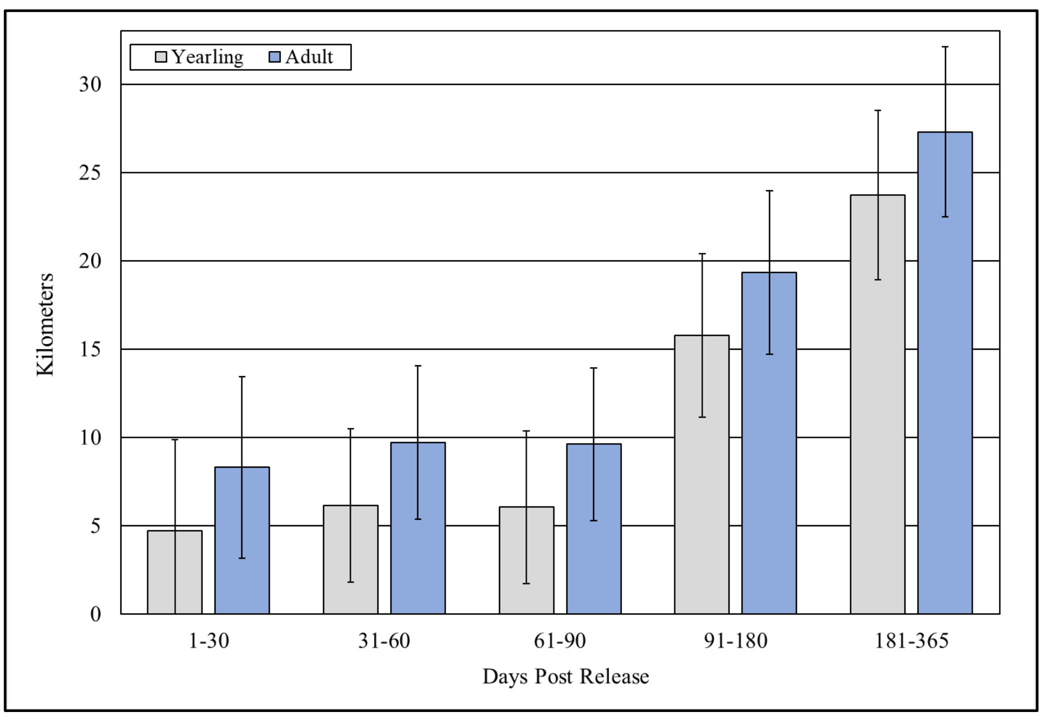


Figure 3. Model-averaged estimates for the age effect on maximum displacement from the release site for elk reintroduced to Jackson County in 2015 and 2016. Error bars equal 95% CI.

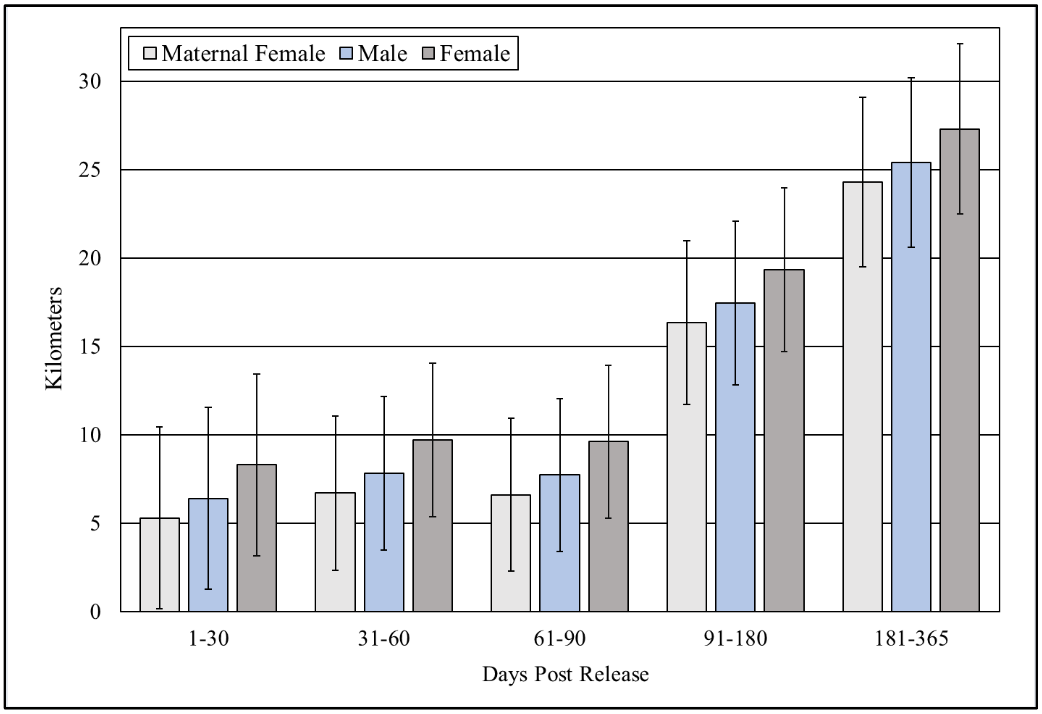


Figure 4. Model-averaged estimates for the sex effect on maximum displacement from the release site for elk reintroduced to Jackson County in 2015 and 2016. Error bars equal 95% CI.

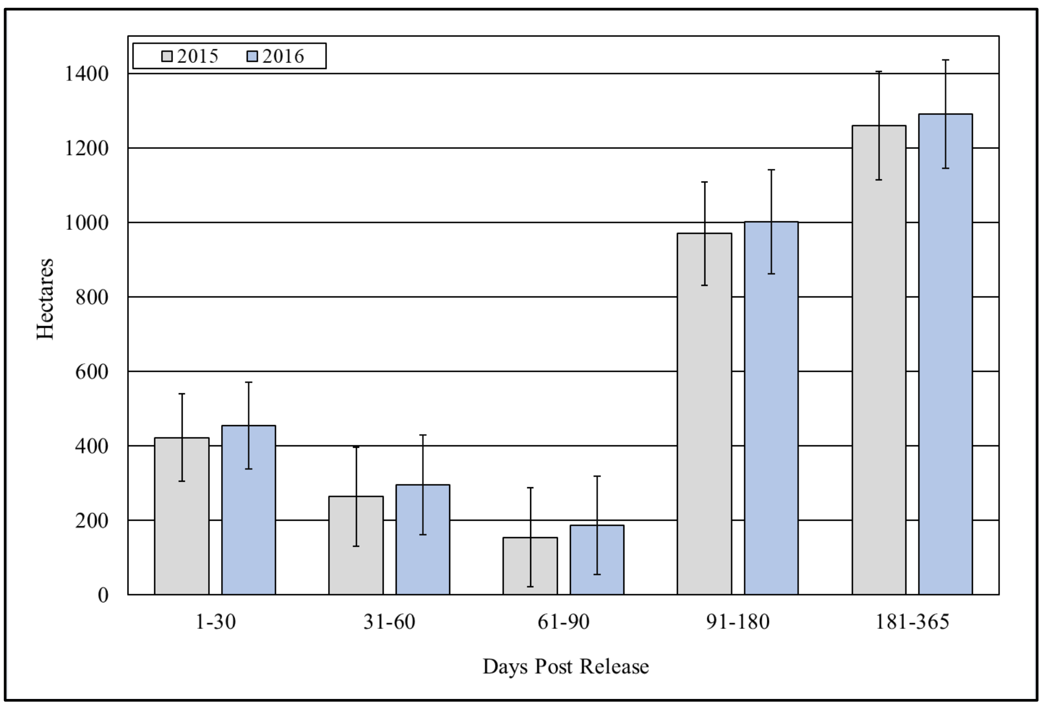


Figure 5. Model-averaged estimates of home range size by release year for elk reintroduced to Jackson County in 2015 and 2016. Error bars equal 95% CI.

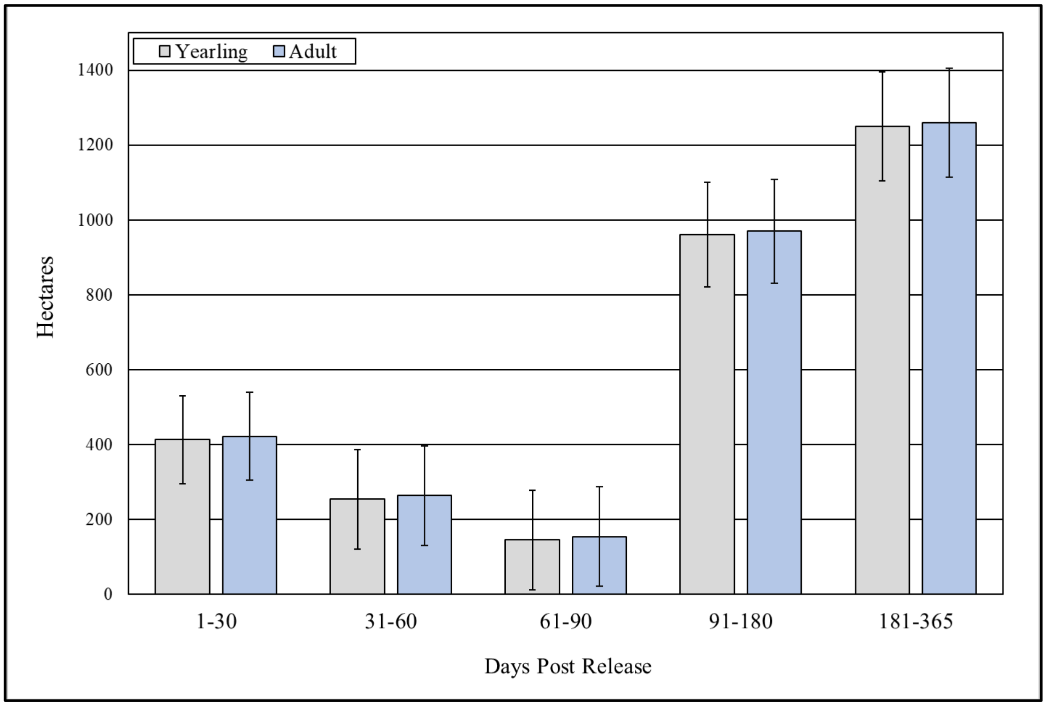


Figure 6. Model-averaged estimates of home range size by age class for elk reintroduced to Jackson County in 2015 and 2016. Error bars equal 95% CI.

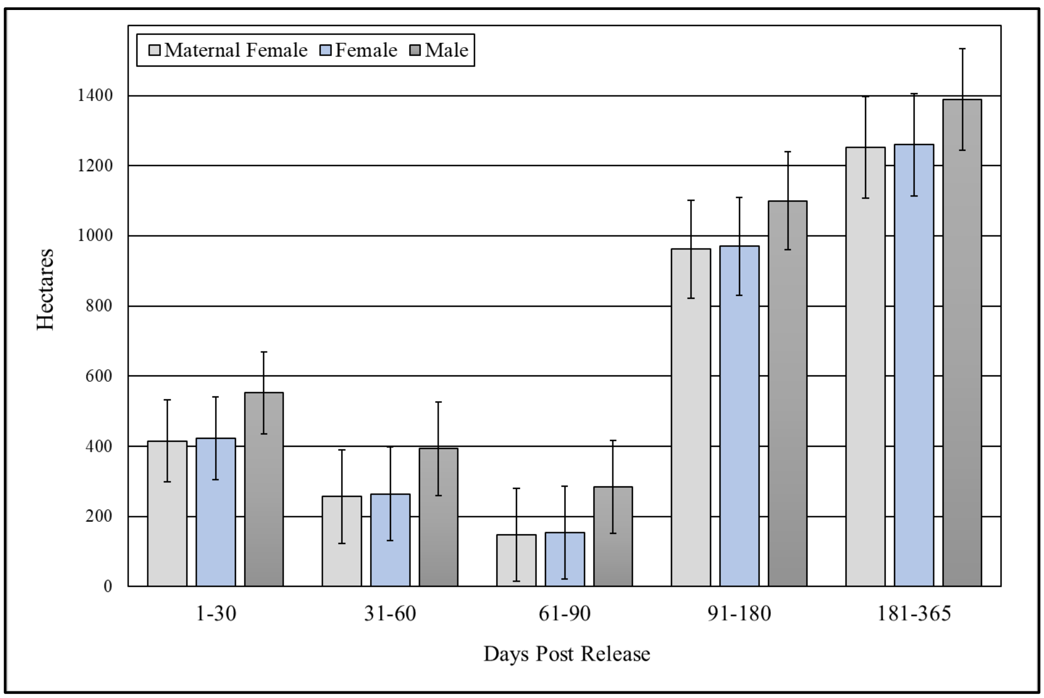


Figure 7. Model-averaged estimates of home range size by sex class for elk reintroduced to Jackson County in 2015 and 2016. Error bars equal 95% CI.

Table 1. Candidate models used to assess the relative importance of time post-release, release year, sex, and age on maximum distance traveled from the release site and home range size per time-period for elk reintroduced to Jackson County in 2015 and 2016.

Candidate Model Structure
1. Null Model
2. Time
3. Release Year
4. Sex
5. Age
6. Time + Release Year
7. Time + Age
8. Time + Sex
9. Time + Age + Sex
10. Release Year + Age
11. Release Year + Sex
12. Release Year + Age + Sex
13. Time + Release Year + Age
14. Time + Release Year + Sex
15. Time + Release Year + Age + Sex (Global Model)

Table 2. Model selection results for maximum distance traveled from the release site for elk reintroduced to Jackson County in 2015 and 2016. Models 2, 6, 7, 8, 9, and 13 were used for model averaging.

Rank	Model	Model Components	Intercept	K	logLik	AICc	ΔAICc	wi
1.	2	Time	7.810	7	-922.479	1859.455	0	0.329
2.	7	Time + Age	9.267	8	-921.604	1859.851	0.395	0.270
3.	6	Time + Release Year	6.318	8	-922.233	1861.108	1.653	0.144
4.	13	Time + Release Year + Age	8.362	9	-921.537	1861.882	2.426	0.098
5.	9	Time + Age + Sex	10.760	10	-920.922	1862.835	3.379	0.061
6.	8	Time + Sex	8.795	9	-922.107	1863.021	3.565	0.055
7.	14	Time + Release Year + Sex	7.323	10	-921.881	1864.754	5.298	0.023
8.	15	Global Model	9.930	11	-920.866	1864.927	5.471	0.021
9.	1	Null Model	13.157	3	-958.776	1923.658	64.202	0
10.	3	Release Year	10.324	4	-957.998	1924.171	64.715	0
11.	4	Age	14.868	4	-957.655	1923.485	64.029	0
12.	5	Sex	15.210	5	-956.890	1924.045	64.590	0

13.	10	Release Year + Age	12.535	5	-957.265	1924.795	65.339	0
14.	11	Release Year + Sex	12.214	6	-956.064	1924.500	65.045	0
15.	12	Release Year + Age + Sex	15.664	7	-954.369	1923.237	63.781	0

Table 3. Model selection results for home range size for elk reintroduced to Jackson County in 2015 and 2016. Models 2, 6, 7, 8, 9, and 14 were used for model averaging.

Rank	Model	Model Components	Intercept	K	logLik	AICc	ΔAICc	wi
1.	8	Time + Sex	415.415	9	-1638.180	3295.186	0	0.326
2.	2	Time	450.031	7	-1640.820	3296.159	0.973	0.201
3.	14	Time + Release Year + Sex	389.977	10	-1637.950	3296.917	1.731	0.137
4.	9	Time + Age + Sex	425.039	10	-1638.100	3297.228	2.043	0.118
5.	6	Time + Release Year	433.178	8	-1640.740	3298.137	2.951	0.075
6.	7	Time + Age	445.555	8	-1640.800	3298.266	3.08	0.07
7.	15	Global Model	397.867	11	-1637.920	3299.078	3.893	0.047
8.	13	Time + Release Year + Age	421.304	9	-1640.680	3300.189	5.003	0.027
9.	1	Null Model	589.105	3	-1740.320	3486.754	191.568	0
10.	3	Release Year	500.830	4	-1739.250	3486.690	191.504	0
11.	4	Age	601.798	4	-1740.230	3488.641	193.456	0
12.	5	Sex	603.002	5	-1738.750	3487.769	192.584	0
13.	10	Release Year + Age	500.726	5	-1739.250	3488.782	193.596	0
14.	11	Release Year + Sex	497.359	6	-1737.200	3486.779	191.594	0
15.	12	Release Year + Age + Sex	545.766	7	-1736.790	3488.088	192.903	0

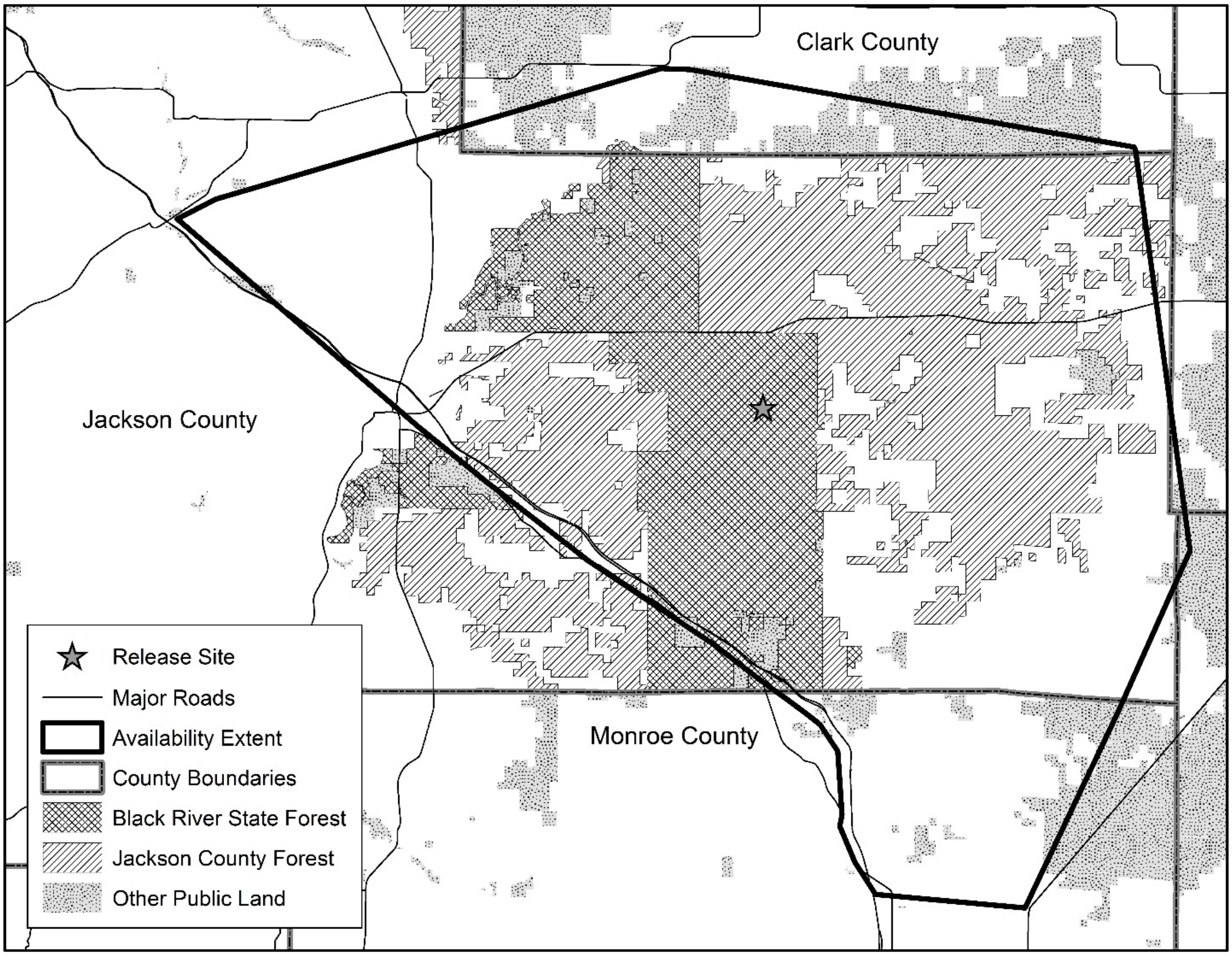


Figure 8. The availability extent constructed using a 100% MCP truncated along U.S. Interstate 94 as it proved to be a significant barrier to elk movements.

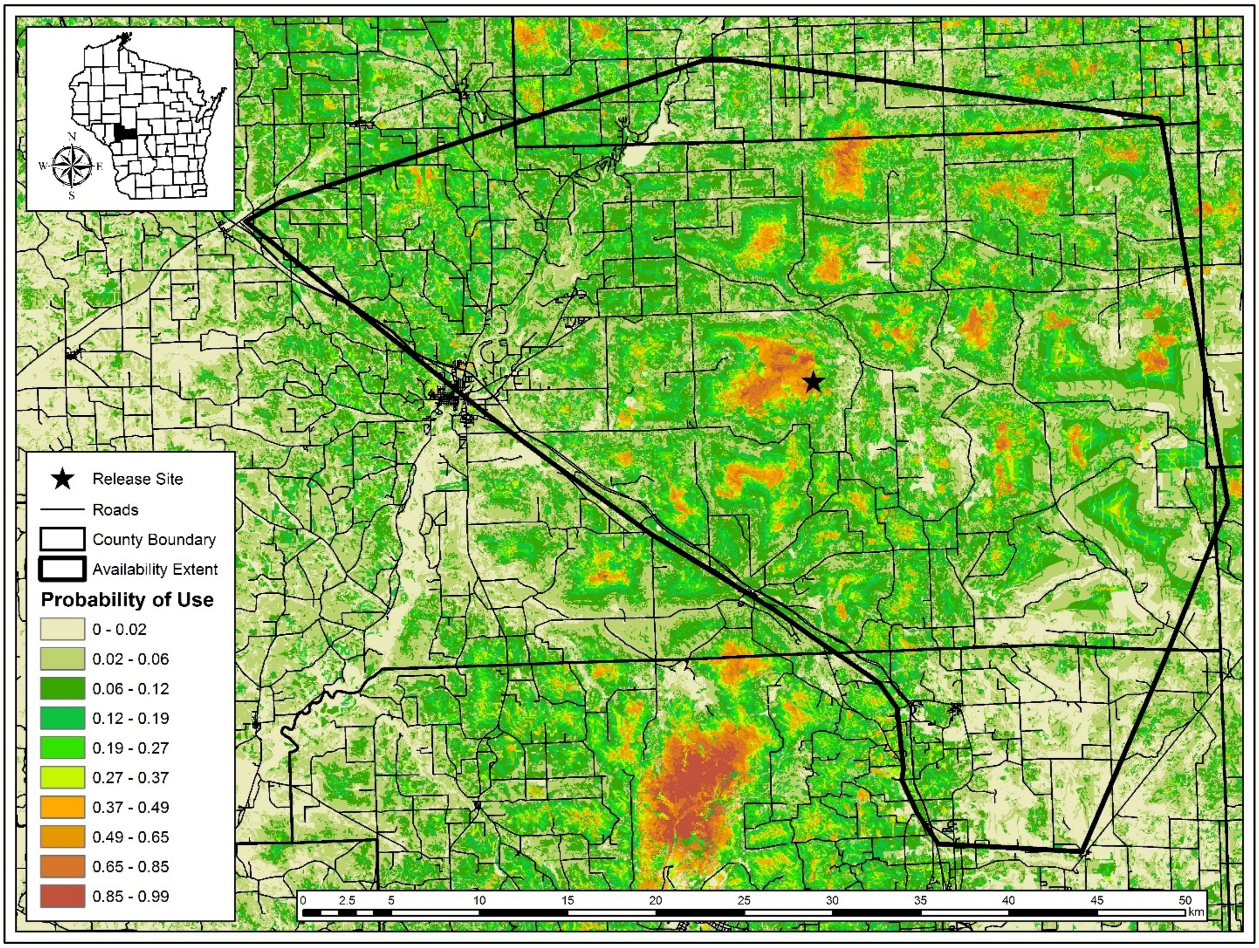


Figure 9. Probability map of elk habitat use for days 1 – 90 post-release for elk reintroduced to Jackson County in 2015 and 2016. The map was constructed by applying model coefficients to the model variable raster dataset. Probability values coincide with the 10 RSF bins used for model validation. RSF bins were sorted by natural breaks in ArcGIS.

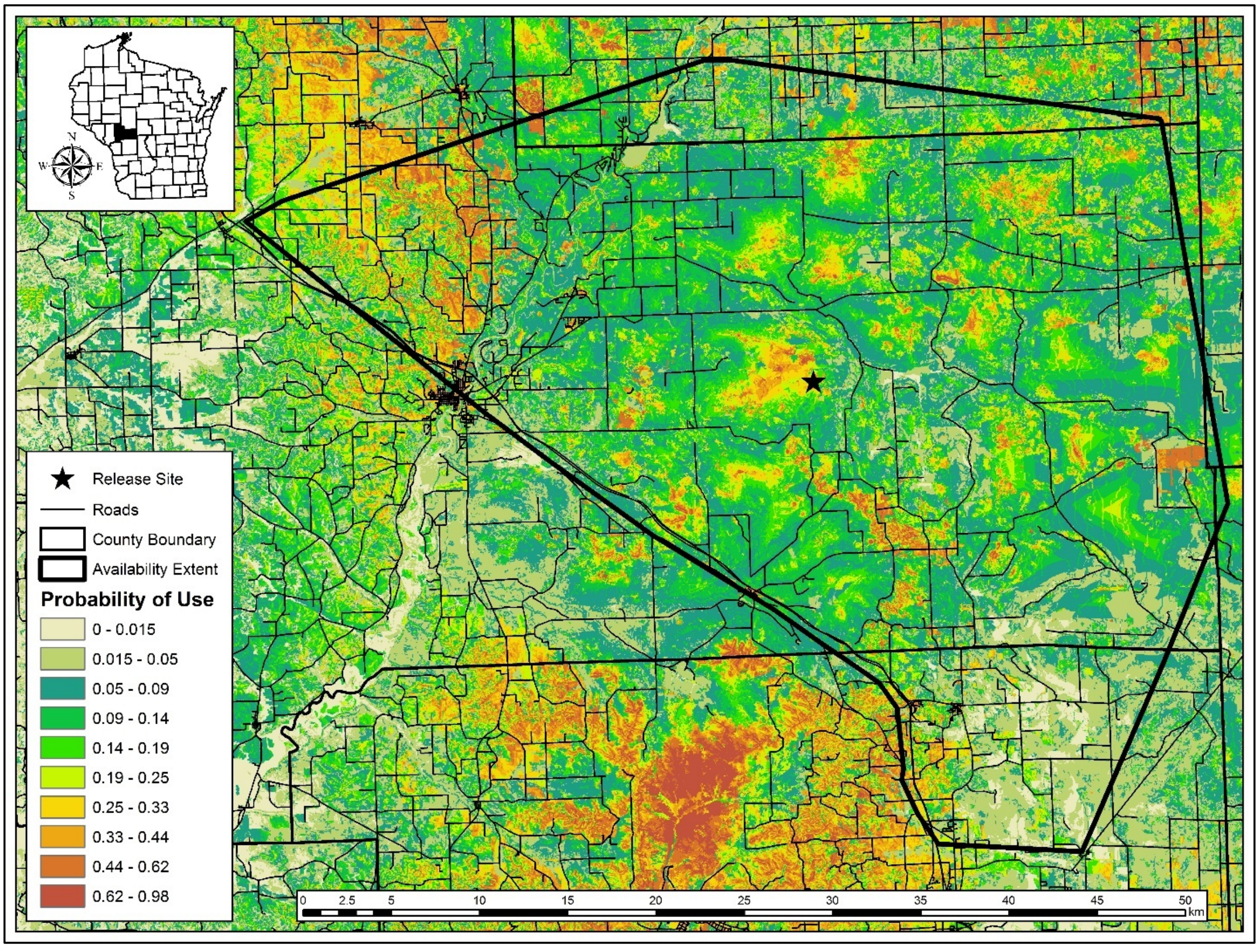


Figure 10. Probability map of elk habitat use for days 91 – 180 post-release for elk reintroduced to Jackson County in 2015 and 2016. The map was constructed by applying model coefficients to the model variable raster dataset. Probability values coincide with the 10 RSF bins used for model validation. RSF bins were sorted by natural breaks in ArcGIS.

