Montana Cooperative Wildlife Research Unit

Report of Activities for the Coordinating Committee Meeting

April 18, 2018

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 2017 through 31 March 2018

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Birds

Mammals

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Kenneth Loonam, MSc Candidate **
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Sarah Sells, PhD Candidate

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Andrew Boyce, PhD Candidate *
Karolina Fierro-Calderon, PhD Candidate *
Adam Mitchell, PhD Candidate
James Mouton, PhD Candidate

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Charlie Henderson, PhD Candidate
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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 2017

Unit and Administrative Operating Funds		
University of Montana - Full-time Accounting Manager	$ 42,900	
SPABA – returned to Unit in FY17/FY18	70,000	
Subtotal		**$ 112,900**
FY 2017 – Research Projects Funding		
Montana Fish, Wildlife and Parks - Operating Funds		**$ 20,000**
T. Martin – PI		
New Funding:		
NSF – Energetic Consequences of Rain and Nest Structure for Songbirds	$824,336	
UM Research Administration – Graduate Support	46,000	
Subtotal		**$ 870,336**
Continued Funding:		
NSF – Graduate Research Fellowship	$ 88,000	
NSF – Effects of El Nino Drought on Tropical Songbirds	198,410	
NSF – Graduate Research Fellowship	44,000	
NSF – Dissertation Improvement Grant	18,705	
USGS – Climate and Habitat Change	465,433	
Subtotal		**$ 814,548**
M. Mitchell – PI or Co-PI		
New Funding:		
MTFWP – Wolverine Study	$ 27,500	
MTFWP - Sage Grouse Research	54,435	
MTFWP – Migratory Songbird and Grazing	135,195	
MTFWP – Statewide Mule Deer Study	75,479	
MTFWP – Sapphire Elk Project – Technician	57,684	
MTFWP – Black Bears & Bobcats Population Modeling	42,000	
IDFG – Cougar Study	32,973	
IDFG – Sandhill Cranes	79,790	
IDFG – Mule Deer Population Dynamics and Modeling	328,832	
IDFG - Big Horn Sheep Genetics	3,500	
IDFG – Large Mammal Predator/Prey	49,297	
USDI – Linking Exposure to Sub-Lethal Stressors	92,299	
State of Colorado Moose Study	39,532	
Subtotal		**$ 1,018,516**
Continued Funding**:**		
MTFWP – Elk Distribution Sapphire Mountains	$ 67,389	
USDI - Linking Exposure to Sub-Lethal Stressors to Vital Rates	129,997	
MTFWP - Montana Wolf Monitoring	274,003	
NSF Fellowship	146,000	
WDFG - Moose Demography	88,000	
Subtotal		**$ 705,389**
Total Budget		**$3,541,688**

Completed Projects – 1 January 2017 – 31 December 2017

End Date	Student	Funding Agency	Title
May 2017	Sarah Bassing	UM Wildlife Biology Dept.	Effects of harvest on wolf populations: Impact for monitoring and managing abundance
December 2017	Andy Boyce	NSF, American Ornithologists Union	The fight for space: Exploring the role of competition and physiological tolerance in limiting elevational distributions and structuring communities in tropical birds
November 2017	Karolina Fierro	PEO International Peace Scholarship	Understanding variation in habitat use among Orange-Crowned Warblers (Oreothlypis Celata) in Central Arizona, USA

MTCWRU – Federal and State Vehicles

Description	Tag number	Odometer as of 3/31/2018
1999 Ford Truck, Extended Cab Pickup 4 x 2	FED 252524	112,300
2006 Ford F250 Crew Cab Pickup, 4 x 4	FED 430965	103,354
2010 Ford Expedition 4 x 4	FED 433441	71,824
2011 Ford F250 Crew Cab Pickup, 4 x 4	FED 433440	46,724
2011 Ford F250 Crew Cab Pickup, 4 x 4	FED 433610	55,789
2012 Dodge 1500 Crew Cab 4 x 4	FED 433621	56,576
2017 Ford F150 Crew Cab Pickup, 4 x 4	FED 434302	712
2005 Ford Explorer, 4 x 4	UM 3787	152,384

BIRDS

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

Student: **William Blake**

Degree: MSc Candidate

Advisor: Thomas Martin

Project Duration: 2015 – 2017

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Source: MPG Ranch

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 and considered of management concern at the national level. 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 selection and reproductive success. I therefore propose to examine how Lewis's Woodpecker habitat selection compares with its reproductive success, in burned and riparian forests, the two habitats it most commonly uses. I am investigating factors generally known to influence the reproductive success of cavity nesting species: nest site availability, food availability and vegetation characteristics. Understanding habitat influences on reproductive success is critical for habitat management of such species of management concern.

Progress and Status

We finalized three seasons of fieldwork (2015-2017) and conducted analyses of abundance, reproductive success and habitat selection. I am in the process of submitting my thesis to my academic committee and will defend my MS this coming spring semester. I communicated main results through annual reports to all private landowners involved in the study, and through oral presentations at four statewide professional conferences, and with local chapters of the Audubon Society. We plan to publish the main study results in coming months.

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

Advisor: Thomas Martin

UM Affiliation: WBIO, MTCWRU

Project Duration: 2011 – 2017

Funding Sources: National Science Foundation
University of Montana, MTCWRU
American Ornithologists Union

Dissertation Abstract

Environmental gradients provide natural forums for understanding how and why species differ. The study of interspecific variation across gradients has provided foundations for our understanding of community ecology, species distributions, life-history evolution and physiological ecology (Janzen 1967; Macarthur 1972; Martin 2015). In this dissertation, I explore questions in these disciplines, using a comparative approach on elevational and latitudinal gradients. My primary focus is understanding the biotic and abiotic processes that limit species distributions and how those same forces scale up to influence the composition of communities on an elevational gradient. I also test a physiological hypothesis for the gradient of life history strategies, the pace-of-life hypothesis, by examining the relationship between metabolic rate and adult mortality probability across a global latitudinal gradient.

