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U.S. Fish and Wildlife Service Summer Fellowship: GIS Study of Threatened and Endangered Species in Colorado

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Submitted to the faculty of Clark University, Worcester, Massachusetts,

in partial fulfillment of the requirements for

the degree of Geographic Information Science for Development and Environment

(GISDE), Master of Science in the department of International Development,

Community, and Environment

And accepted on the recommendation of

Yelena Ogneva-Himmelberger, Academic Advisor

ABSTRACT

U.S. Fish and Wildlife Service Summer Fellowship:
GIS Study of Threatened and Endangered Species in Colorado

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This report provides a detailed account of my fellowship experience with the U.S. Fish and Wildlife Service (USFWS) Region 6 Office in Lakewood, CO during the summer of 2017 made possible by the Student Conservation Association (SCA) sponsored by Directorate Fellows Program. The internship was completed in the Region 6's Branch of Decision Support in Ecological Services under the direction of Spatial Ecologist John Guinotte. I was a GIS Technician tasked with work responsibilities involving listed threatened and endangered species relevant to the region. Those work responsibilities included refining spatial Area of Influence (AOI) ranges, updating databases, and creating a habitat conservation potential map. These tasks required personal responsibility with field travel and communication with field office biologists.

This fellowship provided a unique and meaningful summer experience with a federal bureau dedicated to nationwide conservation of listed threatened and endangered species. I had the opportunity to not only learn about USFWS's mission and operations and network with the dedicated scientists and resource management professionals of USFWS, but also, to apply my skills acquired from academic settings into a federal government conservation bureau. The skills obtained, people encountered, and tasks completed involving listed species have encouraged my

lifelong desire for learning and shaped my career aspirations. This fellowship experience has been essential for gaining insight into the important work of USFWS and influencing my career goals. I would highly recommend the USFWS's Directorate Fellows Program for students who have a strong interest in a career someday with the USFWS. This fellowship allows you to gain a network with USFWS, partake in a proposed project in support of USFWS's mission, and apply research, technical, and communication skills to accomplish project tasks. The following chapters provide a comprehensive discussion of USFWS organization structure, the fellowship experience and overall reflections.

Yelena Ogneva-Himmelberger ,Ph.D.

Chief Instructor

ACADEMIC HISTORY

Name: Jeanie Lai **Date**: May 2018

Place of Birth: Baltimore, MD **Date:** February 3rd, 1992

Baccalaureate School: University of Maryland, Baltimore County (UMBC)

Date: December, 2014

Baccalaureate Subject: B.Sc., Environmental Science

Undergraduate Certificate: Geographic Information Science Applications (Distinction)

DEDICATION

I dedicate this to all those throughout my life who have epitomized the meaning of hard work, persisted in times of difficulty, and dedicated and invested time and resources to bring me where I am today –

Family that never wavered on providing the foundation for achievement,

Teachers and instructors that fed me knowledge and bolstered my confidence,

Friends of the past and present who have spread laughter and shared memorable stories.

These people have instilled my lifelong goal of learning.

ACKNOWLEDGEMENTS

I give my deepest gratitude and thanks to the dedicated faculty and staff past and present of the International Development, Community, and Environment (IDCE) Department. My Clark journey started with meeting the enthusiastic and insightful Yelena Ogneva-Himmelberger, John Rogan, Jie Tian, and Florencia Sangermano during orientation. Throughout my Clark journey, I have had the privilege of being a student in such fundamental and interesting GIS courses taught by those instructors. To Yelena Ogneva-Himmelberger, thank you for your leadership in facilitating student success in the GISDE Internship track . To Sharon Hanna, thank you for being an excellent resource and voice-of-reason as students prep for their post-Clark career steps. To Kate Norman and John Guinotte, thank you for taking me under your wing and providing a great fellowship experience this summer . To all I crossed paths with, thank you for the help, guidance, and friendship that have been pivotal to my growth at Clark and beyond.