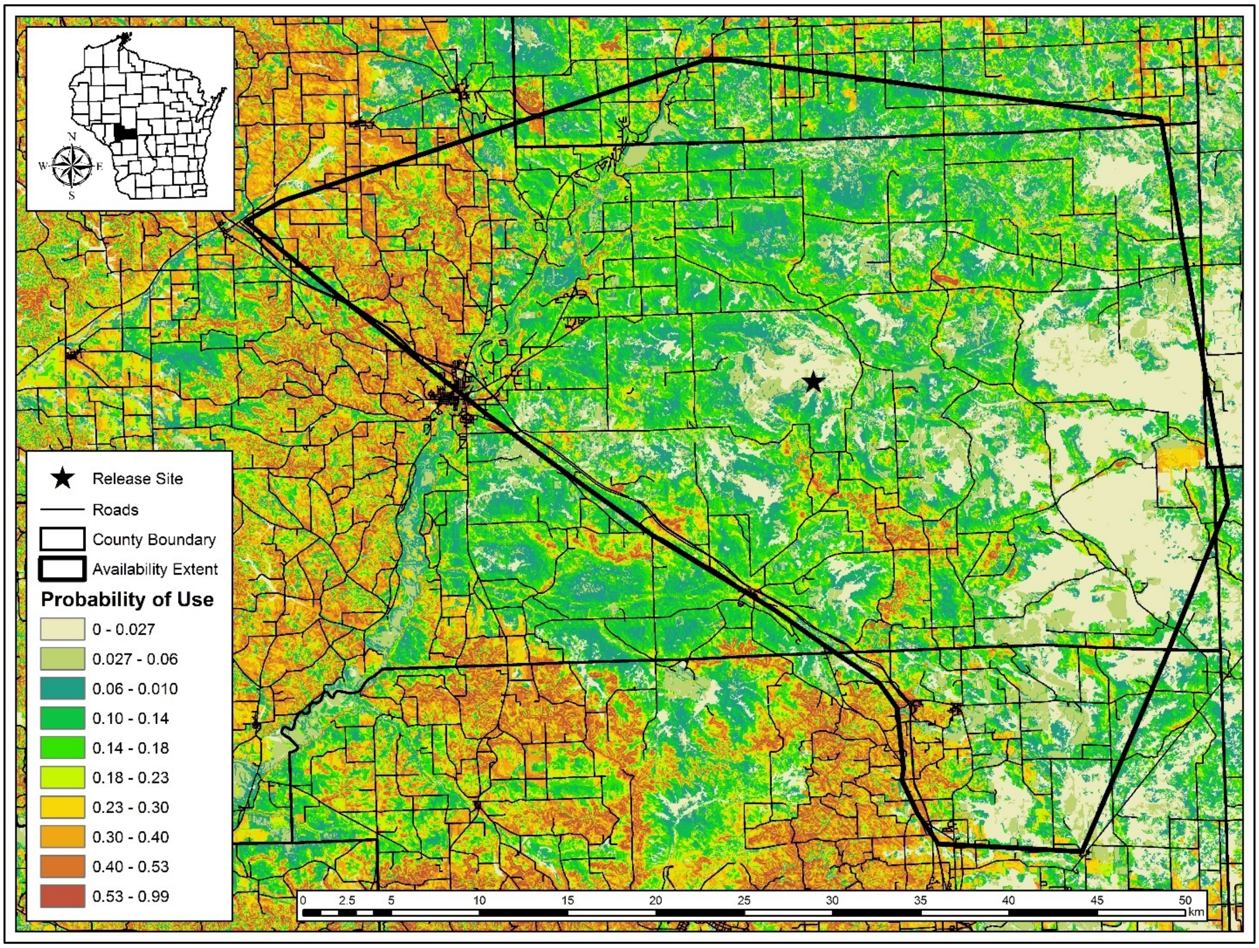


Figure 11. Probability map of elk habitat use for days 181 – 270 post-release for elk reintroduced to Jackson County in 2015 and 2016. The map was constructed by applying model coefficients to the model variable raster dataset. Probability values coincide with the 10 RSF bins used for model validation. RSF bins were sorted by natural breaks in ArcGIS.

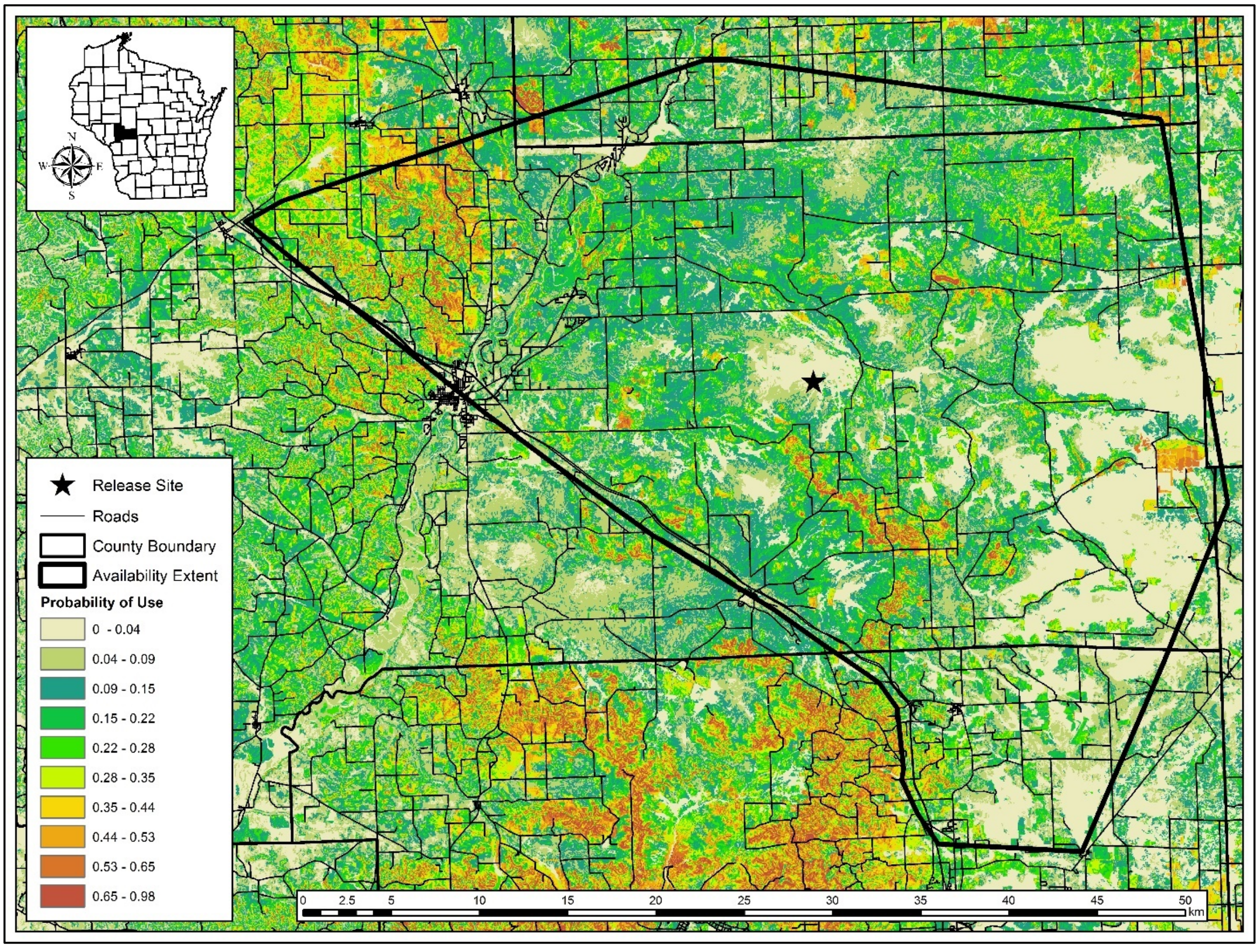


Figure 12. Probability map of elk habitat use for days 271 – 365 post-release for elk reintroduced to Jackson County in 2015 and 2016. The map was constructed by applying model coefficients to the model variable raster dataset. Probability values coincide with the 10 RSF bins used for model validation. RSF bins were sorted by natural breaks in ArcGIS.

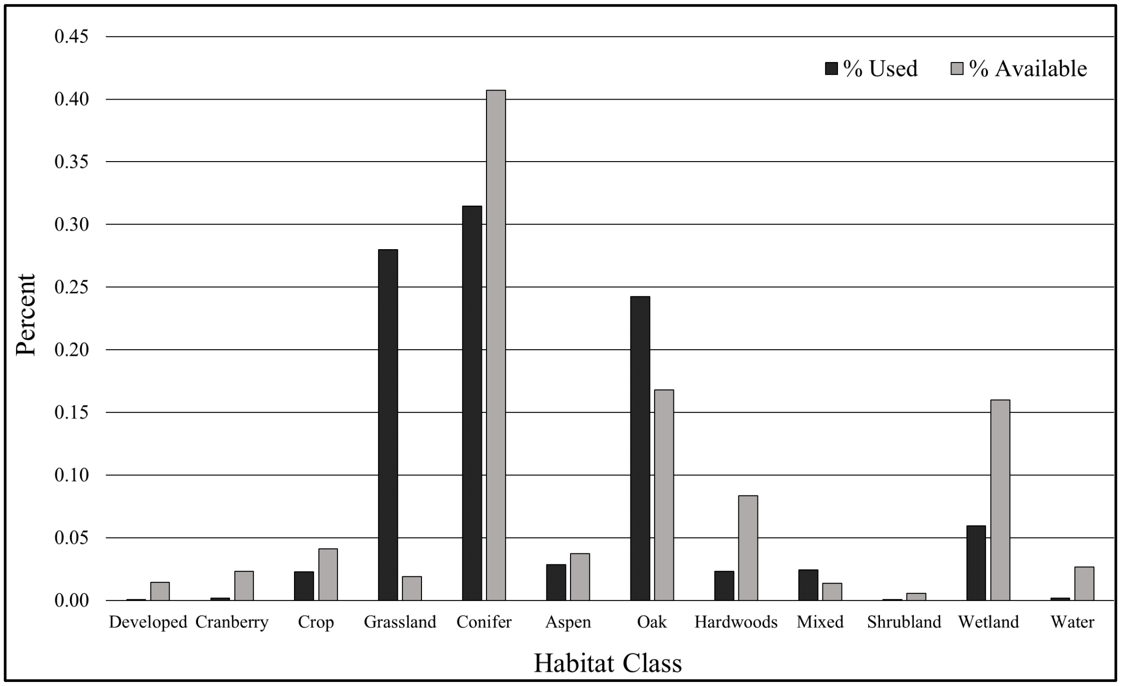


Figure 13. Percent use vs. percent of available habitat types within the availability extent, for elk reintroduced to Jackson County in 2015 and 2016,1 - 90 days post-release. Used is based on the habitat type at individual elk locations, and availability is based on the habitat type at the random locations.

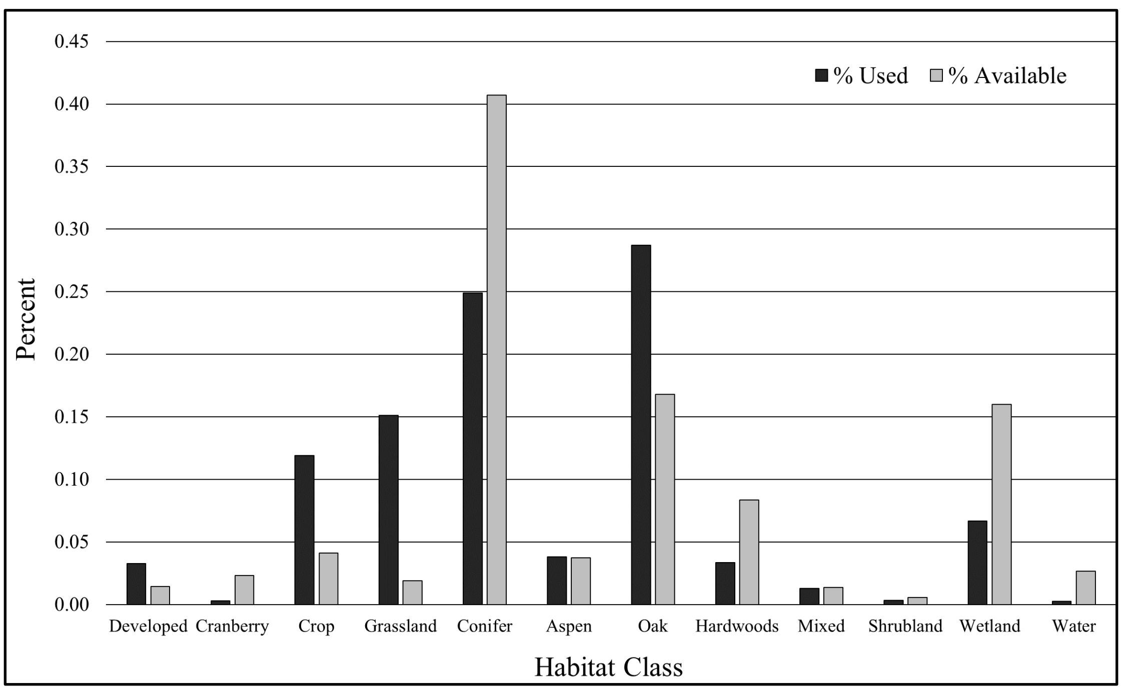


Figure 14. Percent use vs. percent of available habitat types within the availability extent, for elk reintroduced to Jackson County in 2015 and 2016,91 - 180 days post-release. Used is based on the habitat type at individual elk locations, and availability is based on the habitat type at the random locations.

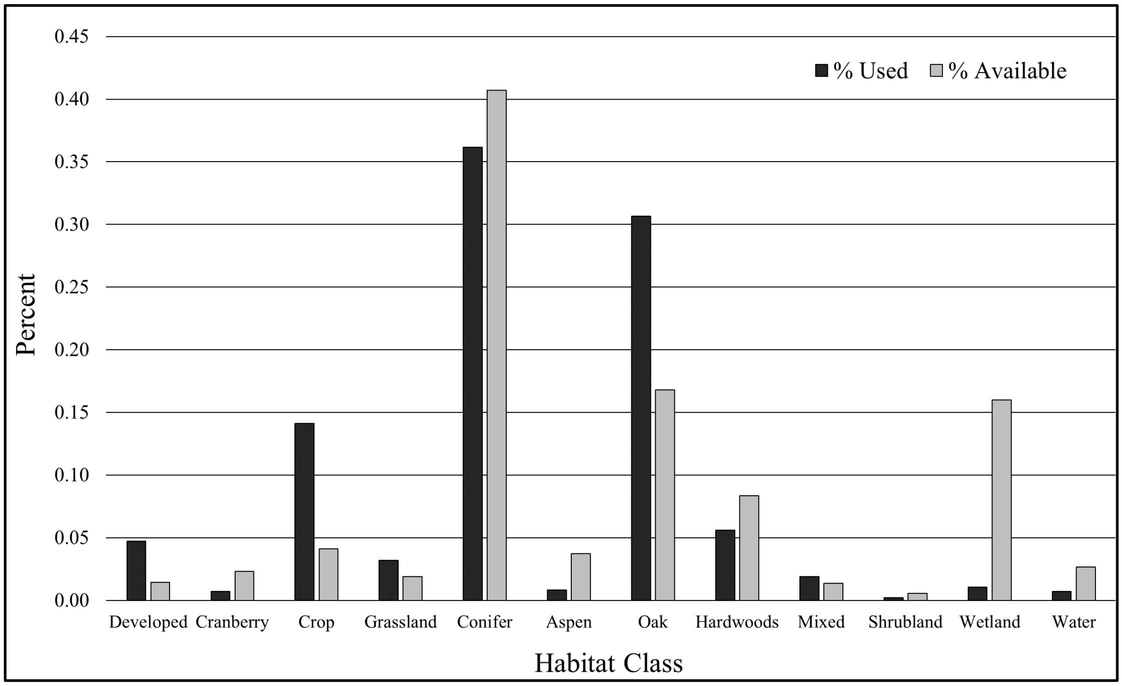


Figure 15. Percent use vs. percent of available habitat types within the availability extent, for elk reintroduced to Jackson County in 2015 and 2016,181–270 days post-release. Used is based on the habitat type at individual elk locations, and availability is based on the habitat type at the random locations.

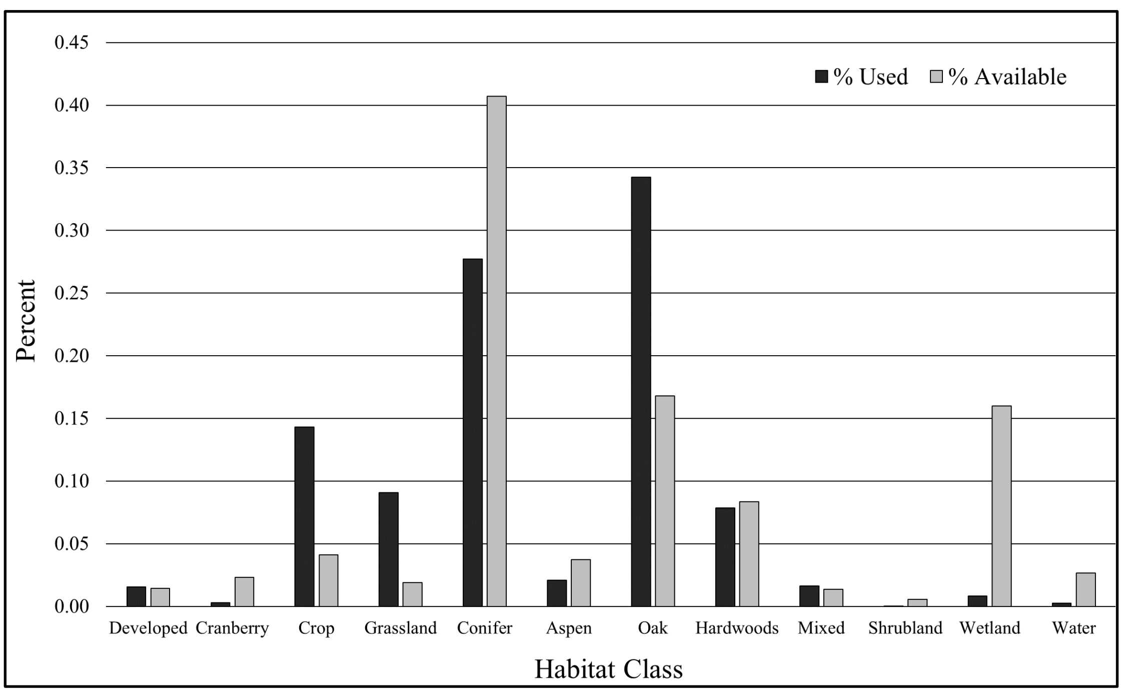


Figure 16. Percent use vs. percent of available habitat types within the availability extent, for elk reintroduced to Jackson County in 2015 and 2016,271-365 days post-release. Used is based on the habitat type at individual elk locations, and availability is based on the habitat type at the random locations.

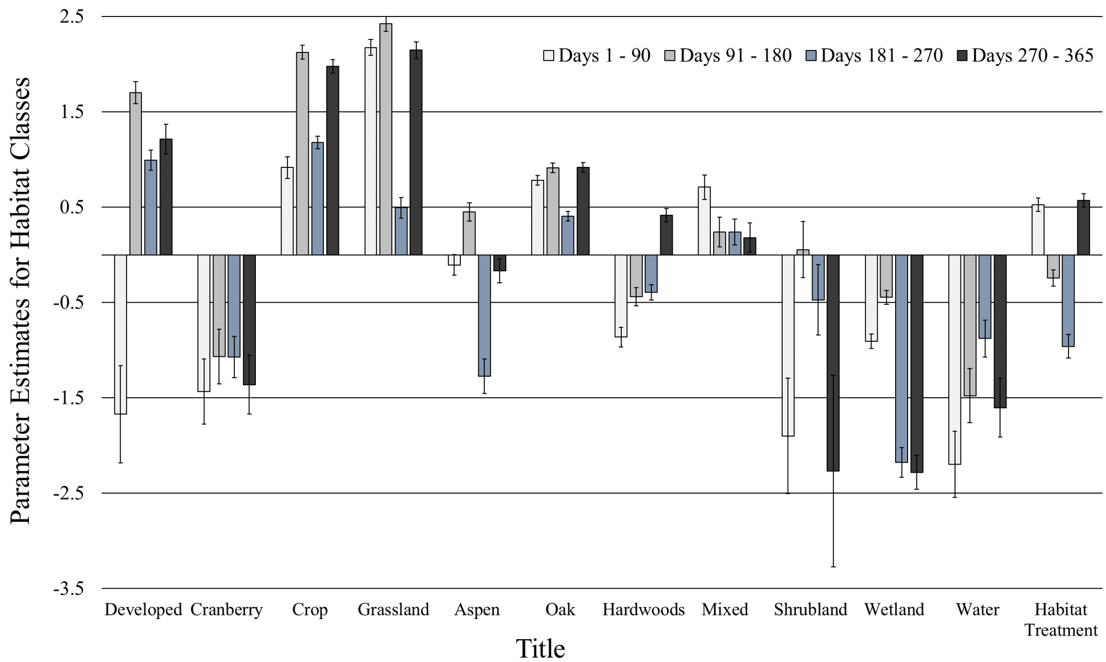


Figure 17. Coefficient estimates for the habitat variables of the RSF models for each time period for elk reintroduced to Jackson County in 2015 and 2016. Estimates are in reference to the coniferous habitat class. Error bars equal standard errors.

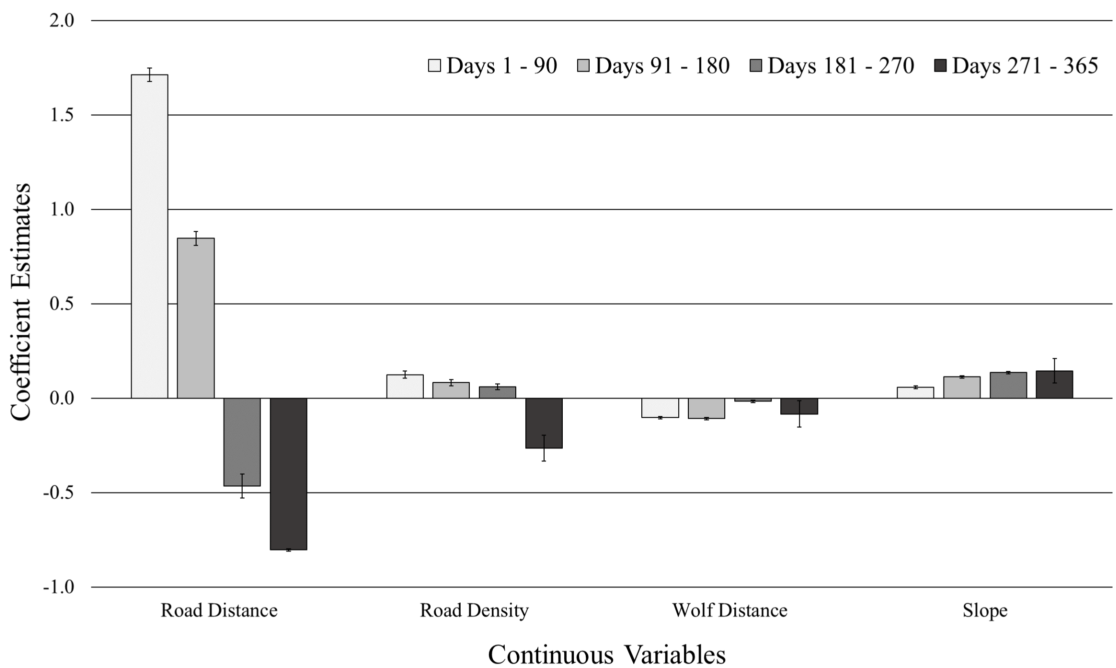


Figure 18. Coefficient estimates for the continuous variables of the RSF models for each time period for elk reintroduced to Jackson County in 2015 and 2016. Error bars equal standard errors.

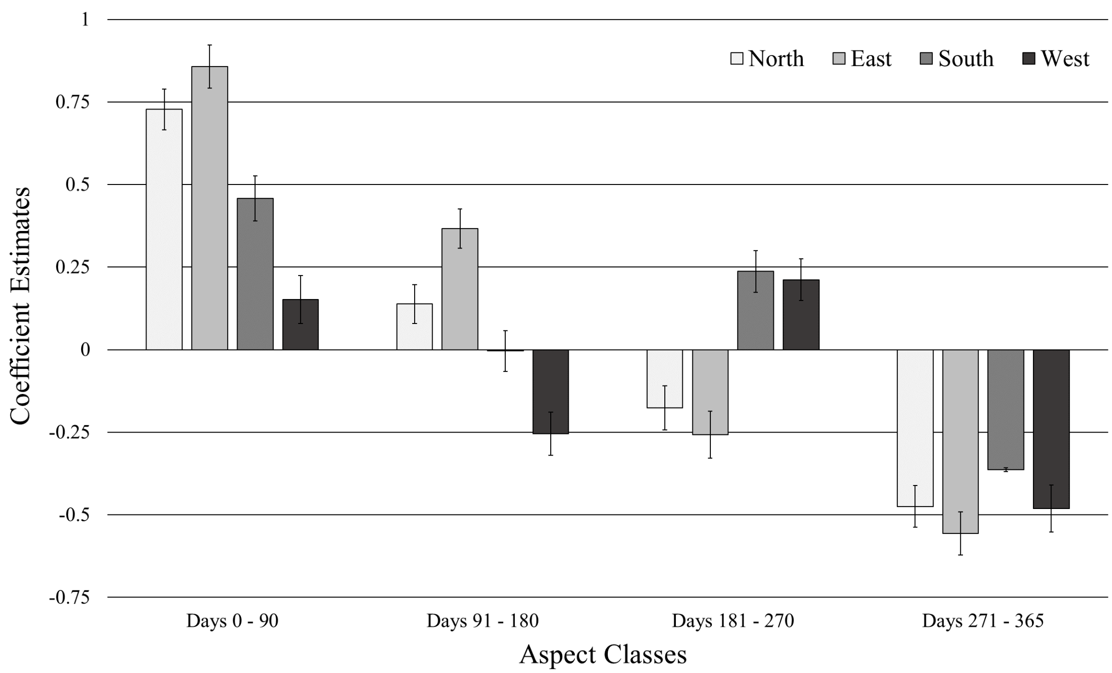


Figure 19. Coefficient estimates for the aspect classes of the RSF models for each time period for elk reintroduced to Jackson County in 2015 and 2016. Estimates are in reference to the no aspect class. Error bars equal standard errors.

