# Montana Cooperative Wildlife Research Unit

## Report of Activities for the Coordinating Committee Meeting
**April 13, 2016**

## Cooperating Agencies
U. S. Geological Survey, Biological Resources Division
Montana Fish, Wildlife and Parks
The University of Montana
Wildlife Management Institute
U. S. Fish and Wildlife Service

**Project and fiscal information included in this report:**
**01 April 2015 through 31 March 2016**

Montana Cooperative Wildlife Research Unit
The University of Montana
Natural Science Building – Room 205
Missoula, MT 59812
Ph: 406-243-5372
Fax: 406-243-6064
www.umt.edu/mcwru

# Table of Contents



## BIRDS

# MAMMALS

# Coordinating Committee Members

***U. S. Geological Survey***

F. Joseph Margraf
Supervisor Cooperative Research Units
U. S. Geological Survey
Box 25046 MS 406 DFC
Denver, CO 80225-0046

***Wildlife Management Institute***

Chris Smith
Wildlife Management Institute
5450 Tumbleweed Drive
Helena, MT 59602

***U. S. Fish and Wildlife Service***

Steve Torbit, Regional Director
Mountain-Prairie Region
134 Union Boulevard
Lakewood, CO 80228

***Montana Fish, Wildlife and Parks***

Ken McDonald
Wildlife Bureau Chief
P.O. Box 200701
Helena, MT 59620-0701

Justin Gude
Wildlife Research & Technical Services Supervisor
1420 East 6th Avenue
Helena, MT 59620

***The University of Montana***

Scott Whittenburg, Vice President
Office of Research and Creative Scholarship
Main Hall 116
Missoula, MT 59812

Chad Bishop, Program Director
Wildlife Biology Program
Forestry 311C
Missoula, MT 59812

***Unit Staff***

Mike Mitchell, Unit Leader
Thomas E. Martin, Assistant Unit Leader
Tina Anderson, Accounting Manager

# Graduate Students Advised by Unit Faculty

**Mike Mitchell**

David Ausband, PhD Candidate *
Kristin Barker, MSc Candidate
Sarah Bassing, MSc Candidate
Nathan Crum, PhD
Shannon Forshee, MSc Candidate
James Goerz, MSc Candidate
Charles Henderson, PhD Candidate *
Mark Hurley, PhD Candidate
Allison Keever, PhD Candidate
Sarah Sells, PhD Candidate
Jeff Stetz, PhD Candidate

**Tom Martin**

William Blake, MSc Candidate
Andrew Boyce, MSc Candidate
Karolina Fierro-Calderon, MSc Candidate
Joseph LaManna, PhD Candidate
Adam Mitchell, MSc Candidate
James Mouton, MSc Candidate
Juan Carlos Oteyza, PhD Candidate
Riccardo Tom, PhD Candidate

# Unit Faculty on Graduate Students' Committees

**Mike Mitchell**

Dan Eacker, MSc Candidate
Karolina Fierro, PhD Candidate
Jessie Golding, MSc Candidate
Charlie Henderson, PhD Candidate
Theresa Laverty, PhD Candidate
Devin Landry, MSc Candidate
William Janousek, PhD Candidate
Anna Moeller, MSc Candidate
Juan Oteyza, MSc Candidate
Wesley Sarmento, MSc Candidate
Keith Slauson, PhD Candidate
Derek Spitz, PhD Candidate
Robin Steenweg, PhD Candidate
Tshering Tempa, PhD Candidate
Sara Williams, PhD Candidate

**Tom Martin**

David Ausband, PhD Candidate
Katie Baer, MSc Candidate
Sara Berk, PhD Candidate
Ryan Hegstad, PhD Candidate
Joseph Smith, PhD Candidate

* Graduated

## Research Associates

Connor Armstad
Alan Harrington
James Nowak
Julia Brandauer
Amy MacLeod
Maggie Riordan
Dan Eacker
Anna Moeller
Keith Slauson

## Research Assistants

Derek Arnold
Nicole Biladeau
Quinn Ballard
Loni Blackman
Lilly Bock-Brownstein
Stephen Brenner
Heather Brower
Aaron Campbell
Sam Case
Ethan Chadick
Laura Cleveland
Brandon Connare
Ed Conrad
Jacob Decker
Macy Dugan
Eliana Fierro-Calderon
Philip Fortman
Nick Gondek
Angela Haas
Todd Hoggan
Chelsea Hutton
Bonny Jurunin
Alaina Lamb
Sam Lane
Randi Lesagonicz
Molly McDevitt
Raina Milnes
Ashley Minnich
Inga Ortloff
Amanda Reininger
Cristina Santa Maria
John Schoen
Mary Schvetz
Tucker Seitz
Alyssa Semerdjian
Jane Sheffer
Ryan Steiner
Thomas Thalhuber
Keegan Tranquillo
Frances Vierela
Katherine Welch
Derek White
Ethan Young

## Students Workers

Audrey Aamot
Kate Amsden
Abigail Asan
Sonia Bergmann
Gabriella Berman
Margo Bruguier
Emily Cohen
Cayla Daily
Jeremy Deal
Shalynn Fernau
Kadie Heinle
Julian Jamerson
Zach Jones
Danielle Kelly
Josie Kerrigan
Susan Keiser
Nikki Kupfner
Jordan Lyman
Kaleah Mantanona
Kyrie McCullough
Alexa Morris
Michael Nelson
Matthew Nordhagen
Stephanie Parker
Angette Pastuszek
Mikaela Pederson
Christina Peterson
Britney Radford
Kaitlyn Reintsma
Christ Roberts
Rebecca Romero
Skylar Sargent
Tayler Scherr
Dylan Snyder
Erika Swanson
Hilary Turner
Chase Waterland
Shelby Weigand
Jeremy Welch
Kelsey Whitaker

# DIRECTION STATEMENT

The Montana Cooperative Wildlife Research Unit performs research designed to address the needs of cooperators, bridging the gap between applied and basic wildlife science. Our studies provide new insights useful to management and conservation, based on understanding the ecological mechanisms that underlie habitat requirements and demography of individual and coexisting wildlife species. Research emphases within the Unit include ecology and management of carnivores, applied landscape ecology, management of large game, interactions between forest management and wildlife, environmental influences (predators, habitat, ungulates) on demography and diversity of birds, habitat requirements and community ecology of birds, and comparative demography and life history strategies of birds in differing environmental and geographical contexts. Other research topics are addressed as needed, in keeping with the Cooperative Research Program's mission to best meet the needs of the Cooperators by remaining flexible and open to new areas of inquiry. When Cooperator's needs occur outside Unit expertise, the assistance of appropriate University faculty will be recruited.

Unit staff will advance the training and education of graduate students at the University of Montana by teaching up to one graduate-level course per year in wildlife science, chairing graduate committees of Unit students, and serving on graduate committees of non-Unit students. Technical support and training will be provided to Cooperators and other agencies as the need exists.

# OPERATING BUDGET 2015

| | | |
|---|---|---|
| **Unit and Administrative Operating Funds** | | |
| USGS – Cooperative Research Units – Administrative Funds | 0 | |
| University of Montana | | |
| Full-time Administrative Associate - Salary/Benefits | 41,394 | |
| SPABA – FY13 IDC returned to Unit in FY16 | 66,540 | |
| **Subtotal** | | **$ 107,934** |
| | | |
| **FY 2016 – Research Projects and Increase in Funding** | | |
| Montana Fish, Wildlife and Parks | | |
| Operating Funds | | **$ 20,000** |
| | | |
| T. Martin – PI | | |
| New Funding: | | |
| National Geographic Society | 19,920 | |
| EPA Star Fellowship Award | 42,000 | |
| USGS – Climate and Habitat Change | 100,000 | |
| UM Research Administration – Graduate Support | 46,000 | |
| **Subtotal** | | **$ 207,920** |
| Continued Funding: | | |
| NSF – Graduate Research Fellowship | 88,000 | |
| USGS – Climate and Habitat Change | 365,433 | |
| Colciencias Fullbright Scholarship | 16,000 | |
| EPA Star Fellowship Award | 126,000 | |
| NSF - A New Theory of Clutch Size Evolution | 536,534 | |
| NSF – Historical Influence/Biodiversity in Tropical Asia | 1,326,660 | |
| **Subtotal** | | **$2,458,627** |
| | | |
| M. Mitchell – PI or Co-PI | | |
| New Funding: | | |
| MTFWP – Elk Distribution Sapphire Mountains | 29,304 | |
| MTFWP - Sage Grouse Research | 88,523 | |
| MTFWP – Mountain Goat Historical Data Monitoring | 10,000 | |
| MTFWP – Mountain Lion Support | 16,000 | |
| IDFG – Mule Deer, Linking Resource Selection to Population Dynamics | 34,269 | |
| NSF Fellowship | 46,000 | |
| **Subtotal** | | **$ 224,096** |
| Continued Funding: | | |
| MTFWP - Montana Wolf Monitoring | 162,808 | |
| IDFG - Computer Programmer Support – Mule Deer | 60,000 | |
| IDFG - Improving Ungulate Sampling – Mule Deer | 28,000 | |
| IDFG - Linking Resource Selection to Population - Mule Deer | 48,326 | |
| IDFG - Evaluating Occupancy Estimation – Mule Deer | 109,444 | |
| NSF Fellowship | 92,000 | |
| WDFG - Moose Demography | 88,000 | |
| National Park Service - Humboldt-Marten Prey | 70,740 | |
| U.S.G.S. – Rocky Mountain Elk Survival | 292,799 | |
| U.S.G.S. – Migratory Birds | 342,407 | |
| Waterton Biosphere - Test Monitoring Wolves | 174,742 | |
| **Subtotal** | | **$ 1,469,266** |
| | | |
| **Total Budget** | | **$ 4,487,843** |

