USGS WISCONSIN COOPERATIVE WILDLIFE RESEARCH UNIT

FISCAL YEAR 2021

(October 1, 2020-September 30, 2021)



ANNUAL REPORT

An African elephant dust bathing in Etosha National Park, Namibia. Research within the coop assesses how host behavior affects the risk of anthrax transmission at local and landscape scales. A coop-associated MS student in Namibia, Hendrina Joel, completed her MS degree studying how elephant carcasses alter the local environment and which host species are at risk of exposure to this soil-borne pathogen at elephant carcass sites.

USGS WISCONSIN COOPERATIVE WILDLIFE RESEARCH UNIT

Room 204 Russell Labs
1630 Linden Drive
University of Wisconsin-Madison
Madison, WI 53706
Phone: 608/263-4519
Fax: 608/262-9922

COOPERATING AGENCIES:

U.S. Geological Survey
University of Wisconsin
Wisconsin Department of Natural Resources
Wildlife Management Institute
U.S. Fish and Wildlife Service

October 1, 2020-September 30, 2021

MISSION STATEMENT
OF THE
WISCONSIN COOPERATIVE WILDLIFE RESEARCH UNIT

The Cooperative Units Program of the U.S. Geological Survey has been an integral part of the Department of Wildlife Ecology at the University of Wisconsin-Madison since 1972. With direction from the Coordinating Committee, the Unit's research has been conducted on a wide variety of wildlife topics in cooperation with federal agencies, the University, the Wisconsin Department of Natural Resources, and various private organizations. The Unit's research spans the range from problem-oriented projects designed to provide cooperators with useful information on resource issues to basic scientific discovery to move the state of knowledge forward.

Work has been carried out in both terrestrial and aquatic environments. Major areas of present research include the effects of agriculture on wildlife populations, wildlife disease issues, and global climate change. The Unit, along with cooperating scientists, has the expertise to investigate environmental problems from the cellular to the landscape level. Current Unit personnel have research interests that include population ecology, community ecology, disease ecology, and landscape ecology. Future project selection is primarily dependent on the needs of the cooperators and the availability of funds.

PERSONNEL AND COOPERATORS

Coordinating Committee

Michael W. Tome	Eastern Region Supervisor, Cooperative Research Units U.S. Geological Survey, Reston, VA
Eric Kruger	Chair, Department of Forest and Wildlife Ecology University of Wisconsin-Madison
Scott Hull (Office of Applied Science) and Tami Ryan (Bureau of Wildlife Management)	Representatives, Wisconsin Department of Natural Resources, Madison, WI
William Moritz	Representative, Wildlife Management Institute, Johnstown, OH
Bradly Potter	Representative, U.S. Fish and Wildlife Service, East Lansing, MI

Unit Staff

Christine Ribic	Unit Leader, Wildlife
Wendy Turner	Assistant Unit Leader, Wildlife
Susan Laufenberg/Christine Terrien	Administrative Assistant, University of Wisconsin-Madison

Cooperating Scientists

Dr. Bruce Klein	Professor, School of Medicine and Public Health, University of Wisconsin-Madison
Dr. Jorge Osorio	Assistant Professor, School of Veterinary Medicine University of Wisconsin-Madison
Dr. Joel Pederson	Associate Professor, Department of Soil Science, University of Wisconsin-Madison
Dr. Zach Peery	Associate Professor, Department of Forest and Wildlife Ecology, University of Wisconsin-Madison
Dr. Ben Zuckerberg	Associate Professor, Department of Forest and Wildlife Ecology, University of Wisconsin-Madison

ACADEMIC PERSONNEL

Post-doctoral Fellows

Scott Nelson (Chris Ribic) (co-mentored by B. Zuckerberg). Scott will be working on climate change adaptation strategies for grassland birds in the Central Flyway. This work is in collaboration with USFWS Habitat and Evaluation team in Bismarck, ND. The purpose of the project is to conduct a comprehensive synthesis of scientific information on how climate change is interacting with other drivers of change (e.g., land management practices) to affect grassland habitats and grassland-dependent migratory birds within the Central Flyway.

Laura Nunes (Chris Ribic) (co-mentored by B. Zuckerberg). Laura will be working on estimating Wisconsin's grassland bird populations as well as population estimates for the Upper Mississippi River and Great Lakes Joint Venture region.

Ellen Brandell (Wendy Turner). Ellen is researching the effects of harvest on chronic wasting disease dynamics in white-tailed deer in the midwestern US. The goal of this project is to leverage historical information maintained by state agencies to evaluate impacts of CWD management activities on population and disease dynamics, and to establish a framework that will improve coordination and information exchange. This framework will serve as the basis for the creation of an adaptive management strategy for CWD mitigation among Midwestern, state and federal, wildlife management agencies.

Marie Gilbertson (Wendy Turner). Marie is studying deer movement ecology and chronic wasting disease transmission in south-west Wisconsin. Her project will investigate the impact of CWD infection on deer movement behavior, and the reverse, the impact of deer movement behaviors and contacts on CWD spread. Outcomes will include a better understanding of deer ecology, demography and population dynamics as relates to CWD transmission.

Kristyna Rysava (Wendy Turner). Isty is characterising the evolutionary context of anthrax virulence emergence from the *Bacillus cereus* sensu lato group in dynamical environments, as part of a project investigating ecological and evolutionary drivers of anthrax outbreak variability among ecosystems.

Academic Staff

Alison Ketz (Chris Ribic/Wendy Turner) (Assistant Scientist). Alison is working in collaboration with the WDNR and the USGS National Wildlife Health Center to understand deer population dynamics in the CWD-endemic region of southwestern Wisconsin.

Albert Beck (Chris Ribic) (Research Specialist). Albert is working in collaboration with the US Forest Service (Rhinelander, WI) to archive long-term datasets from USFS natural research areas and experimental forests. The purpose of the project is to document previously collected data and make it available to the public as part of the USFS Research Data Archive.