Days 1-90 Post-release

Rank:	Model:	Model Components	Intercept	K	logLik	AICc	ΔAICc	Wi
1.	Global	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-3.199	21	-8834.069	17710.173	0	1
2.	46	Habitat + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-3.038	20	-8851.749	17743.529	33.356	0
3.	27	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Habitat Treatment	-3.214	20	-8859.829	17759.690	49.517	0
4.	26	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope	-3.116	20	-8860.615	17761.260	51.088	0
5.	44	Habitat + Road Distance + Wolf Distance + Aspect + Habitat Treatment	-3.062	19	-8875.163	17788.355	78.182	0
6.	43	Habitat + Road Distance + Wolf Distance + Aspect + Slope	-2.965	19	-8876.665	17791.358	81.185	0
7.	23	Habitat + Road Density + Road Distance + Wolf Distance + Aspect	-3.13	19	-8887.532	17813.092	102.919	0
8.	40	Habitat + Road Distance + Wolf Distance + Aspect	-2.989	18	-8901.285	17838.595	128.422	0
9.	35	Habitat + Road Density + Road Distance + Wolf Distance + Slope + Habitat Treatment	-2.793	17	-8963.867	17961.757	251.584	0
10.	45	Habitat + Road Distance + Wolf Distance + Slope + Habitat Treatment	-2.624	16	-8983.473	17998.966	288.793	0

Table 4. Model selection results for resource selection by elk reintroduced to Jackson County in 2015 and 2016.

Days 91-180 Post-release

Rank:	Model:	Model Components	Intercept	K	logLik	AICc	ΔAICc	Wi
1.	Global	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-2.285	21	-9962.671	19967.378	0	0.963
2.	26	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope	-2.309	20	-9966.922	19973.876	6.499	0.037
3.	46	Habitat + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-2.16	20	-9975.392	19990.817	23.439	0
4.	43	Habitat + Road Distance + Wolf Distance + Aspect + Slope	-2.183	19	-9980.239	19998.506	31.128	0
5.	35	Habitat + Road Density + Road Distance + Wolf Distance + Slope + Habitat Treatment	-2.259	17	-10019.559	20073.141	105.763	0
6.	24	Habitat + Road Density + Road Distance + Wolf Distance + Slope	-2.286	16	-10024.234	20080.489	113.111	0
7.	45	Habitat + Road Distance + Wolf Distance + Slope + Habitat Treatment	-2.132	16	-10032.151	20096.323	128.945	0
8.	41	Habitat + Road Distance + Wolf Distance + Slope	-2.157	15	-10037.448	20104.914	137.537	0
9.	27	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Habitat Treatment	-2.312	20	-10139.689	20319.410	352.032	0
10.	23	Habitat + Road Density + Road Distance + Wolf Distance + Aspect	-2.335	19	-10144.345	20326.719	359.341	0

Table 5. Model selection results for resource selection by elk reintroduced to Jackson County in 2015 and 2016.

Days 181-270 Post-release

Rank:	Model:	Model Components	Intercept	K	logLik	AICc	ΔAICc	Wi
1.	Global	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-1.802	21	-9483.135	19008.307	0	0.999
2.	46	Habitat + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-1.677	20	-9491.554	19023.140	14.833	0.001
3.	34	Habitat + Road Density + Wolf Distance + Aspect + Slope + Habitat Treatment	-2.106	20	-9511.645	19063.323	55.016	0
4.	26	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope	-1.861	20	-9520.851	19081.734	73.427	0
5.	43	Habitat + Road Distance + Wolf Distance + Aspect + Slope	-1.731	19	-9530.302	19098.633	90.326	0
6.	35	Habitat + Road Density + Road Distance + Wolf Distance + Slope + Habitat Treatment	-1.754	17	-9541.661	19117.345	109.039	0
7.	45	Habitat + Road Distance + Wolf Distance + Slope + Habitat Treatment	-1.62	16	-9550.824	19133.669	125.363	0
8.	31	Habitat + Road Density + Wolf Distance + Aspect + Slope	-2.174	19	-9550.995	19140.019	131.712	0
9.	53	Habitat + Wolf Distance + Aspect + Slope + Habitat Treatment	-2.019	19	-9560.179	19158.388	150.081	0
10.	33	Habitat + Road Density + Wolf Distance + Slope + Habitat Treatment	-2.048	16	-9570.753	19173.527	165.220	0

Table 6. Model selection results for resource selection by elk reintroduced to Jackson County in 2015 and 2016.

Days 271 – 365 Post-release

Rank:	Model:	Model Components	Intercept	K	logLik	AICc	ΔAICc	Wi
1.	Global	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-0.998	21	-8828.076	17698.189	0	1
2.	26	Habitat + Road Density + Road Distance + Wolf Distance + Aspect + Slope	-0.941	20	-8858.409	17756.851	58.662	0
3.	35	Habitat + Road Density + Road Distance + Wolf Distance + Slope + Habitat Treatment	-1.32	17	-8869.500	17773.024	74.835	0
4.	24	Habitat + Road Density + Road Distance + Wolf Distance + Slope	-1.256	16	-8897.525	17827.071	128.882	0
5.	34	Habitat + Road Density + Wolf Distance + Aspect + Slope + Habitat Treatment	-1.576	20	-8904.670	17849.374	151.185	0
6.	46	Habitat + Road Distance + Wolf Distance + Aspect + Slope + Habitat Treatment	-1.456	20	-8907.026	17854.085	155.896	0
7.	53	Habitat + Wolf Distance + Aspect + Slope + Habitat Treatment	-1.641	19	-8926.299	17890.629	192.440	0
8.	31	Habitat + Road Density + Wolf Distance + Aspect + Slope	-1.509	19	-8931.605	17901.239	203.050	0
9.	43	Habitat + Road Distance + Wolf Distance + Aspect + Slope	-1.403	19	-8939.250	17916.529	218.340	0
10.	33	Habitat + Road Density + Wolf Distance + Slope + Habitat Treatment	-1.864	16	-8942.672	17917.364	219.175	0

Table 7. Model selection results for resource selection by elk reintroduced to Jackson County in 2015 and 2016.

Table 8. Parameter estimates, standard errors, and 95% confidence intervals for habitat variables of the top model as determine by AIC for the 1 – 90 day time period.

Model Variable	Parameter Estimate	SE	Lower 95% CI	Upper 95% CI
(Intercept)	-3.199	0.079	-3.354	-3.046
Developed	-1.670	0.510	-2.855	-0.800
Cranberry	-1.433	0.343	-2.180	-0.821
Crop	0.915	0.111	0.695	1.129
Grassland	2.175	0.085	2.010	2.342
Aspen	-0.105	0.106	-0.316	0.099
Oak	0.781	0.050	0.682	0.879
Hardwoods	-0.862	0.104	-1.070	-0.662
Mixed Conifer/Deciduous	0.710	0.128	0.456	0.957
Shrubland	-1.899	0.604	-3.327	-0.875
Wetland	-0.906	0.076	-1.055	-0.759
Water	-2.195	0.347	-2.951	-1.573
Habitat Treatment	0.526	0.071	0.387	0.664
Road Distance	1.712	0.035	1.644	1.781
Road Density	0.124	0.020	0.085	0.163
Wolf Distance	-0.104	0.007	-0.118	-0.089
Slope	0.057	0.008	0.042	0.071
Aspect North	0.727	0.062	0.606	0.850
Aspect East	0.857	0.065	0.729	0.985
Aspect South	0.458	0.068	0.325	0.592
Aspect West	0.152	0.072	0.010	0.293

Table 9. Parameter estimates, standard errors, and 95% confidence intervals for habitat variables of the top model as determine by AIC for the 91 – 181 day time period.

Model Variable	Parameter Estimate	SE	Lower 95% CI	Upper 95% CI
(Intercept)	-2.285	0.069	-2.421	-2.150
Developed	1.701	0.116	1.473	1.926
Cranberry	-1.066	0.285	-1.676	-0.550
Crop	2.125	0.071	1.986	2.263
Grassland	2.422	0.080	2.266	2.579
Aspen	0.449	0.095	0.260	0.633
Oak	0.911	0.050	0.813	1.008
Hardwoods	-0.439	0.093	-0.625	-0.260
Mixed Conifer/Deciduous	0.239	0.156	-0.076	0.537
Shrubland	0.055	0.294	-0.563	0.597
Wetland	-0.445	0.073	-0.590	-0.303
Water	-1.476	0.285	-2.087	-0.960
Habitat Treatment	-0.245	0.086	-0.416	-0.079
Road Distance	0.846	0.037	0.774	0.918
Road Density	0.081	0.016	0.050	0.112

Wolf Distance	-0.108	0.006	-0.120	-0.096
Slope	0.112	0.006	0.101	0.124
Aspect North	0.138	0.059	0.023	0.254
Aspect East	0.367	0.060	0.249	0.484
Aspect South	-0.004	0.062	-0.125	0.117
Aspect West	-0.255	0.065	-0.383	-0.127

Table 10. Parameter estimates, standard errors, and 95% confidence intervals for habitat variables of the top model as determine by AIC for the 181 – 270 day time period.

Model Variable	Parameter Estimate	SE	Lower 95% CI	Upper 95% CI
(Intercept)	-1.802	0.073	-1.947	-1.659
Developed	0.993	0.105	0.785	1.199
Cranberry	-1.072	0.217	-1.525	-0.671
Crop	1.180	0.065	1.052	1.308
Grassland	0.494	0.108	0.280	0.702
Aspen	-1.274	0.180	-1.645	-0.937
Oak	0.405	0.049	0.308	0.502
Hardwoods	-0.394	0.080	-0.553	-0.240
Mixed Conifer/Deciduous	0.240	0.136	-0.032	0.501
Shrubland	-0.473	0.369	-1.281	0.186
Wetland	-2.177	0.157	-2.499	-1.883
Water	-0.877	0.192	-1.274	-0.519
Habitat Treatment	-0.959	0.124	-1.209	-0.723
Road Distance	-0.465	0.064	-0.591	-0.341
Road Density	0.060	0.014	0.031	0.088
Wolf Distance	-0.018	0.006	-0.029	-0.006
Slope	0.135	0.006	0.124	0.146
Aspect North	-0.176	0.067	-0.308	-0.045
Aspect East	-0.257	0.071	-0.397	-0.118
Aspect South	0.237	0.063	0.114	0.361
Aspect West	0.212	0.063	0.088	0.336

Table 11. Parameter estimates, standard errors, and 95% confidence intervals for habitat variables of the top model as determine by AIC for the 271 – 365 day time period.

Model Variable	Parameter Estimate	SE	Lower 95% CI	Upper 95% CI
(Intercept)	-0.998	0.077	-1.148	-0.848
Developed	1.213	0.154	0.902	1.508
Cranberry	-1.362	0.308	-2.028	-0.808
Crop	1.978	0.071	1.839	2.117
Grassland	2.146	0.086	1.976	2.315
Aspen	-0.169	0.125	-0.420	0.070
Oak	0.916	0.051	0.816	1.015
Hardwoods	0.415	0.073	0.271	0.556

Mixed Conifer/Deciduous	0.181	0.153	-0.126	0.473
Shrubland	-2.268	1.006	-5.138	-0.765
Wetland	-2.280	0.178	-2.647	-1.948
Water	-1.602	0.308	-2.268	-1.048
Habitat Treatment	0.571	0.071	0.431	0.709
Road Distance	-0.803	0.069	-0.941	-0.669
Road Density	-0.265	0.023	-0.311	-0.221
Wolf Distance	-0.084	0.006	-0.096	-0.072
Slope	0.144	0.006	0.133	0.156
Aspect North	-0.475	0.064	-0.601	-0.348
Aspect East	-0.556	0.069	-0.691	-0.422
Aspect South	-0.363	0.064	-0.488	-0.239
Aspect West	-0.481	0.065	-0.609	-0.353

2018 RANGE-WIDE STATUS OF BLACK-TAILED AND MULE DEER

Mule Deer Working Group. Western Association of Fish and Wildlife Agencies

Abstract – The purpose of this document is to provide a general overview of the current black-tailed and mule deer (*Odocoileus hemionus*) population status and general abundance trends throughout their range in North America. The Mule Deer Working Group (MDWG) consists of representatives from the 23 state and provincial agencies that comprise the Western Association of Fish and Wildlife Agencies (WAFWA). The purpose of the MDWG is to provide a collaborative approach to finding solutions to improve black-tailed and mule deer conservation and management. One of the most common types of information requested of the MDWG is regarding the general population status and trajectory of black-tailed and mule deer populations. Stakeholders are interested in whether mule deer are still declining or in the process of recovering. To provide a quick snapshot of the status of this species, we assembled this information by having each agency MDWG representative provide a current population status, as well as general survey and harvest information for their respective jurisdiction. All states and provinces use very different methods to survey and estimate populations parameters and harvest. Some have more scientifically rigorous processes than others, based on their resources and management needs. Black-tailed and mule deer populations are below agency goals in all but a couple jurisdictions, however, only a few are currently declining. Most states and provinces report their populations are stable or recently recovering from previous declines. The last two years have been favorable with several state and provincial mule deer populations showing noticeable improvement.

Black-tailed and Mule Deer Distribution

Range-wide estimation of population size, harvest, and hunter numbers of mule deer provided by member agencies of WAFWA.

	Estimated Population[1]	Total Harvest	% males in Harvest	Hunter Numbers
Alberta	154,762	15,198	48%	36,117
Arizona	85,000 - 100,000	10,964	96%	38,611
British Columbia[2]	100,000 - 170,000	13,292	87%	67,127
California[3]	470,000	29,394	98%	175,357
Colorado[4]	419,000	37,761	80%	84,185
Idaho	280,000	25,496	80%	85,067
Kansas	47,935	1,917	93%	17,471
Montana	386,075	55,544	77%	152,213
Nebraska	120,000 – 145,000	12,058	81%	No Estimate
Nevada	92,000	7,307	83%	16,100
New Mexico[4]	80,000 - 100,000	11,316	99%	32,017
North Dakota[5]	24,500 (Badlands)	6,147	71%	11,091
Oklahoma[6]	1,500 - 2,000	196	99%	No Estimate
Oregon	220,000 - 230,000	16,126	89%	60,695
Saskatchewan	40,000-60,000	6,275	55%	10,000
South Dakota[7,8]	69,000	7,300	81%	68,100
Texas[9]	285,918	9,804	90%	23,492
Utah	363,650	33,701	88%	101,527
Washington[10]	90,000 - 110,000	7,197	88%	106,977
Wyoming	396,000	31,237	88%	53,018
Yukon	1,000	10	100%	12

[1] Estimated population may be presented as ranges to denote the difficulty and levels of uncertainty in gathering an estimate over a large spatial scale.

[2] All data presented are from the most recent year available.

[3] Black-tailed and mule deer numbers combined. “Hunter Numbers” is “number of tags issued” so the actual number of hunters will be less.

[4] Estimated population, harvest, and hunters include mule deer and white-tailed deer. These estimates cannot be easily removed because most deer licenses are for either species (In Colorado, approximately 5% of the estimates are white-tailed deer. White-tailed deer comprise approximately 3% of the total harvest in New Mexico).

[5] Population estimate is determined for the Badlands, total harvest includes gun and archery harvest, and number of hunters is based on mule deer licenses and any deer gun licenses within mule deer range.

[6] Numbers are difficult to estimate as many permits allow the take of mule deer or whitetail deer.

[7] Total deer hunters, includes both mule deer and white-tailed deer hunters.

[8] Estimates are preliminary 2018 pre-season.

[9] Total harvest, % males, and hunter numbers are reported for the 2016 hunting season.

[10] Estimates of Total Harvest and % males reflect 2017 general season harvest only. Estimate of Hunter Numbers reflects all deer hunters for the general season; WA does not estimate hunters by species or subspecies.

Range-wide estimation of population size, harvest and hunter numbers of black-tailed deer provided by WAFWA member agencies.

	Estimated Population[1]	Total Harvest	% males in Harvest	Hunter Numbers
Alaska[2]	333,000-346,000	23,131	84%	19,408
British Columbia[3]	98,000 - 157,000	7,490	77%	13,448
Hawaii[4]	1,000-1,200	36	100%	No Estimate
Oregon	No Estimate	18,252	91%	87,530
Washington[5]	90,000 - 110,000	9,150	88%	106,977

[1] Estimated populations may be presented as ranges to denote the difficulty and levels of uncertainty in gathering an estimate over a large spatial scale.

[2] Alaska population size is provided from our population objectives, rounded up to the closest thousand. These objectives were derived based on a combination of habitat capability modeling and expert opinion panels. This gross estimate is not re-calculated from year to year, but is rather a general ball-park figure.

[3] All data presented are from the most recent year available.

[4] Estimates are reported for the 2016 hunting season. Population estimate includes only public hunting areas, not private land.

[5] Estimates of Total Harvest and % males reflect 2017 general season harvest only. Estimate of Hunter Numbers reflects all deer hunters for the general season, WA does not estimate hunters by species or subspecies

Alaska

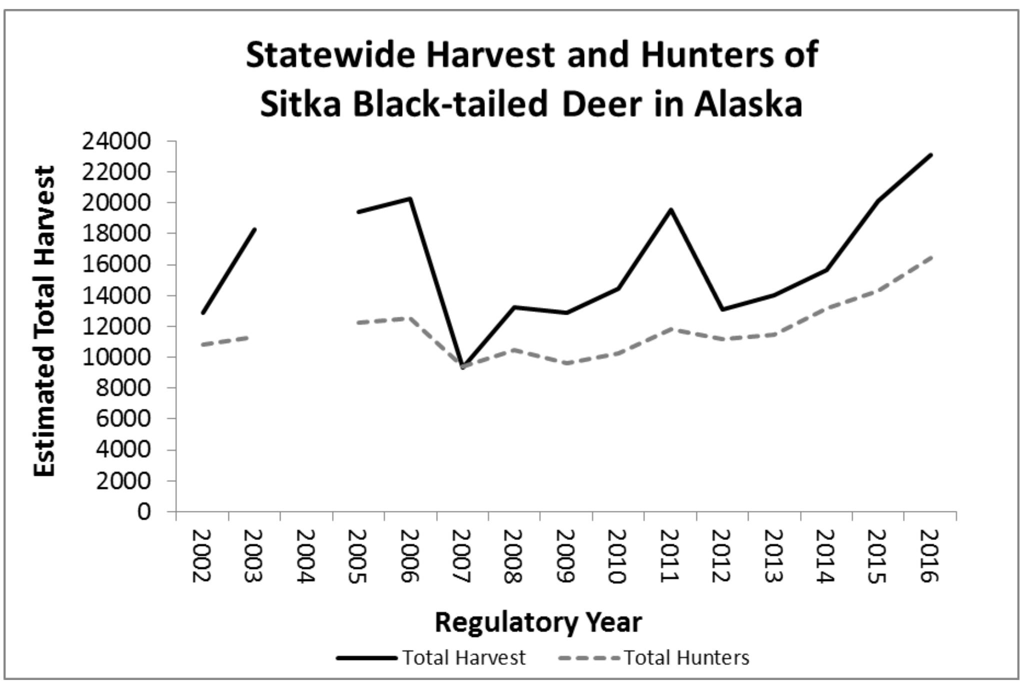
Sitka black-tailed (SBT) deer are native to the wet coastal rainforests of Southeast Alaska. Due to historic transplant efforts between 1916 and 1934, SBT deer also now have established populations in parts of South Central Alaska, including Prince William Sound and on Kodiak and Afognak islands. Deer density on the mainland has historically been lower than on the islands, presumably due to lower habitat quality. Because of the island geography, varying weather patterns, different predator guilds, and differences in the extent and pattern of forest logging, deer densities can vary greatly from one game management unit (GMU) to another, and even within GMUs. Population size or density has been a challenge to calculate throughout Alaska, due to the difficulties of employing various techniques in the remote and densely forested habitats that characterize deer range in Alaska. As a result, population objectives were set for each GMU based on expert opinion and analyses of habitat capability. These objectives constitute our best guess of what population levels may be in each GMU, but they are imprecise, and cannot be used to monitor changes in abundance. Based on these objectives, the deer population in Alaska as a whole is likely in the range of 333,000-346,000.

Due to the difficulty of measuring actual population size or density, in the 1980's Alaska Fish and Game (ADF&G) began work to index changes in deer abundance by using pellet count surveys to look at multi-year trends within various watersheds. More recently, ADF&G has used fecal DNA to conduct mark-recapture population and/or density estimation in specific watersheds, and is evaluating the efficacy of this technique for long-term use at broader scales. Lastly, annual harvest and hunter effort data provides information across multiple geographic scales. Prior to 2011, information was collected through a voluntary mail-out survey of ~30% of deer hunters, with an expansion factor applied to estimate total harvest. Approximately 65% of those surveyed responded each year. Since 2011, a deer harvest ticket system with mandatory reporting has been in place, but response rates have remained similar.

In Alaska, populations fluctuate predominately with the severity of winters - increasing during a series of mild winters and sometimes declining dramatically after one or more severe winters. Habitat change resulting from timber harvest affects deer by increasing summer browse (and browse available in mild winters with little snow) for about 30 years, before forests enter a stem-exclusion phase. Where deer become overpopulated with regard to the remaining primary winter range available to them, populations can plummet quickly when deep snow returns, and may remain at lower densities if winter range is damaged from over-browsing. Predation by bears and wolves can also slow recovery of deer after these events. Harvest by deer hunters is believed to be compensatory in Alaska as a whole, due to the remoteness of most areas and lack of extensive road networks. However, where logging roads exist adjacent to communities, a lack of substantial snowfall may allow hunters prolonged access to deer range, and can lead to site-specific higher hunter harvest. In contrast, heavy snowfall can concentrate deer at low elevations or on beaches, and can lead to higher harvests in areas easily accessible by boat. When conditions seem to warrant, management actions have included closing specific areas to hunting, lowering bag limits, and temporary restrictions of "any deer" hunts to "buck only" hunts.

In Southeast Alaska, SBT deer are fairly ubiquitous, and the most frequently pursued big game species. Southeast Alaska experienced 2 severe and 1 above average winter between 2006 and 2009, which led to substantial declines in the deer population and management actions such as doe harvest closures were taken in parts of the region. Subsequent to the high harvest in 2006-2007, pellet-group counts went down, and much lower harvest levels were experienced. Some of this lower harvest was a result of lower effort on the part of hunters, who indicated they wanted to allow populations time to recover. From 2010-2016 we have experienced average to below average winter severity across most of the region, with the winter 2015-2016 being one of the mildest on record. Overall hunter harvest and effort trends appear to be rebounding from previously mentioned lows. Similarly, pellet group counts and populations estimates (in the limited areas where they have been conducted) indicate an increasing or stable trend in most areas. However, monitoring deer densities in GMUs 1A and 3Z remains a concern. The reduced number of deer in these GMUs from historical highs is thought to involve the effects of periodic severe winters, reduced habitat quality, and predation slowing deer population recovery. Due to a failure to meet harvest objectives, intensive management (predator control) proposals were reviewed and approved by the Board of Game in 2013. In 2013, research commenced to assess deer population status and habitat conditions in certain watersheds to better evaluate the potential causes of the decline of deer in these areas. Initial DNA mark-recapture efforts failed to produce population density estimates due to low recapture rates in these GMUs, where the number of pellet groups seen was approximately 70% lower, and the number of fresh pellet groups collected was 90% lower, than in areas where the technique had been successfully employed in areas with greater deer abundance. More recently, increased effort at a smaller geographic scale enabled us to produce a density estimate for part of Gravina Island in GMU 1A in 2014 and Mitkof Island in GMU 3Z in 2016. Efforts to evaluate changes in habitat utilization as well as habitat quality also continue, and the investigation of using alpine surveys to index deer abundance has also been implemented. All of these different methods together indicate that deer numbers are starting to rebound in these units, and deer also appear to be doing well in most areas of the region. There are no plans to initiate any predator control measures at this time.

In South Central Alaska, Sitka black-tailed deer are at the northern extent of their range. While still a maritime environment, the weather patterns can differ substantially from what is occurring in Southeast Alaska. During the winter of 2011-2012, the effects of winter severity in GMU 6 was the worst in 30 years with over 27 feet of snowfall recorded in Cordova. Winter mortality was estimated at >50% overall, and was likely as high as 70% in areas of western Prince William Sound. Deer congregating on beaches due to early and heavy snowfall increased hunter success in winter 2011-2012 to a record high, but subsequent effects of this harvest combined with high winter mortality caused a decrease in harvest numbers of approximately 80% after the winter of 2012-2013. Hunting seasons were modified in regulatory years 2012 and 2013 to reduce harvest while the population was recovering. Deer numbers are still lower than prior to 2011, but signs of recovery are noted with improvements in winter survival and body condition. GMU 6 researchers are planning to implement DNA mark-recapture to obtain density estimates in some areas. In GMU 8, the deer population of the Kodiak archipelago also declined due to the same severe weather winter of 2011-2012. For reasons similar to those stated for GMU 6, harvest for the winter of 2012-2013 was down by over 40% from the previous year. Deer mortality was greatest on the northern portion of Kodiak and the western side of Afognak Island. Since then deer populations have been rebounding in both units, with mild winters during 2013-2016, and average winter severity the winter of 2016-2017. Hunters observations in regulatory year 2016 indicated deer were plentiful and in good condition. Deer pellet counts are not conducted in GMU 8, but counts in Unit 6 in 2017 were the highest observed since 1998. No regulatory action is anticipated for either GMU 6 or GMU 8 at this time.



-Karin McCoy, Alaska Department of Fish and Game

Alberta

The 2017 pre-hunting season population estimate of mule deer in Alberta is 154,762. The population increase from 2016 can be attributed to a sequence of mild winters in 2015-2016 and 2016-2017. The population goal in Alberta's most recent management plan for this species (1989) is 97,000. However, a new provincial management plan for mule deer is currently being written and this will see a change in the provincial population goal that is much nearer to the current population estimate.