# Completed Projects – 1 January 2015 – 31 December 2016

| End Date | Principal Investigator | Funding Agency | Title |
|---|---|---|---|
| September 2015 | Mike Mitchell / Todd Cross | USGS | Sage Grouse Genetics |
| December 2015 | Mike Mitchell / Kate Kendall | Lincoln County | Grizzly Bear Population Status in Cabinet-Yaak Ecosystem |
| December 2015 | Mike Mitchell / Kate Kendall | USGS | Grizzly Bear DNA Study |
| December 2015 | Mike Mitchell / Dave Ausband | Bernice Barbour Foundation | Pilot Study Report for Using a Biofence to Manipulate Wolf Pack Movements in Central Idaho |
| December 2015 | Tom Martin / Joe LaManna | EPA Star Award, MT FWP, Bair Foundation | Effects of aspen forest restoration on songbird diversity, habitat selection, and reproductive strategies and success |
| December 2015 | Mike Mitchell / Jessie Golding | USGS | Assessing land use practices on the ecological characteristics of sagebrush ecosystems: multiple migratory bird responses |

# MTCWRU – Federal and State Vehicles

| Description | Tag number | Odometer as of 3/31/2016 |
|---|---|---|
| 1999 Ford Truck, Extended Cab Pickup 4 x 2 | FED 252524 | 105,765 |
| 2006 Ford F250 Crew Cab Pickup, 4 x 4 | FED 430965 | 100,609 |
| 2010 Ford Expedition 4 x 4 | FED 433441 | 50,256 |
| 2011 Ford F250 Crew Cab Pickup, 4 x 4 | FED 433440 | 30,860 |
| 2011 Ford F250 Crew Cab Pickup, 4 x 4 | FED 433610 | 30,316 |
| 2012 Dodge 1500 Crew Cab 4 x 4 | FED 433621 | 40,728 |
| 1997 Chevy Suburban, 3/4 ton, 2wd | UM 7787 | 152,479 |
| 1998 Ford Taurus 4 Door Sedan | UM 7623 | 151,779 |
| 2005 Ford Explorer 4 x 4 | UM 3787 | 137,572 |

# BIRDS

photo by Tom Martin

photo by Juan Oteyza

## *Habitat preference and reproductive success of Lewis's Woodpeckers in western Montana*

**Student:** William Blake

**Degree:** MS Candidate

**Advisor:** Thomas E. Martin

**Project Duration:** 2015 – 2017

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Source:**

- MPG Ranch

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**Objectives**

Habitat selection is a major influence on populations. Determining how environmental factors influence habitat selection is central for management of wild populations, particularly for species of concern. Therefore, understanding which, and how, environmental factors interact to influence habitat selection, and how habitat selection may play a role in population dynamics is quintessential to conservation of species.

Lewis's Woodpecker is thought to be declining in most of its range and is a level II Species of Concern in Montana. During the breeding season, populations are typically found in patches of riparian and burned forests. Based on prior research, 10-15 year old burns are thought to be particularly good for Lewis's Woodpecker reproductive success. One prior study reported low reproductive success in riparian habitat, possibly indicating an ecological trap. The generality of these patterns requires testing in other key areas of the species' range. Moreover, prior studies have failed to define a strong relationship between habitat preference and reproductive success. I therefore propose to examine how Lewis's Woodpecker habitat preference compares with its reproductive success, in burned and riparian forests, the two habitats it most commonly uses. I propose to investigate factors generally known to influence the reproductive success of cavity nesting species: nest site availability, food availability and habitat patchiness and proximity to edge.

**Progress and Status**

I conducted a pilot season in the summer of 2015 and monitored 63 nests. I am expanding my comparative study to 8 field sites across the Bitterroot Valley for the next two seasons and will bolster my comparisons in reproductive success between sites with abundance estimates, insect availability, parental feeding rates and habitat characteristics. I will analyze my first set of results after the 2016 breeding season and will communicate my findings through three presentations including a presentation for the local chapter of the Audubon Society (December 2016), and presentations at two annual conferences: the Montana TWS conference (February 2017), and during the MPG Conference (March 2017).

## *The fight for space: Exploring the role of competition and physiological tolerance in limiting elevational distributions and structuring communities in tropical birds*

**Student:** Andrew Boyce

**Degree:** PhD Candidate

**Advisor:** Tom Martin

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Project Duration:** 2011 – 2016

**Funding Sources:**

- National Science Foundation
- The University of Montana
- Montana Cooperative Wildlife Research Unit
- American Ornithologists Union

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**Objectives**

I am conducting an observational and experimental study to investigate the importance of competition and physiology in limiting species distributions. Groups of closely-related species with abutting, non-overlapping elevational ranges are key components of biodiversity and endemism in the tropics and have been documented across taxa (Cadena et al. 2011). However, the mechanisms underlying this pattern are poorly understood. I will perform playback to determine the degree to which pairs of species compete and possible limit each other's ranges. I am also measuring physiological tolerance to temperature among closely-related species that exist at different elevations to determine if adaptation to a particular range of temperatures could limit the elevations at which a given species could persist. Additionally, I will be examining phylogenetic community structure across elevationally stratified bird communities. Phylogenetic community structure, or the degree to which species in a community are related to one another, is thought to reflect the relative importance of interspecific competition and environmental filtering in a given community (Losos 1996, Webb 2000, Graham 2009).

**Progress and Status**

I'm currently a PhD student in Tom Martin's lab at the University of Montana. I'm interested in exploring how physiology and competition act to constrain species ranges, shape communities and shape species life-history strategies. My current study system is the avian community at Kinabalu Park in Sabah, Malaysia. Kinabalu provides an opportunity to work on an amazing avian assemblage across an extensive elevational gradient from 500m to 4,100m. This has introduced a strong elevational component to my research and I am excited to continue exploring interesting ecological and physiological questions in this system and others.

I'm in the midst of my final field season in Borneo and will be returning to Montana in June. I plan to defend my dissertation in May 2017.

## *Delineating Greater Sage-Grouse Conservation Units to Preserve Genetic Variation Across a Changing Landscape*

***Obligated Funds: $165,094***

**Student:** Todd Cross
**Degree:** PhD Candidate
**Advisors:** David Naugle & Michael Schwartz
**Project Duration:** 2011-2016
**UM Affiliation:** Wildlife Biology Program; MTCWRU
**Funding sources:**

- Bureau of Land Management; USDA NRCS Sage Grouse Initiative
- Montana Fish, Wildlife & Parks; USFWS
- U.S. Geological Survey – Research Work Order 99

**Objectives**

The greater sage-grouse (*Centrocercus urophasianus*) is a charismatic icon of the western sagebrush landscape, ranging across 11 Western states and 2 Canadian provinces. Sage-grouse are sagebrush obligates. They rely on sagebrush habitat for food, nesting, and spring breeding congregations known as leks (the male lek display can be viewed here: http://goo.gl/KAuIPd). Sagebrush habitat is rapidly being fragmented and lost due to anthropogenic impacts including subdivision, agricultural tillage, energy development, and invasive species. Sage-grouse currently occupy only 56% of potential pre-western settlement habitat and are warranted but precluded from the Endangered Species Act due to higher priority actions. Habitat loss and fragmentation, and overall range contraction have heightened concerns regarding the risk of local population extinction due to the severing of genetic connectivity.

My team of laboratory technicians and I are partnered with multiple state, federal, and non-governmental agencies to gain a more comprehensive understanding of greater sage-grouse genetic connectivity across the species' entire range. We are using non-invasive collecting techniques, and molecular genetics monitoring tools in a landscape genetics framework to: 1) Assess the relative importance of individual leks in the network of leks across the range, 2) Determine the importance of the persistence of individual leks to maintaining range-wide genetic connectivity, 3) Test multiple hypotheses about which landscape and environmental features are critical to maintain genetic connectivity, and which features hinder gene flow among leks, 4) Identify corridors of conservation priority to be included in updating resource management plans, and 5) Model connectivity between and within the thirteen recently designated MTFWP core breeding areas.

**Progress and Status**

We have collaborated with geneticists and researchers across the entire range of greater sage-grouse to extract DNA from 8861 genetic samples, representing 840 leks across ID, MT, ND, and SD. From these 8861 samples we have identified 3460 individuals. We have applied network theory analyses to examine genetic connectivity of the population network across the range. These approaches are allowing us to identify the importance of each individual lek to maintaining range-wide genetic connectivity, and to examine the effects of different management scenarios on overall genetic network connectivity. We have used microsatellite genotypes to identify genetic substructure across MT, ND, and SD. We also identified landscape and anthropogenic factors that may influence the patterns we found. We have resubmitted a manuscript detailing our findings and are awaiting reviews following a round of revisions. We collaborated with statisticians at the University of Denver to use existing genetic data to parameterize a model that we then used to prioritize which previously un-sampled locations would be most beneficial to sample. We then sampled as many of these locations as possible in the spring of 2013 to optimize our sample coverage and resolution across ID, MT, ND, and SD. We developed and employed an enrichment assay designed to target and capture genome-wide DNA sequence for over 80,000 single nucleotide polymorphisms (SNPs) associated with gene function. We have used this assay to analyze twenty-four samples from across ID, MT, ND, and SD from each of which we've captured over 8.5 million base pairs of DNA sequence. From our results, we will learn a great deal about the greater sage-grouse and about functional variation (SNPs that affect gene function) across the species' range.