Erica Diehl (Chris Ribic) (Research Specialist). Erica is working in collaboration with the US Forest Service archive long-term datasets from USFS natural research areas and experimental forests. The purpose of the project is to document previously collected data and make it available to the public as part of the USFS Research Data Archive.

Graduate Students

Jacy Bernath-Plasted (Chris Ribic) (Ph.D., Wildlife, co-advised by B. Zuckerberg). Jacy will be working on a project to quantify microclimates within grassland patches and evaluate their importance on the nesting biology of grassland birds.

Yen-Hua Huang (Wendy Turner) (Ph.D., Wildlife). Yen-Hua is studying how environmental variability, animal movement ecology and foraging behavior affect anthrax dynamics in herbivorous wildlife in southern Africa.

Zoe Barandongo (Wendy Turner) (Ph.D., Wildlife). Zoe is studying microbiological, molecular and genetic factors that may affect the persistence, infectivity and virulence of *Bacillus anthracis* strains in southern Africa, with a focus on bacteriophages in soils and bacterial genomes.

Amélie Dolfi (Wendy Turner) (Ph.D., Wildlife). Amélie is developing models of anthrax transmission dynamics. She uses agent-based models to investigate the interactions of *Bacillus anthracis* with its herbivorous hosts comparing two ecosystems in southern Africa that vary in outbreak dynamics.

Kimberlie Vera (Wendy Turner) (Ph.D., Wildlife). Kimberlie is investigating anthrax transmission dynamics in a guild of herbivorous mammals, using camera trapping and quantitative ecology methods to investigate how seasonal changes in host density affect anthrax transmission dynamics comparing two ecosystems in southern Africa.

Heather Inzalaco (Wendy Turner) (Ph.D., Comparative Biomedical Sciences). Heather is studying the indirect transmission pathway for chronic wasting disease, looking at prion accumulation in soils at carcass sites, supplemental feeding/bait sites, natural areas of deer aggregation and in ticks.

Samantha Hoff (Wendy Turner) (Ph.D., Ecology and Evolutionary Biology, University at Albany, co-advised by Ing-Nang Wang). Samantha is studying the ecology of the northern long-eared bats, a species experiencing drastic population declines due to the fungal disease white-nose syndrome. She is investigating mechanisms supporting persistence of coastal populations despite infection, including factors influencing occupancy, hibernation behavior, and population genetics.

Matt Hunsaker (Wendy Turner) (M.S., Wildlife). Matt is investigating how movement patterns, activity patterns, and mate search strategies of male white-tailed deer change over the breeding season, and how these are affected by the timing of hunting season.

Casey Pendergast (Wendy Turner) (M.S., Ecology and Evolutionary Biology, University at Albany, co-advised by Ing-Nang Wang). Casey is studying foraging activity and diet of coastal Northern long eared bat populations during the hibernation period.

Sunday Ochai (Wendy Turner) (M.S., Veterinary Tropical Diseases, University of Pretoria, co-advised by Henriette van Heerden). Sunday is studying host immunity against *Bacillus anthracis* across ecosystems and gradients of anthrax incidence in southern Africa, and how haemoparasite coinfections affect host immune response.

Hendrina Joel (Wendy Turner) (M.S., Biology, University of Namibia, co-advised by John Mfune). Hendrina is studying the effect of large body size on anthrax transmission dynamics. She is examining how large carcasses alter the environment, *Bacillus anthracis* spore concentrations in soil, and animal behavioral contacts with carcass remains.

Kamini Govender (Wendy Turner) (M.S., Veterinary Science, University of Pretoria, co-advised by Henriette van Heerden). Kamini is studying *Bacillus anthracis* spore persistence among pathogen strains and in different soil types from Kruger and Etosha National Parks in southern Africa.

Prudent Mokgokong (Wendy Turner) (M.S., Veterinary Science, University of Pretoria, co-advised by Henriette van Heerden). Prudent is conducting whole genome analysis of virulence factors in isolates of *Bacillus anthracis* from Kruger National Park, South Africa.

NEW AND ONGOING PROJECTS

CWD-prion accumulation dynamics at bait sites for free-ranging deer

Investigator: *Wendy Turner, USGS, University of Wisconsin-Madison*
Funding: *USDA APHIS Wildlife Services, Wild Cervid Chronic Wasting Disease Management and Response Activities*
Expected Completion: *August 31, 2022*

Attracting deer with food or minerals to specific locations for the purpose of sport hunting, observation, or tagging is a common practice. CWD-infected deer shed prions into the environment, raising the possibility that bait sites in CWD zones may become "hot spots" of prion deposition. Regulation of deer baiting is inconsistent across jurisdictions, and no empirical data have been reported regarding the impact of deer baiting on prion deposition onto the landscape. The project directly addresses this critical knowledge gap and provides tangible data that can be used to inform regulatory decision making. This project quantifies the extent of prion deposition at former and active bait sites within CWD zones in southern Wisconsin and Tennessee. This will provide insight into environmental transmission risk and for future decisions regarding management regulations and recommendations for deer baiting.