I examine these issues in songbird communities on Mt. Kinabalu in Malaysian Borneo (6°N). Kinabalu Park is a large protected area encompassing the largest intact elevational gradient in southeast Asia (400m – 4100m). It is a reserve with tremendous conservation importance; it is a stronghold for more than 90% of Borneo's endemic bird species including several whose mountaintop ranges put them at risk of extinction assuming upward range shifts due to climate change (Colwell et al. 2008). Understanding the mechanisms that underpin elevational distributions in such megadiverse threatened areas is a central goal of ecology and vitally important to conservation locally and globally.

In chapters 1-3 I used experimental and descriptive approaches to assess the importance of interspecific competition and physiology in setting elevational range limits and structuring communities across elevations. We found evidence that interspecific competition may set range limits in some species, but that aggressive interactions with close relatives could not explain range boundaries in other cases. We also found that birds occupying different elevations had similar thermal physiology, suggesting range limits are not directly set by climatic variables like temperature. Using phylogenetic and trait-based approaches, we found evidence that interspecific competition plays a strong role in structuring bird communities at low elevations, while environmental filtering appears to be important at high elevations. Based on clustering of morphological traits, particularly bill shape, we speculate that the influence of climate on prey size and diversity may restrict many species from high elevation communities.

Finally, we tested the ability of metabolic rate to explain variation in average lifespan within and across latitudes. The pace-of-life hypothesis posits that damaging byproducts from cellular metabolism are the primary physiological driver of lifespan, such that long- lived tropical species are expected to have low metabolic rates (Pearl 1928; Hulbert et al. 2007; Wiersma et al. 2007; Williams et al. 2010). We tested this hypothesis by measuring metabolic rates and estimating adult survival probability in songbirds at Kinabalu Park.

Understanding variation in habitat use among Orange-Crowned Warblers (Oreothlypis Celata) *in Central Arizona, USA*

Student: **Karolina Fierro**

Degree: PhD

Advisor: Thomas Martin

UM affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Project duration: 2012 – 2017

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

Dissertation Abstract

Habitat use is expected to be adaptive with individuals occupying habitats that confer high fitness. Breeding habitat use in particular has a strong influence on offspring survival. Although environmental factors that determine use of breeding sites are generally well studied, some gaps still exist regarding our understanding of the effects of temporal variation in vegetation, predation, and temperature on offspring growth and survival.

I first investigated whether nest site use and nest survival shifted across 28 years with a decrease in vegetation abundance. Orange-crowned warblers (*Oreothlypis celata*) showed preference for patches with more canyon maple (*Acer grandidentatum*) and did not shift nest site use. Nest survival was highly correlated with maples and did not shift across years. Nest substrate shifted from maple to leaf litter, but nesting under litter did not increase nest survival. I concluded that shifting or not habitat use may depend on the availably of preferred habitat and the availability of better options to choose from.

Breeding habitats vary significantly in quality and can be positively correlated with individual quality. Individuals usually re-nest more than once due to predation, and yet, we do not know why quality varies across successive breeding sites. I tested three non-mutually exclusive hypotheses to explain variation in quality. The "optimizing nest survival" hypothesis explained first nesting attempts and predicted that nest quality increases as nest predation increases during the breeding season. Individuals did not maximize nest survival because they probably gained thermoregulation benefits from less concealed nests during cold weather at the beginning of the breeding season. Individual quality based on arrival date from spring migration did not explain differences in nest quality. Further tests regarding the effect of individual quality on offspring survival and movement within territories suggested that nest site selection did not differ among individuals of different qualities.

Finally, I examined the influence of fluctuations in temperature on growth parameters in the dark-eyed junco (*Junco hyemalis*). Ambient temperature across 17 years and within breeding seasons had an indirect effect on growth throughout food availability and nest predation, whereas the temperature experienced by the offspring in warmer nest sites and experimentally heated nests directly influenced physiological processes. Although slower growth rates seem a disadvantage of warmer and heated nests, longer wings can improve offspring survival.

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

Obligated funding: $1,001,967

Principal Investigator: **Thomas E. Martin**

Project Duration: 1985-2017 (finished in 2017)

UM Affiliation: Montana Cooperative Wildlife Research Unit

Funding Sources: U.S. Geological Survey – RWO #102
National Science Foundation

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.

Recent work included studies of fledgling survival, a critical influence on demography that is poorly studied across species. We measured fledgling flight mobility to examine the consequences for fledgling mortality rates, using radio transmitters. Management depends on understanding which species and life stages are most sensitive to environmental perturbations for population maintenance.

We also examined 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. We used 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). We are waiting for lab analyses of the doubly-labeled water samples.

The results have important implications for elk and ecosystem management in this vulnerable habitat type and have influenced forest management in this area. This project also had 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 Source: National Science Foundation

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.