# *UNDERSTANDING VARIATION IN HABITAT USE AMONG ORANGE-CROWNED WARBLERS (Oreothlypis celata) IN CENTRAL ARIZONA, USA*


**Student:** Karolina Fierro
**Degree:** PhD Candidate
**Advisor:** Thomas E. Martin
**UM affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit


**Project duration:** 2012 - 2017


**Funding source:**

- Montana Cooperative Wildlife Research Unit
- University of Montana
- Scholarship "Francisco Jose de Caldas" COLCIENCIAS and FULBRIGHT Colombia
- PEO International Peace Scholarship


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**Objectives**

Classic habitat selection theory predicts that individuals will choose habitats that confer higher fitness. Yet, we see cases where individuals use habitats associated with low reproductive success, even if highly suitable habitat is available. Using a 20-year dataset of Orange-crowned warblers (*Oreothlypis celata*) in Arizona, I will examine first what factors determine territory suitability. Furthermore, I propose two hypotheses that might explain variation in territory use. My hypotheses state that low-quality individuals may not always experience low reproductive success, as the Ideal Despotic Distribution affirms, but instead might increase their fitness, and therefore the territory suitability, via two strategies. These low-quality individuals may use territories with 1) higher variation in the survival probability of multiple nest sites, which will increase the cumulative survival probability of the territory, and 2) higher variation in the survival probability of eggs, nestlings and fledglings, which may increase territory suitability. Hence, I suggest that natural selection may favor different habitat selection strategies in both high- and low-quality individuals that allow them to achieve similar fitness.

**Progress and Status**

- I started my pilot field season in the Coconino National Forest, central Arizona, on May 2012. During three months, I collected preliminary data about the distribution of territories, interspecific interactions, and foraging strategies of four ground-nesting bird species.
- My research proposal was approved by my doctoral committee on December 2013. Since then, I have collected data on survival of eggs, nestlings, and fledglings in territories occupied by high- and low-quality individuals.
- Also, I have carried out my building interruption experiment in order to determine the cumulative probability of survival for multiple nest sites within the territories occupied by high- and low-quality individuals.
- Last summer 2015, I started a new experiment to test whether an increase in the temperature experienced by the nestlings on the nest increases their growth rate and modifies parental behavior
- I passed my comprehensive written exams in the fall 2014 and I finished all my classes in the spring 2015.

## *Assessing land use practices on the ecological characteristics of sagebrush ecosystems: multiple migratory bird responses*

**Obligated Funds: $477,620**

**Student:** Jessie Golding
**Degree:** MSc 2015
**Principal Investigator:** Mike Mitchell and Victoria Dreitz
**Project Duration:** 2012 – 2015
**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding source:**

- USFWS – Plains and Prairie Pothole Landscape Conservation Cooperative ($417,620)
- Bureau of Land Management ($30,000)
- Montana Fish, Wildlife and Parks ($30,000)
- Stacie Ann DeWolf Memorial Scholarship, Wildlife Biology Program, University of Montana
- Montana Fish Wildlife and Parks Nongame Program Grant, $5,000 (8/2013)
- Hunting GPS Maps Equipment Grant, $1,000 (4/2013)
- Les Pengelly Scholarship, Wildlife Biology- University of Montana, $2,100 (03/2013)
- Montana Fish Wildlife and Parks Nongame Program Grant, $5,000 (8/2012)

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**Objectives**

This project, completed in 2015, was designed inform natural resource managers and private landowners of the impacts of conservation-oriented livestock grazing practices in sagebrush ecosystems. Specifically, we: 1) evaluated the impact of rest-rotational grazing management on migratory bird species associated with sagebrush landscapes, and 2) provided information to ensure the persistence of multiple sagebrush-obligate bird species and assist in developing natural resource policies

**Thesis Abstract**

In order to effectively assess effects of grazing, it is essential to have reliable models to predict changes in abundance of multiple species. Multispecies abundance models (MSAM) use a Bayesian N-mixture structure, which relies on repeated counts, to estimate detection and calculate adjusted abundance estimates for multiple species. While useful, current MSAMs fail to account for false positives, the detection of an individual that is not present because of either misidentification or double count of another individual. False positives can inaccurately inflate abundance and biodiversity estimates. Nichols et al. (2000) provides a field method, the dependent-double observer (DDO) survey method, which is suggested to reduce false positives because it relies on two observers working collaboratively to identify individuals. To date, the DDO approach has not been combined with MSAMs. We derived a new form of the MSAM using the DDO survey method to create a multispecies dependent double-observer abundance (MDAM) model. We used the MDAM to explore how two widely used grazing systems, season-long and rest-rotation, affect the abundance of eight songbird species with varying reliance on grassland vegetation in a sagebrush ecosystem: Brewer's sparrow (*Spizella breweri*), brown-headed cowbird (*Molothrus ater*), chestnut-collared longspur (*Calcarius ornatus*), horned lark (*Eremophila alpestris*), lark bunting (*Calamospiza melanocorys*), McCown's longspur (*Rhynchophanes mccownii*), vesper sparrow (*Pooecetes gramineus*), and western meadowlark (*Sturnella neglecta*). We compared the abundance of these eight songbird species using data collected in 2013 and 2014. Our results suggest grassland and sagebrush associated species, many of which are of conservation concern, exhibit a response based on their reliance on grassland vegetation. Most grassland associated species were more abundant in season-long grazing than rest-rotation grazing systems (brown-headed cowbird, lark bunting, western meadowlark) or showed little difference between the two systems (chestnut-collared longspur, horned lark, vesper sparrow). In contrast, sagebrush associated species (Brewer's sparrow) showed no difference in abundance between the two grazing systems. Although a grassland associated species, McCown's longspur did not exhibit the same patterns as other grassland species and was more abundant on rest-rotation systems than season-long systems. These results suggest that grazing management may have the largest impact on grassland associated species. Our findings suggest that multiple grazing systems on a landscape may be necessary to support a suite of songbird species with different vegetation requirements.

## *Habitat influences on nest predation and consequences for diversity, density and reproductive success of songbirds in aspen stands*

**Student:** Joseph LaManna **Obligated funding: $508,000**

**Degree:** PhD Degree, December 2015

**Advisor:** Thomas E. Martin

**Project Duration:** 2009-2015

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Sources:**

- The Bair Foundation
- Montana Fish, Wildlife and Parks
- Environmental Protection Agency – STAR Fellowship Program

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**Objectives**

Understanding habitat features that enhance bird diversity, sustain avian populations, and determine reproductive success is critical for conservation. Aspen forests are biodiversity hotspots, but they are declining due to numerous factors, with one large factor being conifer encroachment. Conifer encroachment into aspen stands may be associated with population declines of a variety of organisms dependent on this community type, including many species of birds. Conifer trees were removed from some aspen stands as an adaptive management treatment to test if it leads to an increase in aspen recruitment, and similar treatments are being planned and executed across western North America. However, the effects of such forest treatments on wildlife populations, such as breeding birds, are unknown. Conifer removal not only greatly alters vegetation structure but also affects predator communities which may strongly affect bird populations within treated aspen stands. Therefore, I am interested in understanding how bird diversity and demography changes in aspen to conifer gradients, and how conifer removal may benefit or impact diversity and populations to improve management decisions. More specifically, I want to know how changes in predator and plant community assemblages influence songbird diversity, habitat selection, and reproductive success.

**Progress and Status**

Bird diversity, predator abundance, various measurements of reproductive success, and vegetation structure were surveyed during the 2009-2014 songbird breeding seasons. Bird diversity has been monitored each year with intensive point counts. A total of 2,697 nests from 45 songbird and woodpecker species were found and monitored during the six field seasons. Nest predation rates varied strongly along the vegetation gradient, but species differed in the form and direction in which predation changed. Results indicate that nest predation risk largely explained songbird species distributions along natural aspen-conifer gradients and with experimental conifer removal. These results were published in the journal *Ecology* in 2015. Because natural and experimentally altered vegetation structure affected nest predation risk, I wanted to understand the full extent to which nest predation affected demography to allow a better understanding of the effects of habitat management actions on bird demography. I conducted experiments using playback of predator sounds to examine potential non-lethal demographic costs and found they were quite strong; nest predation affected demography through direct predation, but also by reducing the number of young produced from parental responses to 'fear of predation'. These latter results were published in *Ecology Letters* in 2016. I also modeled the relative impacts of direct versus indirect predation for demography and this work will be submitted to *American Naturalist.* Finally, I prepared for publication a global meta-analysis and review of the effects of logging on avian communities.

## *Climate change and elk browsing on bird demography and trophic interactions in a high elevation riparian ecosystem*

**Obligated Funds: $1,001,967**

**Principal Investigator:** Thomas E. Martin

**Project Duration:** 1985-2017

**UM Affiliation:** Montana Cooperative Wildlife Research Unit

**Funding Source:**

- U.S. Geological Survey – Research Work Order 102
- National Science Foundation

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**Objectives**

Measure and examine: 1) annual variation in avian nest success and predation, adult survival, fledgling survival, population size, habitat selection, parental care behaviors, and physiological metrics, and 2) changing vegetation density and species composition in a high-elevation riparian ecosystem in north-central Arizona relative to climate variation and elk browsing.

**Progress and Status**

Climate has had large consequences for 32 bird species by affecting trophic levels below (plants) and above (predators) them from study of their populations over the past 29 years. Winter snowfall has declined strongly across this time, as typical throughout western North America, and has increased over-winter densities of elk in the study area. This decline in snowfall and increase in overwinter elk led to the loss of deciduous aspen and other trees that represent preferred bird habitat, and causing a decline in bird abundance. In addition, summer precipitation has declined over the 29 years of study and drier summers have yielded greater predation on offspring. Three large (10 ha) exclosures were established in fall 2004 to test the effects of elk and winter snow on plant, bird and small mammal communities. Results showed a large effect on aspen recruitment and ground cover, and a slower but increasing effect on maple and locust recruitment; plant abundance and diversity increased after fence establishment. In addition, several bird species increased in abundance compared with adjacent controls. Some small mammal species (deer mice, wood rats) also increased and others (chipmunks) decreased on fenced areas compared with controls.