Influence of chronic wasting disease and predators on deer survival and population dynamics in southwest Wisconsin

Investigator: *Wendy Turner, USGS, University of Wisconsin-Madison*
Funding: *Wisconsin Department of Natural Resources*
Expected Completion: *June 30, 2024*

Chronic wasting disease (CWD) was discovered in Wisconsin white-tailed deer harvested in fall 2001. Since then, CWD prevalence has increased in all sex and age classes and increased in spatial extent. For example, in the highest-prevalence areas, prevalence exceeds 30 percent in adult males and 15 percent in adult females. It is uncertain what impact CWD is currently having on deer populations and what impact it may have as prevalence increases. Not knowing the contribution of CWD, predators, habitat change, or other potential factors makes it difficult to develop an effective management strategy. A better understanding of factors affecting survival and population growth would enable more informed deer population management, by facilitating antlerless quota adjustment in the face of changes in mortality rates from other sources. The goal of this research is to provide technical information, scientific guidance, and related assistance to WDNR scientists and policy makers regarding deer population dynamics in the CWD-endemic region of southwestern Wisconsin. This project is being done in collaboration with Michael Samuel (Senior Scientist University of Wisconsin-Madison), Daniel Storm (Wisconsin Department of Natural Resources, Rhinelander) and Dan Walsh and Robin Russell (US Geological Survey National Wildlife Health Center).

Movement of deer in southwest Wisconsin and its role in CWD spread

Investigator: *Wendy Turner, USGS, University of Wisconsin-Madison*
Funding: *Wisconsin Department of Natural Resources*
Expected Completion: *June 30, 2024*

This project focuses on the spatiotemporal context of how landscape heterogeneity, seasonality, and deer movement behavior (individually and in aggregate) affect chronic wasting disease (CWD) spread. The goal is to better understand the mechanisms of CWD spread and the causes of the observed directional (rather than uniform) CWD diffusion and growth across the landscape. The project will investigate the impact of CWD infection on deer movement behavior, and the reverse, the impact of deer movement behaviors and contacts on CWD spread. Understanding the times and places where deer are most likely to congregate and the weather, landscape, phenological and demographic factors that alter movement patterns and direct and indirect contact rates will help predict CWD dynamics and may inform management activities. Further, better understanding how sex- and age-specific movements and habitat selection vary according to landscape composition and configuration, weather, plant and crop phenology is of interest to ecologists and the general public and may help managers understand variation in deer population dynamics.

Looking backwards to know where to go: leveraging historical data to guide CWD management

Investigator: *Christine A. Ribic and Wendy Turner, USGS, University of Wisconsin-Madison and Dan Walsh, USGS, National Wildlife Health Center*
Funding: *USGS Emerging Diseases*
Expected Completion: *August 31, 2023*

Management of chronic wasting disease (CWD) is one of the most significant challenges facing many wildlife agencies in North America. One of the difficulties in managing this disease is that CWD-affected species range across jurisdictional boundaries; yet currently there is little communication or coordination among management agencies regarding CWD response. Unified efforts to evaluate the effectiveness of the suite of management actions that agencies have applied for disease control are lacking. This project is aimed at filling these gaps by leveraging historical information maintained by state agencies to evaluate impacts of CWD management activities on population and disease dynamics and establishing a framework that will improve coordination and information exchange. This framework will serve as the basis for the creation of an adaptive management strategy for CWD mitigation among Midwestern, state and federal, wildlife management agencies. The objectives of this project are to investigate the impacts of deer harvest regulations on the realized harvest within and between states in the Midwest, tie the analytical results to CWD dynamics to determine the harvest regulations most likely to have the desired outcome for managing CWD, and plan an adaptive management workshop for participating state agencies to effectively use the results of the modeling effort regarding harvest strategies.

Transmission and Evolution of a Persistent Pathogen: Anthrax Infection Dynamics Comparing Two Natural Systems

Investigators: *Wendy C. Turner, USGS, University of Wisconsin-Madison and Pauline L. Kamath, University of Maine, Orono*

Funding: *National Science Foundation, Division of Environmental Biology, Ecology and Evolution of Infectious Diseases Program*
Expected Completion: *July 31, 2022*

Anthrax is a globally distributed disease of wildlife, livestock, and humans. Successful prediction of and response to outbreaks of anthrax is limited by a lack of understanding of the geographic differences in the ecology of the pathogen as well as the pattern of disease outbreaks. This project investigates the roles of host, pathogen, and environment to understand how the pathogen-host interaction evolves and contributes to the differences in anthrax occurrence between two study areas: Etosha National Park, Namibia, and Kruger National Park, South Africa. The project builds on detailed records of disease and population dynamics in each park as well as archived pathogen samples and new data collection and analyses and mathematical modeling to understand these different dynamics. We are linking variability in *B. anthracis* genomes to phenotype (i.e., pathogen survival in the environment, virulence to hosts, and transmission across host and geographic range). We are identifying host immunological signatures of infection and genes under pathogen-mediated selection in four species: plains zebra (*Equus quagga*), greater kudu (*Tragelaphus strepsiceros*), blue wildebeest (*Connochaetes taurinus*) and common impala (*Aepyceros melampus*). We are building landscape-level models of epidemiology and population dynamics incorporating host movement, transmission routes, pathogen virulence, and host resistance. Finally, we will develop models predicting anthrax transmission dynamics across ecosystems. In a broader sense, this research will facilitate the development of predictive tools to better manage public health and related policies for complex, multi-host zoonotic diseases such as anthrax.

A Retrospective Analysis of California Spotted Owl Territory Occupancy in Southern California

Investigator: *M. Zachariah Peery, Department of Forest and Wildlife Ecology, University of Wisconsin-Madison*
Funding: *U.S. Fish and Wildlife Service*
Expected Completion: *December 31, 2022*

Spotted owls reside at the epicenter of forest management debates in the western US. The current status of the southern California spotted owl population is not well understood following the end of our demographic study in the San Bernardino Mountains in 1998. However, semi-regular occupancy surveys have been conducted since that time that include most, if not all, of the territories surveyed as part of the original demography study. This project will analyze spotted owl occupancy data, spanning a 32-year period (1988 to 2019), to address determine the current territory occupancy rate of California spotted owls in the San Bernardino Mountains, the trend in the territory occupancy rate from 1998 to 2019, and how territory occupancy has been affected by factors such as habitat loss due to wildfire and fuels treatments.