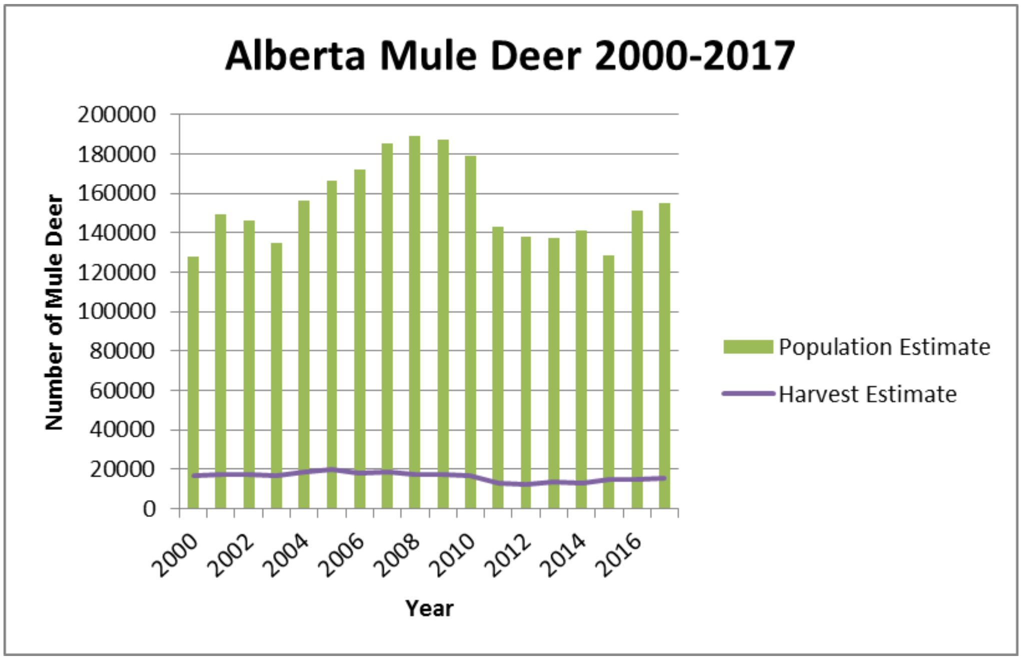
Interest in mule deer hunting continues to increase in Alberta. The number of antlered mule deer special license applicants has steadily increased in the past 3 years with 75,122 in 2015, 81,068 in 2016, and a considerable increase to 101,980 in 2017. Antlerless mule deer special license applicants is also on the rise with 32,292 in 2015, 36,666 in 2016, and 43,191 in 2017. Based on voluntary hunter harvest surveys, during the 2017 hunting season 36,117 mule deer hunters in Alberta directed an estimated 225,528 days hunting for mule deer, producing an estimated harvest of 15,198 mule deer (~48% antlered deer).

The 2018 hunting season will support ~11,000 antlered mule deer special licenses and ~16,500 antlerless mule deer special licenses in addition to certain Wildlife Management Units (WMUs) providing unlimited licenses to harvest mule deer. Alberta also supports a healthy commercial hunting industry, with approximately 1,500 antlered mule deer licenses available for non-residents through outfitter-guide allocations. There is an unknown number of rights-based hunters in Alberta that do not require a license to hunt for sustenance and thus information on effort and harvests by these groups are unknown.

Alberta implements a big game population monitoring program that aims to survey ungulates at a 5-year interval at the WMU scale, although admittedly several WMUs undergo longer survey intervals. Additionally, there are no long-term intensive monitoring programs for mule deer (i.e. collaring programs). As a result, Alberta is not in a position to confidently report on trends in buck to doe ratios, survival rates, or recruitment rates.

Alberta mule deer management objectives currently implement density goals at the WMU scale. These are used in combination with allocation percentages by cohort and estimated harvest rates from online voluntary hunter harvest surveys to determine special license numbers (i.e. draw quotas). In 2017, for those WMUs that reported on density goal and pre-season population estimate, 16.3% of 92 WMUs were within 10% of the goal, 33.7% were 10-20% deviation from goal, and 50% of WMUs were greater than 20% deviation from goal.

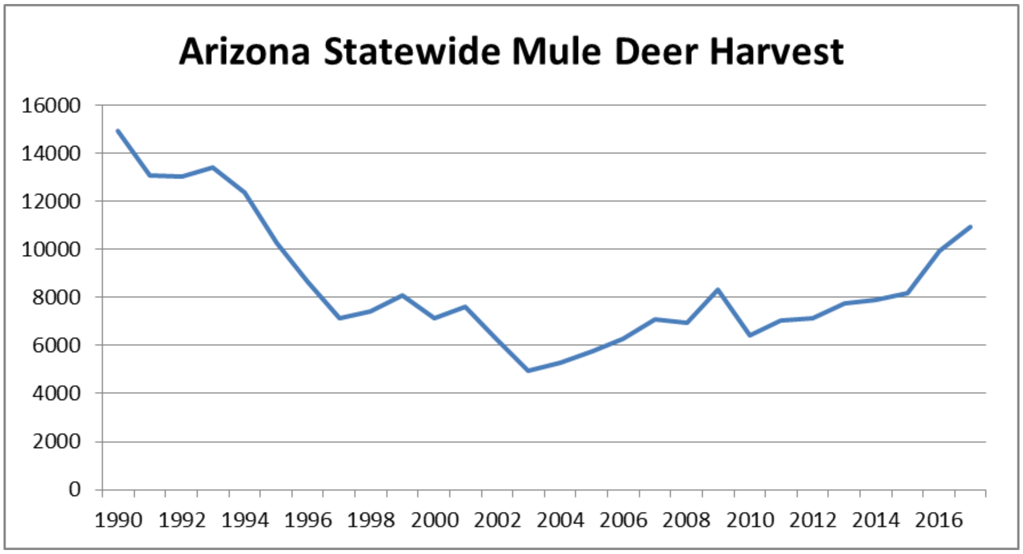
Chronic wasting disease (CWD) is present in Alberta, primarily in eastern Alberta along the Saskatchewan border. Prevalence in 2017/18 increased to 5.2% (n=6,340 deer heads tested), up from 3.5% in 2015/16 (n=5,112 deer heads tested). In 2017/18, CWD was detected in 7 additional WMUs where CWD was not known to occur. In Alberta CWD occurs primarily in mule deer and males. Local prevalence in mule deer bucks in several WMUs exceeds 20%, with a record high of 27% in one WMU. More information on CWD in Alberta is found at http://alberta.ca/cwd



-Justin Gilligan, Alberta Environment and Parks

Arizona

Mule deer populations reached the most recent peak in the mid-1980s. Mule deer declined through 2000 and since then have increased gradually. Total mule deer harvest reached the most recent low in 2003, with a harvest of only 4,638 (all weapon types). In 2017, 10,964 mule deer were harvested, representing a 10% increase in harvest from 2016, a 136% increase from the historic low point in 2003, but still only 63% of the 1986 peak harvest of 17,413. Population parameters indicate the statewide population continues to gradually increase. Most deer populations within the state were surveyed annually using fixed-wing aircraft or helicopter with supplemental ground surveys used as well. Mule deer were surveyed during the breeding season to estimate buck:doe and fawn:doe ratios.



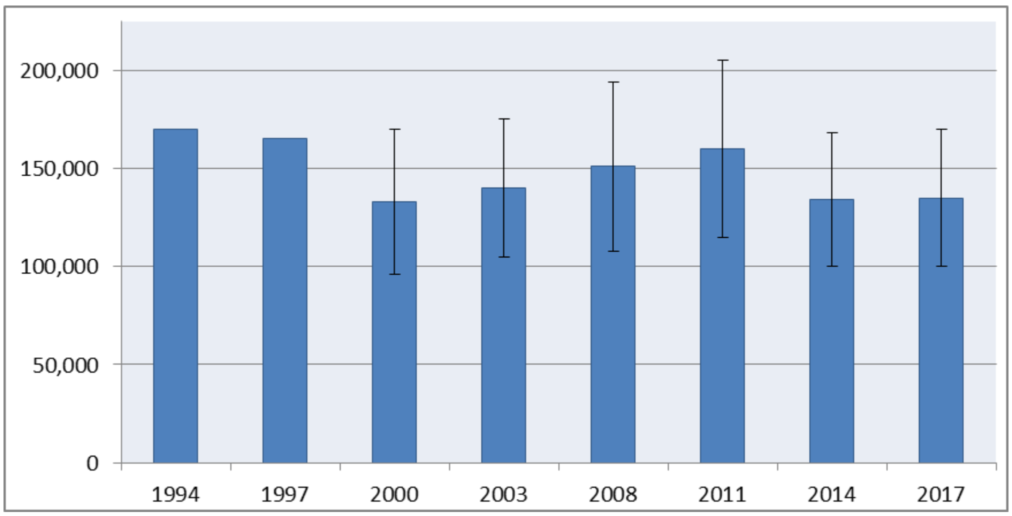
Hunter harvest was estimated using a voluntary post card questionnaire that may be returned with postage prepaid or responses may be entered online. In 2016, Arizona changed to an online option only for submitting hunter questionnaire. Since moving to an online only response option for the hunter questionnaire, return rates have significantly declined, from about 40% in 2014 to 24% in 2017. Buck:doe ratios for mule deer were managed at 20–30:100 and currently the statewide average is 28. Alternative management units were managed at higher buck:doe ratios with added guidelines regarding the age structure of the harvest or hunter density. These units approximate about 5% of the opportunity offered annually. The statewide number of fawns per 100 does is 42 which is within management guidelines (40-50).

-Amber Munig, Arizona Game and Fish Department

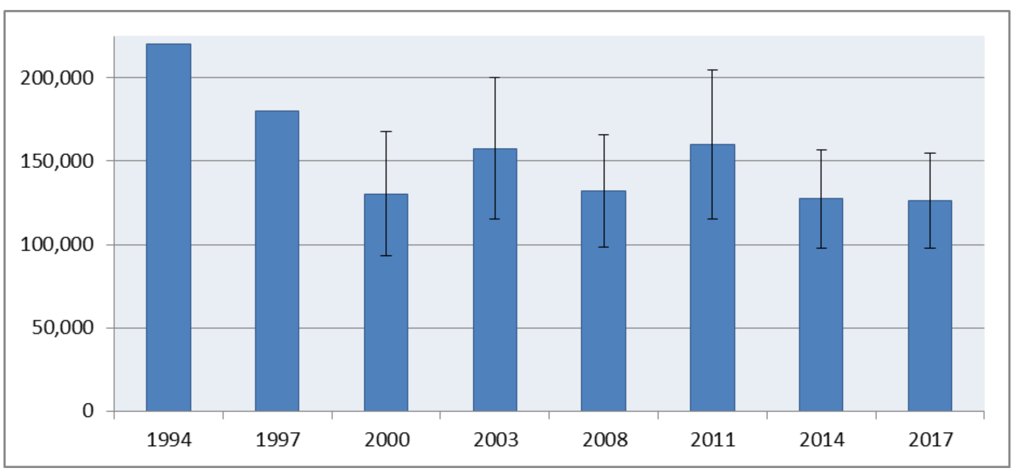
British Columbia

There remain localized differences in mule deer abundance throughout the province which may be attributed to habitat quality, predation, severe winter conditions, and varied historical and contemporary land-use/habitat modification. Extensive wildfires during the summer of 2017 in the southern and central parts of the province may provide increased availability of forage, except where snow interception may have been compromised on some winter ranges. Some parts of the province experienced higher than normal snowfall and prolonged snow cover which may have influenced mule deer fawn survival in some areas but recent spring fawn carryover surveys in other areas of the province have found fawn:doe ratios of 65-75 fawns per 100 does. In addition, recent surveys have found buck:doe ratios generally above the provincial objective of 20 bucks per 100 does. Harvest of mule deer bucks is managed through general open seasons using a combination of antler point restrictions (i.e., 4-point only) and any-buck seasons in most areas, while some areas only have an antler restriction season. There are some opportunities for antlerless harvest through limited entry hunts. Increased hunter access, combined with reduced habitat quantity and quality could challenge future management objectives. A new research project has been initiated in the south-central part of the province to examine mule deer population response to landscape change.

Trends in provincial abundance of black-tailed deer were similar to mule deer; black-tailed deer numbers also appear to have stabilized from 2014 to 2017. Predation from wolves and cougars on black-tailed deer continues to be a concern in most areas as well as the need for effective measures to conserve high quality habitat. Black-tailed deer buck harvest has dropped by approximately half since the early 1990s. There is some opportunity for antlerless harvest which is mostly limited to agricultural areas. In general, black-tailed deer numbers are thought to be most impacted by increased predation and reduced habitat quality. Overall, in most areas of intensive forestry activity, increased road density and is assumed to result in increased predation rates on deer. Maintaining or increasing the present hunter harvest will remain challenging given the current predator densities and lack of measures available to mitigate disturbance and enhance critical seasonal ranges.



Mule deer population trends in British Columbia



Black-tailed deer population trends in British Columbia.

-Gerry Kuzyk, British Columbia Ministry of Forests, Lands and Natural Resource Operations

California

California's mule and black-tailed deer populations appear to be stable over the last 10 years (2008 – 2018) with the current estimated population at approximately 470,000 animals (Figure 1). Estimated harvest has also been stable while hunter success for California has fluctuated between 15 and 22 percent over the last 10 years. Survival estimates for adult female deer averaged across several areas of the state from 2013 – 2016 remain high at approximately 0.83. California buck:doe and fawn:doe ratios also appear to be stable statewide, although these estimates can vary widely among population across the state (Figure 4).

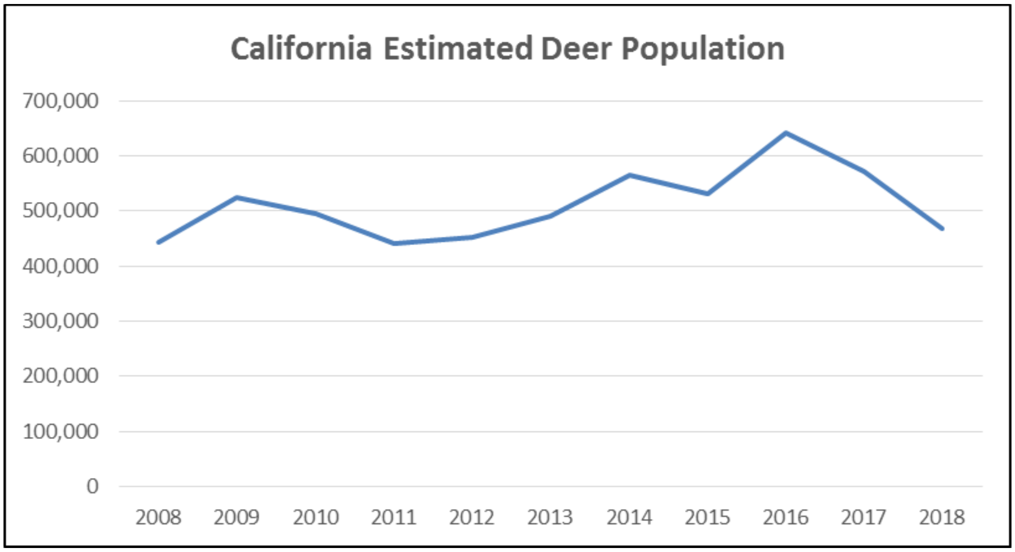


Figure 1. California estimated mule and black-tailed deer population 2008-2018.

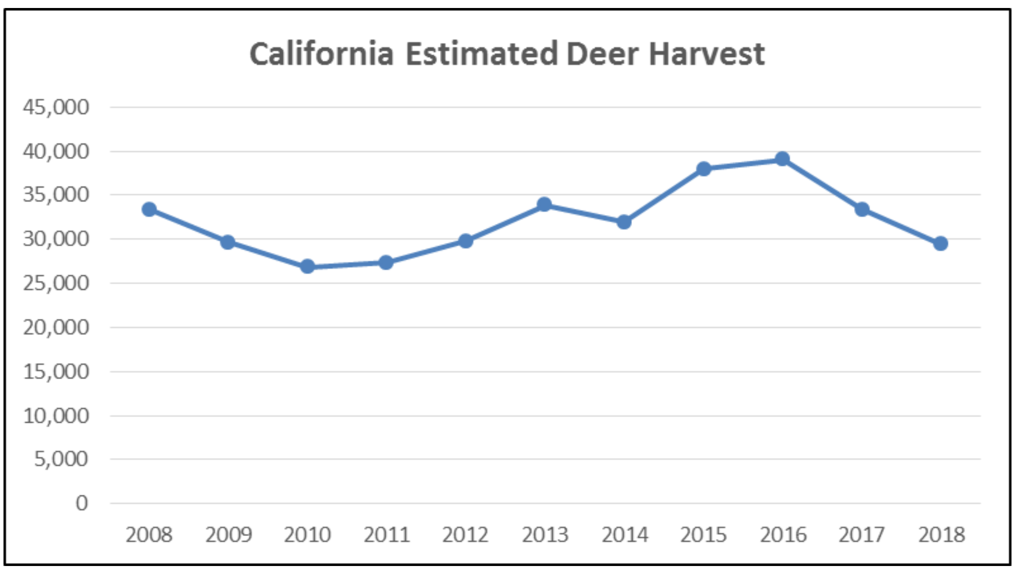


Figure 2. California estimated mule and black-tailed deer harvest 2008-2018.

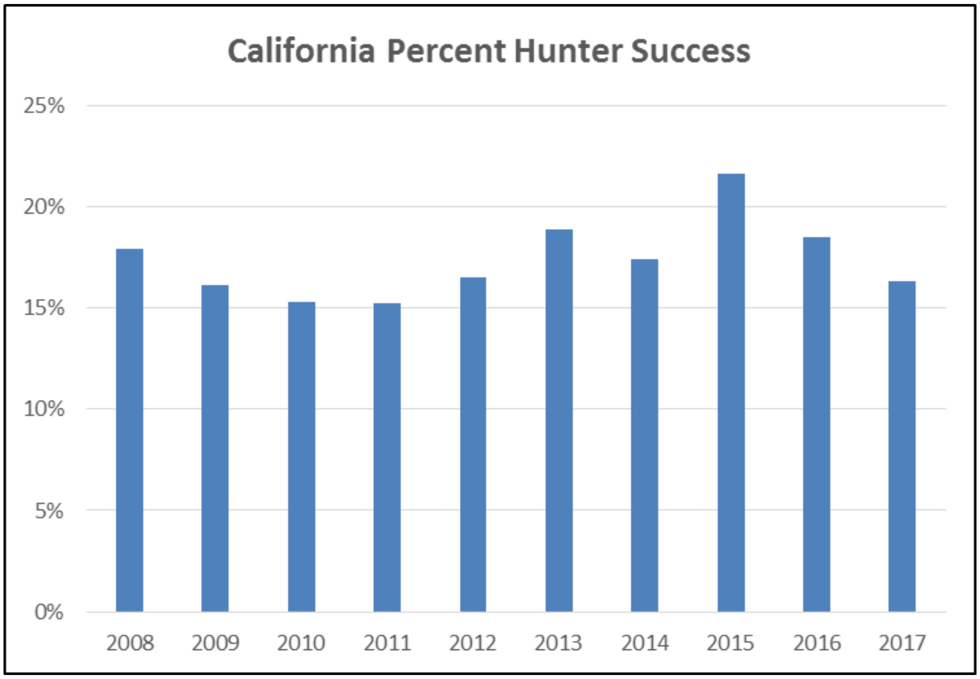


Figure 3. California estimated mule and black-tailed deer hunter success 2008-2018.

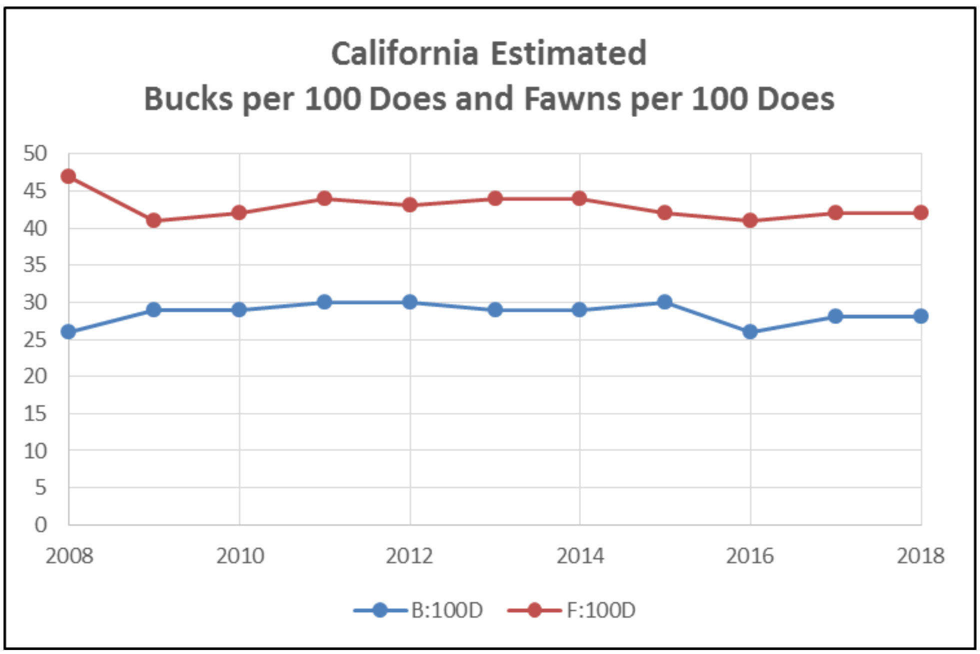


Figure 4. California estimated bucks per 100 does and fawns per 100 does 2008-2018.

California is currently updating our statewide management plan. The plan will evaluate and refine as necessary strategies to acquire deer abundance estimates across California using a combination of helicopter based methods, fecal DNA mark-recapture, camera traps, and GPS collars to estimate survival, home range, migratory routes, and habitat connectivity. The plan updates will also include population and harvest objectives set by management unit.

- David Casady, California Department of Fish and Wildlife

Colorado

The statewide post-hunt 2017 deer population estimate is 419,000, which is the same as post-hunt 2016 (Figure 1). Population estimates are still far below the sum of statewide population objective ranges of 493,000 - 551,000 for all 54 deer herds combined. Many western slope herds have not recovered yet from the severe winter of 2007-2008. Higher population objectives reflect Colorado Parks and Wildlife's (CPW) desire to stabilize, sustain, and increase deer herds that have experienced declines and are below population objective.

CPW uses spreadsheet models to estimate population size. These models rely on data from age and sex classification, harvest surveys, and survival monitoring. Annual population and sex ratio estimates are compared to long-term Herd Management Plan population and sex ratio objectives for each herd to establish harvest quota recommendations for the next hunting season.

Diverse habitat types and environmental conditions around the state create considerable geographic variability in population performance. Many deer herds are performing well, and population sizes and license numbers are increasing. Despite these increases, there's still reason for concern because of declines in many of the large westernmost herds in Colorado.

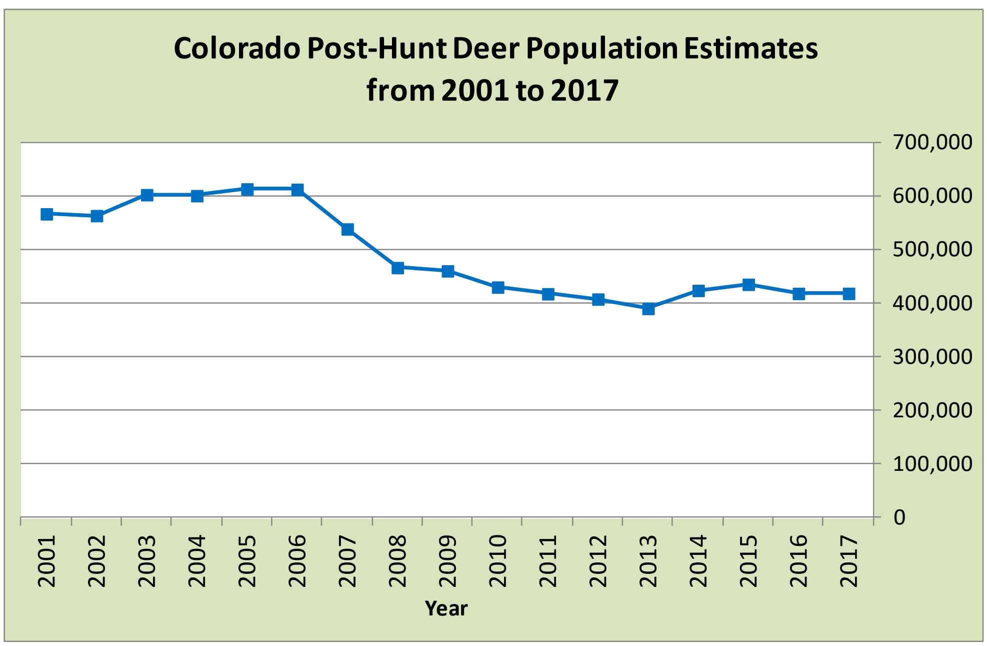


Figure 1. Colorado post-hunt deer population estimates from 2001-2017.

CPW intensively monitors annual adult doe survival and winter fawn survival in five mule deer herds. We also monitor buck survival in two of these herds. These herds were selected to ecologically and geographically represent mule deer west of Interstate I-25. CPW annually monitors over 1000 radio-collared mule deer in the five intensive monitoring areas and other areas. Survival rates from these herds are used in deer population models for the rest of the herds west of Interstate I-25. Since 1997, annual adult doe survival has averaged 82.5% and over-winter fawn survival has averaged 68.1%. Since 2008, annual buck survival in two of the five monitoring areas has averaged 81.4%. Survival rates for this past winter of 2017-2018 are currently at or above average because of a very mild winter.

CPW conducts post-hunt herd inventories with helicopters to estimate the sex ratios of males:100 females and the age ratios of young:100 females. In addition to survival rates, these ratios are needed to estimate population size using population models. The average of sex ratio objectives for deer herds statewide is 30 bucks:100 does. During the post-hunt herd inventories in 2017, CPW staff classified 61,000 deer and observed an average sex ratio of 34 bucks:100 does which is down towards the objective from the peak of 38 bucks:00 does in 2015 (Figure 2). Mild winters resulted in high over-winter fawn and buck survival in 2013 and 2014 which had the combined effect of increasing populations and buck:doe ratios in many herds (Figures 1 and 2). Buc:doe ratios were reduced by increasing buck licenses to manage ratios down to objectives. Reproduction and fawn survival to December was up this year compared with last year, as the statewide average observed age ratio from helicopter inventory was 57 fawns:100 does compared with 54 fawns:100 does in 2016.

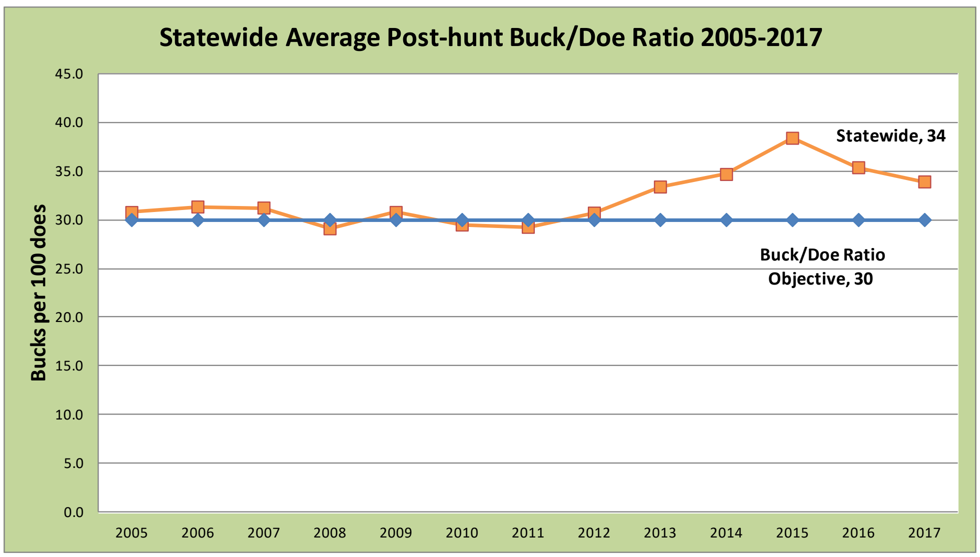


Figure 2. Colorado statewide average of observed post-hunt bucks:100 does for 2005-2017 weighted by herd population size.