Progress and Status

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 ten seasons, 5,560 nests were found and monitored, adult and nestling resting metabolism and daily energy expenditure measured, nestling growth measured, parental care videotaped, and egg temperatures quantified. In addition, a total of 17,805 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. For example, our data show for the first time that tropical birds will skip breeding in El Niño drought years when environmental conditions are harsher. More importantly, our data show that species differ in the extent to which they curtail breeding, with species with the highest survival rates and greatest longevity showing the greatest reduction in breeding activity. Such demographic responses to environmental variation have critical consequences for population vulnerability. Moreover, using diverse field techniques, we also showed that adult survival estimates for tropical birds have been flawed and under-estimated due to a reliance on standard effort netting alone. These results have potentially important implications for the national MAPS program in the USA. In addition, data collected on both adult and nestling metabolism shows that species vary strongly in their sensitivities to temperature. The importance of temperature suggests that global warming may be particularly important to long-term reproductive success of tropical birds. Work is focusing on a novel issue, the potential demographic costs of rainfall, an issue of concern for management in both temperate and tropical regions.

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

Effects of rainfall on nestling bird energetics

Student: **Adam E. Mitchell**

Degree: PhD Candidate

Advisor: Thomas Martin

Project Duration: 2014 – 2020

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

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

Objectives

My research addresses theoretical gaps in avian reproductive strategies, life history evolution, physiological effects of harsh weather events, and the evolution of different nest types.

Organisms living at higher elevations often have slower life histories, but the causes of this shift are not fully understood. Ambient climatic conditions (e.g. temperature, rainfall, humidity, etc.) are often harsher at higher elevations, and this may have significant effects on the growth, development, and survival of organisms. This is particularly true in birds, but few studies directly test the effects of harsh, high elevation climate on avian life histories. I am testing if harsh ambient conditions at high elevations constrains avian life histories, leading to slower strategies than relatives at lower elevations.

Rainfall can be a harsh weather condition, even in tropical mid-elevation rainforests, where birds may be particularly adapted to heavy rain. This selection pressure may explain the increased prevalence of enclosed nests in these habitats, despite literature favoring protection from predation as the primary driver of these nest types. My research explores the effects of rainfall on the energetics of nestling birds in the tropical mountain forests of Borneo. The effects of rainfall variation on nestling energetics are almost entirely unknown, even though rainfall patterns are shifting due to climate change. This limits our understanding of nest success, which can affect demographic rates, as well as ecosystem stability. Furthermore, many tropical montane birds are vulnerable due to habitat loss, and these effects are likely to be exacerbated as mountains warm, allowing lower-elevation species to displace those in the highlands. Through my research, I hope to improve our understanding of the basic processes that influence wildlife, helping us predict future change and protect our vulnerable resources.

Progress and status

I am currently collecting field data in Malaysian Borneo I am using a manipulation experiment to test the effects of harsh weather on avian development at high elevations. I am doing this by ameliorating the harsh climate 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.

At lower elevations, I am measuring the energetics of nestlings to correlate with ambient weather conditions. I am also conducting an experiment by adding rain (using a make-shift portable shower) on nests during dry periods 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 energetics and life histories.

Plastic reproductive strategies in response to nest predation risk

Obligated funding: $138,000

Student: **James C. Mouton**

Degree: PhD Candidate

Advisor: Thomas Martin

Project Duration: 2013 – 2018

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

Funding Sources: National Science Foundation
MT Institute on Ecosystems
Toelle-Bekken Family Fund
Drollinger-Dial Foundation
Montana Cooperative Wildlife Research Unit
University of Montana

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 and test how responses in these traits affect performance and survival during the fledgling stage. 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 am finished with the field work for this project and have started working on a paper examining how nest predation risk can influence survival later in life which was funded by an NSF Dissertation Improvement Grant. I will soon begin work on several other papers from this project. I will return for my final field season in Kinabalu Park in Malaysian Borneo this spring to finish collecting data on parental responses to begging behavior.

The thermal advantages of nest structure and offspring number during juvenile development

Student: **Sarah M. Straughan**

Degree: MSc Candidate

Advisor: Tom Martin

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

Project Duration: 2018 – 2019

Funding Sources: National Science Foundation
University of Montana
Montana Cooperative Wildlife Research Unit

Objectives

Parental effort and growth rates vary extensively within and across species, with critical consequences for offspring quality that impact fitness and demography. Yet, the causes of this variation remain unclear. Traditionally, studies in birds have focused on relative energy input based on parental provisioning rates. Yet, net energy (input – loss) is the actual determinant of energy available to offspring for growth and development. The 'loss' side of the equation has received little attention, but may vary extensively among species due to differences in rates of heat loss as a function of nest structure, parental effort (i.e., brooding young), and the number of offspring huddling together per brood.

My research will focus on these three factors in order to better understand variation in heat loss as an energetic cost for offspring. I will manipulate brood size and measure offspring cooling rates and growth rates across nest types in order quantify variation in heat loss and the potential costs. Additionally, I will examine parental behavior, such as provisioning and brooding rates, in order to understand how adults may reduce the energetic cost of heat loss to offspring.

Progress and Status

I am currently a Master's student in Tom Martin's Lab at the University of Montana. I am about to embark upon my first field season in Kinabalu National Park in the state of Sabah, Malaysia where I will investigate the effects of offspring number and nest structure on the cooling rates of offspring. Although the tropics are generally thought of as warm, temperatures range from 15-22 ^{o}C, well outside of the thermoneutral zone of birds. Therefore, our mid-elevation tropical site provides a great study area to examine the role that heat plays in the development of offspring and adult behavior during reproduction.

MAMMALS

Causes and consequences of partial migration in elk

Student:	**Kristin Barker**	**Obligated funding: $67,390**
Degree:	MSc Candidate	
Advisors:	Mike Mitchell	
Project Duration:	2015-2018	
UM Affiliation:	Wildlife Biology Program Montana Cooperative Wildlife Research Unit	
Funding Source	Montana Fish, Wildlife & Parks	

Objectives

Seasonal migration of large ungulates plays an important role in transferring nutrients, structuring vegetative communities, and altering presence of large carnivores across broad spatial and temporal scales. Migratory behavior of many ungulates has declined in recent decades, leading some researchers to question whether migration may be an endangered phenomenon. Effective management of ungulate populations and conservation of ecosystem functioning requires an understanding of why these migratory behaviors are changing and how we may be able to influence those changes. This project aims to improve our understanding of a) the primary factors influencing migratory behavior of ungulates, and b) the fitness consequences of migratory and non-migratory behaviors, using elk (*Cervus canadensis*) as a model species.