A bat skin model to identify therapeutic approaches that enhance fungal recognition and augment innate immune response to white-nose syndrome

Investigators: *Bruce Klein, School of Veterinary Medicine, School of Medicine and Public Health, University of Wisconsin-Madison*
Funding: *U.S. Geological Survey (National Wildlife Health Center)*
Completion: *November 30, 2022*

The introduced fungus *Pseudogymnoascus destructans* (Pd) infects the skin of little brown bats (*Myotis lucifugus*) of North America, killing them by the millions due to WNS1. Keratinocytes represent 95% of the epidermal cells in skin and are the first barrier against microbes in bats, secreting antifungal peptides and cytokines, recruiting leukocytes, and initiating adaptive immunity 2–5. The goal of this project is to define how keratinocytes detect Pd compared to a non-pathogenic cutaneous fungus *Trichophyton rendellii* (Tr) 6 in order to develop a method of topical immunization against WNS. We hypothesize that keratinocytes detect the two fungi differently, driving distinct innate immune responses that are, in part, responsible for different infection outcomes. During hibernation bats become torpid and immune quiescent with periodic arousal and immune activation 7–9. Despite such immune restriction, hibernating little brown bats do clear infection by native, Pd-like, ascomycete fungi such as Tr 6. Although innate immune response is upregulated in the skin of WNS bats, this response is insufficient to halt Pd invasion of skin. There are remarkably similar paradigms involving human fungal infections. In chromoblastomycosis, a chronic, severe skin fungal infection caused by a Pd-like ascomycete *Fonsecaea pedrosoi*, innate immune recognition by a pattern recognition receptor (PRR) called Mincle is weak and insufficient to clear the fungus10. Yet, engagement of a second PRR, TLR7, together with Mincle clears the fungus. Chromoblastomycosis can thus be treated successfully by cutaneous application of Imiquimod® cream, which promotes Mincle and TLR7 co-receptor engagement and resolution of infection10,11. Based on this paradigm, we propose that understanding how keratinocytes recognize and respond to Pd (as compared to non-pathogenic Tr) will enable a rational basis for developing a preventive strategy to bolster innate immunity in hibernating bats, enabling them to resist infection with Pd. We have 3 specific aims: 1) Identify the PRR(s) that recognize Pd using reporter cells and validate results with bat keratinocytes; 2) Compare the innate response of keratinocytes on interaction to Pd and Tr; 3) Test commercial PRR ligands that trigger, together with Pd, an augmented innate response in bat keratinocytes (in vitro) and on little brown bats (in vivo).

Finding safe haven in a warming world: Microclimatic buffering in grasslands and its influence on threatened birds

Investigator: *Benjamin Zuckerberg, University of Wisconsin-Madison, and Christine A. Ribic, USGS, University of Wisconsin-Madison*
Funding: *USDA Hatch Formula Funds*
Expected Completion: *September 30, 2023*

Many species and ecosystems are vulnerable to a rapidly changing climate, and the most effective route for reducing this vulnerability is through climate-change adaptation. A common adaptation strategy is to increase the resistance of ecosystems by maintaining or creating climate change refugia. In modern conservation, the concept of refugia applies to areas characterized by local climatic conditions (i.e., microclimates) that persist despite widespread changes at regional and global scales. Landscape features, such as topographic complexity,

promote a diversity of cool and warm microclimates considered important for “buffering” refugial populations during periods of rapid climate change and even reduce extinction risk for climate-sensitive species. If microclimate buffering reduces the vulnerability of species from the negative consequences of climate change, then identifying and managing the features that promote microclimate diversity is a critical complement of conserving threatened ecosystems. Prairies were once widespread across North America (Samson et al. 1998), but are now one of the most endangered and least protected ecosystems in the world. Agriculture and residential development have reduced once extensive prairies into a patchwork of “surrogate” grasslands consisting of hayfields and grazing pastures. Concurrent with habitat loss, rising temperatures and shifting precipitation patterns are disproportionately affecting temperate grasslands. Many temperate grasslands are in low-lying regions, and as a result, the pace of modern climate change has been fastest in open habitats compared to any other terrestrial biome in the world. The degradation of grassland ecosystems has been detrimental to its fauna, including many grassland birds that are declining faster than any other bird guild across North America (Sauer et al. 2012). In response to the widespread population declines of many grassland birds, conservation agencies employ a number of strategies such as maintaining large grasslands, land acquisition, and promoting restoration practices, but little work has addressed the importance of climate-change adaptation in the conservation of grassland birds. Given the ongoing loss of grassland habitat, adaptation strategies will likely need to focus on building the resilience of existing grasslands for maintaining current and future biodiversity in a warming world. Herein, we propose a novel, multi-scaled quantification of microclimates within grassland fragments and evaluate their importance on the nesting biology of declining grassland bird populations. By exploring the drivers of microclimates in remnant grasslands, we offer a unique empirical evaluation of how microclimatic buffering influences the demography and distribution of grassland-dependent species.

Estimating grassland bird populations to inform landscape-level conservation in Wisconsin

Investigator: *Benjamin Zuckerberg, University of Wisconsin-Madison, and Christine A. Ribic, USGS, University of Wisconsin-Madison*
Funding: *U.S. Fish and Wildlife Service*
Expected Completion: *April 3, 2023*

A primary goal of the Upper Mississippi River and Great Lakes Joint Venture (UMRGL JV) is to “strive for sustainable populations of all birds through regionally coordinated conservation actions based on the best (or state-of-the-art) scientific information and techniques available." To achieve this goal, accurate and unbiased bird population estimates are needed. Flawed inferences about population status can waste limited resources or prevent managers from recognizing when populations are vulnerable. Thus, the need for robust population estimates is apparent. The goal of this project is to provide an assessment of Partners-In-Flight (PIF) population estimates in comparison to those derived from Wisconsin’s 2nd BBA point-count project, and to integrate Breeding Bird Atlas (BBA) and Breeding Bird Survey (BBS) data for analysis of Wisconsin’s grasslands as well as to predict population estimates to the entire UMRGL JV region. We will use Wisconsin’s BBA point-count data to build species-specific hierarchical models that incorporate habitat and detection covariates to derive population

estimates for 20 species that vary in their abundance and breeding habitat and compare PIF and our BBA derived estimates for all focal species, construct a shared model that integrates BBA and BBS data and compares those estimates to both "single" (BBS only and BBA only) data estimates, demonstrate the applicability of our shared model to determine the importance of three focal grassland landscapes in Wisconsin for two "umbrella" grassland species, and estimate population size for the 20 species across the UMRGL region using BBA data from three states (MN, OH, WI) that have at least two years of BBA point-count data, and BBS data from all states within the UMRGL JV region.