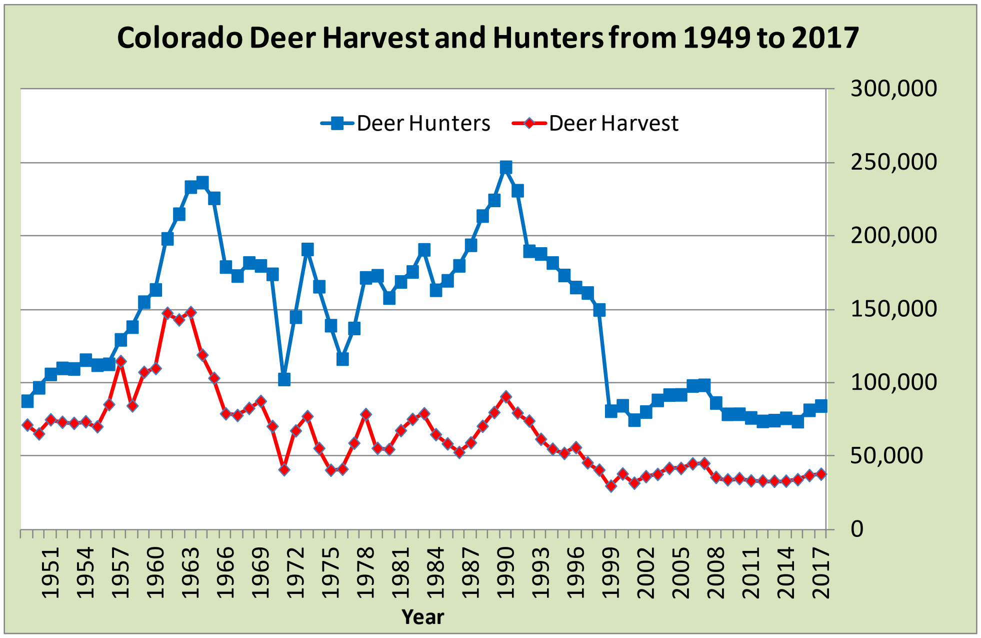


Figure 3. Colorado statewide hunters and harvest from 1949-2016.

Since 1999, all mule deer hunting in Colorado is by limited license. In 2017, the estimated harvest from the 84,185 hunters who hunted with those licenses was 37,761 (Figure 3). Based on these high observed post-hunt sex ratios and a high average hunter success rate of 50% for all rifle seasons in 2017, overall deer hunting continues to be good. Buck/doe ratios have shown a response to our management actions, and Colorado remains a premier destination for deer hunters.

-Andy Holland, Colorado Parks and Wildlife

Hawaii (Kauai Island: Introduced Black-tailed Deer, 2015 Information)

Since the introduction of the Oregon black-tailed deer to west Kauai in 1961, its range has expanded to south and east sections of the island. The deer population on Kauai's public hunting areas is estimated to be between 1000 to 1200 animals. Population estimates on private lands are not known at this time. Kauai uses the Aldous (1944) browse survey method which was modified to better fit Hawaiian environments. Kauai experienced 2 major wildfires in 2012, the Kokee forest fires consumed just over 1000 acres of State Forest Reserves and severely impacted much of the deer hunting range. The 2013 deer hunting season was restricted to portions of the range not impacted by the wildfires. In 2014, all black-tailed deer hunting units were re-opened following adequate habitat and population recovery to justify full open season. The average body weights improved slightly from the previous season and the overall health of the herd appeared to be very good. In July, 2015, two hunting units underwent changes to include year-round hunting and increased bag limits. The changes were needed to address ungulate damage to native forest watershed and to protect threatened and endangered plants. Six deer hunting units remain seasonal during the fall months.

Trends in harvest of black-tailed deer from 2003 to 2015 on Kauai public hunting areas.

Year	Bucks	Does	Total
2003	45	19	64
2004	39	12	51
2005	32	8	40
2006	32	2	34
2007	32	4	36
2008	51	2	53
2009	29	0	29
2010	26	0	26
2011	30	0	30
2012[1]	4	0	4
2013[1]	5	0	5
2014[2]	36	0	36
2015[3]	36	15	51

[1] Two units closed to hunting due to wildfires
[2] All units reopened to deer hunting
[3] Two units open to year-round hunting

-Thomas Kaiakapu, Hawaii Division of Forestry and Wildlife

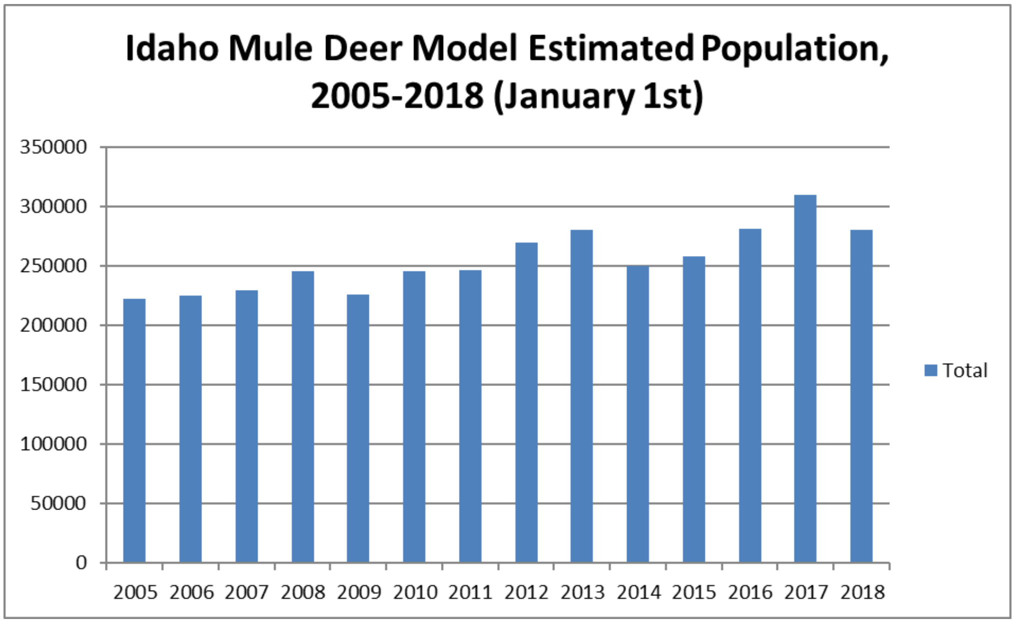
Idaho

After four years (2013-2016) of population increases, the winter of 2016-2017 saw statewide winter fawn survival at 30%. Reductions in antlerless hunting opportunity for the fall of 2017 and 2018 were made across several regions in southern Idaho.

The state continues the process of converting population monitoring techniques to allow total population estimates through a combination of sightability, survival estimates, composition surveys and modeling. Although not all areas have yet been assessed, recent winter population levels have likely decreased slightly to 280,000 mule deer. Short- and long-term objectives are to increase mule deer numbers. Post-season buck ratios exceed the statewide minimum objective of 15:100 does. Over the last several years December fawn:doe ratios have generally shown increases over the typical (mid-50s to mid-60s), and winter fawn survival have generally been high from 70% to 78%.

Mule deer harvest in Idaho has been stable to increasing since the mid-1990s following a steep decline in harvest in the early 1990s. Recent years' license and tag sales data indicate an increase in nonresident hunters in Idaho. Percent bucks with 4-point or better antlers harvested in the rifle-controlled hunts have remained at or above 40% since 2010.

The next step of implementing our 2008 mule deer plan is to set population objectives by population management unit statewide. A statewide mule deer hunter attitude and opinion survey was completed in 2017. Results were similar to the 2007 survey.



Mule deer population estimate from the Salmon River drainage south. Estimates are midpoint of Confidence Limits based on Integrated Population Model, from January 1, 2018.

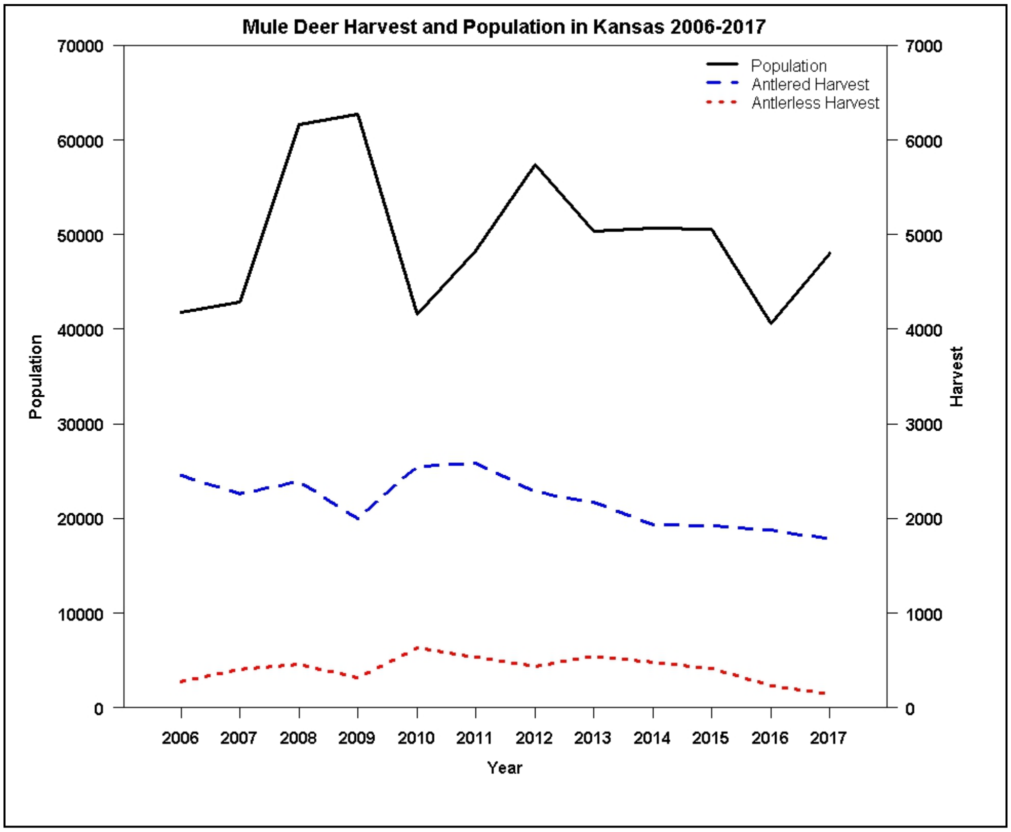
-Daryl Meints, Idaho Department of Fish and Game

Kansas

Mule deer populations have declined along the eastern tier of counties where mule deer occur in Kansas. A spotlight distance sampling survey was implemented to mule deer estimate density and population size. The mule deer population in the west zone of Kansas in 2017 was estimated to be 1.7 mule deer/mile^2 (95% CI: 1.0 – 2.9) while the density in the eastern zone was estimated to be only 0.2/mile^2 (95% CI: 0.07 – 0.7) resulting in a pre-firearm season population estimate of 47,935 mule deer. In the west zone, the mule deer buck:doe ratio was 29.5B:100D. In the east zone the ratio was higher at 38.5B:100D but the difference may be a result of low sample size. In the east zone, where population declines and range retraction is occurring at the greatest rates, only 26 mule deer were observed over 334.6 miles of private land spotlight transects in 2017. Fawn:doe ratio in the west zone was 24.8F:100D and in the east zone was 46.2F:100D, but again the higher ratio in the east may be an artifact of the low sample size.

The major goal of deer management in Kansas is to maintain herd size at socially acceptable levels. This largely means minimizing landowner damage complaints and deer/vehicle accidents, while maintaining quality hunting opportunities in regards to hunter observations of deer and harvest opportunities. Currently, both hunters and landowners are expressing concern about the declining mule deer population in the eastern zone, thus the current management goal is “more” mule deer and current population levels are below the goal.

Management for mule deer receives enthusiastic support from deer hunters. Hunters want more mule deer and fewer hunters competing for permits and hunting locations. Hunting regulations in Kansas have been liberal for white-tailed deer while being restrictive for mule deer. Mule deer could be taken on 15.7% of the either sex deer permits issued in Kansas last year. Landowners received 54.0% of those permits. Each of those permits allowed only one deer to be taken but it could be either a mule deer or a white-tailed deer. By allowing either species to be taken, the permit system generally takes hunters out of the field earlier in the season compared to a mule deer only permit system and takes pressure off mule deer while allowing approximately 17,000 people to have the potential to pursue mule deer. Hunters have taken an average of 2,569 mule deer/year during the last 10 years. In an effort to expand and increase the mule deer population, reductions in the permit quotas have been made in recent years. In 2017, no antlerless permits allowing the take of mule deer were issued. This coincided with the lowest estimated harvest of antlerless mule deer (139) since 1983 (84), and the lowest estimate of total harvest (1,917) of mule deer since 1985 (1,831).



Little information is available on survival or reproductive rates of mule deer in Kansas, and much has been inferred from studies conducted in other locales. In 2017, Kansas Department of Wildlife and Parks secured funding for a three-year study, which was initiated in February 2018, to investigate adult and fawn survival rates, reproductive rates, home range size, habitat use, harvest vulnerability, and inter-species interactions of mule deer and white-tailed deer in western Kansas. During February 15-18, 2018, 133 total deer were captured. GPS collars were attached to 120 deer total, 15 collars per each sex of each species at two study sites. Each marked doe also received a vaginal implant transmitter (VIT), was measured for body condition and had disease samples collected for testing. Assuming a rate of 1.5 fawns birthed per doe, 90 fawns total will be marked with expanding VHF collars during the spring of 2017. A new group of does and fawns, and replacement bucks will be captured in the second and third years of the study. Additionally, as part of the habitat use investigation, habitat metrics will be taken at locations marked deer utilize with greater emphasis on fawn habitat use. Spotlight surveys are planned during October and November on the study sites to use mark-recapture methods and the GPS marked deer to assess spotlight survey detection rate biases in the road-based distance sampling methods currently used to estimate deer densities and population size in Kansas.

Public interest and concern about chronic wasting disease (CWD) has been renewed recently. CWD currently is found only in the western portion of the Kansas where mule deer are endemic. A human dimensions survey regarding public knowledge, concerns, and support for various management activities is being considered. The afore mentioned study will also provide important information about deer movement within areas with differing levels of CWD prevalence. Kansas has no regulations in place for CWD management, but strongly recommends that hunters harvesting deer in areas with CWD use the photo check process that allows deer to be deboned so the carcass can be left in the field and to have CWD testing completed before consumption.

-Levi Jaster, Kansas Department of Wildlife, Parks and Tourism

Montana

Montana Fish, Wildlife and Parks (FWP) annually estimates the statewide mule deer population because of a statutory requirement that the agency provides one. However, that estimate is based on a crude model that biologists have low confidence in and is not used for making management recommendations. For management purposes, FWP relies on harvest and population survey data. Harvest data is collected through annual post hunting season phone surveys that randomly survey a sample of deer hunters that self-report success and effort. The survey provides an estimate of harvest within an 80% confidence interval. Population trend data are collected through aerial surveys of 102 trend survey areas across the state that represent publicly accessible deer across a diversity of habitat types.

Antlered mule deer hunting regulations have remained unlimited allowing one per resident hunter and approximately 25,000 non-resident opportunities valid across much of the state for many years. Therefore, antlered mule deer harvest has been viewed as an index of population size and trend. Statewide antlered mule deer harvest increased annually from 2010 through 2016 to a 22 year high of 45,564. In 2017, the statewide mule deer buck harvest estimate declined to 42,851 – compared to the 1960-2016 average of 45,366. The statewide population estimate (Figure 1) and antlered mule deer harvest (Figure 2) suggest that the statewide mule deer population experienced a modern low within years 2010 – 2012. This low was strongly influenced by severe conditions (extended cold temperatures and deep snow) across the eastern half of the state during winter periods 2009-2010 and 2010-2011. From 2011 through 2017, the statewide population estimate increased from 211,361 to 386,075 (Figure 1) and statewide antlered mule deer harvest increased from 28,985 to 42,851 (Figure 2), suggesting a population increase during that period.

Within the state, long-term mule deer populations have varied. Those across the western 1/3 of the state, the mountain/foothill environments, have generally trended down and remain below historic highs and averages. Habitat changes facilitated by conifer forest succession, over-utilization of browse resources by mule deer, and increased resource competition from growing populations of elk and white-tailed deer are thought to be primary influencers of mule deer trend across the mountain/foothill environments. On the contrary, populations across the eastern 2/3 of the state, the prairie breaks environment, have generally remained stable or increased.

The statewide estimate for deer (mule and white-tailed) hunters was 152,213 in 2017, compared to 158,896 in 2016 and a 1986-2016 average of 164,520. The number of deer hunters in Montana peaked at 201,576 in 1994, annually decreased to 148,736 in 1998, and has remained relatively stable since that time. Following the 2016 hunting season, the statewide average buck:doe and fawn:doe ratios were 29: 100 and 65: 100, respectively.

Since 2001, mule deer harvest regulations across Montana have been determined by following guidelines outlined by the state's Adaptive Harvest Management (AHM) plan. This plan provides harvest regulation guidelines for antlered and antlerless mule deer based on population survey, recruitment, and hunter harvest data for five population management units based on ecotype. Working within these guidelines, biologists have reduced and more recently increased antlerless harvest opportunity as modern populations have trended down and back up, (Figure 2). Beginning with the 2016 hunting season, biologists in a portion of southwest Montana recommended a liberal antlerless harvest season outside of AHM plan guidelines, working with the hypothesis that declining populations are being influenced more by habitat limitations than hunter harvest. This effort is currently being implemented and monitored with an experimental approach that may or may not inform future AHM guidelines for southwest Montana.

Over the past year plus, an FWP mule deer working group has been reviewing the AHM plan and developing recommendations for updates. This review, along with recommended changes, is expected to be completed in 2018.

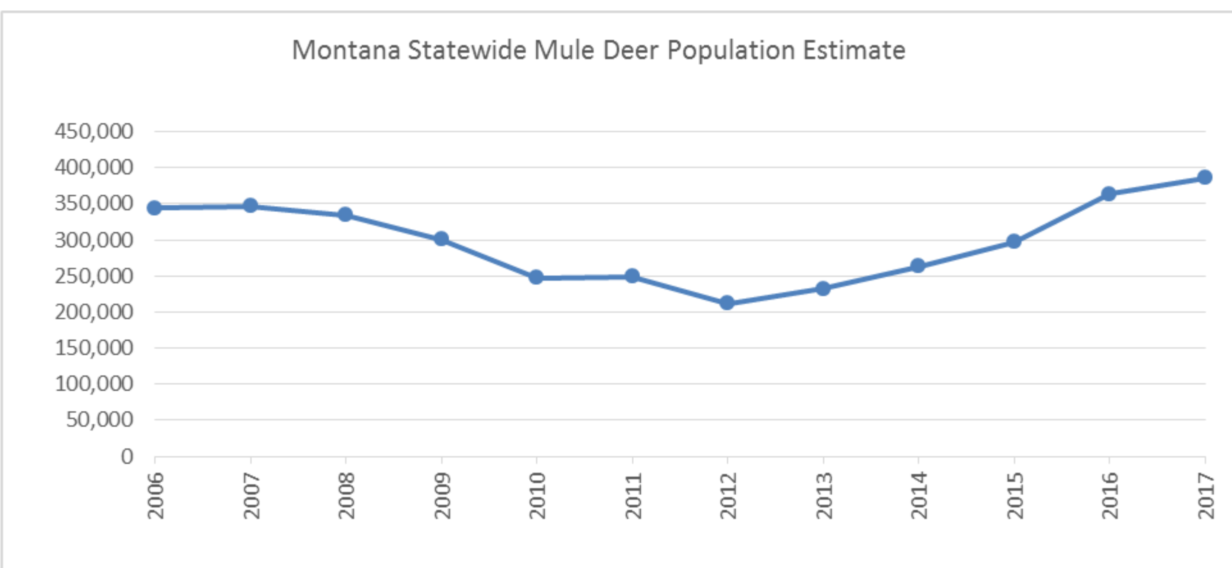


Figure 1. Montana statewide mule deer population estimate, 2006-2017.

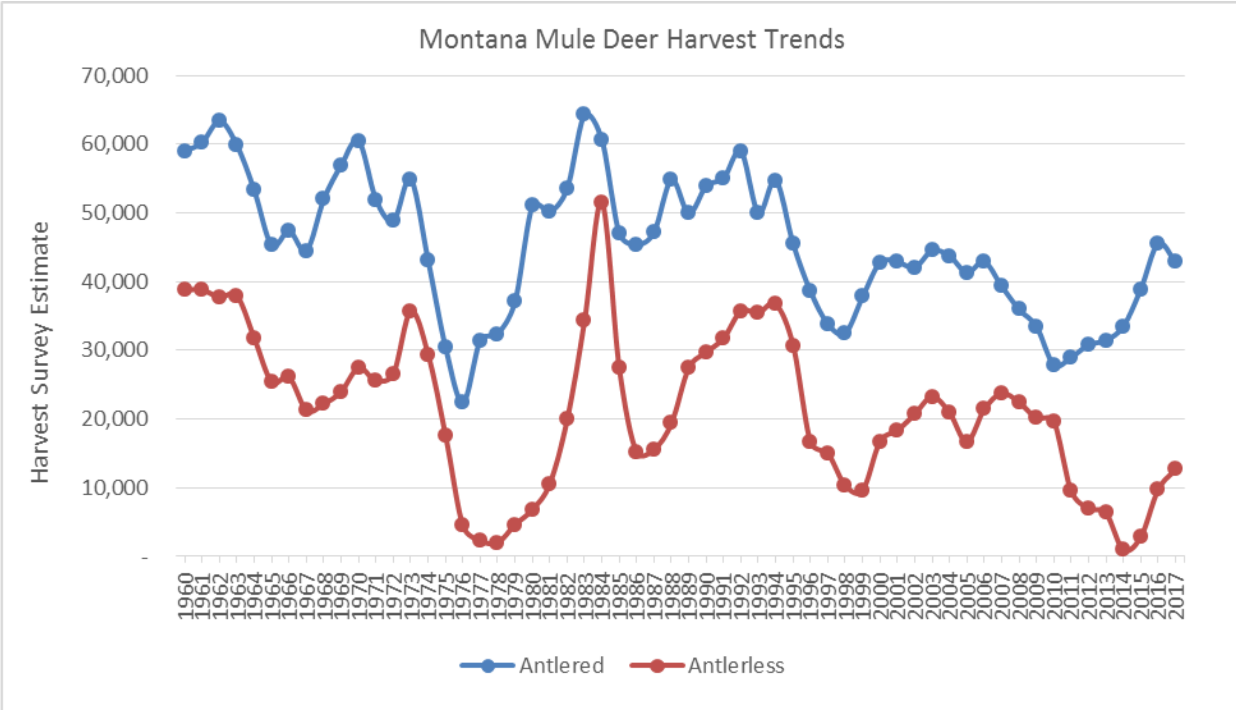


Figure 2. Montana statewide mule deer harvest, 1960-2017.

-Dean Waltee, Montana Fish, Wildlife and Parks

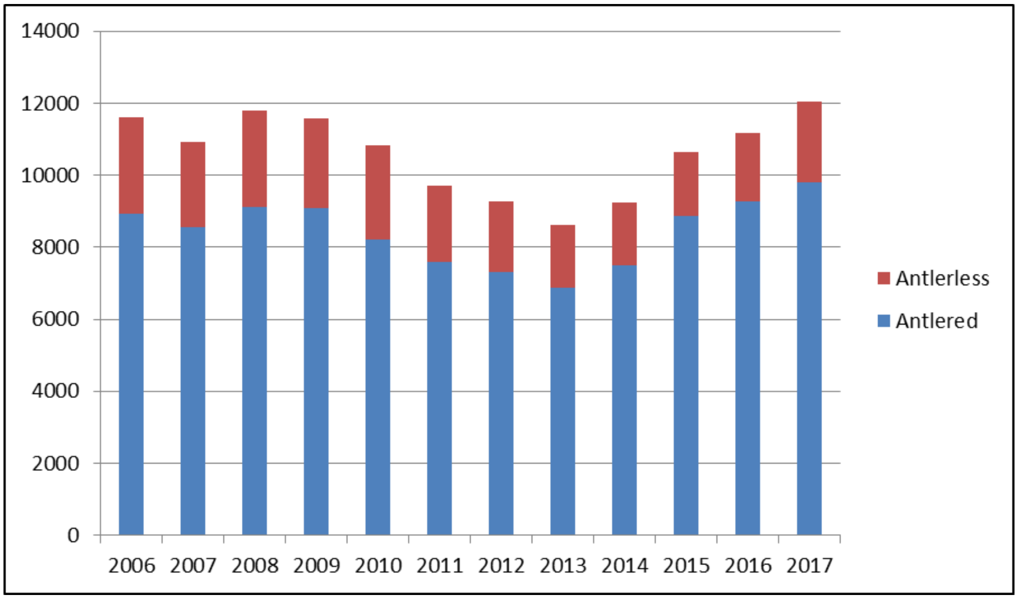
Nebraska

Mule deer population trends are based on total adult buck harvest at Deer Management Unit (DMU) level. Mandatory check of all harvested deer is required. Age data is collected annually on more than 4,000 mule deer; 49% of harvested bucks were age 3 or older. Barring significant change in buck permit allocations this provides a consistent indicator of annual population and age structure change at DMU level.

Management objectives for each DMU are based on: population trends, agricultural damage complaints, age of harvested bucks, buck harvest, permit demand, deer vehicle collisions, and public input.

Harvest of mule deer bucks was a record 9,801 in 2017, and accounted for 25% of total buck harvest. Mule deer outnumber white-tailed deer in 5 of 18 DMUs and are abundant in 10 of 18 DMUs.

Herd growth is desired in five DMUs where antlerless mule deer restrictions are in effect. Habitat conditions remain good for healthy herds and population growth. Population growth the past five years was driven by low antlerless harvest (the lowest recorded since 1980) and normal precipitation levels. Buck and doe harvest should increase in 2018.