Current work includes studies of fledgling survival, a critical influence on demography that is poorly studied across species. I am measuring fledgling flight mobility to examine the consequences for parental energy expenditure per offspring, measured using doubly-labeled water, and fledgling mortality rates, using radio transmitters. Management depends on understanding which species and life stages are most sensitive to environmental perturbations for population maintenance.

I am also examining the potential consequences of rain for adult and offspring energy expenditure. Climate change studies have focused on temperature effects because they are easier to model. However, rainfall is also changing strongly, not only over the long-term, but also in the short-term over El Niño cycles. Lab studies have demonstrated that wetting increases thermal conductance and energy expenditure of adult and juvenile endotherms, and rain may constrain foraging (energy acquisition). Any such energy constraints may be particularly significant when parents are trying to meet the needs of growing offspring, such that rain may play a critical role in demography of endotherms during reproduction. I am using doubly-labeled water to examine energy expenditure of parents and offspring on rainy versus dry days and with respect to variation in habitat (overhead cover).

The results will have important implications for elk and ecosystem management in this vulnerable habitat type. This project also has a strong training component, training up to 20 students each year in a diversity of field techniques and conduct of hypothesis-testing science.

## *Historical and contemporary influences on elevational distributions and biodiversity tested in tropical Asia*

**Obligated funding: $1,325,620**

**Principal Investigator:** Thomas E. Martin

**Project Duration:** 2013-2020

**UM Affiliation:** Montana Cooperative Wildlife Research Unit

**Funding Sources:**

- National Science Foundation

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**Objectives**

This project parallels work being conducted in the Arizona project with respect to environmental influences on demography (clutch size, nest predation, development rates, parental care, adult survival rates) of bird species in montane Malaysian Borneo (Kinabalu Park) to compare tropical versus U.S. birds studied at similar elevations. Tropical birds are often longer-lived and slower developing than north temperate birds in the U.S. and extend the range of variation in demographic strategies which provides critical new insight into environmental influences on demography. We are also measuring metabolic sensitivity of adults and offspring to temperature variation, possible role of competition in constraining elevational ranges, measuring dispersal through both capture/recapture and gene flow, and measuring genetic differentiation across elevations. Examine the relative importance of nest predation, food limitation, and adult mortality on variation in demography and life history strategies. Ultimately, this work provides critical information on environmental determinants of demography and how it varies among tropical compared with north temperate species.

**Results**

We work in tropical Borneo because it retains large blocks of pristine forest at mid-elevation from 1450 to 1950 m elevation. In the past seven seasons, 4,412 nests were found and monitored, nestling metabolism and nestling growth measured, parental care video-taped, and egg temperatures quantified. In addition, a total of 13,630 capture/recapture/resight events were accrued to aid in estimating adult survival. Adult survival and nest predation interact to strongly influence reproductive strategies and demography not only in Borneo but also in North America. This integration of adult and offspring survival data across suites of species have never been available previously and has yielded critical new insight into environmental influences on demography. In addition, data collected on both adult and nestling metabolism shows that species vary strongly in their sensitivities to temperature, but we have not yet examined whether this can explain elevational distributions as more data are still needed. The importance of temperature suggests that global warming may be particularly important to long-term reproductive success of tropical birds. Work on genetics remains in development.

This work continues to include an important training component for young US and Malaysian scientists. The perception that reproduction cannot be studied in the field is corrected by training young scientists in the conduct of this field work. In addition, the most motivated are invited to the lab in Montana where they are taught to write their first publications on the life history of some species that is previously undescribed.

## *Are long lives of south temperate songbirds explained by reduced energy expenditure of parents compared with north temperate species?*

**Obligated funding: $19,920**

**Principal Investigator:** Thomas E. Martin

**Project Duration:** 2016

**UM Affiliation:** Montana Cooperative Wildlife Research Unit

**Funding Sources:**

- National Geographic Society
- University of Montana

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**Objectives**

This ONE-season project parallels work being conducted in the Arizona and Borneo projects on the environmental determinants of adult survival and longevity. Studies conducted 15 years ago provided background information on adult survival probability, and current existence of birds banded 15 years ago provide an indicator of much greater longevity than north temperate species. Adult survival and longevity are often the most important influence on demography in songbirds, such that understanding determinants of variation in adult survival can provide critical insight into sensitivity of species to environmental perturbations, and therefore critical for species management. As in Arizona and Borneo, we will use doubly-labeled water to measure energy expenditure of parents across species of this bird community to compare with measures of their adult survival and longevity. This project will support work of three graduate students to also include work on metabolic variation in adults relative to adult survival, and the effects of rain on energy expenditure of offspring to extend the work being conducted in the Arizona project. Work will commence in late August 2016.

# *Effects of climatic conditions on avian energetics and life history patterns*

**Student:** Adam Mitchell

**Degree:** PhD – Wildlife Biology
**Advisor:** Thomas Martin
**Project Duration:** 2014 – 2019
**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Sources:**
University of Montana
Montana Cooperative Wildlife Research Unit
National Science Foundation (NSF)

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**Progress and status**

I recently switched from a MS to a PhD project and am currently working on developing interesting questions and experiments that expand my MS project by testing the effects of different climatic conditions on avian energetics and life history strategies.

**Background information**

Organisms living at higher elevations typically have slower life histories, but the causes of this shift are not fully understood. Ambient climatic conditions (e.g. temperature, rainfall, humidity, etc.) can be very different between elevations (harsher at higher elevations), and also can have significant effects on the growth, development, and survival of organisms. This is particularly true in birds, yet direct tests of the effects of harsh, high elevation climate on avian life histories are lacking. I am testing a hypothesis that the harsh weather at high elevations acts as a constraint on avian life histories.

Climate change models predict increasing temperatures and varying rainfall across the globe. This is exacerbated by the fact that El Nino and La Nina events are expected to increase in both frequency and magnitude as global climates change. The tropical pacific (including the island of Borneo) expects drought conditions during El Nino events and extreme rain during La Nina events. Therefore, in the future we can expect severe impacts on the nesting birds living in typically non-seasonal environments and their respective life histories. I will try to test some of these effects by measuring energetics of nestling birds during both dry and wet periods, and use the data to try to predict how the life history traits of tropical montane species may respond to changing climates.

**Field site and experiments**

I am working at a montane field site at two different elevations on Mt. Kinabalu, on the tropical island of Borneo (appx. 1500 m asl and appx. 3200 m asl). I will continue the experiment from my MS project by ameliorating the harsh climate at high elevations by adding supplemental heat and placing rain covers over bird nests. If harsh weather at high elevations does constrain avian life histories, I expect to see heated/covered nestlings grow faster with reduced energetic costs. I also expect to see the benefit of ameliorated nests realized by the parents by reduced brooding rates (i.e. nestling warming) and increased feeding rates.

I will measure the energetics of nestlings at the lower elevation site to correlate with ambient weather conditions, as well as add experimental rain (using a make-shift portable shower) on nests during dry periods in order to directly test the energetic and behavioral effects of rainfall on nestling and adult birds. This experiment will allow me to infer the costs of increased rainfall on avian life histories under climate change models.

## *Plastic reproductive strategies in response to nest predation risk*

**Student:** James C. Mouton

**Degree:** PhD Student

**Advisor:** Thomas E. Martin

**Project Duration:** 2013 – 2016

**UM Affiliation:** Division of Biological Sciences
Montana Cooperative Wildlife Research Unit

**Funding Source:**

- National Science Foundation
- Montana Cooperative Wildlife Research Unit
- The University of Montana

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**Objectives**

Life history theory predicts that organisms will allocate limited time and energy between current and future reproduction to maximize lifetime fitness. Age specific mortality can affect this allocation such that increased risk of offspring predation is expected to reduce reproductive value of current broods and decrease reproductive effort. Studies examining mortality patterns and evolved levels of reproductive effort across taxa support theory. Organisms may also plastically adjust overall reproductive effort and the expression of different life history traits (e.g. clutch size, food provisioning behaviors, growth and developmental rates) in response to variation in offspring mortality risk. Such plasticity can have important consequences for the rate of evolution and the persistence of populations in ecological time. However, we know little about plastic responses of life histories to changes in current brood reproductive value caused by offspring predation risk.

My research will examine how reduced brood value caused by nest predation risk affects reproductive effort expended by parents and growth and development in offspring in four songbird species. I will test the effect of nest predation risk on parental effort by manipulating the perceived level of risk and measuring parental energy expenditure. I will examine how nest predation risk affects offspring growth and development through the amount of food received by each nestling or prioritized development of traits required for nestlings to leave the nest and escape nest predation risk (i.e. endothermy and locomotor traits). Additionally, I will be examining how predation risk influences offspring begging and how parents respond to it by using playback experiments at nests across species. Understanding the plastic responses of organisms to important sources of selection, such as offspring predation, is vital for a full understanding of life history evolution and can help explain ecological differences between populations.