Understanding the Importance of the Landscape Scale for Wildlife Management in the Chequamegon-Nicolet National Forest and Developing Best Practices for Archiving Research Data

Investigators: *Christine A. Ribic, USGS, University of Wisconsin-Madison,*
Funding: *US Forest Service*
Expected Completion: *June 30, 2023*

We are working collaboratively with the US Forest Service Northern Research Station to (1) evaluate two long-term projects: amphibian use of ephemeral ponds and wetlands within forested systems and beaver colony activity along trout streams and (2) investigate archiving and presentation of data sets used for analysis and high impact data collections. For the long-term projects, we will evaluate the datasets and determine additional environmental and spatial variables required to address management concerns. Once evaluation is completed, we will retrieve identified environmental (e.g., water quality, climate data) and spatial (e.g., surrounding land cover/use of surrounding landscape) data and incorporate all data into a GIS. We will calculate landscape metrics identified in the conceptual model and analyze both data sets. Other areas of research of interest to the Forest will also be developed, such as Kirtland's Warbler management and the use of fire to restore pine barrens ecosystems.

Besides the data used in the analysis, high impact USFS data collections will be archived. We will work with the US Forest Service to develop protocols and standards for archiving research data collected by the US Forest Service Research & Development branch. The primary focus of this work is on historical data collected on the Experimental Forest System, with additional sub-projects coming from any of the Research Stations or the International Institute of Tropical Forestry. We propose to process the historical record of at least seven Experimental Forests, and identify at least 15 data sets for archiving. Formal metadata will be created to document each data set, along with other descriptive material as appropriate for the particular data set. As appropriate, we will also engage in the administrative deposit activities associated with an OAIS-compliant data repository.

Strategies for reducing the vulnerability of grassland birds to climate change within the Central Flyway

Investigator: *Benjamin Zuckerberg, University of Wisconsin-Madison, and Christine A. Ribic, USGS, University of Wisconsin-Madison*
Funding: *USGS National Climate Adaptation Science Center*
Expected Completion: *August 31, 2022*

Prairies were once widespread across North America, but are now one of the most endangered and least protected ecosystems in the world. Agriculture and residential development have reduced once extensive prairies into a patchwork of remnant prairies and "surrogate" grasslands (e.g., hayfields, planted pastures). Concurrent with habitat loss, rising temperatures and shifting precipitation patterns are disproportionately affecting temperate grasslands. The degradation of grassland ecosystems has been detrimental to its fauna, including many grassland birds that are declining faster than any other bird guild across North America. In response to the widespread population declines of many grassland birds, conservation agencies employ a number of strategies such as maintaining large grasslands, funding land acquisition, and promoting prairie restoration, but little work has addressed the importance of climate-change adaptation in the conservation of grassland birds. To incorporate climate-change adaptation into grassland conservation, we will conduct a synthesis of climate change vulnerability for grassland ecosystems and grassland-dependent birds within the Central Flyway. Our goal is to produce a synthesis of strategies for grassland managers interested in developing climate adaptation plans. In doing so, we will i) organize a steering committee to identify current strategies in grassland management and priority grassland birds of conservation concern; ii) conduct a literature review and survey of our steering committee to describe the state of scientific knowledge on climate change impacts on grassland habitats and grassland-dependent birds; and iii) organize a meeting to produce a scientific review of current and future adaptation strategies for the conservation of grassland ecosystems and grassland-dependent birds.

PROJECTS COMPLETED THIS YEAR

Further development and testing of vaccine candidates against white nose syndrome in bats

Investigator: *Jorge E. Osorio, School of Veterinary Medicine, University of Wisconsin-Madison*
Funding: *U.S. Geological Survey (National Wildlife Health Center)*
Completed Date: *August 31, 2021*

Since its discovery in the US in 2006, white-nose syndrome (WNS), caused by the fungus *Pseudogymnoascus destructans* (Pd), has killed an estimated 7 million bats, causing significant population declines in numerous bat species, including the little brown bat. Several recent studies conducted by our research team have provided proof-of-concept for oral delivery of vaccine antigens to bats and several vaccine candidates that could be used to protect bats from WNS. Our research team has identified and targeted two potentially protective Pd antigens. One is calnexin, a fungal antigen that is highly conserved among Ascomycete fungi, including Pd. It resides on the endoplasmic reticulum of fungal cells and is displayed on the fungal surface. Another potential vaccine candidate is a 27.9 kDa subtilisin-like serine protease, the most heavily secreted protein by Pd, which may be involved in fungal invasion of wing tissue. We propose to further develop and evaluate these potential vaccine candidates and methods for delivering oral vaccines to bats in both field and laboratory settings.