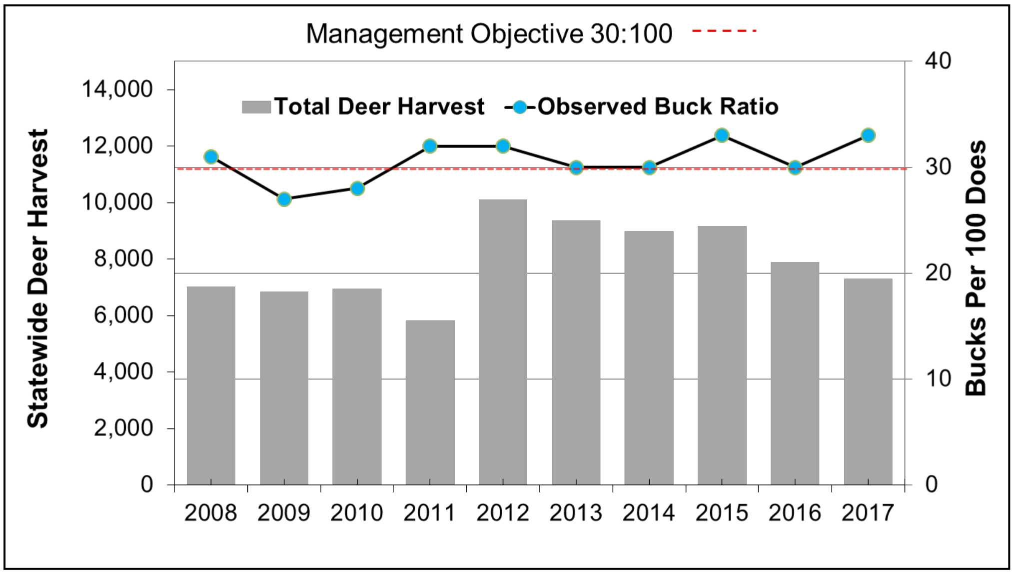


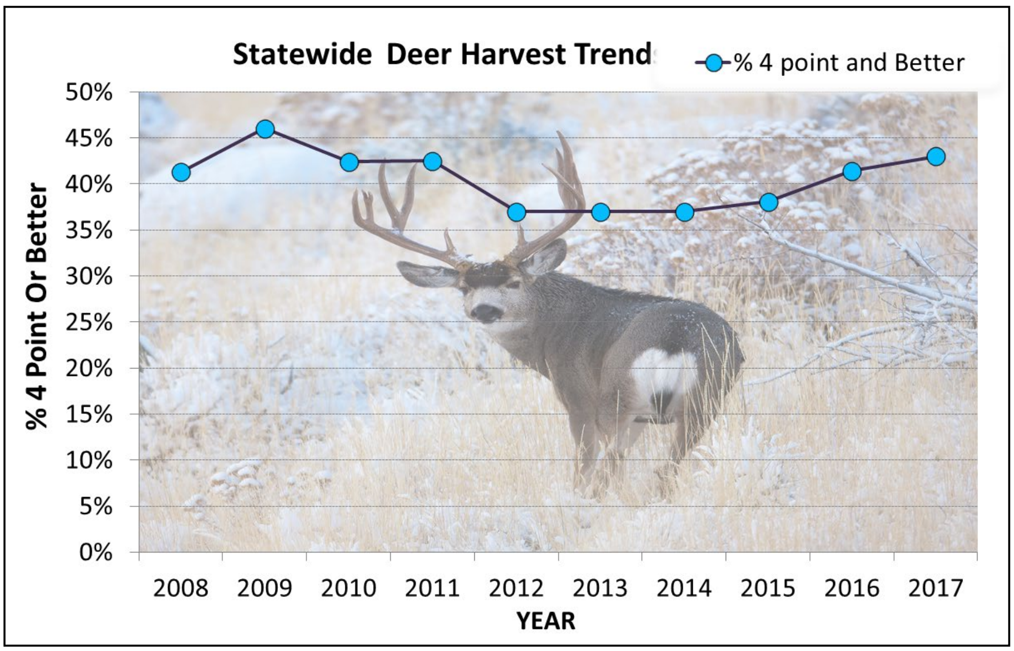
-Kit Hams, Nebraska Game and Parks Commission.

Nevada

Nevada hunters purchased 16,100 mule deer tags in 2017. The decrease in tag sales was reflective of a decrease in the 2017 quotas approved by the Nevada Board of Wildlife Commission. Total harvest for 2017 was approximately 7,300 mule deer including bucks and does. Hunt return questionnaires indicated a statewide success rate of 49% for all deer hunters, which was higher than the reported 46% during 2016. Total buck harvest was about 6,234 and of those bucks harvested about 43% had 4 (or greater) antler points on one side. The 2017 post-season aerial survey resulted in about 25,685 mule deer classified statewide compared to 31,770 in 2016. Statewide fawn production was slightly lower during 2017 with 45 fawns:100 does counted during post-season surveys (compared to 48 fawns:100 does during 2016). The 2018 spring deer surveys classified 22,760 mule deer, with a ratio of 35 fawns:100 adults statewide, which is equal to the long-term average. The statewide observed buck ratio was 33 bucks:100 does for 2017.

The state of Nevada uses 30 bucks:100 does as a statewide management objective for standard hunts, while up to eight alternative Hunt Units are managed for 35 bucks:100 does and a higher percentage of 4 point or greater bucks in the harvest. Nevada's mule deer populations have been stable the past several years. The 2018 population is estimated at about 92,000 mule deer. Many of Nevada's northern water basins experienced above average precipitation during 2017-2018; however, snowpack measurements for many SNOTEL sites were well below long term averages indicating the potential for poor forage quality and reduced water availability for some regions.





Trends in statewide mule deer harvest and observed post-hunt buck ratio for Nevada, 2008 to 2017. Observed buck ratios are obtained by directed search helicopter surveys. Harvest data are from mandatory return questionnaires.

-Cody Schroeder, Nevada Department of Wildlife

New Mexico

Prior to the 1990's, all deer licenses were issued over the counter. During the early-1990s, the New Mexico Department of Game and Fish began issuing public land deer hunting licenses through the draw in select areas of the state; starting in 2005 the Department began issuing all public land deer licenses through the draw. Private land deer hunting licenses can be obtained over-the-counter in most areas of the state, however.

During the 2017-2018 hunting season, an estimated 32,018 hunters harvested 11,316 deer in New Mexico (Figure 1). Harvest reporting has been mandatory since 2006; unless a hunt is for a specific species, white-tailed deer and mule deer are not reported separately. The majority of deer harvested in New Mexico are mule deer with white-tailed deer comprising of approximately 3% of the total harvest. Hunter success was approximately 35% during the 2017-2018. The long-term average success rate for deer hunters in New Mexico is 29% (1953-2018). Except for a few youth antlerless hunts and an antlerless archery hunt to target an urban deer population, New Mexico implements a buck only bag limit.

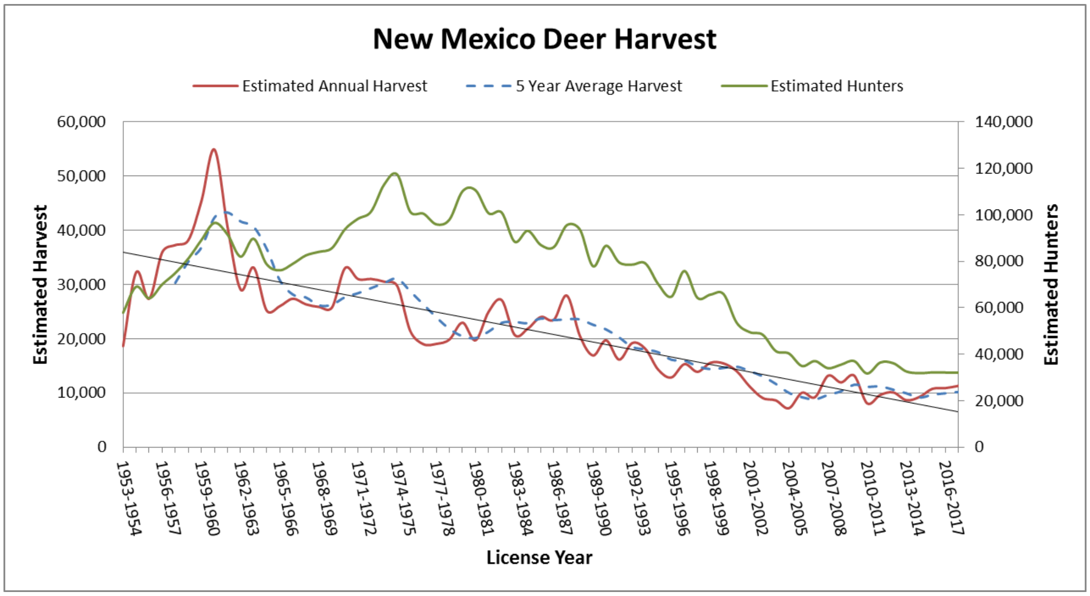


Figure 1. Estimated annual deer hunters and harvest in New Mexico 1953 – 2018.

The Department conducts annual post-hunt surveys in December or January to obtain composition ratios. During winter 2017 surveys, the statewide buck to doe ratio was 35 bucks:100 does (Figure 2). Although this is slightly down from recent years, the long-term trend continues to increase. The 2017 fawn to doe ratio (34 fawns:100 does) was also slightly down; however, the long-term trend is increasing as well. The increasing trend in composition ratios are likely a result of the increased precipitation that New Mexico has experienced in recent years which has improved habitat in many portions of the state.

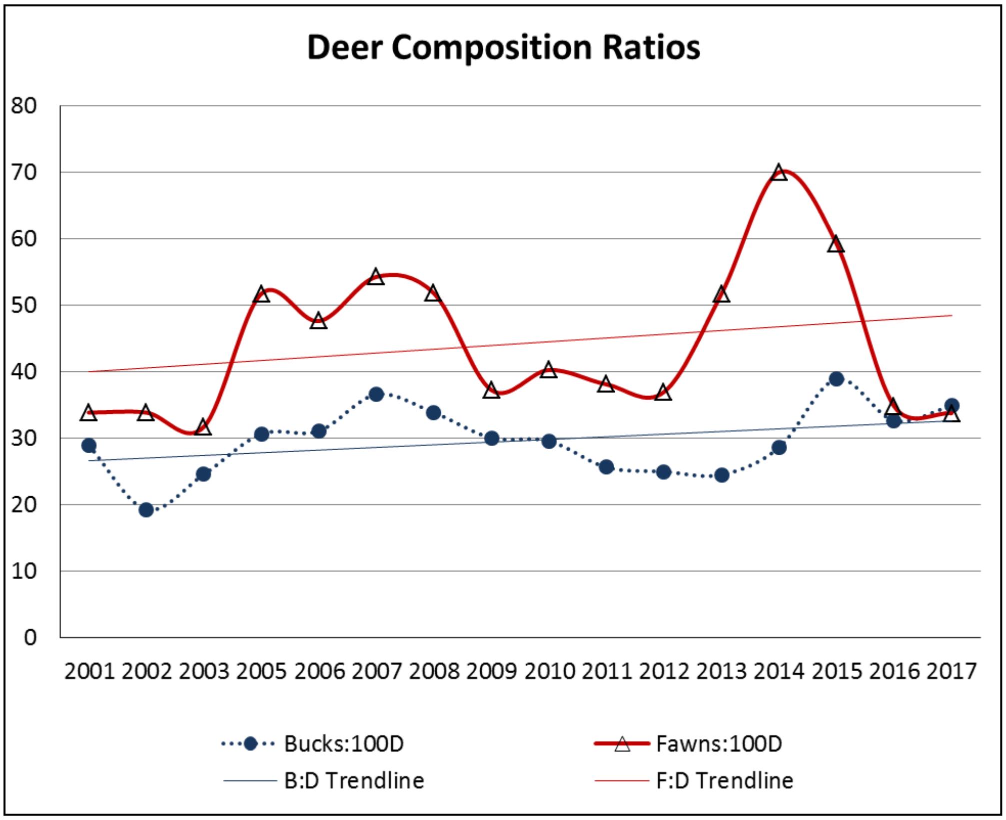


Figure 2. New Mexico statewide composition ratios obtained during post-hunt winter surveys from 2001-2017.

Precipitation for the 2017-2018 winter was poor throughout New Mexico; however, good moisture in recent years should help the mule deer populations remain healthy. Additionally, habitat in areas of New Mexico that experienced wildfires in the last 10 years is rebounding and providing nutritious forage for mule deer; as a result, deer populations in these areas show signs of growth. Most desert mule deer populations continue to struggle, however, due to a long-term drought in the southern half of the state.

New Mexico Department of Game and Fish is working to address suppressed mule deer population through the Department's Habitat Stamp Program. This program has funded over 100,000 acres of habitat treatments intended to benefit mule deer in the last several years.

-Orrin Duvuvuei, New Mexico Department of Game and Fish

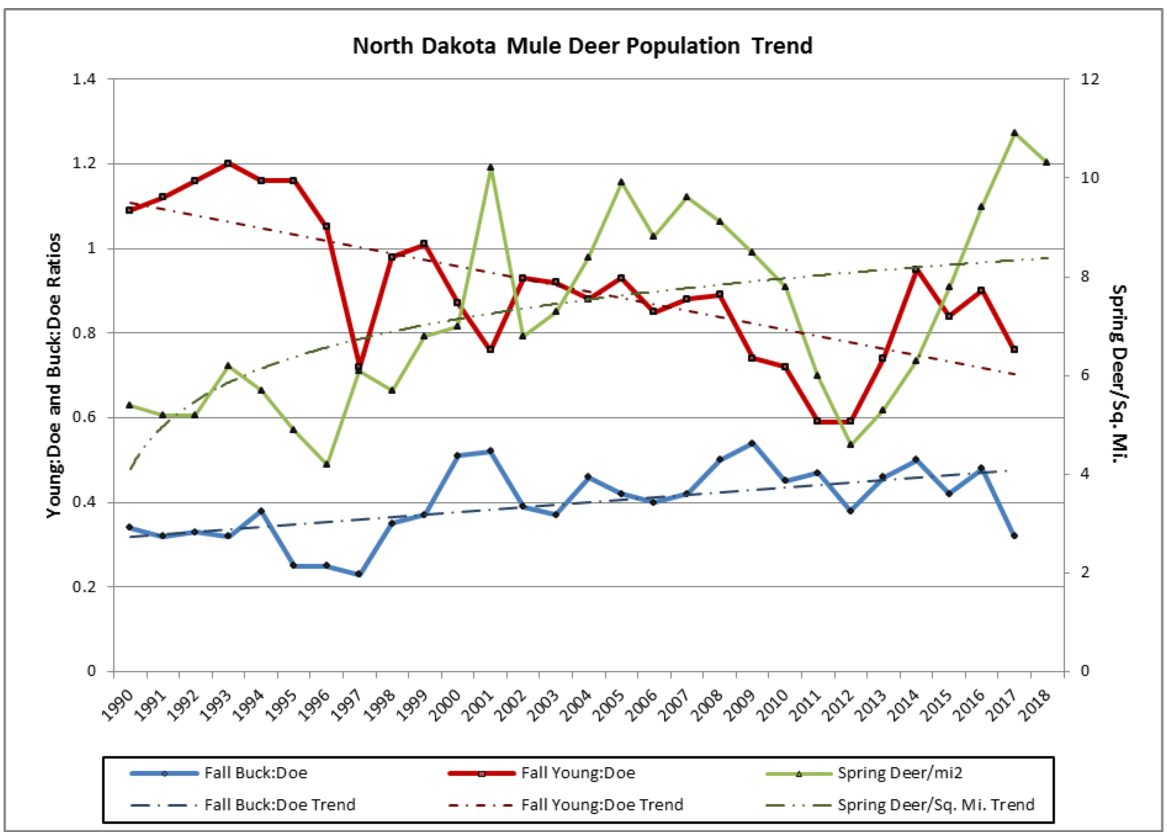
North Dakota

North Dakota's badlands mule deer population showed an increasing trend with high fawn production from 1990-2007. Mule deer fawn production was typically greater than 90 fawns:100 does during these years. Winter weather conditions were mild during this time period except in 1996. Mule deer numbers peaked in 2005-2007. Following this population peak, North Dakota experienced three of the most severe winters on record from 2008-2010. Consequently, mule deer abundance in the badlands decreased by 50% and reached a population low in 2012. Record low fawn:doe ratios were recorded in 2009-2012 following these winters. Winter weather conditions moderated in 2011-2015 and the mule deer population has increased since 2013. The 2018 spring index was 6% lower than the 2017 index, but still 45% higher than the long-term average. Fawn production has trended upward since the population low in 2012.

The combination of eliminating antlerless harvest and milder winter weather conditions in 2011-2015 is responsible for mule deer population growth in the badlands. North Dakota has a limited quota license system and a goal of maintaining at least 30 bucks:100 does prior to the gun season.

The mule deer buck:doe ratio has remained stable and above objective since 1999. Mule deer are currently above the objective of maintaining at least six deer per square mile in the badlands. A conservative harvest strategy with a limited number of antlerless licenses is being used to encourage additional population growth of mule deer in the badlands.

We analyzed survival for 203 mule deer using radio-tracking data. The estimated annual adult survival probability was 85.6%, and overwinter juvenile survival probability (Dec – May) was 67.7%. Survival probabilities were lowest in the winter season for adults and juveniles. The leading cause of mortality for adults was predation (32%) and for juveniles was malnutrition (22%).



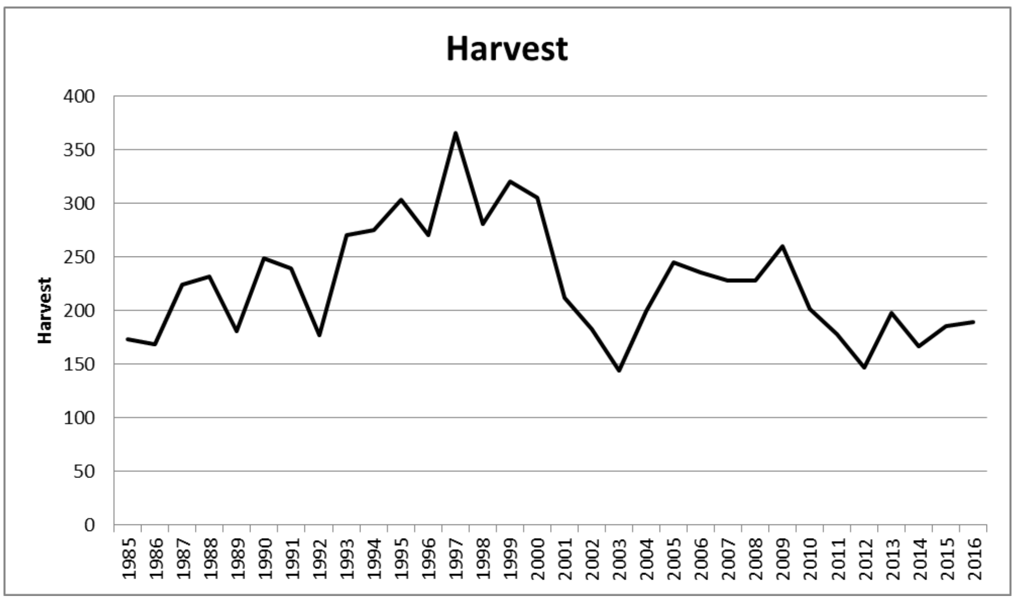
- Bruce Stillings, North Dakota Game and Fish Department

Oklahoma

With Oklahoma being the eastern edge for what is considered mule deer habitat, we estimate between 1,500 and 2,000 animals pre-hunting season in our panhandle, NW and far SW portions of the state. Most harvest occurs on private lands, but opportunities to harvest a Mule Deer does exist on some of our public hunting areas.

Oklahoma does not differentiate between mule deer and white-tailed deer in our tagging system. A statewide deer permit allows the harvest of either species, mule deer harvest was up slightly for the 2017-2018 season (196) compared to the 2016-2017 hunting season (189 mule deer).

Similar to several states throughout the west, the lack of rain across some of these areas in Oklahoma is staggering. Some areas have just received their first rains since October of 2017 which will likely result in lower fawn recruitment during 2018.



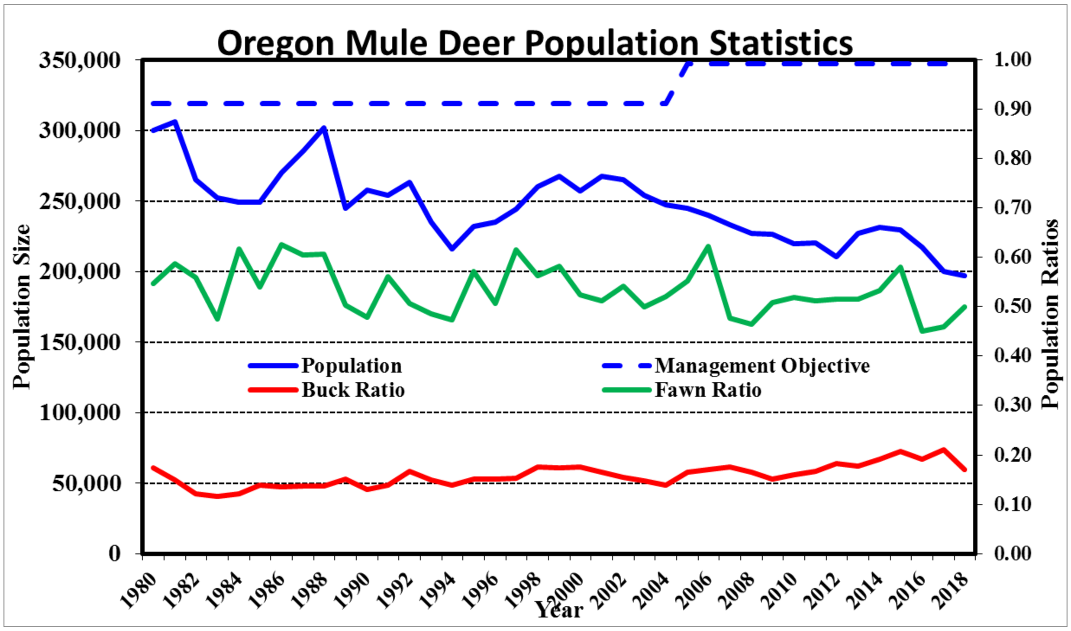
-Dallas Barber, Oklahoma Department of Wildlife Conservation

Oregon

Both mule deer and black-tailed deer are substantially below the long-term statewide management objectives and benchmarks. Oregon's estimated mule deer population continues to hover around 220,000–230,000. Because of the difficulties with surveying black-tailed deer we have been unable to develop annual population estimates. However, in 1998 the black-tailed deer population was estimated at 387,000, declining to 320,000 in 2004; the population seems to have been relatively stable since that time.

Density estimates and population modeling developed using non-invasive fecal DNA sampling northwestern Oregon indicate that black-tailed deer populations have stabilized over the last 10-12 years. This effort also indicates that the ratio of bucks:100 females is much higher than indicated by our traditional survey methods. Application of these non-invasive methods have moved to include two wildlife management units in southwest Oregon. This effort is in slightly different habitats and management strategies will prove to be very insightful.

During winters of 2015–2018, a total of 888 GPS radio-collars have been deployed on 1,030 mule deer across their eastern Oregon distribution to refine herd range boundaries for data collection and monitoring. Survival continues to vary considerably across the landscape but has improved over the very low levels observed during winter 2016–2017.



Trends in Oregon's mule deer population size and structure, 1979 – 2018.

-Don Whittaker, Oregon Department of Fish and Wildlife

Saskatchewan

In Saskatchewan, winter severity is a key driver of mule deer mortality, especially in prairie and farmland regions where winter forage can quickly be made unavailable by a major snow event. Generally speaking, Saskatchewan mule deer populations are currently considered stable or slightly increasing and to have recovered from a recent series of severe winters that occurred 2010-2014. Results of our long-standing, citizen-science based Co-operative Wildlife Management Survey for 2017 indicate a stable population structure (Figure 1) and improving fall recruitment (Figure 2), likely due to another mild winter in 2016-2017.

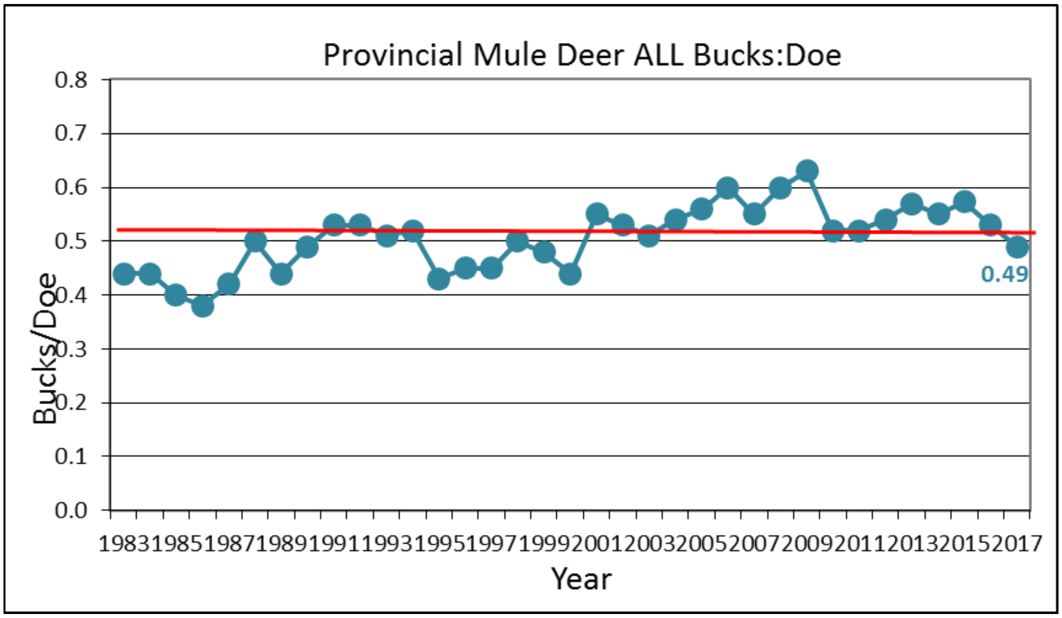


Figure 1. Estimated annual buck:doe ratios for mule deer in Saskatchewan since 1982 based on data from the citizen-science based Co-operative Wildlife Management Survey. Note the 2017 buck:doe ratio of 0.49 is slightly below the long-term average of 0.51.

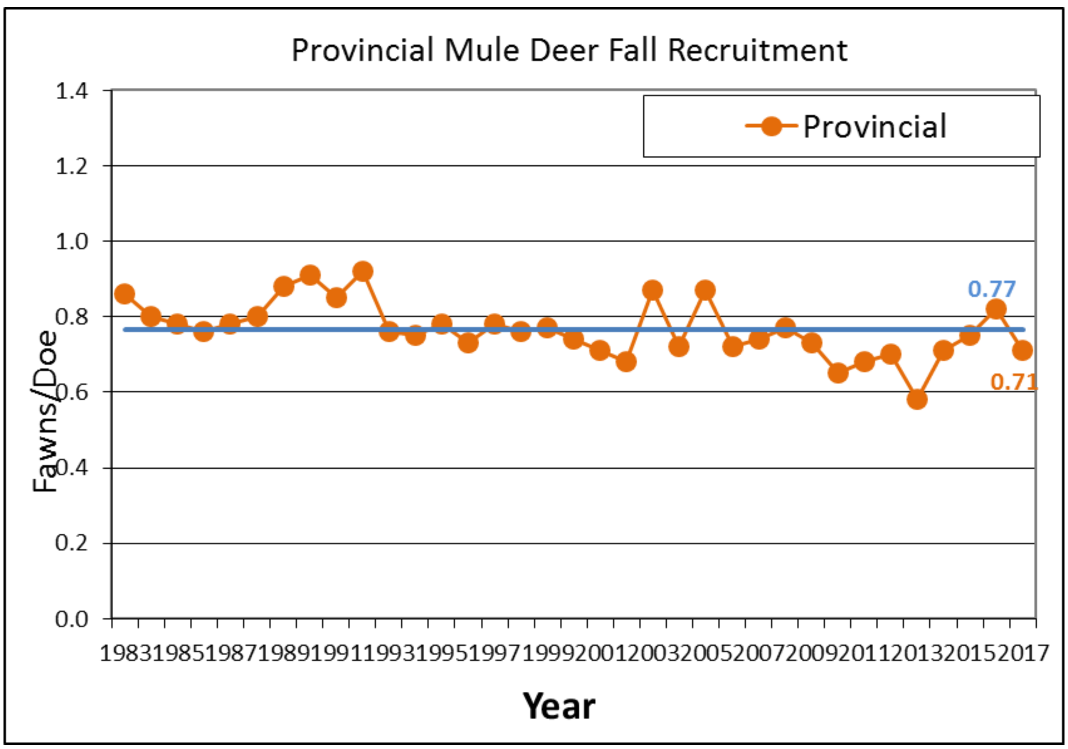


Figure 2. Estimated annual productivity of Mule Deer in Saskatchewan since 1982 based on data from the citizen-science based Co-operative Deer Management Survey as reflected by the fawn:doe ratio. Note the estimated 2017 fawn:doe ratio of 0.71 is below the long-term average of 0.77.