**Progress and Status**

I have manipulated the perceived level of predation risk at bird nests by playing recorded vocalizations from nest predators (i.e. Red Squirrels) and a songbird species that does not pose any threat to the study species. I have measured the daily energy expenditure of parents using doubly labeled water to examine the effect of nest predation risk on parental effort. I will also examine parental food provisioning strategies, nestling growth, and the development of heterothermy. I began fieldwork in summer 2014 will continue work at least through the summer of 2017. Most fieldwork will take place in the in high-elevation forested snowmelt drainages in the Coconino National Forest, AZ, USA. This year I have also expanded my project to include species from another field site in Kinabalu Park, Sabah, Malaysia. I have defended my proposal for this work and will take comprehensive exams in Fall 2016.

## *The influence of nest predation on parental and offspring strategies*

**Student:** Juan C. Oteyza

**Degree:** PhD Candidate

**Advisor:** Thomas E. Martin

**Project Duration:** 2011 – 2016

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Source:**

- National Science Foundation
- Montana Cooperative Wildlife Research Unit
- The University of Montana

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**Project:**

Predation is an important selective force that can have important consequences for prey populations. In addition to this direct effect via direct killing of prey, the perception of predation *risk* alone is itself powerful enough to affect wildlife population dynamics. Animals can assess predation risk and adjust their behaviors, and this adjustments can also have demographic consequences. In birds, nest predation can have important consequences on parental care strategies (e.g. incubation and nestling feeding rates), offspring begging behavior, offspring growth strategies and, consequently, parent and offspring fitness.

Parental care traits, such as feeding rates, may be sensitive to predation risk because increased activity at the nest can attract visually-oriented predators. Thus, when predation risk increases provisioning rates are expected to decrease, with negative consequences on energy available to offspring for growth. Yet, at an ultimate level increased predation risk should favor faster nestling growth and shorter development periods to reduce exposure to risk at the nest. This leads to an antagonistic interaction between the nestling's need to develop fast under constrained access to food resources. To better understand the consequences of proximate changes in predation risk, I am experimentally manipulated the *perceived risk of nest predation* by broadcasting predator calls near nests of tropical birds. I then measured changes in parental care behaviors (such as feeding rates) and offspring development rates, and compare them to control nests.

**Progress and Status:**

How strongly will parents reduce parental care in the presence of a predator may depend on the survival probability of the adults (a measure of longevity). Life history theory predicts that long-lived species should be more risk-averse (less willing to put themselves at risk) than shorter lived ones. I tested this idea by presenting robotic raptor –a model of a predator– to the parents of several species and measured how much they adjusted their incubating behavior. This experiment was performed across species that differed dramatically in their survival probability, including short-lived temperate birds (in collaboration with James Mouton in Arizona) and long-lived tropical species (in Borneo).

Lastly, nest predation can also influence the evolution of nestling begging behaviors. Begging serves as a signal to solicit food which is thought to benefit young by leading to an increase in allocation of resources. However, begging can also incur a cost by attracting acoustically-oriented predators to the nest. Theory predicts that offspring of species that are under high predation risk will evolve vocalizations that are harder to locate by predators (e.g. high frequency and low amplitude). To test whether the structural characteristics of nestling begging calls correlate with nest predation rates, I recorded nestling begging calls across 22 species that show great variation in predation rates in Malaysian Borneo. Data analysis and writing is currently underway.

## *Test of the Causes of Evolved Differences and Plasticity in Growth and Development Rates of Passerines Offspring Across Three Continents*

**Student:** Riccardo Ton

**Degree:** PhD Candidate

**Advisor:** Thomas E. Martin

**Project Duration:** 2011 – 2016

**UM Affiliation:** Division of Biological Sciences –OBE
Montana Cooperative Wildlife
Research Unit

**Funding Source:**

- National Science Foundation
- The University of Montana

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**Objectives:**

The two overarching aims of my dissertation are: a) to test the role of temperature in causing the broad pattern of interspecific variation in development rates among ectothermic songbird embryos; b) to explore the role of interspecific variation in metabolism of endothermic offspring, potentially resulting from the differential selective pressure of predation, in contributing to interspecific variation in growth rate. To achieve these goals, I use an experimental and comparative approach among passerine species on three different continents.

**Progress and Status:**

After completing all data collection in the field and most of my writing I am now ready to defend my PhD dissertation in May 2016.

## *MAMMALS*

photo by James Goerz

photo by Sarah Bassing

## *Effects of human-caused mortality on gray wolves*

Research Associate: David Ausband
Project Duration: 2011 - 2015
UM Affiliation: MTWCRU

**Funding Sources**:

- Regina B. Frankenberg Foundation for Animal Welfare ($150,000)
- Leonard X. Bosack & Bette M. Kruger Foundation ($9,600)
- Bernice Barbour Foundation ($69,680)
- Eppley Foundation for Scientific Research ($24,000)
- Steven Leuthold Foundation ($31,000)
- Idaho Department of Fish and Game ($60,000)
- National Park Service ($7,500)
- U.S. Fish and Wildlife Service ($22,500)
- Alberta Conservation Assoc. ($5,000)
- Waterton Biosphere Reserve Association ($174,742)
- Shikar Safari Club International ($4,000)
- Coypu Foundation ($31,269)
- Alberta Environment and Sustainable Resource Development ($20,000)
- Nancy Carroll Draper Foundation ($10,000)
- Wesley M. Dixon Fellowship ($30,000)

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**Objectives**

Wolves (*Canis lupus*) live in family groups comprising a breeding pair, their offspring, and several related helper wolves. Mortality, however, can affect this family group structure and result in smaller packs with adopted, unrelated individuals. Little is known about how characteristics of groups (i.e. size, composition, tenure) affect population growth. Furthermore, group characteristics may also affect individual behavior, group stability, and reproduction. States in the Rockies recently initiated public hunting and trapping seasons for gray wolves and our study is well-positioned to answer important questions about how that new source of mortality might affect gray wolf pack composition and reproduction.

**Project and Status**

Preliminary wolf population modeling shows that established packs (i.e., extant $\geq$ 3 years) have higher survival than nascent packs, particularly during periods characterized by high competition between packs. This lends support to our hypothesis that group stability may be important for wolf population growth. Full analyses and insights into the effects of wolf pack stability on population growth will be conducted once all of the data are compiled. We began genetically sampling wolves in Idaho in 2008 and currently have a multi-year dataset for packs in central Idaho that spans both before and after hunting and trapping began. We finished field surveys in summer 2014 in three focal study areas that encompass a range of human-caused mortality; Alberta, Idaho, And Yellowstone National Park. DNA analyses of collected samples are currently underway and will identify breeder, helper, and pup in every pack, i.e., a pack "pedigree." Tracking these pedigrees over time will allow us to examine how pack composition and recruitment change under the influence of human-caused mortality from hunting and trapping. Lastly, we have finished gathering wolf satellite-collar location data from multiple collaborators that can be used to answer questions about how wolf pack composition affects helping behavior in packs. Changes to pack composition may affect such helping behavior. We are currently preparing a manuscript that outlines the results of these analyses.

We have made substantial progress collecting the data necessary to adequately answer how packs affect population growth and how population management (i.e., hunting and trapping) might, in turn, affect packs. We plan to complete analyses and publish full study results in 2015.

## *Resource selection and movement decisions made by individuals in a partially migratory, sexually segregated population*


**Student:** Kristin Barker

**Degree:** MSc Candidate

**Advisors:** Mike Mitchell

**Project Duration:** 2015-2017

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit


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**Objectives**

I am broadly interested in using science and technology to help inform wildlife management. Prior to moving to the University of Montana, I studied movements and habitat selection of red fox at Western State Colorado University, where I received my bachelor's degree in biology. I also hold a BA in English from the University of Georgia. Since receiving my biology undergraduate degree in 2012, I have worked in the field on studies of carnivores, mesopredators, ungulates, birds, amphibians, insects, trees, and understory plants for federal agencies, state agencies, university researchers, and private consulting companies. My varied work experience has strongly impressed upon me the importance of rigorous scientific research (in addition to social and economic considerations) in helping wildlife managers identify and achieve management goals. My current work, in collaboration with Montana Fish, Wildlife, and Parks, focuses on an elk population that provides important recreational and hunting opportunities to residents and visitors of the Bitterroot Valley south of Missoula.

**Project**

Generally, my project seeks to understand the causes and consequences of different behavioral decisions made by elk. The North Sapphire Mountains provide an ideal opportunity to study a range of behaviors exhibited by individuals in a sexually segregated, partially migratory elk population. Landowners and sportsmen have expressed concerns that potential recent changes in elk distributions in the area may be causing game damage on private land and limiting hunter opportunities during fall. This project will provide stakeholders and managers with information about current elk behaviors and distributions, the factors influencing elk behaviors, and the effects of individual behaviors on population health. Specifically, I aim to determine 1) the nutritional consequences of different migratory behaviors, 2) the survival consequences of different fall resource selection behaviors, and 3) the relative strength of factors influencing male and female elk resource selection during archery and rifle hunting seasons.

## *Effects of Harvest on Wolf Populations: Impacts for Monitoring and Managing Abundance*


**Student:** Sarah B. Bassing

**Degree:** MSc Candidate

**Advisors:** Mike Mitchell

**Project Duration:** 2014-2016

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit


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**Objectives**

I began working for MTCWRU in 2010 as a field technician and led wolf survey crews in southwest Alberta for 3 years. Based on survey and harvest data, wolf mortality appears to be particularly high in this region. Managers and local communities alike are keenly interested in the wolf population but high turnover in the population makes long-term monitoring difficult and there is currently no wolf monitoring program in place. My objectives are to assess the application of patch occupancy models as a monitoring framework for this harvested wolf population and to better understand the effects of current wolf harvest on population dynamics, such as pack turnover and distribution.