Progress and Status

We began work on this project in collaboration with Montana Fish, Wildlife and Parks (FWP) and local stakeholders in fall 2015. Since that time, we have co-authored quarterly updates and a final project report with FWP, presented results at 5 scientific conferences and 3 public meetings, and submitted a manuscript about the nutritional consequences of partial migration to the Journal of Wildlife Management. A second manuscript summarizing the primary drivers of migratory behavior is nearing completion and will be submitted to a peer-reviewed scientific journal in spring 2018. This study contributes new information to ecological theories of ungulate migration while also providing stakeholders and managers information about current patterns of elk behavior and how we might be able to influence those behaviors to achieve management and conservation goals.

Access to high-quality forage has historically been considered the primary benefit of migration for ungulates. Using elk forage data collected throughout the Sapphire Mountains, we found that when portions of elk winter range are converted to irrigated agriculture, migration may no longer provide elk access to higher-quality forage than that available on their winter range. Thus, land management practices have potential to alter traditional benefits of migratory behavior and may contribute to observed declines in migration.

Harvest and persistence of wolf populations: variable effects on wolf packs in the Rocky Mountains

Student: **Sarah B. Bassing**

Degree: MSc

Advisors: Mike Mitchell

Project Duration: 2014-2017

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Thesis Abstract

Public harvest is a common method used to manage populations of wolves (*Canis lupus*) in North America. Although wolves appear resilient to the effects of harvest management the influences on demography and pack stability are uncertain. Packs generally drive population dynamics for wolves; thus, we were interested in how harvested populations were maintained and how harvest influenced the abundance and distribution of packs. We used noninvasive genetic data collected in Idaho, USA (2008–2014) and Alberta, Canada (2012–2014) to test whether immigration compensated for harvest mortality and helped maintain population densities. We further fit occupancy models to detection data derived from noninvasive genetic samples and hunter surveys from Alberta, Canada (2012–2014) to test the stability of pack abundance and distribution in a harvested population of wolves. We genetically identified 461 unique wolves across our study areas; 762 hunters reported seeing live wolves in southwestern Alberta. We found our hypothesis that immigration did not compensate for harvest mortality was supported. Density of wolves in the U.S. population declined from 15.49 wolves/1000 km^2 (95% credible interval [CRI]: 12.38–18.57) without harvest to 10.20 wolves/1000 km^2 (95% CRI: 7.47–12.90) with harvest, whereas the proportion of long-distance immigrants was low and did not change with harvest (ranged 0.01–0.02, SD = 0.1). Density and proportion of immigrants were similar among study areas where harvest occurred. We also found we could not reject our hypothesis that occurrence of packs was generally stable in a harvested population of wolves. The mean annual probability for wolf pack occupancy ranged 0.72–0.74 and the estimated distribution of wolf packs was consistent over time. Model selection indicated harvest did not have a strong effect on pack occurrence but that the probability of detecting a wolf pack was positively associated with the intensity of harvest for wolves. Although immigration did not appear to compensate for harvest mortality, pack occurrence remained generally stable over time, likely due to movement between packs from within the population. Harvest therefore appears to affect within-pack dynamics, but may not directly affect the number and distribution of packs across a population.

Analyzing Conflict of Grizzly Bears with Agricultural Attractants Using Electric Fencing

Obligated funding: $50,000

Student: **Kari Eneas**

Degree: MSc Candidate

Advisors: Mike Mitchell
Chad Bishop

Project Duration: 2017-2020

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Sources: Confederated Salish Kootenai Tribes
Alfred P. Sloan Foundation
Vital Ground
Charles Schwab

Objectives

My passion for wildlife and the complexities of natural ecosystems began for me at an early age. I grew up within the heart of the Flathead Indian Reservation, and today I am employed as a wildlife biologist with the Confederated Salish and Kootenai Tribes Wildlife Management Program. After starting as a wildlife biologist trainee in 2008, I completed my Bachelor of Science Degree in Wildlife Biology in 2013 while establishing a barn owl survey protocol for the Mission Valley and conducting a dietary analysis between barn owls and short eared owls. I have since then conducted breeding bird surveys and worked on the monitoring of long-billed curlew populations and interagency planning efforts for sharp-tailed grouse restoration in western Montana.

Project

To better understand how agricultural attractants such as chickens, pigs, sheep and lamas affect bear behavior we are using iridium GPS collars to observe fine scale movements of grizzly bears. We are installing electric fencing and stealth trail cameras as well to assess how electric fences prevent depredation of these attractants. We are entering into our first field season of this study. As both human and grizzly bear populations continue to increase and expand within the Northern continental Divide Ecosystem, the need to address increasing management conflicts and concerns has developed. This study aims to quantify the effectiveness of electric fencing in reducing depredation conflicts between grizzly bears and small scale poultry and livestock producers in the Mission Valley. These fences will be monitored during the study and compared with collar data to determine the success and effectiveness of the fencing in preventing further conflict.