Identifying Important Forage fish for Marbled Murrelets in Washington with High-throughput Sequencing

Investigator: *M. Zachariah Peery, Department of Forest and Wildlife Ecology, University of Wisconsin-Madison*
Funding: *U.S. Fish and Wildlife Service*
Completed Date: *August 30, 2021*

Marbled murrelets are listed as "threatened" under the US Endangered Species Act due to the loss and fragmentation of their old-forest nesting habitat, and nest predation from syanthropic species. Understanding how changes in the marine environment threaten marbled murrelets and their foraging resources is challenged by a lack of basic dietary information. Dietary information for murrelets is scarce because of the species' secretive inland nesting habits, which make monitoring prey delivered to nests nearly impossible. New next-generation-sequencing (NGS) technologies provide a promising tool for characterizing marbled murrelet diet at the species level. NGS methods allow for the sequencing of massive amounts of prey DNA fragments collected from predator fecal material without very time consuming and expensive cellular cloning procedures. Forage fish and marine invertebrate trawls currently being conducted by the Washington Department of Fish and Wildlife, and marbled murrelet surveys conducted by Oregon State University, and Humboldt University provide a unique opportunity to assess prey selection by comparing prey use to indices of availability. We used NGS methods – coupled with ongoing forage species surveys - to characterize the diet of marbled murrelets in Washington, Oregon, and California. Murrelets consumed a high diversity of prey with 17 fish species and 10 invertebrates detected, indicating this species is a generalist forager – as has been suggested previously. However, in contrast to previous studies based on more traditional approaches, our results support Pacific herring (*Clupea pallassi*) as the primary food source for murrelets in Washington and Oregon (frequency of occurrence= 0.84 and 0.69, respectively), whereas Californian anchovy (*Engraulis mordax*) was the most commonly consumed prey in California (frequency of occurrence= 0.77). Diet composition varied among in Oregon where sample size allowed interannual comparison, with a decline in the proportional consumption of energy dense prey from 2017 to 2018 – potentially resulting from shifts in ocean conditions associated with marine climate warming events. Diet varied nearly significantly between males and females, largely because of differences in rare prey – with common and energy dense prey consumed in equal proportions perhaps because of similar inland flight behavior and thus energy demands between the sexes. Diet, however, did not vary according to breeding status as measured by the presence of a well-developed brood patch. In conclusion, our study offers the first detailed report on the diet of adult marbled murrelets, a threatened and coastal indicator species.

Prions in Plants: Defining the Risks

Investigator: *Joel A. Pedersen, Departments of Soil Science and Civil & Environmental Engineering, University of Wisconsin-Madison*
Funding: *US Geological Survey (National Wildlife Health Center)*
Completed Date: *September 30, 2021*

Transmissible spongiform encephalopathies (TSEs; prion diseases) are a family of invariably fatal neurodegenerative diseases that afflict a variety of mammalian species after a long incubation period (months to years). Animal TSEs have been a major concern to food safety since recognition in the 1990s that BSE can transmit to humans, presumably through consumption of BSE-infected meat. Of present concern to public health and food safety is CWD, the only TSE known to affect free-ranging species (wildlife). Along with an expanding geographical distribution, CWD prevalence in current epizootics is increasing and has been reported at >80% in some captive herds, including one in WI, and >50% in a free-ranging herd in WY. In environments likely to be contaminated with CWD, vegetation is ubiquitous. Plants absorb a variety of substances from soil, ranging from nutrients to contaminants. Plants may serve as a conduit between CWD-contaminated soils and naïve deer hosts. This project established the ability of several crop and other plant species to take up prions via their roots and translocate them to above-ground tissues from various growth media including soils. We demonstrate that plants can accumulate prions in above-ground tissues to levels sufficient to transmit disease after oral ingestion. Our results suggest plants may serve as vectors for prion transmission in the environment—a finding with implications for wildlife conservation, agriculture, and public health

Survival mechanisms of remnant northern long-eared bat (*Myotis septentrionalis*) populations

Investigators: *Wendy Turner, USGS, University of Wisconsin-Madison and Ing-Nang Wang, University at Albany*
Funding: *US Fish and Wildlife Service*
Completed Date: *July 31, 2021*

The northern long-eared bat (*Myotis septentrionalis*, MYSE) is one of the species most affected by white-nose syndrome (WNS), leading to its federal listing in 2015 as Threatened under the Endangered Species Act. Our recent work provides evidence that MYSE populations off the coast of the northeastern US are infected with *Pseudogymnoascus destructans* (Pd), the causative agent of WNS, and yet these populations are persisting. This project investigated the mechanisms that allow for the persistence of coastal MYSE populations, while populations elsewhere have experienced drastic declines. We hypothesized that availability of abundant anthropogenic hibernacula and the ability to forage in milder winter weather may allow MYSE to reduce Pd exposure and/or WNS infection severity. Our study was replicated on three coastal islands: Long Island, New York, and Martha's Vineyard and Nantucket, Massachusetts. The project objectives were to i) assess coastal MYSE fall and winter behavior, and identify and characterize coastal hibernation locations, ii) evaluate Pd exposure and infection load of coastal MYSE and their hibernacula, iii) determine winter activity patterns of coastal MYSE and assess prey availability, and iv) investigate the genetic structure of coastal MYSE and compare with the mainland population. A total of 69 MYSE were captured and 54 radio-tagged at 20 capture locations across all three study sites. Bats were tracked daily, resulting in 88 roosts and 15 hibernacula documented. Final Pd testing and bat genetic sequencing results are expected in the next few months.

PUBLICATIONS AND PROFESSIONAL PAPERS

Peer-reviewed articles
Unit Staff and Students (underlined)

Bruce, S.A., Y-H. Huang, P.L. Kamath, H. van Heerden and **W.C. Turner.** 2021. The roles of antimicrobial resistance, phage diversity, isolation source and selection in shaping the genomic architecture of *Bacillus anthracis*. *Microbial Genomics*

Dudzinski, K.M., **C.A. Ribic**, H.M. Manitzas Hill, and T.T. Bolton. 2021. Bottlenose dolphin calf initiated pectoral fin contact exchanges with mother, other kin and non-kin. Animal Behavior and Cognition 8:376-390.