In addition, there is growing interest in the effects shifts in wolf management practices (i.e., from federally protected under the Endangered Species Act to delisted with annual hunting and trapping seasons) have on the recently recovered wolf population in the U.S. Northern Rocky Mountains. Recent research from the MTCWRU (Ausband et al. 2015) demonstrated that wolf pup recruitment in central Idaho has declined since the initiation of harvest. My objectives are to determine whether dispersal (immigration) into heavily harvested regions compensates for harvest mortality and aids in population persistence when pup recruitment is reduced.

**Project**

My research focuses on studying the effects of heavy harvest on wolf pack distribution and dispersal across landscapes dominated by human-land use in the Rocky Mountains. I am using patch occupancy models, populated with wolf pack detection data from 3 years of field surveys, to estimate pack distribution and turnover in southwestern Alberta in collaboration with Alberta Environment and Parks. I am incorporating habitat, human land use, and harvest data to assess the relationship between pack occupancy, distribution, turnover, and harvest in this population. I am also using assignment tests and measuring relatedness among noninvasively genetically sampled wolves to quantify immigration rates in response to harvest in southwest Alberta and central Idaho in collaboration with both Alberta Environment and Parks and Idaho Department of Fish and Game. I recently completed my occupancy models and am currently working with the genetic samples to identify immigrants in the southwest Alberta and central Idaho wolf populations.

## *Evaluating the Influence of Intraspecific and Interspecific Competition, Hunting and Predation on Mule Deer Buck Movement and Survival*

Student: Nathan Crum

Degree: PhD student

Advisors: Mike Mitchell and Paul Lukacs

Project Duration: 2015 – 2019

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Source: Boone and Crockett Club

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Objectives

Although mule deer doe ecology has been extensively studied, the ecology of mule deer bucks is less well understood. Since mule deer bucks can regulate mule deer populations through density dependent mechanisms, understanding their survival and how they share resources with other mule deer can inform how much a mule deer population may be influenced by buck density. In order to address this gap in knowledge, I have developed the following objectives: to understand 1.) the influence of hunters' movements and space use on the movement, space use, and location of mortalities of mule deer bucks, 2.) how characteristics like age, size and antler morphology influence the probability of mortality during the hunting season, 3.) the influence of spatial patterns of predator density on the space use and location of mortalities of mule deer bucks, 4.) the influence of cover, forage and spatial patterns of density of ungulate competitors on mule deer buck movement and space use and 5.) how plant green up and senescence influence mule deer buck seasonal migration patterns.

Progress and Status

We flew a pilot aerial survey this winter (January 2016) with a goal of estimating spatial patterns of density of mule deer bucks, does and fawns, white-tailed deer and elk across the Northern Rocky Mountain Front of Montana. This coming winter we plan to deploy GPS collars on mule deer bucks in the region to track movements and mortality events as well as fly additional aerial surveys to improve our estimation of spatial patterns of ungulate density in the region.

## *Evaluating Spatiotemporal Patterns of Parturition and Juvenile Recruitment in Sierra Nevada Bighorn Sheep*

**Student:** Shannon Forshee
NSF Fellowship Award

**Degree:** MSc Candidate

**Advisors:** Mike Mitchell

**Project Duration:** 2015- 2018

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Sources:** California Dept. of Fish and Wildlife

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**Objectives**

My interests range broadly from genetics to conservation of endangered species. I've been fortunate to work with a wide variety of projects and species across the country, ranging from stingrays to large carnivores and now ungulates. My recent work has been centralized on predator-prey relationships concerning endangered mammals. While working for the California Dept. of Fish and Wildlife on the Sierra Nevada Bighorn Sheep Recovery Project, my interest in species conservation and predator-prey interactions converged. CDFW has made great progress towards the recovery of Sierra Nevada bighorn sheep, yet high variable juvenile recruitment over the past decade could jeopardizing the future conservation efforts. Trying to understand the causes and consequences of juvenile, specifically neonatal, mortality is important for maintaining positive population growth. Preliminary and anecdotal information suggests that predation may be the primary factor driving juvenile mortality. Understanding juvenile recruitment are essential management tools for CDFW's SNBS Recovery Project. Additionally, I will be collecting data on adult female behavior pre, during and post parturition and quantify characteristics of chosen parturition sites to enhance CDFW's ability to monitor reproductive success.

**Project**

We are in the preliminary stages of developing a monitoring plan for SNBS juvenile survival including the use of high-fix rate GPS collars and VITs to track pregnant ewes' movements, parturition site selection and neonatal survival. In March, we deployed our first round of high frequency GPS collars and vaginal implant transmitters (VITs). We will be consistently monitoring female movements and locations. When a VIT is expelled during birth, we will investigate the site to add to our understanding of selection of parturition site. With this information, I will develop a parturition resource selection function that can be incorporated into CDFW's translocation protocols and location selection criteria. Additionally, I will be developing a method for detecting parturition using GPS movements so that CDFW predict parturition events for collared females. We will be attempting to collar neonatal lambs in order to determine the spatiotemporal patterns of mortality. We will make every attempt to determine cause-specific mortality by performing necropsies.

## *Effects of summer foraging strategy on reproduction and survival of moose in northeast Washington*

**Obligated Funding: $72,000**

**Student:** James Goerz

**Degree:** MSc Candidate

**Advisor:** Mike Mitchell

**Project Duration:** 2014 - 2017

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Source:**

- Washington Department of Fish and Wildlife
- UM College of Forestry and Conservation
- National Science Foundation Graduate Research Fellowship

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**Objectives**

We are currently monitoring 40 GPS/VHF radio-collared adult female moose within two study areas of Northeast Washington to estimate pregnancy, calf production, and adult/calf survival. To explain variation in these vital rates, we are studying the spatial and temporal foraging patterns employed by moose to meet the competing needs of energy acquisition and predator avoidance during critical but thermally-stressful summer months. Data obtained over the next three years may reveal behavioral plasticity in moose that increases their probability of persistence despite rapidly increasing temperatures and expanding large carnivore populations.

**Progress and Status**

In North America, moose (*Alces alces*) populations are experiencing widespread declines due in large part to the cascading effects of warming climate. These large, cold-weather adapted herbivores may have difficulty meeting the energetic demands of survival and reproduction amidst increasingly high seasonal temperatures. Late spring through early fall is a critical energy acquisition period for adult female moose when they must give birth, lactate, protect offspring, restore fat reserves, and breed again before the approaching winter. This physiological stress is compounded by the expanding presence of large carnivores across much of the Northwestern U.S. Paradoxically, moose in Northeast Washington are reportedly stable to increasing, raising interest in the possible behavioral mechanism responsible for their success.

## *Optimizing the use of wildlife monitoring resources*

**Obligated Funds: $80,963**

**Student:** Charles R. Henderson, Jr.

**Degree:** PhD

**Advisor:** Paul Lukacs, Mike Mitchell

**Project Duration:** 2014 – 2018

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Source:**

- Idaho Department of Fish and Game

**Objectives**

The main goal of this project is to provide the Idaho Department of Fish and Game (IDFG) with information and tools to more effectively monitor wildlife populations. The study system that this project will use to quantify monitoring effectiveness and develop tools to optimize the use of monitoring resources is the IDFG's mule deer monitoring program. This project will have 5 lines of research. The first line will be a cost-effectiveness analysis of the current methods used by IDFG to monitor mule deer abundance. The next research line will be the development of a method for weighting different types of data included in the current IDFG population model. This should facilitate the appropriate use of different data types and suggest how to prioritize the collection of data. The third line of investigation will focus on improving survival estimates from data gathered using radio collars. Specifically, this research will address the differences in data generation between GPS and VHF radio tracking devices and its effects on missing data points. The fourth line of research will focus on the efficiency of monitoring conditional mule deer habitat to inform the frequency of winter aerial surveys. Monitoring conditional habitats via less expensive and risky methods, i.e. camera traps or driving transects, has the potential to reduce the frequency of winter aerial surveys which should reduce cost and the risk to personnel. The culmination of this project will be to simultaneously optimize over cost and abundance estimate precision using information generated by the previous lines of research. This should produce a set of monitoring strategies that are tailored to specific budgets and management requirements. This optimization process can then be applied not only to mule deer but can be expanded to include other game and non-game species both inside and outside of Idaho.

**Progress and Status**

Data for this analysis is being provided by IDFG and is the product of their mule deer monitoring from the past 20 years. To date the cost effectiveness analysis of different monitoring methods is nearing completion and research is beginning on the development of a method to weight different data types for inclusion in the IDFG state population model. I recently presented a poster describing this project at the 2016 Montana chapter of The Wildlife Society's annual meeting.