Evaluating spatiotemporal patterns of parturition and juvenile recruitment in Sierra Nevada bighorn sheep

Obligated funding: $138,000

Student:	**Shannon Forshee**
Degree:	MSc Candidate
Advisors:	Mike Mitchell
Project Duration:	2015- 2018
UM Affiliation:	Wildlife Biology Program Montana Cooperative Wildlife Research Unit
Funding Sources:	National Science Foundation Graduate Fellowship California Dept. of Fish and Wildlife

Objectives

My interests range broadly from genetics to applied conservation management of endangered species. I've been fortunate to work on wide variety of projects and with species across the world; ranging from stingrays to large African carnivores and now alpine ungulates. In 2014, I began working for the California Dept. of Fish and Wildlife (CDFW) on the Sierra Nevada Bighorn Sheep Recovery Program. CDFW has made great progress towards the recovery of Sierra Nevada bighorn, yet variable trends in juvenile recruitment could jeopardize conservation efforts. Evaluating the causes and consequences of juvenile, specifically neonatal, mortality is important for maintaining positive population growth. In addition to understanding mortality factors, we are also interested in learning how maternal behavior decisions influence mortality risk. Neonatal lambs are dependent on their mothers for several months, as such, her selection of habitat during this critical period can potentially explain the level and type of mortality risk that neonates face. Understanding juvenile recruitment and maternal habitat selection are essential management tools for CDFW's SNBS Recovery Project.

Project and Status

To track juvenile recruitment and maternal habitat selection, we are using high-fix rate GPS collars and vaginal implant transmitters (VITs) to track the movement of maternal ewes and determine when lambs are born. When we detect a birth we collar the neonate to track survival and measure other intrinsic factors influencing mortality (birth weight, sex). Preliminary and anecdotal information suggests that predation and low genetic diversity may be driving juvenile mortality rates We are in our second season of the project and will continue to collect data through spring of 2018. To increase my sample size, I have developed a method for detecting birth using GPS movements from females without VITs. With this information, I will develop a resource selection function for lambing season that can be incorporated into CDFW's translocation protocols and location selection criteria. I will also be evaluating the factors that most strongly influence a neonates risk of mortality.

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

Obligated funding: $159,000

Student: **James Goerz**

Degree: PhD Candidate

Advisor: Mike Mitchell

Project Duration: Fall 2014 – Spring 2020

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

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

Objectives

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.

Because of these currently challenging circumstances, our project has two general and related objectives. First, we seek to understand the relative influence of predation, vegetation community composition, and summer heat stress on the survival and reproduction of moose in NE Washington. Second, we seek to identify general patterns of habitat selection by individual moose which are adaptive amidst multiple stressors such as heat stress and predation risk (if they exist).

Progress and Status

Over the last four years of continuous fieldwork, we have monitored 67 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 currently studying the spatial and temporal foraging patterns employed by these moose to meet their competing needs of energy acquisition and predator avoidance during critical but thermally-stressful summer months (May-Sept). Four years of GPS data coupled with four years of demographic data on known individuals may help us distinguish successful from unsuccessful behavioral strategies of moose. Results from this research, may identify environmental features which are uniquely important to adaptive individual moose behavior, thereby influencing fitness and ultimately population persistence.

Spatial variability in mule deer nutrition: a survey of Northwest Montana

Student: **Teagan Hayes** **Obligated funding: $134,263**

Degree: MSc Candidate

Advisors: Mike Mitchell
Chad Bishop

Project Duration: 2017 – 2020

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Sources: Montana Fish, Wildlife, and Parks
Montana Cooperative Wildlife Research Unit

Objectives

Many factors influence the distribution of nutrition for mule deer, and habitat management often seeks to use disturbance to increase forage availability. My objectives for this research are to: 1) quantify the effects of disturbance on the spatio-temporal distribution of forage nutrition in each of three study areas; and 2) evaluate the effects of nutritional distribution on the probability of use.

Progress & Status

I spent the first summer of the project planning for and conducting field work, along with my project partner and fellow student Collin Peterson. We were able to test monitoring methods, sample vegetation in available and used locations, and collect mule deer fecal samples in the Rocky Mountain Front study area. As of February 2018, MFWP field staff has captured and collared 14 mule deer does in the Whitefish Range, 22 does in the Fisher River area of the Salish Mountains, and 35 does in the Rocky Mountain Front using a combination of clover traps and helicopter netgunning. Additional capture efforts will continue through March 2018. We will conduct vegetation and habitat monitoring in all three study areas during the next two summer seasons. I will use this data to compare nutrition available to mule deer in each study area and to understand how disturbances including fire and logging influence mule deer migration and use of habitat.

Optimizing the use of wildlife monitoring resources

Obligated funding: $68,620

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

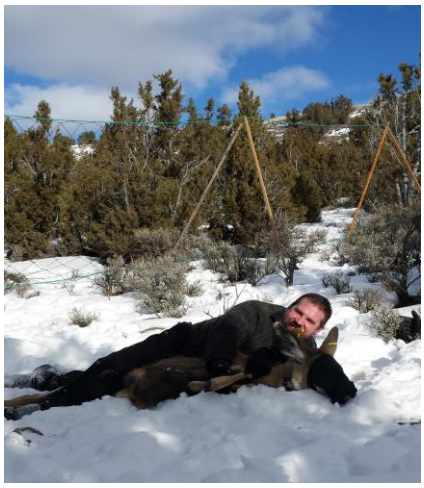
Degree: PhD Candidate

Advisor: Paul Lukacs

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 efficiently monitor wildlife populations. The study system being used to quantify monitoring effectiveness and develop tools to optimize the use of monitoring resources is IDFG's statewide monitoring program for mule deer. This project is split into 5 lines of research. The first line of research is a cost-effectiveness analysis of the current methods used by IDFG to monitor mule deer abundance. The next research line is the development of a method for weighting different types of data included in the current IDFG population model. The development of a weighting method will 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 differences in data generation between GPS and VHF radio tracking devices and the impact of these differences 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 less risky methods, i.e. camera traps or driving transects, has the potential to reduce the frequency of winter aerial surveys thereby reducing cost and the risk to personnel. The overarching goal of this project will be to develop a tool for managers that simultaneously optimizes over cost and abundance estimate precision using information generated by the previous lines of research. The expected result of the optimization process is to produce a set of potential monitoring strategies that are tailored to specific budgets and management requirements. This optimization process is also expected to be flexible enough for application to other game and non-game species management scenarios.