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CHAPTER 1: INTRODUCTION

I have spent an overwhelming majority of my life within the urban confines of Baltimore City. In early school years, I recall instructors from a nature center visiting my summer camp program weekly. Those lessons about and activities regarding our natural environment and its components sparked my appreciation and interest in the natural environment which would carry on into my college studies in the years to come. I have remained dedicated to scientific research and technology that contribute to the conservation efforts of natural resources for the benefit of all people. Ultimately, I seek a career applying my environmental science and GIS skills and knowledge to complete meaningful conservation tasks with a special interest in increasing awareness and access of these valued natural resources to urban populations.

For summer 2017, I completed a fellowship with U.S. Fish and Wildlife Service (USFWS)'s Directorate Fellows Program sponsored by Student Conservation Association (SCA). This fellowship program presents a 12-week (with training) summer opportunity where students take on proposed projects stationed at one of many USFWS host sites. USFWS's mission is to conserve and protect our nation's unique fish, plant, and wildlife species and habitats which benefit people today and of future generations. USFWS's mission is fulfilled through federal wildlife law enforcement, endangered species protection, migratory bird management, and so much more. I fulfilled a proposed project in USFWS's Mountain-Prairie Region, specifically, the Region 6 Office in Lakewood, CO. Within the regional office, I was placed in Ecological Services' Branch of Decision Support, in which the decision support team is responsible for analytical, geospatial, and other decision support tasks for field offices that may not have the necessary skillsets and resources. Spatial Ecologist John Guinotte, one of the current five experienced and expert staff members in decision support, was my supervisor.

I was a GIS Technician tasked with creating and updating GIS products for four listed species: Southwestern Willow Flycatcher, Colorado Hookless Cactus, Greenback Cutthroat Trout, and Preble's Meadow Jumping Mouse. For the Southwestern Willow Flycatcher and Colorado Hookless Cactus species, I revised, refined, and created spatial Area of Influence (AOI) ranges, which were then, formatted and uploaded into the Information for Planning and Consultation (IPaC) system. In order to effectively refine AOIs, I communicated with field office biologists to establish AOI refinement methodology. As an additional task responsibility for refining the flycatcher AOI, I digitized species presence points from currently inaccessible, hard-copy surveys. For the Greenback Cutthroat Trout, I updated the Greenback Cutthroat Trout's database by locating and identifying green verses blue lineage streams in Colorado based on a 2010 genetic characterization survey study by Colorado Parks and Wildlife (CPW). Lastly, for the Preble's Meadow Jumping Mouse, I created a habitat conservation potential map by researching and identifying variables, and weighting and reclassifying those selected variables.

My education at Clark University has been a pivotal component to the successful completion of my fellowship position as a GIS Technician at a USFWS regional office. Skills I obtained during my tenure as a GISDE graduate student at Clark included applying analytical vector tools. Specifically, those essential skills included digitization/spatial data creation, data organization and analysis, and multi-criteria decision-making. I did not apply remote sensing directly for my fellowship positon, but through shadowing other USFWS decision support offices, I witnessed the relevance of remote sensing skills and understanding for projects involving for instance, satellite imagery classification to quantify instances of change. Skills I acquired on-the-job were more interpersonal skills, such as communication and discussion capabilities with expert scientists on species, and written communication as well. Other skills

included applying ecological understanding, independence/ personal responsibility, and strategic/critical thinking and problem solving.

Overall, I am extremely grateful to have been granted this opportunity to complete a proposed project assigned as a part of USFWS's Directorate Fellows Program. This fellowship has aided in my career and skill growth as a GIS analyst. From this fellowship, I learned about the mission, structure, and operations of USFWS. Specifically, I learned about one aspect of decision support within the large-scaled and dynamic operations within USFWS, and processes associated with addressing federally listed species. As a final thought, I highly recommend this fellowship opportunity to students interested in a career of natural resource conservation, or who have a natural resource background/organismal coursework. USFWS is an exemplar organization with employees dedicated to public service.

CHAPTER 2: DESCRIPTION OF ORGANIZATION

History and Mission

Over 100 years ago, United States' fish and wildlife resources began declining at alarming rates [(1)]. The history of U.S. Fish and Wildlife Service (USFWS) traces back to 1871 when the U.S. Congress created the U.S. Commission of Fish and Fisheries to address fisheries decline [(1)]. Years following, many legislative actions were implemented continuing our nation's interests of conserving fish and wildlife species. In 1903, President Theodore Roosevelt established the nation's first wildlife refuge at Pelican Island National Bird Reservation [(1)]. This is one of the many noteworthy actions on the timeline of our nation's fish and wildlife conservation efforts. Currently, USFWS's programs and efforts remain among the oldest dedicated to natural resource conservation [(1)].