Dudzinski, K. M., **C. A. Ribic**, H. M. Hill, and T. T. Bolton. 2021. Evidence for maternal style among adult female dolphins when sharing pectoral fin contacts with their calves. Animal Behavior and Cognition 8: 52-68. https://doi.org/10.26451/abc.08.01.05.2021

Gomez, L.M., V.A. Meszaro, **W.C. Turner** and C.B. Ogbunugafor. 2020. The epidemiological signature of pathogen populations that vary in the relationship between free-living survival and virulence. *Viruses*, 12(9):1055.

Huang, Y.-H., H. Joel, M. Küsters, Z.R. Barandongo, C.C. Cloete, A. Hartmann, P.L. Kamath, J.W. Kilian, J.K.E. Mfune, G. Shatumbu, R. Zidon, W.M. Getz and **W.C. Turner.** 2021. Disease or drought: environmental fluctuations release zebra from a potential pathogen-triggered ecological trap. *Proceedings of the Royal Society B, Biological Sciences*, 288: 20210582.

Johnson, D. H., C. Anderson, R. Applegate, L. Bailey, E. Cooch. J. Fieberg, A. Franklin, R. Gutierrez, K. Miller, J. D. Nichols, N. Niemuth, D. Otis, **C. A. Ribic**, M. M. Rowland, and T. L. Shaffer. 2021. A perspective on the Journal of Wildlife Management. Journal of Wildlife Management 85:1305–1308. DOI: 10.1002/jwmg.22110

Pasternak, G., **C.A. Ribic**, E. Spanier, and D. Zviely. 2021. Stormwater systems as a source of marine debris: a case study from the Mediterranean coast of Israel. Journal of Coastal Conservation 25: article 27 (Online). https://doi.org/10.1007/s11852-021-00818-3

Ribic, C.A., D.J. Rugg, K. E. Ellison, N. Koper, and P.J. Pietz. 2021. Diel patterns of predation and fledging at nests of four species of grassland songbirds. Ecology and Evolution 11:6913–6926, DOI: 10.1002/ece3.7541.

Stears, K., M.H. Schmitt, **W.C. Turner**, D.J. McCauley, E.A. Muse, H. Kiwango, D. Matheyo and B.M. Mutayoba. 2021. Hippopotamus movements structure the spatiotemporal dynamics of an active anthrax outbreak. *Ecosphere,* 12(6):e03540.

Starkloff, N.C., **W.C. Turner**, A.M. Fitzgerald, M.C. Oftedal, E. Martinsen and J.J. Kirchman 2021. Disentangling the effects of host relatedness and elevation on haemosporidian parasite turnover in a clade of songbirds. *Ecosphere,* 12(5):e03497.

Starkloff, N.C., J.J. Kirchman, A.W. Jones, B.M. Winger, Y.-H. Huang, P.C. Pulgarín-R, and **W.C. Turner.** 2020. Drivers of community turnover differ between avian haemoparasite genera along a North American latitudinal gradient. *Ecology and Evolution*, 10(12): 5402-5415.

Themelin, M., **C. A. Ribic**, K. Melillo-Sweeting, and K. M. Dudzinski. 2020. A new approach to the study of relationship quality in dolphins: framework and preliminary results. Behavioural Processes 181:104260. doi.org/10.1016/j.beproc.2020.104260

Turner, W.C., P.L. Kamath, H. van Heerden, Z. Barandongo, Y.-H. Huang, S.A. Bruce and K. Kausrud. 2021. The roles of environmental variation and parasite survival in virulence-transmission relationships. *Royal Society Open Science*, 8: 210088.

Unit Affiliates
None

Posters and Papers Presented at Professional Meetings
Unit Staff and Students

Barandongo, Z.R., Huang, Y.-H., Dolfi, A.C., Bruce, S.A. and **W.C. Turner**. 2021. Environmental and genetic factors affecting *Bacillus anthracis* spore concentrations at anthrax carcass sites. 9th International Conference on *Bacillus anthracis*, *B. cereus* and *B. thuringiensis*, Paris, France, April 26-28, 2021 (virtual).

Hoff, S., C. Pendergast, E. Olson, L. Johnson, D. O'Dell, C. Herzog, J. Foster, & **W.C. Turner**. Persistence of coastal northern long-eared bats in the face of white-nose syndrome. Invited presentation at the Northeast Bat Working Group annual meeting, Saratoga Springs, NY January 2020.

Huang, Y.-H., H. Joel, M. Küsters, Z.R. Barandongo, C.C. Cloete, A. Hartmann, P.L. Kamath, J.W. Kilian, J.K.E. Mfune, G. Shatumbu, R. Zidon, W.M. Getz and **W.C. Turner**. Disease or drought: environmental fluctuations release zebra from a potential pathogen-triggered ecological trap, Research Frontiers in Animal Behavior and Parasitism, A Virtual Symposium at the Center for the Ecology of Infectious Diseases, May 20-21, 2021, University of Georgia, Athens, Georgia.

Huang Y-H, Kausrud K, Hassim A, Ochai SO, van Schalkwyk OL, Dekker EH, Alexander B, Cloete CC, Kilian JW, van Heerden H and **Turner WC**. Bi-seasonal dynamics of a multi-host pathogen: the role of environment in the dynamics of anthrax. Online Wildlife Disease Association and EWDA joint conference, September 2021, Spain.

Huang Y-H, Joel H, Küsters M, Barandongo Z, Cloete CC, Hartmann A, Kamath P, Kilian JW, Mfune JKE, Shatumbu G, Zidon R, Getz WM and **Turner WC**. Disease or drought: environmental fluctuations release zebra from anthrax transmission hotspots. Online ecology and evolution of infectious diseases conference, June 2021, France.