## *Linking resource selection to population dynamics of mule deer*

**Obligated Funds: $48,326**

**Student:** Mark Hurley

**Degree:** PhD Candidate

**Advisors:** Mike Mitchell
Mark Hebblewhite

**Project Duration:** 2010 – 2016

**UM Affiliation:** Wildlife Biology
Montana Cooperative Wildlife Research Unit

**Funding Source:**

- Idaho Department of Fish and Game

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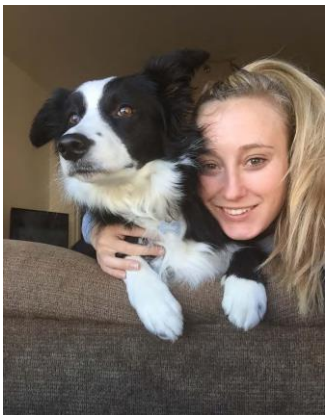
**Dissertation Abstract**

Ecologists aim to understand and predict the effect of management actions on population dynamics of animals, a difficult task in highly variable environments. Mule deer (*Odocoileus hemionus*) occupy variable environments and display volatile population dynamics, challenging their management. I first investigate the ecological drivers of overwinter juvenile survival, the most variable life stage in this ungulate. I tested for both direct and indirect effects of spring and fall phenology on winter survival of 2315 mule deer fawns from 1998 –2011 across a wide range of environmental conditions in Idaho, USA. I showed that early winter precipitation and direct and indirect effects of spring and especially fall plant productivity (NDVI) accounted for 45% of observed variation in overwinter survival. I next develop predictive models of overwinter survival for 2,529 fawns within 11 Population Management Units in Idaho, 2003 –2013. I used Bayesian hierarchical survival models to estimate survival from remotely-sensed measures of summer NDVI and winter snow conditions (MODIS snow and SNODAS). The multi-scale analysis produced well performing models, predicting out-of-sample data with a validation R2 of 0.66. Next, I ask how predation risk and deer density influences neonatal fawn survival. I developed a spatial coyote predation risk model and tested the effect on fawn mortality. I then regressed both total fawn mortality and coyote-caused mortality on mule deer density to test the predation-risk hypothesis that coyote predation risk increased as deer density increased, filling the low predation risk habitats. Fawn mortality did not increase with density, but coyote predation increased with increasing deer density, confirming density-dependence in fawn mortality was driven by coyotes, not density per se. Finally, I use integrated population models (IPM) to collate the previous findings into a model that simultaneously estimates all mule vital rates to test ecological questions concerning population dynamics drivers. I test whether density-dependence or environmental stochasticity (weather) drives mule deer population dynamics. The vital rate most influenced by density was recruitment, yet across most populations, weather was the predominant force affecting mule deer dynamics. These IPM's will provide managers with a means to estimate population dynamics with precision and flexibility.

## *Adaptive harvest management and estimation of recruitment for wolves in Montana*



**Student:** Allison Keever

**Degree:** Ph.D. – Wildlife Biology

**Advisor:** Mike Mitchell

**Project Duration:** 2015 – 2020

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Sources:**

- Montana Fish, Wildlife, and Parks

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The wolf (*Canis lupus*) population in the United States northern Rocky Mountains (NRM) increased rapidly due to natural recolonization in the 1980s and reintroductions in 1995. Wolves were delisted from the endangered species list in 2011, and responsibility for management fell to individual states (Idaho and Montana). Harvest is an important tool for managing wolf populations. Harvest regulations are set to reach a desired population size or objective. To be successful in this endeavor requires that the current population size is known and the effects of harvest on the population can be accurately predicted. Both of these requirements, however, can be difficult to achieve. To predict the effects of harvest on the wolf population we need to understand key factors influencing population dynamics, or changes in the population over time. One of the most important aspects to population dynamics is recruitment, or the number of young that survive to a point at which they contribute to the population. Currently, recruitment is gauged by a proxy, the breeding pair metric (a male and female wolf with at least 2 surviving pups by December 31), via direct counts. The breeding pair metric, however, is an ineffective measure of recruitment, as it gives little insight into population growth rate or the level of harvest that could be sustained. Harvest decisions for wolves are further hindered by poor understanding of the effects of harvest on the wolf population. Given uncertainty in wolf population dynamics and the effects of harvest on those dynamics, it is difficult to make informed harvest decisions. An adaptive harvest management (AHM) model for wolves could help guide harvest decisions in an adaptive framework, which would allow the formal assessment of harvest regimes in meeting objectives and determination of underlying biological processes.

**Objective 1:** Produce approach to estimate recruitment that is more tractable, cost effective, and biologically credible than the breeding pair metric. This will increase understanding of mechanisms driving recruitment, identify the best analytical approach to estimating recruitment, and thus further refine monitoring of factors relevant to recruitment.

**Objective 3:** Develop framework for adaptive harvest management to help guide harvest decisions while learning about the effects of harvest on wolves via management and monitoring. This will not only be a useful tool for managers to guide harvest decisions for wolves, but also provide a means to learn about basic biological processes and improve decision making over time.

**Objective 4:** Conduct sensitivity analyses and propose an efficient monitoring regime. I will use sensitivity analyses to understand the characteristics influencing estimates produced by our models. I will then identify factors that require monitoring to produce robust population estimates and reduce uncertainty associated with making harvest decisions.

## *Western elk research collaborative*

**Obligated Funds: $181,799**

**Principal Investigator:** Paul M. Lukacs, Mike Mitchell

**Project Duration:** 2010 - 2015

**UM Affiliation:** College of Forestry and Conservation
Montana Cooperative Wildlife Research Unit

**Funding Source:**

- U.S. Geological Survey – Research Work Order 97
- Idaho Department of Fish and Game
- State of Colorado
- Rocky Mountain Elk Foundation

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**Objectives**

The challenges facing elk management in Western landscapes are increasing at a rapid pace as modifications to predator communities; habitat and climate influence the demography and behavior of elk populations. Uncertainty about the influence of predation in the context of other limiting and regulating factors on elk populations initiated communication among wildlife researchers in the northwestern states of Idaho, Montana, Wyoming, Oregon, Washington, Utah, and Colorado about shared management challenges and research needs. Whereas individual states conduct their own research projects on how these factors influence elk, the collaborators recognize the benefits of a region-wide analysis for informing local ecological processes. A region-wide analysis allows collaborators to assess greater spatial and temporal variation in these drivers than could be achieved within any single study site or state, and gain a more general understanding of factors influencing elk populations to inform future management strategies (i.e., harvest, predator management, habitat management, etc.). Furthermore, collaborative analyses increase and add value to pre-existing local data sets, maximizing their utility in guiding elk and carnivore management beyond individual jurisdictions. Therefore, the Western Elk Research Collaborative (WERC) is pooling data on elk (and other covariates) from populations across the Northwest to assess the relative influence of predation, habitat quality, weather, and their interactions on elk demography.

**Progress and Status**

We completed the analysis of factors affecting the survival of adult female elk across seven western states, using one of the largest datasets analyzed for any large mammal. We collaboratively developed a manuscript that has been published in the Journal of Applied Ecology. We have also completed analysis of factors affecting recruitment across populations and submitted the completed work to the Journal of Applied Ecology.

Upon publication of the recruitment analysis, WERC will have explored adult female survival, calf survival, and recruitment over a broad temporal and spatial scale. Our next step will be to combine these components into an integrated population model to better understand cumulative population processes in elk. In addition, the population model provides a tool for state agencies to use in making decisions about elk management.

## *Carnivore Territoriality and Sociality: Optimal Behavior for Gray Wolves in the Northern Rocky Mountains*

**Student:** Sarah Sells

**Degree:** PhD– Wildlife Biology

**Advisor:** Mike Mitchell

**Project Duration:** 2015 – 2020

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Sources:**

- Montana Fish, Wildlife, and Parks

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**Objectives**

Abundance estimates are a key component of monitoring gray wolves (*Canis lupus*) in Montana and Idaho. In Montana, abundance is estimated using 3 parameters. Area occupied is estimated with a Patch Occupancy Model (POM) based on hunter observations and field surveys. Average territory size is assumed to be 600 $km^2$ with minimal overlap, and annual average pack size is estimated from field surveys. Total abundance is then calculated as area occupied ÷ $\bar{x}$ territory size × $\bar{x}$ pack size.

Although estimates of area occupied from POM are reliable, development of accurate methods to estimate territory size, territory overlap, and pack size is critical for accurate estimates of abundance. Assumptions of fixed territory size and minimal overlap are simplistic; in reality, territories vary spatiotemporally, and this variability is likely even greater under harvest. Meanwhile, estimating pack size requires packs to be located and accurately counted each year, which is increasingly difficult due to the number of packs and declining funding for monitoring. Furthermore, our understanding of territories and pack sizes are based on abundant data collected prior to delisting and implementation of harvest in 2009. Data collected post-delisting and concurrent with harvest are comparatively sparse; meanwhile, those data that do exist show behaviors of wolves have changed. Abundance estimates may therefore become increasingly inaccurate.

My objectives are to develop territory and group size models based on hypothesized behavioral mechanisms of wolves. The models will yield biologically based, spatially explicit predictions for territory size, location, and overlap and group size at any spatiotemporal scale, in absence of abundant empirical data. Alongside POM, the models will help accurately estimate abundance of wolves in the northern US Rocky Mountains. Results of this work will negate need for intensive monitoring efforts and aid in decision-making for wolf management.

**Progress & Status**

Much of year 1 was devoted to literature reviews, communicating and meeting with wolf specialists, identifying target packs for collaring, managing collar orders and data, and helping coordinate contracts and capture plans for winter aerial captures for January and February 2016. As of February 2016, we have purchased 35 collars for this project. MFWP field staff has successfully captured 40 wolves, deploying 10 collars in 2014, 14 collars in 2015, and 16 collars as of February 2016. Additional capture efforts will continue through ground and aerial capture efforts through 2017. I will compare model predictions with these empirical data to identify territory and group size models with most support.