The mission of USFWS is "working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people" [(2)]. The objectives of USFWS are "1) Assisting in the development and application of an environmental stewardship ethic in our society, 2) Guiding the conservation, development, and management of national fish and wildlife resources, and 3) Administering a national program to provide the public with opportunities to understand and appreciate fish and wildlife resources" [(3)]. Ways in which USFWS meets its mission include federal wildlife law enforcement, endangered species protection, migratory bird management, fisheries and wildlife habitat restoration, and wildlife-dependent recreation (fishing, hunting, etc.) education [(3)]. Today, thousands of USFWS employees all over the U.S. dedicate themselves to managing the 150-million-acre National Wildlife Refuge System comprising of more than 500 National Wildlife Refuges, National Fish Hatcheries, wetlands, and other special management areas [(3)].

USFWS's Directorate Fellows Program

With its first cohort formed in 2014, the USFWS's Directorate Fellows Program (DFP) offers students an 11-week summer fellowship opportunity to demonstrate to supervisors and managers their viability for a USFWS career [(4)]. Selected students (DFP fellows) each take on a proposed project stationed at one of the many USFWS host sites. Throughout the summer, DFP fellows apply their wildlife and conservation biology knowledge, technical expertise, and professional communication to complete their assigned projects aiding in USFWS's mission [(4)].

During May orientation before the start of fellowships, DFP fellows gathered at the USFWS's National Conservation Training Center (NCTC) in Shepherdstown, West Virginia for a weeklong training to interact with USFWS leaders and peers and to learn about USFWS's mission, history, programs, and employment opportunities[(5)]. Important skills development

during training included leadership, science communication, basic field technology, and job readiness [5]. This rigorous program aims to build our nation's next generation of conservation leaders ready to dedicate themselves to public service [5]. The USFWS stands by its conservation principles of stewardship, people, science, partnerships, professionalism, legacy, and service [2]. By continuing to connect people with nature, USFWS strives to maintain its legacy of ensuring a future where natural resource conservation is valued [2].

Organization Structure

The USFWS, comprising of expert scientists and resource management professionals, is one of the nine federal technical bureaus within the U.S. Department of the Interior (DOI) [6]. USFWS headquarters is located in Washington D.C. USFWS management of natural resources is broken down into eight regions [7] (See **Figure 1**).

REGION NUMBER	REGION NAME	REGION TERRITORIES
1	Pacific	Idaho, Oregon, Washington, Hawaii and the Pacific Islands
2	Southwest	Arizona, New Mexico, Oklahoma and Texas
3	Midwest	Illinois, Indiana, Iowa, Michigan, Missouri, Minnesota, Ohio and Wisconsin
4	Southeast	Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Puerto Rico/Virgin Islands, South Carolina and Tennessee
5	Northeast	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia and West Virginia
6	Mountain-Prairie	Colorado, Kansas, Montana, North Dakota, Nebraska, South Dakota, Utah and Wyoming
7	Alaska	Alaska
8	Pacific Southwest	California, Nevada, Klamath Basin area of Oregon
HEADQUARTERS		Washington D.C.

Figure 1. Breakdown of USFWS regions by number, name, and territories.

The Mountain-Prairie region, where my fellowship was hosted, encompasses the heart of the American west[7]. This region consists of eight states: Colorado, Kansas, Montana, North Dakota, Nebraska, South Dakota, Utah and Wyoming [7]. The regional office is located in Lakewood, CO, where the current Regional Director Noreen Walsh oversees USFWS activities for all eight states and leads nearly 1000 employees across the region [8]. These employees exemplify commitment to scientific excellence [8]. This region has public services specific to refuges, ecological services, migratory birds, fish and aquatic, law enforcement, and external affairs – working cohesively to forward natural resources conservation and environmental education [8].