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. Research pertaining to the development of a method for weighting data within the population model has diverged into 3 separate courses of research. These include estimating the influence that biases in ratio data have on estimates of abundance, how changes in the quality and quantity of different data types impact abundance estimates, and estimating the amount of information gained with changes in the cost of gathering various data types. Research on optimization that incorporates the results from the previous analyses will begin in April 2018. All aspects of the project are expected to be completed by December 2018.

Adaptive harvest management and estimation of recruitment for wolves in Montana

Obligated funding: $181,488

Student: **Allison Keever**

Degree: PhD Candidate

Advisor: Mike Mitchell

Project Duration: 2015 – 2020

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Sources: Montana Fish, Wildlife, and Parks
Montana Cooperative Wildlife Research Unit

Objectives

My objectives are to: 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; 2) 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; and 3) Conduct sensitivity analyses and propose an efficient monitoring regime to reduce uncertainty associated with making harvest decisions.

Progress and Status

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. 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.

Estimating cougar abundance with remote camera surveys

Obligated funding: $32,973

Student: **Kenneth Loonam**

Degree: MSc Candidate

Advisors: Hugh Robinson

Project Duration: 2017-2019

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Sources: Idaho Department of Fish and Game

Objectives

I am broadly interested in the community ecology of carnivores and their prey and its applications to the management and conservation of ecosystems. I have had the privilege of working on projects studying a broad array of animals including decapods on the Texas coast, reptiles and amphibians in Alabama, sage grouse in Utah, jaguars in Belize, and Mexican wolves in New Mexico. Currently, I am working with Idaho Fish and Game to measure their cougar populations with camera traps using time-to-event modelling.

Progress and Status

Cougar management relies on accurate estimates of abundance, but these estimates can be difficult to obtain for low density, cryptic animals. Current methods for measuring cougar populations range from high intensity efforts that are limited spatially by the availability of resources, such as mark saturation and genetic capture recapture, to a variety of indices that can be broadly applied but have limited accuracy. We are working with Idaho Fish and Game (IDFG) to adapt a method of estimating abundance using remote cameras and time to event modelling to cougars. Remote cameras can lower the costs of abundance monitoring, allowing accurate measurements to be made across broad spatial extents or in multiple locations. Once the time to event model is adapted, we will use camera data from all of IDFG's monitoring projects to build a predictive model of cougar density based on habitat and community characteristics.

Resource selection for nutrition and physical security by mule deer in northwest Montana

Obligated funding: $134,263

Student: **Collin Peterson**

Degree: MSc Candidate

Advisors: Mike Mitchell and Chad Bishop

Project Duration: 2017 - 2020

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Source: Montana Fish Wildlife and Parks
UM College of Forestry and Conservation

Objectives

Throughout the past 3 decades, mule deer (*Odocoileus hemionus*) populations in the Intermountain West have undergone unpredictable bouts of decline, largely due to habitat degradation and changing food availability. In the thickly forested ecosystems of Northwest Montana, public and scientific perception suggests that mule deer populations are declining or stabilizing below historic levels. However, mule deer movement patterns, resource selection behaviors, and the environmental factors driving those behaviors in this region are poorly understood. I aim to determine how mule deer select for nutritional resources and refuge from predators (physical security in the form of hiding cover), and how they make tradeoffs between food and security. I will be studying 3 mule deer populations in separate study areas with varying levels of food and cover availability, and will compare how broad-scale differences in resource availability influences selection behaviors and tradeoffs. Additionally, I will assess how resource selection patterns are influenced by migratory strategy in partially migratory populations. I will conduct this analysis using Resource Selection Functions (RSFs) at multiple spatial scales. My research will help indicate the factors limiting mule deer populations in a unique forested setting, and will broaden our understanding of how resource selection and tradeoffs by mule deer vary with environmental conditions.

Progress

I am working in tandem with Teagan Hayes on this project. Currently, we have fitted mule deer does with GPS radio collars in the Whitefish Range, the Fisher River/Salish Mountains, and the Rocky Mountain Front. Through intensive vegetation monitoring, we will determine how nutritional resources and cover varies across these deer populations' home ranges by measuring forage quantity and quality throughout a variety of landcover types and degrees of disturbance.

Carnivore Territoriality and Sociality: Optimal behavior for gray wolves in the Northern Rocky Mountains

Obligated funding: $181,488

Student: **Sarah Sells**

Degree: PhD Candidate

Advisor: Mike Mitchell

Project Duration: 2015 – 2020

UM Affiliation: Wildlife Biology Program
Montana Cooperative Wildlife Research Unit

Funding Sources: Montana Fish, Wildlife, and Parks
Montana Cooperative Wildlife Research Unit

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 3 was devoted to developing and evaluating territory models. I taught myself programming and completed complex coding for individual-based models in NetLogo. I presented preliminary results at 5 conferences. In addition, I focused on managing and troubleshooting GPS collars for this project, collecting and organizing data, and communicating with wolf specialists. I also assisted MFWP with collaring efforts. As of February 2018, MFWP field staff have successfully captured and collared 66 wolves in approximately 46 packs. These collars have yielded >26,000 locations of wolves. Additional capture efforts will continue through 2018. I will compare model predictions with these empirical data to identify territory and group size models with most support.