Hunter harvest survey data recorded moderate harvest success for draw hunters in 2017 (81%), slightly up from draw success rates for 2016 (79%). In 2018, draw mule deer opportunities have been recommended for 60 Wildlife Management Zones, with increases to draw quota across many zones to reflect increases in local mule deer populations. Hence, we anticipate an increased mule deer harvest for 2018. Antlerless mule deer hunting opportunities remain, although bag limits remain one antlerless mule deer in select zones.

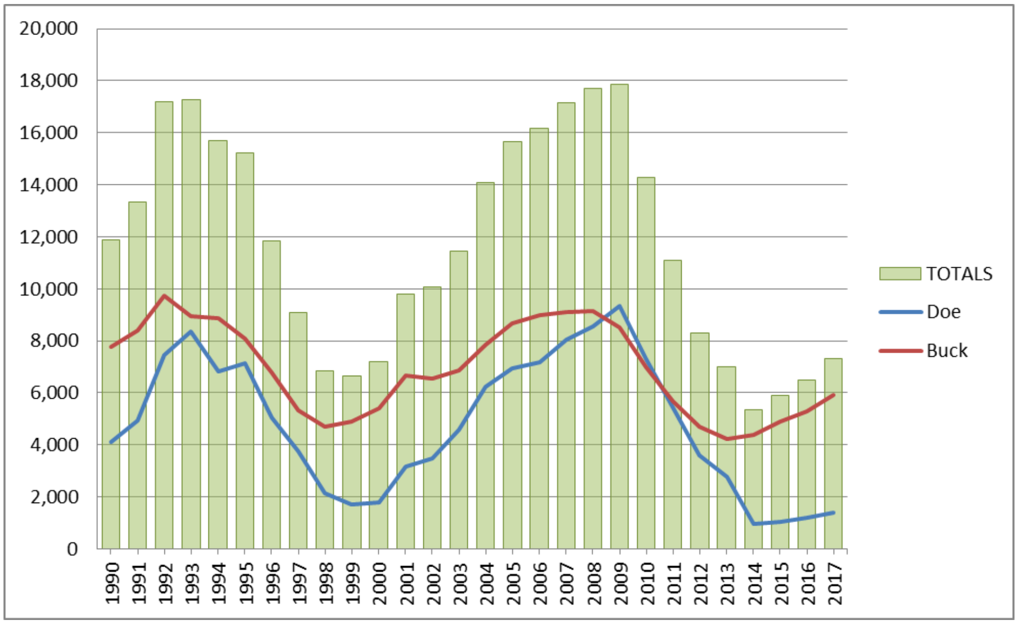
-Allison Henderson, Saskatchewan Ministry of Environment

South Dakota

Mule deer populations in South Dakota appear to be slowly responding to reduced harvest rates in recent years, and results from several biological surveys provide some cautious optimism for the future. Recently the population objectives of 2 management units were modified to reflect increasing mule deer densities. Pre-season herd composition surveys showed decreases in recruitment in almost every Data Analysis Unit (DAU) in 2016, but recruitment showed a slight improvement to 67 fawns:100 does in 2017. The statewide pre-season sex ratio in 2017 was 41 bucks:100 does.

Hunter survey cards are mailed to selected license holders in order to estimate hunter success, deer harvest, and related information for each season. Hunters may also report harvest information through an internet response. Approximately 7,300 mule deer were harvested in 2017 (5,900 males, 1,400 females; Figure 1). Substantial hunting season changes occurred in recent years to address low deer densities, including the elimination of “any antlerless” firearm, archery, and muzzleloader deer hunting licenses. The current harvest of antlerless mule deer occurs from youth deer hunters or hunters with “any deer” licenses.

Radio collaring and survival monitoring efforts have increased substantially in South Dakota, with approximately 750 collared mule deer being monitored across 3 study areas. Survival rates for 2017 in the Black Hills were 62% for fawns (0-4 months of age; 95% CI 28-76), 53% for juveniles (5-17 months of age; 42-64), and 80% for adult females (18+ months of age; 74-85). In the White River study area, survival rates in 2017 were 58% for fawns (24-72), 75% for juveniles (67-83), and 84% for adult females (79-88). And in the Upper Missouri River study area, survival rates were 57% for fawns (23-72), 79% for juveniles (71-86), and 82% for adult females (77-86). These vital rates, in conjunction with other survey data, are used in an Integrated Population Model to estimate abundance and trends at the DAU level. Preliminary pre-season estimates for 2018 are 4,600 mule deer in the Black Hills and 64,000 mule deer on the prairie. Current growth rates in 2018 across DAUs vary from a low 0.96 to a high of 1.15.



Mule deer harvest from all hunting seasons in South Dakota, 1990-2017.

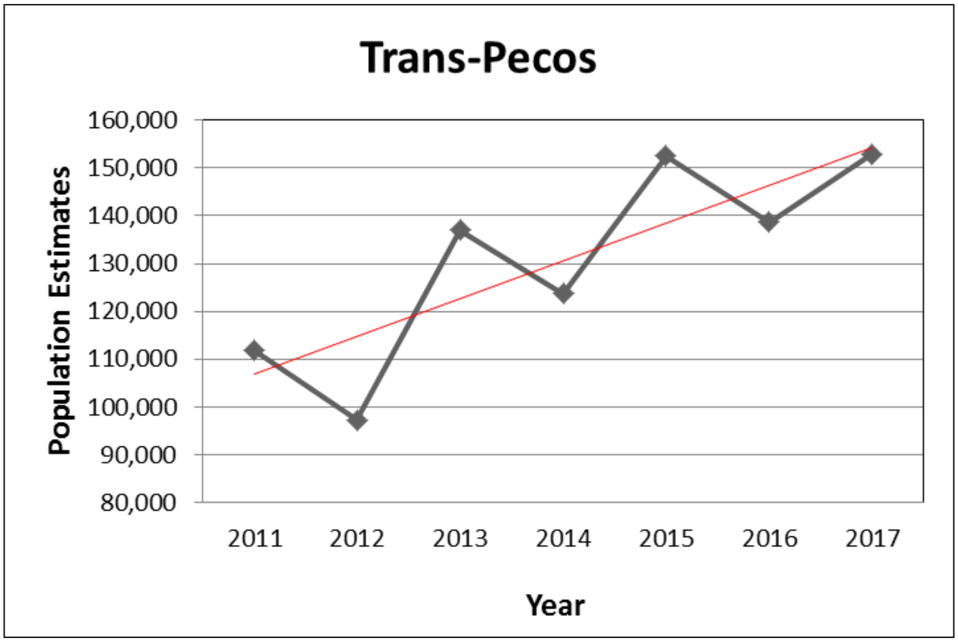
-Andy Lindbloom, South Dakota Department Game and Fish

Texas

Texas Parks and Wildlife Department (TPWD) conducts post-season helicopter surveys for mule deer using a stratified random sampling design within monitoring units. In 2011, a sightability model was initiated to improve population estimates. The data are used to determine population trends, estimate population densities, and document herd composition to evaluate the impacts of regulations and management actions on mule deer at an ecoregion and monitoring unit scale.

Trans-Pecos

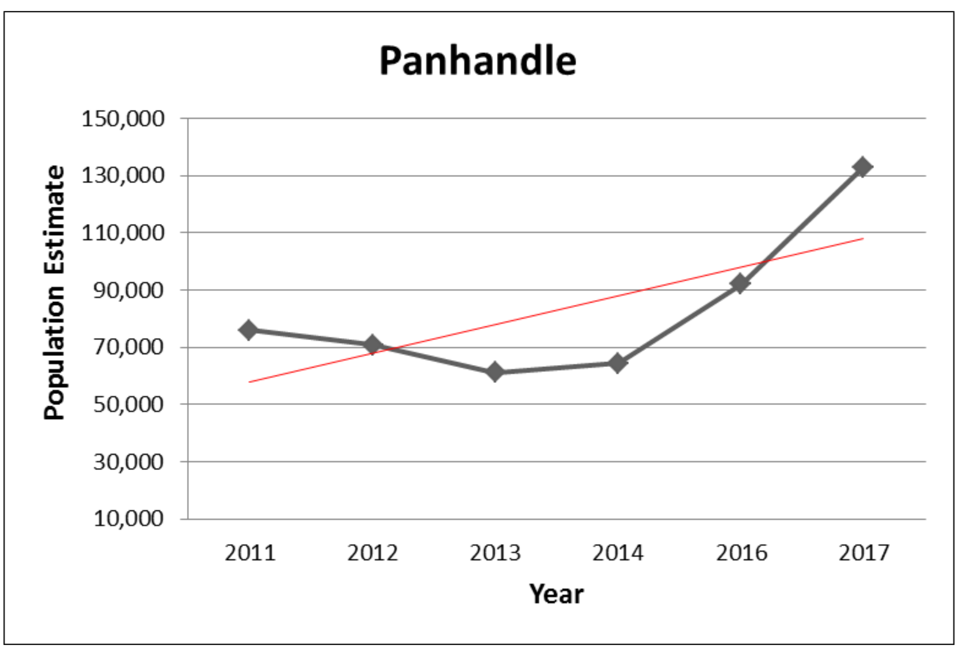
In general, the Trans-Pecos population has been on an increasing trend since 2012 because of good range conditions and fawn production and recruitment from 2013-2017. The 2017 survey estimate (152,870) indicated a 57% increase from 2012 (97,315). Surveys were not conducted in 2007 and 2010. The estimated 2013-2017 fawn crops of 47, 35, 38, 40, and 49 fawns:100 does, respectively were higher than the 2012 estimate of 32. The sex ratio for 2017 was 54 bucks:100 does, the highest bucks:100 does since 2005.



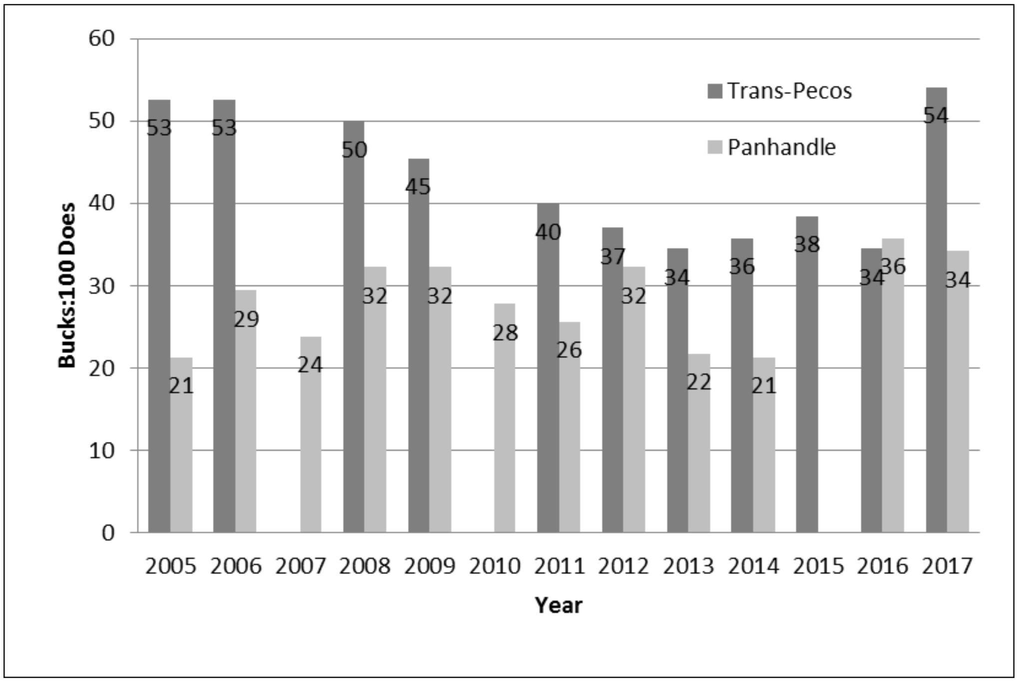
Trends in mule deer population estimates in Trans-Pecos, Texas, 2011-2017.

Panhandle

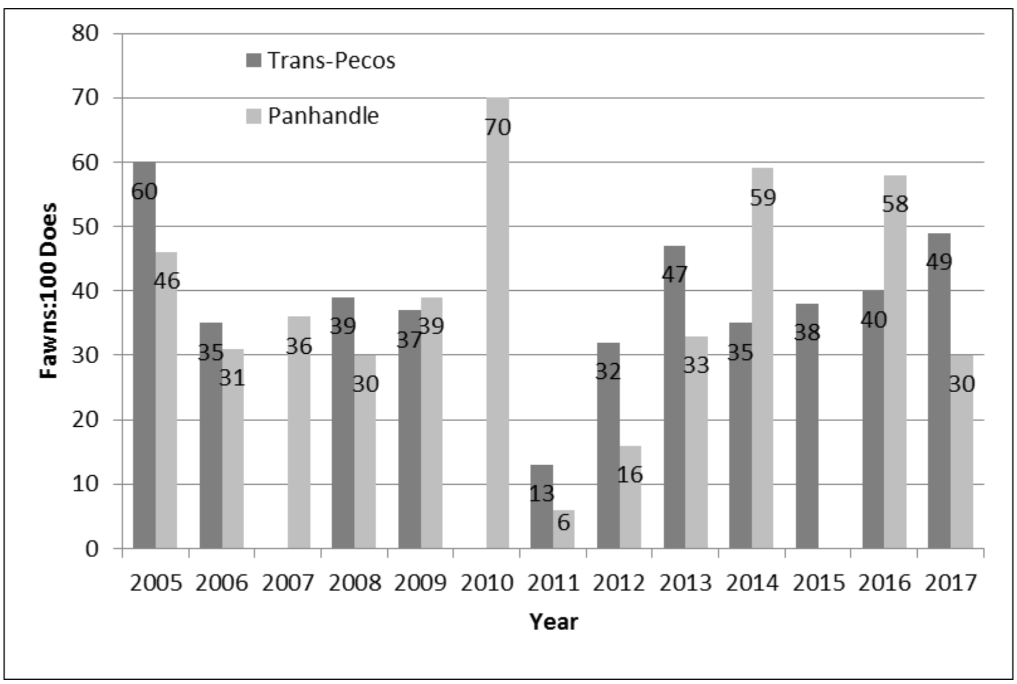
The Panhandle population trend has been stable to increasing since 2011. Surveys were not conducted in 2015. The 2017 population estimate of 133,048 was highest among survey years. Fawn production was 30 fawns:100 does in 2017, which was below the region average (41 fawns:100 does). The sex ratio for 2017 was 34 buck:100 does. Sex ratios have varied from 21 to 36 bucks:100 does since post-season surveys were initiated in 2005. Sex ratio data indicate a higher harvest rate on mule deer bucks compared to the Trans-Pecos in almost all years, but the post-season sex ratio has been above 21 bucks:100 does in 10 out of 12 survey years.



Trends in mule deer population estimates in the Texas Panhandle, 2011-2017.



Trends in the number of mule deer bucks per 100 does in the Texas Panhandle and Trans-Pecos area, 2005-2017.



Trends in the number of mule deer fawns per 100 does in the Texas Panhandle and Trans-Pecos area, 2005-2017.

-Shawn Gray, Texas Parks and Wildlife Department

Utah

Abundance of mule deer in Utah is estimated using models with inputs from age and sex classification (post hunt), harvest surveys, and survival rates of collared animals. These models suggest that abundance of mule deer has slightly decreased over the past two years, but that this decrease was preceded by 5 years of steady increase. The current statewide population estimate is 363,650, and the population objective is 453,100. Fawn:doe ratios have been stable over the past 8 years, and have ranged between 59 and 65 fawns per 100 does. Since 2010, we have radio-collared several hundred does and fawns annually on 7 representative units throughout the state for monitoring purposes and to estimate survival rates. Annual doe survival has averaged 0.83 and ranged between 0.77 and 0.86. Fawn survival has averaged 0.62 and ranged between 0.10 and 0.82. From 2011-2015, mule deer populations in Utah grew by nearly 100,000 animals. In 2016 and 2017, adult and fawn survival rates declined resulting in a decrease of approximately 20,000 deer from 2015 estimates (Figure 1).

Utah manages for diverse hunting opportunities and attempts to balance quality and opportunity. We have 29 general season units that are managed for hunter opportunity with a goal of 15-17 or 18-20 bucks per 100 does following the fall hunts. Utah also has limited entry units that are managed for increased quality at 25-35 bucks per 100 does. In addition, we have 2 premium limited entry units that are managed for 40-55 bucks per 100 does with ≥ 40% harvested bucks 5 years of age or older.

Over the past 25 years, buck to doe ratios have increased as a result of growing populations and decreased buck permits (Figure 2). In 1994, roughly 97,000 public draw permits were issued for general season units, and the post season buck to doe ratio was 8 bucks per 100 does. Last year 89,050 public draw permits were issued, and the post season buck to doe ratio exceeded 19 bucks per 100 does. Additionally in the fall of 2017, hunters in Utah harvested nearly 30,000 bucks on general season units, which is the highest harvest observed since 1996. For the 2018 hunting season, Utah is recommending an overall increase in general season deer permits because we are exceeding buck to doe ratio objectives in some units. This increase is partially a result of a unit by unit hunting strategy which allows for more fine-scale management.

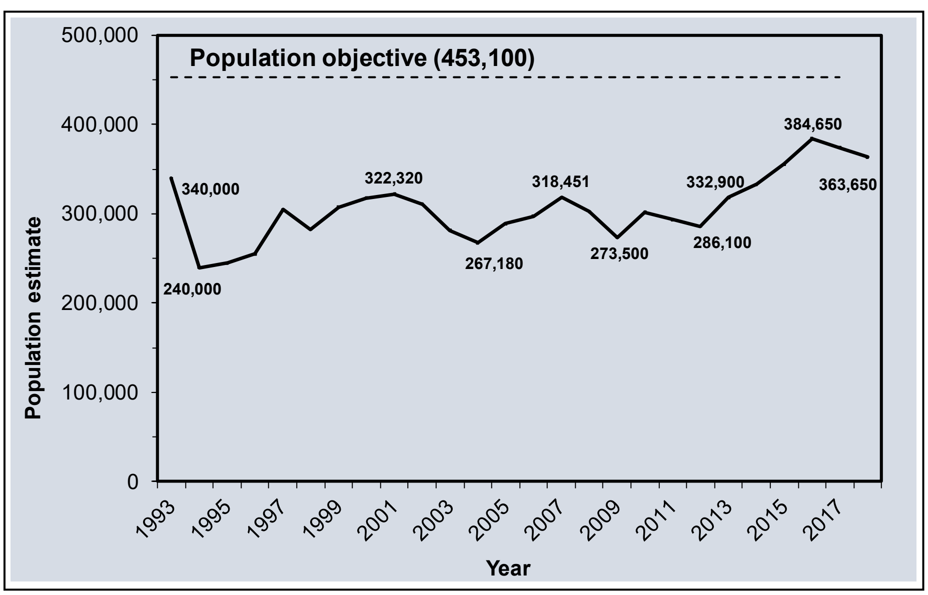


Figure 1. Mule deer population estimates from 1992-2017.

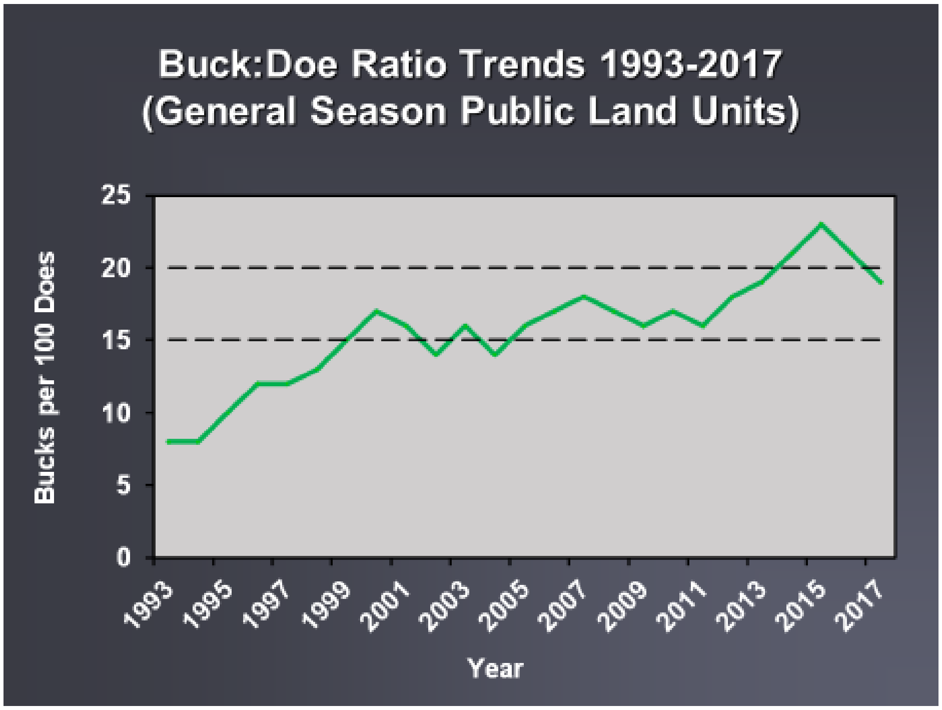
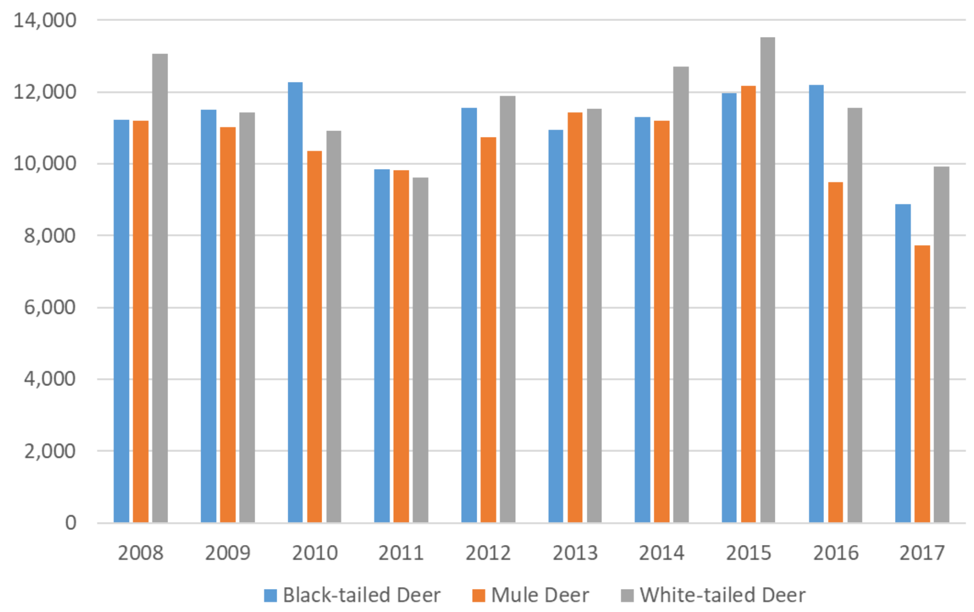


Figure 2. General season buck to doe ratios from 1993-2017.

-Covy Jones, Utah Division of Wildlife Resources

Washington

Populations within WDFW's 7 mule deer management zones and 5 black-tailed deer management zones are stable to decreasing in some zones compared with previous years, but remain within objective. The statewide harvest estimate (all species, general and permit seasons combined) for 2017 was 26,529 deer, below the 10-yr mean (2008-2017) of 33,285 deer, and the harvest estimate for 2016 was 33,230 deer. Harvest estimates and composition ratios from annual monitoring efforts for mule deer indicate populations along the Cascade Mountains have likely decreased from the highs seen two years ago. However, we expect that harvest success was in part affected by the late onset of winter which resulted in migratory deer remaining at higher elevations throughout most of the hunting season. The northern most populations have also been affected by large fires in 2014 and 2015 that substantially reduced available winter browse and lowered herd numbers commensurate with what the landscape can now support. Similar to last year, antlerless permits for mule deer will be limited in most management zones. Management activities for mule deer will continue to focus on habitat enhancement, including prescribed burns and thinning, on public lands. Regional harvest trends indicate black-tailed deer in western Washington have decreased. Some localized population segments in each zone fluctuate due to forest production rotations, but potential remains to increase abundance if private and public forests were managed for greater early successional habitat. Loss of black-tailed deer habitat due to encroaching human development continues to be a concern.

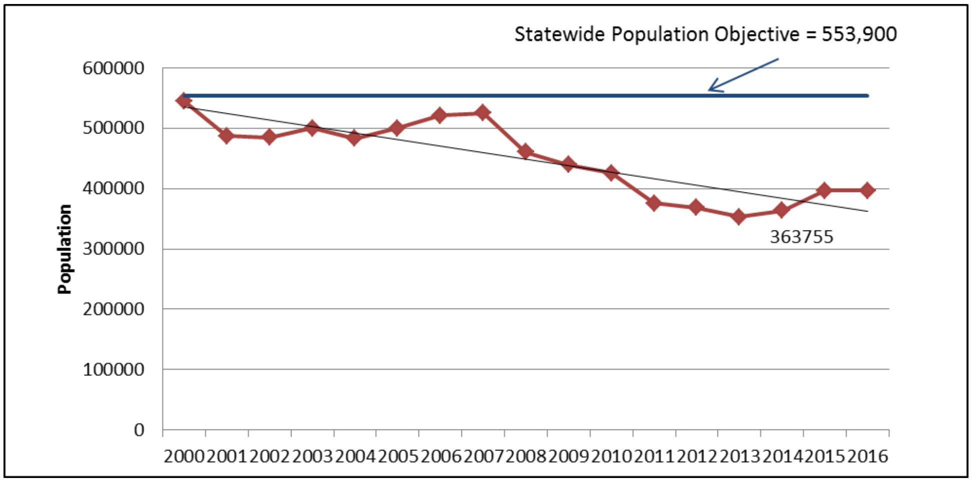


Estimated deer harvest, for general and permits seasons, by species and subspecies in Washington State, 2008 - 2017. Estimates do not include multi-weapon harvest.