USFWS GIS Section

Within the Mountain-Prairie region's Ecological Services lies the Branch of Decision Support, where my fellowship position was located [9]. The Branch Chef oversees the tasks of five experienced and expert staff members with job titles of spatial analyst, spatial ecologist, records manager, and contaminants specialist [9]. This team is responsible for analytical, geospatial, and other kinds of decision support for field offices that may not have the necessary skillsets [9] (See **Figure 2**).

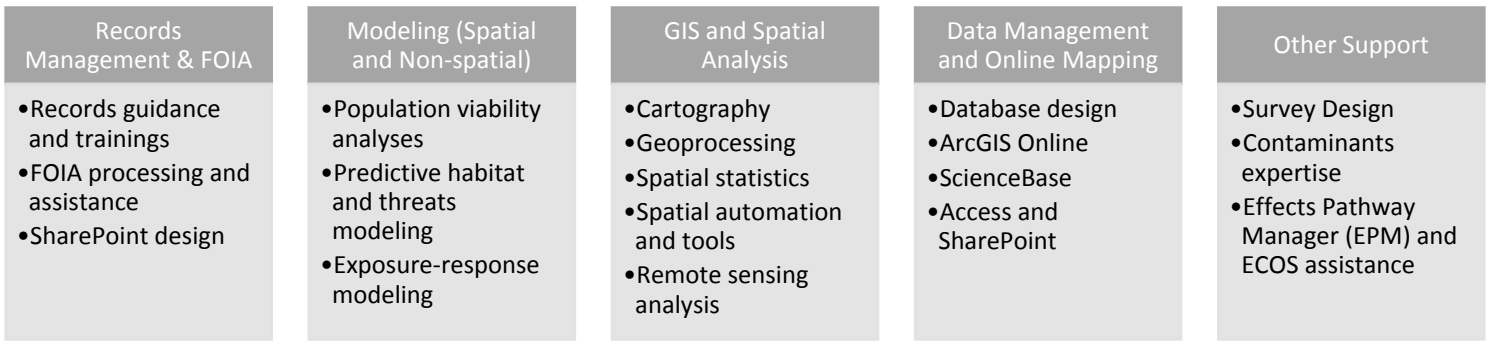

Figure 2. Services of the Branch of Decision Support in the Mountain-Prairie region.

Decision Support consists of experts in modeling, statistics, spatial analysis, and records management [9]. Spatial and non-spatial modeling products include population viability analysis, predictive habitat and threats modeling, and exposure-response modeling [9]. GIS and spatial analysis services include cartography, geoprocessing, spatial statistics, spatial automation and tools, and remote sensing analysis [9]. Data management and online mapping services include database design, ArcGIS online, ScienceBase, and Access and SharePoint [9]. Other decision support services include Survey Design and Effects Pathway Manager (EPM) and Environmental Conservation Online System (ECOS) assistance [9]. Decision support offers many technical skills and tools useful for managing endangered species, energy, contaminants, wetlands, conservation, and more [9].

As a DFP fellow hired by Decision Support Branch Chief Kate Norman, I was stationed at the Mountain-Prairie Region 6 office in Lakewood, CO as a GIS Technician. As a GIS technician, I applied GIS to update public spatial information of several listed threatened or endangered species - Southwestern Willow Flycatcher, Greenback Cutthroat Trout, Hookless Cactus, and Preble's Meadow Jumping Mouse in Colorado. My DFP supervisor was Spatial Ecologist John Guinotte, whom I reported my project progress and updates to weekly. My fellowship required a lot of autonomy, where I developed my own timeline and pace when accomplishing assigned goals on a day-to-day basis. In my particular fellowship experience, I was offered many valuable opportunities to shadow other major USFWS GIS departments and offices within the Mountain-Prairie region. One of my major shadowing experiences included solo travel to Bismarck, North Dakota to visit the Habitat and Population Evaluation Team (HAPET) to learn about some of their major projects involving waterfowl conservation mapping

and quantifying of wetlands via aerial imagery. In the following chapter, Chapter 3, I will provide in detail the specifics of my fellowship responsibilities.