AWARDS AND RECOGNITIONS

Henderson, Charlie - Shikar Safari Club, Susan and John Monson Hunting Heritage Scholarship

Forshee, Shannon - NSF Graduate Research Fellowship ($46,000)

Hayes, Teagan

- International Research Experience for Students - Microbial Research in Greenland & Denmark, NSF & University of Montana, 2017 for travel and research
- Center for Natural Resources & Environmental Policy - Research Development, University of Montana travel award for travel to Shepherdstown, WV for the 2017 National Forum on Landscape Conservation

Martin, T.E. – Keynote Lecture – Ornithological Congress of the Americas – Iguazu, Argentina, 2017

Mitchell, Adam

- Les Pengelly Scholarship, University of Montana, 2017, ($2,500)
- Society for Integrative and Comparative Biology (SICB) student award ($109) for annual conference, January, 2018
- Carl and Camilla Reitman Scholarship ($2,500), Coquille, OR
- Wildlife Biology Program PoND travel award ($500) for travel to San Fransisco, CA for 2018 SICB conference

Mouton, James

- Toelle-Bekken Family Fund 2017 ($2,500), For travel and supplies to measure yolk hormones in Malaysian species.
- Drollinger-Dial Foundation Travel Grant 2017 ($990), Ecological Society of America Conference (taking place Aug 2017).
- NSF Doctoral Dissertation Improvement Grant ($13,000), For radio transmitters needed to measure survival rates of fledglings exposed to increase nest predation risk.
- MT Institute on Ecosystems Graduate Enhancement Award ($5,000), To employ a field technician and purchase supplies needed for measuring the concentration of yolk hormones.
- UMT Research and Creative Scholarship ($450), For airfare to visit the University of Arizona to conduct laboratory work analyzing yolk hormones.
- Drollinger-Dial Foundation Travel Grant 2016 ($1200), For airfare to Malaysia to conduct fieldwork.
- 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 (46,000)

Sells, Sarah - W.A. Franke Wildlife Biology Graduate Fellowship, University of Montana ($15,000)

PRESENTATIONS AND POSTERS

Barker, K. Understanding variation in migratory behavior of elk across Montana. March 2018. MPG Ranch Annual Conference, Missoula, MT

Barker, K. Wildlife biology: The graduate student perspective. October 2017. *UM Student Chapter of the Wildlife Society Meeting*, Missoula, MT

Barker, K. Summer forage quality differs for migrants and residents in a partially migratory population of elk. September 2017. The Wildlife Society National Meeting, Albuquerque, NM

Barker, K. Nutritional consequences of varying elk migratory behaviors. May 2017. Western Association of Fish & Wildlife Agencies Deer and Elk Workshop, Sun Valley, ID

Bassing, S., D. Ausband**, M. Mitchel**l, P. Lukacs, M. Schwartz, G. Hale, L. Waits.September 2017. Variable effects of harvest within and across wolf packs in the Rocky Mountains. The Wildlife Society Annual Conference. Albuquerque, NM.

Bassing, S., D. Ausband**, M. Mitchell**, M. Schwartz, L. Waits. March 2017. Immigration as a compensatory mechanism to offset harvest mortality in harvested wolf populations. The Wildlife Society Montana State Chapter Annual Meeting. Helena, MT.

Bassing, S., D. Ausband, **M. Mitchell**, M, Schwartz, L. Waits. February 2017. Immigration as a compensatory mechanism to offset harvest mortality in harvested wolf populations. The American Fisheries Society and The Wildlife Society Idaho Chapters Joint Meeting. Boise, ID.

Blake, W. - Society for Conservation Biology Symposium. Oral presentation: "Nesting Biology Of The Lewis's Woodpecker In The Bitterroot Valley, MT."

Blake, W. - MPG Annual Conference and MTTWS Conference. Oral Presentation: "Lewis's Woodpecker Nest Success And Nest-Site Selection In The Bitterroot Valley, MT."

Blake, W. - Thesis Defense. Oral Defense: "Lewis's Woodpecker Nest Success And Habitat Selection In Riparian Versus Burned Conifer Habitats

Forshee, S. - Lambing Habitat and Juvenile Recruitment in Sierra Nevada Bighorn Sheep, 24th Annual TWS Conference, Albuquerque, NM September 2017.

Hayes, T. – Clover trapping mule deer in Northwest Montana: Lessons learned in a unique environment. Presented at The Wildlife Society Conference, Butte, Montana.

Henderson, C. R. 2017. Data Weighting for Integrated Population Models. Biennial Conference, 12th Western States and Provinces Deer and Elk Workshop, Sun Valley, Idaho.

Keever, A. C., M. S. Mitchell, K. M. Podruzny, A. D. Luis, and J. T. Peterson – Estimating recruitment of wolves with limited data. The Wildlife Society Annual Conference, Albuquerque, NM, September 23-27, 2017.

Keever, A.C., **M. S. Mitchell,** K. M. Podruzny, A. D. Luis, and J. T. Peterson – Estimating recruitment of wolves with limited data. Poster Session. Annual Meeting of the American Society of Mammalogists, Moscow, ID, June 20-24, 2017.

Mitchell, A.E. Patterns and Causes of Tropical Montane Life Histories: An Observational and Experimental Study Using Birds. Society for Integrative and Comparative Biology (SICB), January 2018, San Francisco, CA. Oral.