Ketz, A. C., Storm, D. J., & Walsh, D. P., Long term dynamics of chronic wasting disease. Oral presentation at the Ecological Society of America Annual Conference, virtual, August 2021.

Ketz, A. C., Storm, D. J., & Walsh, D. P., Long term dynamics of chronic wasting disease. Oral presentation at the Ecology and Evolution of Infectious Diseases Conference, virtual, June 2021.

Ketz, A. C., Storm, D. J., & Walsh, D. P., Long term dynamics of chronic wasting disease. Oral presentation at the Wisconsin Chapter of The Wildlife Society Meeting, virtual, February 2021.

Kausrud, K., **W.C. Turner,** W.R. Easterday, M. Feiring, T. Skjerdal, J. Whittington, Y. Kausrud, B. Ogbunu, Madelaine Norström[1], H. Schønhaug, N.C. Stenseth. Evolving at the speed of risk. One Health EJP Annual Scientific Meeting 2021, June, Copenhagen.

Kausrud, K., K. Lagesen, J. Whittington, W.R. Easterday, C. Wolff, **W.C. Turner**, M. Feiring, N.C. Stenseth. How much time have we got? One Health EJP Annual Scientific Meeting Satellite Workshop 2021 Software Fair

Maresh Nelson, S. B., **C. A. Ribic**, and B. Zuckerberg. 2021. Climate change in US grasslands: impacts on birds and opportunities for climate adaptation. Presentation at the Wisconsin Chapter of The Wildlife Society Virtual Winter Meeting, 22-25 February 2021.

Nunes, L.A., **C. Ribic**, and B. Zuckerberg. 2021. Using citizen science to optimize spatial conservation planning for grassland birds. Joint virtual meeting of the American Ornithological Society (AOS) and the Society of Canadian Ornithologists, 9-13 August 2021.

Nunes, L.A., **C. Ribic**, and B. Zuckerberg. 2021. The value of citizen science in optimizing spatial conservation planning for grassland birds. Wisconsin Chapter of The Wildlife Society Virtual Winter Meeting, 22-25 February 2021.

Nunes, L.A., **C.A. Ribic**, and B. Zuckerberg. 2020. The value of citizen science in optimizing spatial conservation planning for grassland birds. Presentation, British Ecological Society Annual Meeting, 14-18 December, 2020 [Virtual]

Ochai, S.O., **Turner, W.C.**, and van Heerden, H. 2021. Immunological evidence of host variation in exposure and resistance to anthrax in Kruger and Etosha National Parks. 9th International Conference on *Bacillus anthracis*, *B. cereus* and *B. thuringiensis*, Paris, France, April 26-28, 2021 (virtual).

Olah, A., **C. A. Ribic**, S. Warner, and A. Pidgeon. 2021. Kirtland's Warbler habitat use, reproductive success, and fledgling survival in red pine-dominated plantations in Wisconsin. Wisconsin Chapter of The Wildlife Society Virtual Winter Meeting, 22-25 February 2021.

Pendergast, C., S. Hoff, C. Herzog, E. Olson, L. Johnson, D. O'Dell, & **W.C. Turner**. Predator-prey activity and prey availability of northern long-eared bat coastal populations.

Research presented at the Northeast Bat Working Group annual meeting, Saratoga Springs, NY January 2020.

Unit Affiliates
Tonie Rocke, Ariel Leon, Jamie Lopera Madrid, and Jorge Osorio. Development and testing of vaccine candidates against white nose syndrome in bats. White-nose syndrome Workshop. (virtual) 2021

Data Publications
Boggs, Johnny L.; Sun, Ge; McNulty, Steven G. 2020. Hill Demonstration Forest and Umstead Research Farm streamflow data. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2020-0069

Korfmacher, John L.; Hultstrand, Douglas M.; Doebley, Valerie T.; Claybrook, Tanner P.; Ellsworth, Alan C. 2021. Glacier Lakes Ecosystem Experiments Site hourly meteorology tower data. 3rd Edition. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2006-0003-3

Amatya, Devendra M.; Trettin, Carl C. 2021. Santee Experimental Forest, Watershed 80: streamflow, water chemistry, water table, and weather data. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2021-0043

Bragg, Don C. 2020. A century of Forest Service research and development in the southern United States: historical documents and images. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2020-0047

Kastendick, Douglas N.; Palik, Brian J.; Beck, Albert J.; Kragthorpe, Joshua J. 2021. Cutfoot Experimental Forest 1934 cutting experiment in mature red and jack pine, plots 106 - 110. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2021-0027

Theses and Dissertations
None

PROFESSIONAL ACTIVITIES AND OUTREACH

Professional Activities

Unit Leader:

- Member, wildlife subcommittee, Wisconsin State Technical Committee, USDA-Natural Resources Conservation Service (July 2006-present)
- Break-out Session Moderator, Mississippi Flyway Roadmap summit, 26-28 January 2021, virtual meeting.

Assistant Unit Leader:

- Member of the Scientific Program Committee for the Wildlife Disease Association 2022 meeting in Madison, Wisconsin
- Academic Editor, PLOS ONE (December 2018 – present)
- Member, Center for Ecology and the Environment Executive Committee, UW-Madison (2021-present)

Teaching

Ribic, C. A. 2020. Grasslands and Grassland Vertebrates. Guest lecture (virtual) in Agronomy 370 Grassland Ecology, University of Wisconsin-Madison, November 19, 2020.

Turner, W. C. 2021. Disease and Biodiversity. Guest lecture (virtual) in Forest and Wildlife Ecology 360 Extinction of Species, University of Wisconsin-Madison, September 27, 2021.

Outreach

Uni Leader interviewed about the Wisconsin Cooperative Wildlife Research Unit. "Cooperation: The future of natural resource management". The Daily Cardinal, Science section, April 15, 2021

HONORS AND AWARDS

None