-Sara Hansen, Washington Department of Fish and Wildlife

Wyoming

Mule deer populations throughout Wyoming have declined since the early 1990s. It is apparent, given declining production of mule deer fawns starting in the late 1980s, populations were responding in a density-dependent fashion to decreasing habitat availability and/or quality. Over the past 30 years, fawn productivity, on average, has decreased statewide by about 11% and has been below the objective of 66 fawns:100 does 16 times. Buck:doe ratios have ranged from 27 to 39 and averaged 32:100 since 2000. Throughout Wyoming, mule deer populations have declined by an estimated 148,000 (27%) mule deer since 2000. After the 2016 hunting season, it was estimated there were 396,000 mule deer in the state. This is 28% below the statewide objective of 553,900 mule deer. Mule deer populations, while still below objective, have trended upward the past 4 years. Population estimates are derived using post-season fawn and buck classifications in concert with measured harvest and synthesized in a spreadsheet based population model. Harvest has been largely limited to bucks the past several years in response to declining deer numbers.



-Daryl Lutz, Wyoming Game and Fish Department

Yukon

There has been no formal inventory work on mule deer in Yukon and there is no inventory work scheduled for the 2018-19 fiscal period. Trends in abundance and distribution are monitored primarily through sightings and motor vehicle collision reports. Numbers and distribution have generally been on the upswing since first reports in the early 1920's. The current population estimate of 1,000 territory-wide is a guess based on observations in agricultural areas and from aerial surveys for other species.

The first deer hunting season was implemented in 2006. Licensed hunters in Yukon must apply for a male-only permit through a lottery system. Interest in the deer hunt continues to be high with 400 to 500 hunters applying for 10 permits issued each year. As of 2010, two additional permits have been available annually to young hunters. First Nation beneficiaries are entitled to harvest deer under their subsistence rights as of the effective date of their settled final agreements. No records of First Nation harvest are available. The licensed harvest in 2017 was 10 deer. Generally, the annual licensed harvest ranges between 4 and 8 deer.

-Sophie Czetwertynski, Yukon Department of Environment

Acknowledgements

Information in this report was provided by MDWG members from the 23 Western Association of Fish and Wildlife Agencies (WAFWA) and compiled by Orrin Duvuvuei and Jim Heffelfinger. Contributors are listed after their respective state and province report. We would also like to thank Bob Broscheid, our WAFWA Director Sponsor and Miles Moretti of the Mule Deer Foundation for their support.

AWARDS

O.C. WALLMO – For Contributions to Knowledge and Improved Management of Black-tailed and Mule Deer

AWARD CHAIR FOR WORKSHOP AND PRESENTER – Andy Lindbloom; SDGFP

O. C. "Charlie" Wallmo was born in Iowa in 1919 and studied forestry and wildlife at the University of Wisconsin and University of Montana before completing his Bachelor's degree at Utah State University in 1947. He returned to the UW for his Masters Degree and then to Texas A&M University for a Ph.D. Through is work in Texas, Arizona, Alaska and the Rocky Mountains, Dr. Wallmo pioneered research that resulted in many of the fundamental and foundational concepts in wildlife management. He conducted the first comprehensive study of the ecology of scaled quail early in his career. He was also one of the first to use free-ranging tame deer as research tools to elucidate diet, behavior, and metabolism of mule deer. Charlie was sought-after for his knowledge of mule deer nutrition and the effects of habitat manipulations on deer population dynamics. His work in the central Rockies showed the benefits of small forest clearcuts to deer nutrition and early work on deer survey methodology formed the basis for improved management of deer populations. His efforts in Southeast Alaska demonstrated the value of overstory cover for black-tailed deer during winter. Charlie published more than 50 significant publications and his edited tome "Mule and Black-tailed Deer of North America" still serves as the primary source of basic information about that species. Even though he was known for his dedication to science and the scientific process, his legacy is not volumes of esoteric scientific publications or reams of data analysis, but important contributions to the body of knowledge wildlife managers used for decades as the foundation for improved management. In addition, many of his former graduate students have become known for their work with cervids across North America.

PAST RECIPIENTS

2007 – Len Carpenter

2009 – Dale McCullough

2011 – Jim Heffelfinger

2013 – Dave Pac

2015 – R. Terry Bowyer

2017 – Mark Hurley

2019 O.C. WALLMO AWARD RECEIPIENT

DR. GARY WHITE

Andy Lindbloom of SDGFP (Left) with O. C. Wallmo Award recipient Dr. Gary White (Right).

AWARDS

EXCELLENCE IN ELK COUNTRY – WILDLIFE RESEARCH – Career of desire and dedication to benefit the scientific management of elk or elk habitat

AWARD CHAIR FOR WORKSHOP AND PRESENTER– Tom Toman; RMEF

This award, presented by Rocky Mountain Elk Foundation, is to honor an individual scientist or wildlife biologist whose career has demonstrated desire and dedication to benefit the scientific management of elk or elk habitat. The accomplishments and actions of the individual must have shown a desire and dedication to go above and beyond the normal course of duty, as demonstrated by publications, participation in professional organizations and symposiums, recognitions and awards and other activities. The recipient has earned respect and credibility among his/her peers in the wildlife and conservation profession. The recipient has shown a sincere commitment and devotion to the conservation of wild free-ranging elk, other wildlife and their habitat.

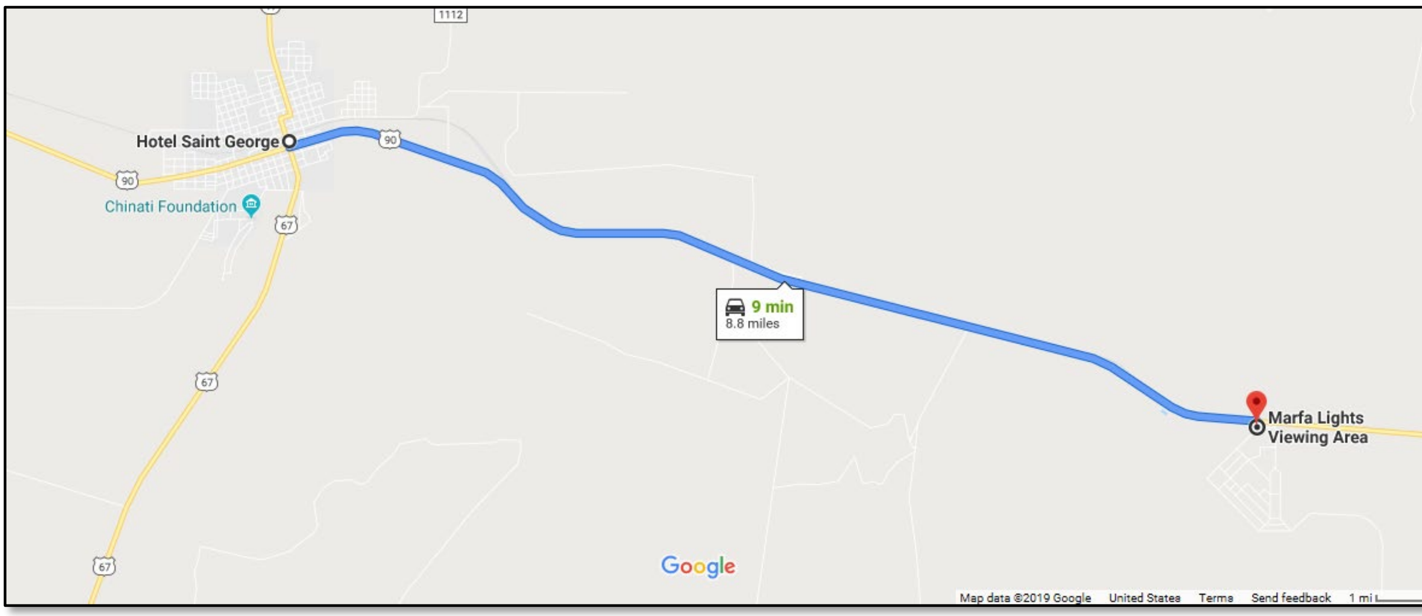
2019 EXCELLENCE IN ELK COUNTRY – WILDLIFE RESEARCH – RECIPIENT

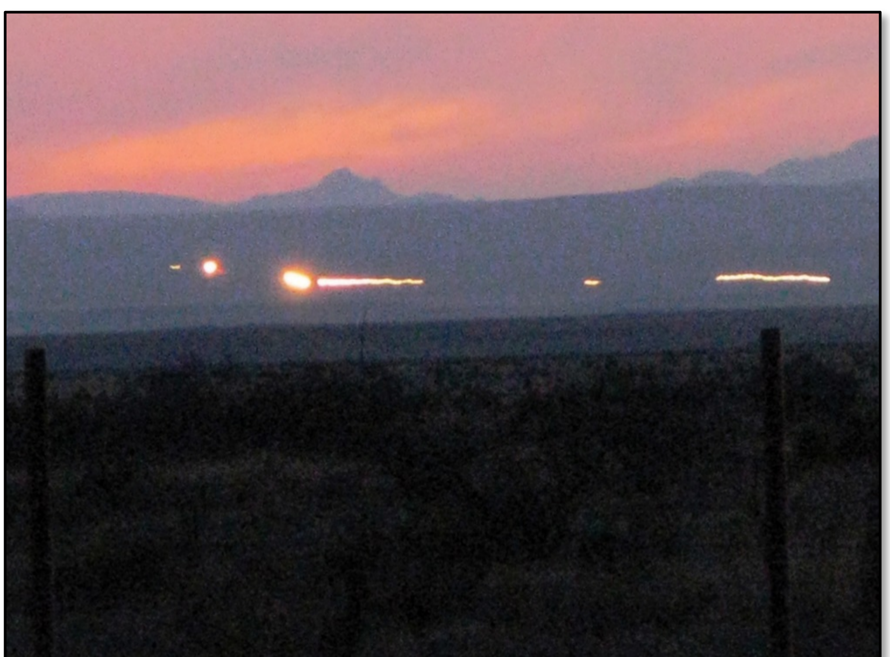
DR. JOSHUA MILLSPAUGH

Award recipient Dr. Joshua Millspaugh (Left) with Tom Toman of RMEF (Right).

MARFA LIGHTS

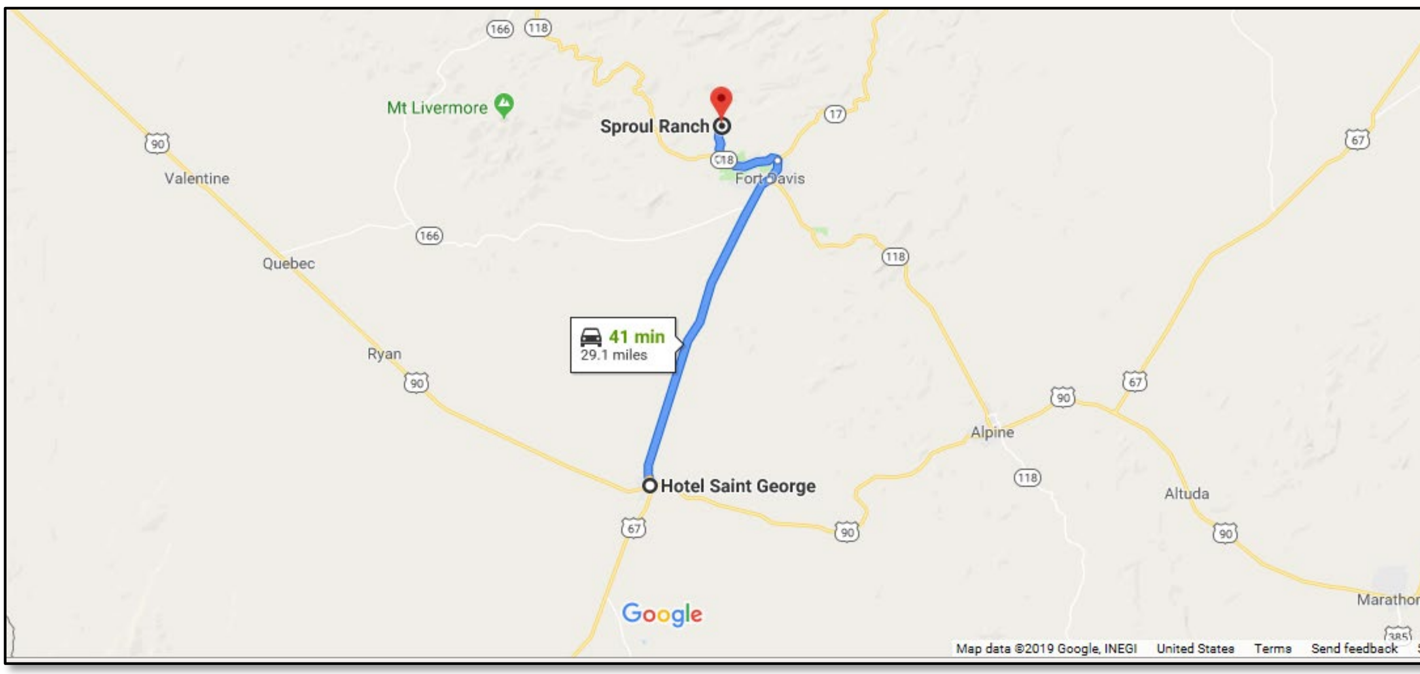
The Marfa Lights—or Marfa Mystery Lights, as some call them—are a top reason to visit Marfa, Texas. The Lights draw visitors from around the globe for a chance to see these unexplained phenomena. Accounts of the strange spectacle just east of Marfa began during the 19th century and continue to this day. Many have reported seeing seemingly sourceless lights dance on the horizon southeast of town. The mystery lights are sometimes red, sometimes blue, sometimes white, and usually appear randomly throughout the night, no matter the season or the weather. The official Marfa Lights Viewing Area is located 9 miles east of town on U.S. 90. The platform built for viewing the mysterious Marfa lights provides parking, shelter, bathrooms and a safe, easy-to-find location for viewing and photographing the dark West Texas skies.





H. E. SPROUL RANCH

Kerith & Roy Hurley own and operate the H.E. Sproul Ranch and Harvard Hotel which are located in the heart of the Davis Mountains of West Texas. The ranch was established in 1886 by R.S. Sproul, Kerith's great-great grandfather and was recognized by the state of Texas in 1986 as being the first ranch in Jeff Davis County to have been family owned and operated for 100 years. Today, more than 120 years later, Kerith continues to operate this historic property as a working cattle and hunting ranch. Beginning in 1998, the existing ranch buildings were extensively renovated, and additional lodging was built to accommodate hunters. Soon, word of the unique guest accommodations and breathtaking scenery spread to area visitors and ranch lodging was opened to the public. In 2005, the Harvard Hotel was built to provide guests who wish to stay "in-town" with the same high-quality accommodations and amenities as those offered to ranch guests.



MCDONALD OBSERVATORY

McDonald Observatory, a research unit of The University of Texas at Austin, is one of the world's leading centers for astronomical research, teaching, and public education and outreach. Observatory facilities are located atop Mount Locke and Mount Fowlkes in the Davis Mountains of West Texas, which offer some of the darkest night skies in the continental United States. Additionally, the observatory is a partner in the forthcoming Giant Magellan Telescope, under construction in Chile. McDonald Observatory's administrative offices are on the UT Austin campus. The Observatory works with the University's Department of Astronomy on both research and teaching.
Constructed 1933-39, the Struve Telescope was the first major telescope to be built at McDonald Observatory. Its 2.1-meter (82-inch) mirror was the second largest in the world at the time. The telescope is still in use today.

Star Party

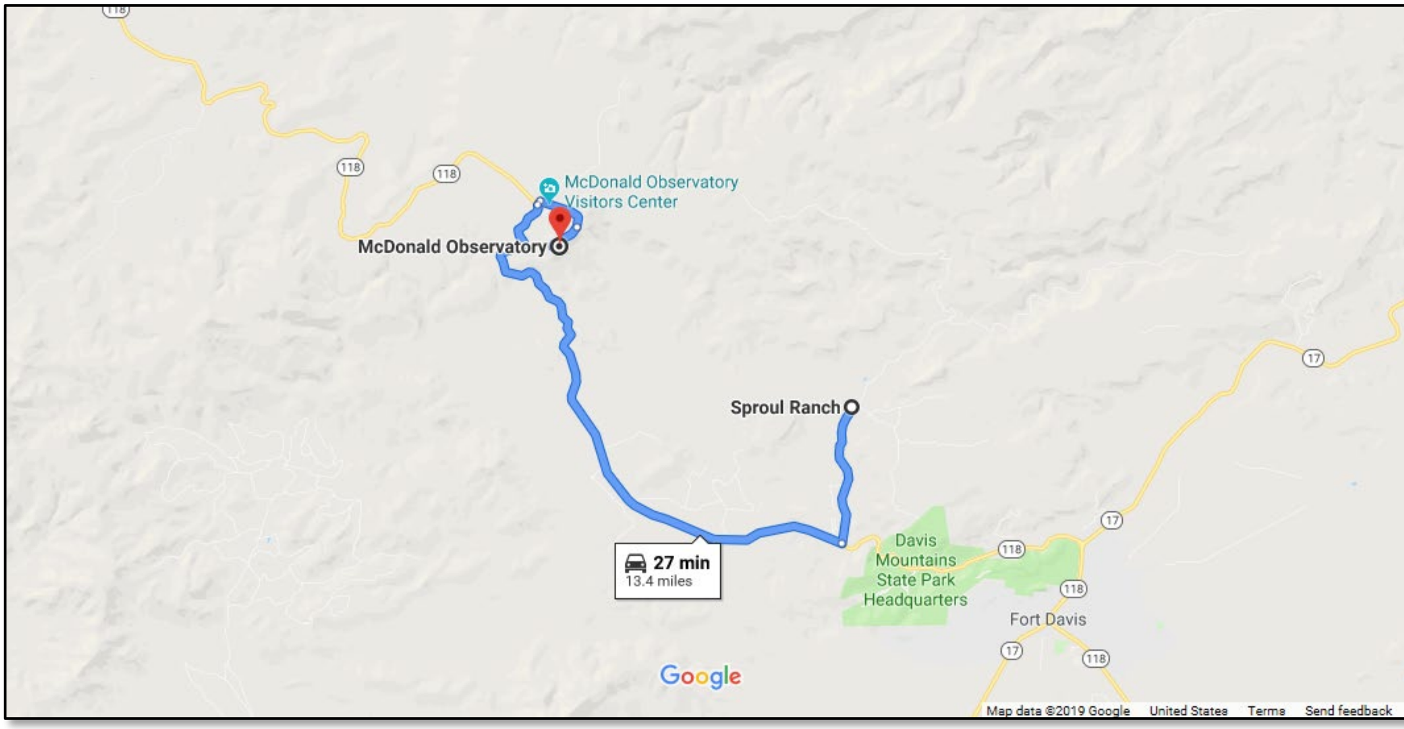
Enjoy night sky constellation tours and views of celestial objects through a number of telescopes in the Rebecca Gale Telescope Park at the Frank N. Bash Visitors Center. The program is approximately 2 hours in length. Dress warmly, the program takes place outdoors. In the event of rain, significant clouds, or high winds/dust/humidity, a series of indoor presentations will stimulate your interest and curiosity.

The Star Party welcomes guests and provides a short introduction in the outdoor Amphitheater at the Visitors Center. They explain the flow of the program, highlight objects we'll view through telescopes, and provide important information about restricting various sources of lights during the program. White-light flashlights, camera screens and flash, phone screens, and shoes with bright flashes are all discouraged as they interfere with your and other's vision adjustment and enjoyment of the night sky. The introduction is ~15 minutes.

Visitor Center staff point out brighter stars and constellations, relating some of the practical uses of the stars, the mythology of some constellations, and the scientific understanding of various patterns and objects in the night sky. These constellation tours serve as an orientation to the night sky and add meaning to the telescope viewing to follow. The constellation tour is ~ 25-35 minutes.

Guests rotate among 5-10 telescopes, viewing different objects with guidance from staff and volunteers. Telescopes range in size from various 8" telescopes, 12" telescopes, a 16" RC, an 18" accessible telescope, two 22" telescopes, and a 24" RC. After about 90 minutes things wind down and folks take their last views through the telescopes.

The Visitors Center, exhibit gallery, café, gift shop and restrooms remain open during the Star Party. The Gift Shop and StarDate Cafe close 20 minutes prior to the end of the program.



CIBOLO CREEK RANCH

History

Milton Faver settled in this area of the Big Bend, according to local history, after fleeing Missouri in the mid-1800s. Local lore says he headed to West Texas after emerging victorious from a deadly duel. Over several decades, Faver established a flourishing trading business along the Rio Grande, on what is now known as Cibolo Creek Ranch. The forts built strategically across the property stood as strongholds against local bandits and Apache and Comanche raiders.

It was in 1857 when Faver constructed the first of his three forts, El Fortin del Cibolo, "Fort of the Buffalo," as a trading and agriculture site along Cibolo Creek. Later, he built El Fortin de la Cienega, "Fort of the Marsh," to serve as headquarters for his growing cattle operation. Finally, he erected El Fortin de la Morita, "Fort at the Little Mulberry Tree," from which he built up his sheep and goat enterprise. From these three defensive centers, Faver cultivated his land and built his livestock herds. The forts also supported Faver's trade with Indians, local settlers, silver miners from the nearby town of Shafter and U.S. Army troops stationed at nearby Fort Davis.

By the 1880s, Faver was recognized as one of the most successful pioneers of West Texas, with more than 20,000 longhorn cattle and sizable sheep and goat herds. When Faver died in 1889, his estate was left to his Mexican-born wife, Señora Francisca Ramirez. His only child, Juan, died in 1913, followed shortly by his mother.

About

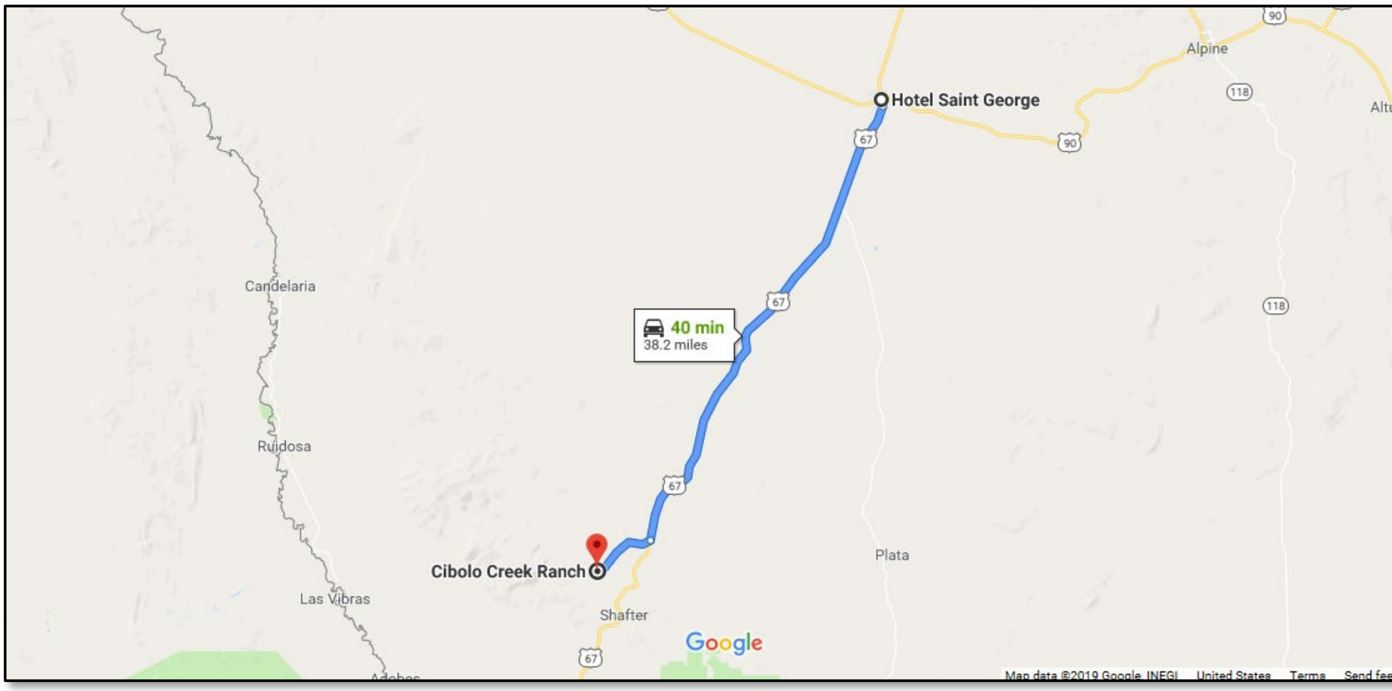
A third-generation Texan, John Poindexter purchased the first component of The Ranch in 1988. John is a history enthusiast with a keen interest in Texas's ranching past, a war veteran and entrepreneur. He had been searching for a property to create a secluded retreat for his friends and business associates – Cibolo Creek Ranch ticked all the boxes. He embarked on planning an extensive restoration of this historically and culturally significant landmark, with advice and input from the Texas Historical Commission.

By 1990, restoration was in full swing. Plans to shore up the structural integrity of the old forts were carefully executed, including the on-site production of hundreds of adobe blocks from original material to replace eroded segments. Old photographs, government and private archives and Faver family memorabilia were scoured for insights. Ranchers on neighboring properties were consulted to glean more architectural and historical detail about the crumbling structures.

John wasn't simply bringing the buildings back to life. Soon he began to reintroduce indigenous animals to the area. Through ongoing habitat restoration efforts, much of the 30,000-acre landscape has been returned to its pre-pioneer condition.

At the end of the planning phase, reconstruction took another seven years to complete under the auspices of the Texas Historical Commission. The revival was all-encompassing: from landscaping to interior decor, no detail was overlooked. Every aspect of the environment reflects features of Spanish and Mexican culture. Most of the modern conveniences are tastefully hidden from view so guests can truly feel that they've slipped back in time, but without forfeiting modern comforts.

The result is an exceptional experience in the inspiring Chinati Mountains of West Texas.



WORKSHOP PLANNING TEAM

Chair ....Shawn Gray; TPWD

Treasurer and Registration ....Kathy Archer, Janell Ward; WAFWA

Website ....Carolyn Boyd; WAFWA

Presentation Abstracts ....Dana Wright, Calvin Richardson; TPWD

Poster Abstracts ....Carlos Gonzalez-Gonzalez; BRI

State/Provincial Status Reports..........Michael Janis; TPWD

Discussion Panel Moderators ....Clayton Wolf (TPWD), James Pitman (NMGF), Justin Shannon (UDWR), Nick Pinizzotto (NDA)

Hospitality/Merchandise.........................Froylan Hernandez, Mark Garrett; TPWD

Program Development..............................Jim Heffelfinger and WAFWA Mule Deer Working Group

On-site Registration ....Doris King, Erin Medley, Gwen Sullivan; TPWD

O. C. Wallmo Award................................Andy Lindbloom; SDGFP

RMEF Award...Tom Toman; RMEF

Workshop Logo Art ....Clemente Guzman; TPWD

Workshop Venue.......................................Lissa Castro, Rob Crowley, Emily Williams