Mitchell, M. S. 2016. 15 years after Ten Years Since Reliable Knowledge: why are we still talking about this? Symposium on integration of research and management, Annual Meeting, The Wildlife Society.

Peterson, C. 2018. Trapping mule Deer in NW Montana to study habitat and behavior. Annual Meeting, The Wildlife Society.

SCIENTIFIC PAPERS AND REPORTS

Henderson, C.R., M. S. Mitchell, W. L. Myers, P. M. Lukacs, and G. P. Nelson. 2018. Attributes of seasonal home range influence choice of migratory strategy in white-tailed deer. Journal of Mammalogy, 99: 89–96.

Sells, S. N., S. B. Bassing, K. J. Barker, S. C. Forshee, A. C. Keever, J. W. Goerz, and M. S. Mitchell. 2018. Increased scientific rigor will improve reliability of research and effectiveness of management. Journal of Wildlife Management 82:485-494.

Keever, A. C., C. P. McGowan, S. S. Ditchkoff, P. K. Acker, J. B. Grand, and C. H. Newbolt. 2017. Efficacy of N-mixture models for surveying and monitoring white-tailed deer populations. Mammal Research 62:413-422.

Mitchell, M. S., H. Cooley, J. A. Gude, J. Kolbe, J. J. Nowak, K. M. Proffitt, **S. N. Sells**, and M. Thompson. 2018. Distinguishing values from science in decision making: setting harvest quotas for mountain lions in western Montana . Wildlife Society Bulletin DOI:10.1002/wsb.861.

Lukacs, P. M., **M. S. Mitchell**, M. Hebblewhite, B. K. Johnson, H. Johnson, M. Kauffman, K. Proffitt, P. Zager, J. Brodie, K. Hersey, A. A. Holland, M. Hurley, S. McCorquodale, A. Middleton, M. Nordhagen, J. J. Nowak, D. P. Walsh, and P. J. White. 2018. Factors influencing elk recruitment across ecotypes in the western United States. Journal of Wildlife Management DOI: 10.1002/jwmg.21438

Sells, S. N., S. B. Bassing, K. J. Barker, S. C. Forshee, A. C. Keever, J. W. Goerz, and **M. S. Mitchell**. 2018. Increased scientific rigor will improve reliability of research and effectiveness of management. Journal of Wildlife Management 82:485-494. DOI: 10.1002/jwmg.21413.

Mitchell, M. S., S. N. Sells, S. B. Bassing, K. J. Barker, S. C. Forshee, A. C. Keever, and **J. W. Goerz**. 2018. Explicitly reporting tests of hypotheses improves communication of science. Journal of Wildlife Management. DOI: 10.1002/jwmg.21461.

Ausband, D.E., M.S. Mitchell, and L.P. Waits. 2017. Effects of breeder turnover and harvest on group composition and recruitment in a social carnivore. Journal of Animal Ecology. DOI: 10.1111/1365-2656.12707.

Ausband, D. E., M. S. Mitchell, C. R. Stansbury, J. L. Stenglein, and L. P. Waits. 2017. Harvest and group effects on pup survival in a cooperative breeder. Proceedings of the Royal Society B 284: 20170580.

LaManna, J. A., and **T. E. Martin**. 2017. Logging impacts on avian species richness and composition differ across latitudes relative to foraging and breeding habitat preferences. Biological Reviews 92: 1657-1674.

Boyce, A. J., and **T. E. Martin**. 2017. Contrasting latitudinal patterns of life-history divergence in two genera of new world thrushes (Turdinae). Journal of Avian Biology 48: 581-590.

Martin, T. E., A**. J. Boyce, K. Fierro-Calderón, A. E. Mitchell, C. E. Armstad, J. C. Mouton**, and E. E. Bin Soudi. 2017. Do enclosed nests provide greater thermal than nest predation benefits compared with open nests across latitudes? Functional Ecology 31: 1231-1240.

Mitchell, A. E., F. Tuh, and **T. E. Martin**. 2017. Breeding biology of an endemic Bornean Turdid, the Fruithunter (Chlamydochaera jefferyi), and life history comparisons with Turdus species of the world. Wilson Journal of Ornithology 129: 36-45.

Ton, R., and **T. E. Martin**. 2017. Proximate effects of temperature versus evolved intrinsic constraints for embryonic development times among temperate and tropical songbirds. Scientific Reports **7**, Article number 895, doi:10.1038/s41598-017-00885-3.

LaManna, J. A., and **T. E. Martin**. 2017. Seasonal fecundity and costs to λ are more strongly affected by direct than indirect predation effects across species**.** Ecology 98: 1829–1838.

Auer, S. K., and **T. E. Martin**. 2017. Parental care mitigates carry-over effects of poor early conditions on offspring growth. Behavioral Ecology 28: 1176-1182.

Martin, T. E., M. M. Riordan, R. Repin, **J. C. Mouton**, and **W. M. Blake**. 2017. Apparent annual survival estimates of tropical songbirds better reflect life history variation when based on intensive field methods. Global Ecology and Biogeography 26:1386–1397.

Martin, T. E., R. Ton, and **J. C. Oteyza**. 2018. Adaptive influence of extrinsic and intrinsic factors on variation of incubation periods among tropical and temperate passerines**.** Auk 135: 101-113.

Kaiser, S., **T. E. Martin, J. C. Oteyza, C. E. Armstad**, and R. C. Fleischer. 2018. Direct fitness benefits and kinship of social foraging groups in an Old World tropical babbler. Behavioral Ecology, in press.

Mouton, J. C., and **T. E. Martin**. 2018. Effects of nest predation risk and nest site competition on interspecific nesting associations and their fitness consequences among cavity nesting birds. American Naturalist, in press.