## *Spatial and temporal scales of population performance in grizzly and black bears in the Northern Continental Divide Ecosystem, Montana*

**Obligated Funds: $56,230**

**Student:** Jeff Stetz

**Degree:** Ph.D. Candidate

**Advisor:** Mike Mitchell

**Project Duration:** 2009-2013

**UM Affiliation:** Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

**Funding Sources:**

- U.S. Forest Service
- U.S. Geological Survey

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**Objectives**

My primary interests are in investigating habitat selection and population performance across the sympatric grizzly and black bear populations in the Northern Continental Divide Ecosystem (NCDE) in the Northern Rocky Mountains of Montana. I am also interested in evaluating the ability of noninvasive genetic sampling (NGS) to detect fine-scale demographic processes in these populations. The specific questions that I am currently exploring include:

1. How does habitat selection vary in space and time for grizzly and black bears in this region? To answer this, I will use a combination of occupancy modeling and spatial interpolation methods using detection data from noninvasive genetic sampling projects.
2. How do habitat selection patterns vary between the sympatric grizzly and black bear populations in the NCDE? I will use the results of Question 1 to identify habitat factors that are shared versus specific to each species. This answer could inform grizzly bear reintroduction/augmentation programs if we determine that, for example, high black bear densities may lead to reduced grizzly bear density.
3. Why do we see such dramatic differences in capture probabilities of grizzly bears in certain NGS methods across populations? I will use detection data from 3-4 distinct populations to model capture probabilities in a meta-analysis framework. These results could be useful in designing future monitoring programs.
4. How can we use NGS method4 to detect fine scale population performance (i.e., population growth rates)? I will use simulations with spatially-explicit mark-recapture methods to explore the conditions under which intra-population (e.g., source-sink) dynamics can be identified.

**Progress and Status**

In 2012 I completed my required coursework and successfully completed my comprehensive exams. I have continued to work with biometricians to develop models for analyzing my data related to two of my proposed chapters. I have pursued a number of grants to aid in model development and acquire computing resources. I also was a teaching assistant in fall 2012, spring and fall 2013, and spring 2014 terms.

The bulk of the data to be used in my dissertation research was collected in 1998-2000 and 2004 during two distinct research projects. I have obtained access to datasets from the Russian Far East, Banff National Park, and Greece for Question 3. My efforts in 2013 focused on developing statistical code and assembling covariates (eg, landcover, sympatric species' density) for grizzly bear density models.

# AWARDS AND RECOGNITIONS

**Boyce, Andrew**

- Wesley M. Dixon Memorial Fellowship, Wildlife Biology Program 2015, Univ. of Montana ($30,000)
- Wildlife Biology PoND Travel Grant, Wildlife Biology Program 2015, Univ. of Montana ($500) (For travel to 2016 SICB Conference)

**Fierro-Calderon, Karolina** - **"**PEO International Peace Scholarship" granted by International Chapter PEO Sisterhood Knowles International Peace Scholar for the 2014-2015 academic year.

**Forshee, Shannon –** NSF Graduate Research Fellowship

**Goerz, James –** NSF Graduate Research Fellowship

**LaManna, Joseph** - EPA Star Fellowship Award

**Mitchell, Mike**

- Bob Watts Communication Award, Montana Chapter of The Wildlife Society
- Faculty Recognition Award for advising the Student Veterans Association, University of Montana

**Mouton, James**

- Drollinger-Dial Foundation Travel Grant 2015 ($1000), Society for Integrative and Comparative Biology Meeting 2016 in Portland, OR (taking place Jan. 2016).
- Drollinger-Dial Foundation Travel Grant 2014 ($849), For travel to conduct laboratory work at the Duckworth lab (University of Arizona) and the Wolf lab (University of New Mexico).
- American Ornithologist Union Research Grant ($1000) For laboratory supplies needed to analyze the concentration of yolk hormones in the Duckworth lab (University of Arizona).
- NSF Graduate Research Fellowship (2013)

**Sells, Sarah**

- George and Mildred Cirica Scholarship, University of Montana (March 2015)
- PoND Fund Conference Travel Grant, University of Montana (October 2015)

**Ton, Riccardo**

- Drollinger-Dial Research Travel Award
- Bertha Morton Scholarship

# PRESENTATIONS AND POSTERS

**Barker**, Kristin. March 2016. Nutritional consequences of migratory behavior by elk in the North Sapphire Range. MPG Ranch Annual Conference, Missoula, MT

**Blake, William**. March 2016. Habitat Selection and Reproductive Success of Lewis's Woodpeckers, MPG Annual Conference, Missoula, MT

**Boyce, A.J.**, B.O. Wolf. and T.E. Martin. September 2014. Divergent physiological tolerance in two allopatric species of White-eye (Zosteropidae) on a tropical elevational gradient. Oral Presentation to the AOU/COS/SCO Joint Meeting. Estes Park, CO

**Bassing, Sarah, Michael Mitchell**, Paul Lukacs, **David Ausband**, Lisette Waits, Greg Hale. February 2016. Wolf Pack Distribution in Relation to Heavy Harvest in Southwest Alberta. Montana Chapter of The Wildlife Society Annual Conference, Missoula MT

**Bassing, Sarah, Michael Mitchell, David Ausband**, Paul Lukacs, Lisette Waits, Greg Hale. October 2015. Developing a Monitoring Framework to Estimate Wolf Occupancy Dynamics in Southwest Alberta. International Annual Conference for The Wildlife Society, Winnipeg, MB Canada

**Bassing, Sarah**. September 2015. Wolves on the Move. Waterton Wildlife Weekend invited speaker, Waterton Lakes National Park, AB Canada

**Crum, Nathan,** Fuller, A. F., Sutherland, C. S., Kretser, H., Glennon, M.,Schwartz, M., and Pilgrim, K. October 2015. Population Structure and Recolonization Dynamics of Moose in Northeastern North America. Presented at The Wildlife Society Conference, Winnipeg, MB

**Crum, Nathan,** Fuller, A. F., Sutherland, C. S., and Hurst. J. April 2015. Estimating the occurrence of moose in New York using hunter observations. Presented at the Northeast Association of Fish and Wildlife Agencies Conference, Newport, RI.

**Golding, Jessie** & V.J. Dreitz. February 2016. Grazing and Songbirds in Sagebrush Ecosystems, 2016 Montana Chapter of the Wildlife Society Annual Research Symposium

**Golding, Jessie** & V.J. Dreitz. February 2016. Grazing and Songbirds in Sagebrush Ecosystems, 2016 Sage-Grouse Oversight Committee Meeting

**Sells, S., M. Mitchell,** J. Gude, & N. Anderson. February 2016. Application of structured decision making to wildlife management in Montana. Annual Meeting, Montana Chapter of The Wildlife Society, Missoula, MT

**Sells, S., M. Mitchell,** V. Edwards, J. Gude, & N. Anderson. October 2015. A decision analytic approach to proactive management of pneumonia epizootics in bighorn sheep. Annual Meeting, The Wildlife Society, Winnipeg, MB Canada

**Sells, S., & M. Mitchell**. August 2015. Proactive decision-making for pneumonia epizootics in bighorn sheep. (Missoula & Lewistown)

# SCIENTIFIC PAPERS AND REPORTS

**Ausband, D.E**., **S.B. Bassing**, and **M.S. Mitchell**. 2015. Final report for testing monitoring techniques for wolves in southwest Alberta. Report submitted to Alberta Environmental Sustainable Resource Development and Alberta Innovates

**Boyce, A.J.**, B.G. Freeman, A.E. Mitchell, and **T.E. Martin**. 2015. Clutch size declines with elevation in tropical birds. The Auk 132; 424-432.

**Lloyd, P., and T.E. Martin**. 2016. Fledgling survival increases with development time and adult survival across north and south temperate zones. Ibis 158:135-143

Ibáñez-Álamo, J. D., R. D. Magrath, **J. C. Oteyza**, A. D. Chalfoun, T. M. Haff, K. A. Schmidt, R. L. Thomson, and **T. E. Martin**. 2015. Nest predation research: Recent findings and future perspectives. Journal of Ornithology DOI 10.1007/s10336-015-1207-4

**LaManna, J.,** A. B. Hemenway, V. Boccadori, and **T. E. Martin**. 2015. Bird species turnover is related to changing predation risk along a vegetation gradient. Ecology 96:1670-1680

**LaManna, J.A., and T.E. Martin**. 2016. Cost of fear: Behavorial and life-history responses to risk and their demographic consequences vary across species. Ecology Letters 19:403-413

**Martin, T. E. 2015.** Age-related mortality explains life history strategies of tropical and temperate songbirds. Science 349:966-970

**Martin, T. E**., **J. C. Oteyza, A. J. Boyce**, P. Lloyd, and R. Ton. 2015. Adult mortality probability and nest predation rates explain parental effort in warming eggs and embryo development time. American Naturalist 186: 223-236

**Martin T.E.**, **J.C. Oteyza**, **A.E. Mitchell**, A.L. Potticary, P. Lloyd. 2015. Post-natal growth rates covary weakly with embryonic development rates and do not explain adult mortality probability among songbirds on four continents. American Naturalist 185(3):380-389

Morgan Henderson, M., M. Hebblewhite, **M. S. Mitchell**, **J. B. Stetz**, K. C. Kendall, and R. G. Carlson. 2015. Modeling multi-scale resource selection for bear rub trees in Northwestern Montana. Ursus 26:28-39

Robinson, H., T. Ruth, J. A. Gude, D. Choate, R. DeSimone, M. Hebblewhite, K. Kunkel, M. R. Matchett, **M. S. Mitchell**, K. Murphy, and J. Williams. 2015. Linking resource selection and mortality modeling for population estimation of mountain lions in Montana. Ecological Modelling 312:11-15

**Sells, S. N**., **M. S. Mitchell**, V.L. Edwards, J.A. Gude, and N.J. Anderson. In press. Application of structured decision making for managing pneumonia epizootics in bighorn sheep. Journal of Wildlife Management.

**Sells, S. N., M. S. Mitchell**, J. J. Nowak, P. M. Lukacs, N. J. Anderson, J. M. Ramsey, J. A. Gude, and P. R. Krausman. 2015. Modeling risk of pneumonia epizootics in bighorn sheep. Journal of Wildlife Management 79:195–210

**Ton, R., and T.E. Martin.** 2015. Metabolism correlates with variation in post-natal growth rate among songbirds at three latitudes. Functional Ecology doi:10.1111/1365-2435.12548