Navigating through Generational and Diversity Gaps

Throughout many conversations during my fellowship arose the topic of generational and diversity gaps within not just USFWS, but many other federal agencies. On July 21, 2017, recently appointed Secretary of the Interior Ryan Zinke held a meeting for DOI employees of the Lakewood, CO region. Zinke mentioned that DOI was a "senior" organization, where most current employees were of retirement age and that percentage of retirement-aged employees would only grow in the coming years. In my perspective, there has been a lack of training and transition initiative to smoothly transition younger generations into important leadership positions that will someday need to be filled upon days of mass employee retirement. The employee generation demographic is extremely skewed towards the employees of older generations. Students who wish to work towards a career trajectory in USFWS need to navigate through generational gaps within their work environments and vice versa. It is important that all employees and staff get the appropriate training needed to navigate these generational gaps in order to increase workflow and accomplishments within USFWS.

On a similar note, a diversity gap exists within many federal agencies. There has been efforts to increase diversity by reaching out to minorities about USFWS career opportunities. As a federal agency, there has been concern of the employee demographics not being reflective of the American population. Diversity recruiters within this region are working hard to attract minority populations within schools with internship initiatives. The diversity gap extends to the populations that USFWS serves. There has been concern surrounding how to increase USFWS resources to urban populations, especially youth, who may not readily have access to more

isolated greenspace. Established in 1972, John Heinz National Wildlife Refuge at Tinicum, nested within urban Philadelphia, became America's First Urban Refuge. Over the years, this refuge has been extremely successful at connecting schools and communities to natural resources and local history. In all regions, diversity outreach is still in the works as far as hiring within USFWS and engaging all school and communities with USFWS resources.

CHAPTER 3: INTERNSHIP RESPONSIBILITIES

During my 11-week fellowship tenure at the Region 6 office as a GIS Technician, I conducted a GIS study of assigned listed threatened or endangered species of focus – Southwestern Willow Flycatcher, Greenback Cutthroat Trout, Hookless Cactus, and Preble's Meadow Jumping Mouse in Colorado. I located and digitized spatial data of species, and created a spatially explicit species observation dataset from hard-copy files. I revised and updated current shapefiles of Areas of Influence (AOI) ranges in the species observation dataset for the listed species. In order to accurately revise and update current AOIs, I worked with Colorado field office biologists to establish AOI refinement methodology. This collaboration with lead biologists ensured that the digitized data accurately represented findings documented in current research and literature. Upon completion, I uploaded the refined AOIs into the Environmental Conservation Online System (ECOs). Lastly, I produced GIS products for other listed species assigned (database update, conservation potential map, etc.).

Information for Planning and Consultation (IPaC) and its Supporting Data

According to Section 7 of the Endangered Species Act of 1973, project proponents (action agencies) consult with USFWS if their actions may influence listed threatened or endangered species and their critical habitats [(10)]. The Information, Planning, and Consultation

(IPaC) system is a decision-guiding tool used by USFWS when facilitating action agencies to outline activities that are considered potential effects to listed species and their habitats [(10)]. Area of Influence (AOI) is defined as "the area within which any project should consider potential effects to the listed species" [(11)]. As a key component in the IPaC system, AOI data allow action agencies and USFWS to know if there are any listed species potentially impacted in a given action area [(11)].

Certain species' AOI data in the IPaC system area are in need of maintenance to eliminate false positives, which cause unnecessary time and effort on behalf of USFWS by monitoring areas of species presence where there is none and vice versa. During my fellowship, I was responsible for refining the AOI for two species in Colorado: the Southwestern Willow Flycatcher and Colorado Hookless Cactus. I did so through a collaboration with biologists at the Grand Junction Sub-Office. This project comprised of GIS, research, and communication with field biologists to establish AOIs that are more accurate in an effort to improve efficiency in the Section 7 consultation processes.

Task 1 - Southwestern Willow Flycatcher

The first listed species that I conducted AOI refinement research on was the Southwestern Willow Flycatcher (SWWF) (*Empidonax traillii extimus)*. According to USFWS, the SWWF is currently listed as endangered. SWWF is usually around 6 inches in length and requires dense riparian habitats (ECOS). Loss and degradation of dense riparian habitats are the primary habitat threat to this species (ECOS). I focused on refining the current SWWF AOI specifically in Colorado as shown in **Figure 3**.

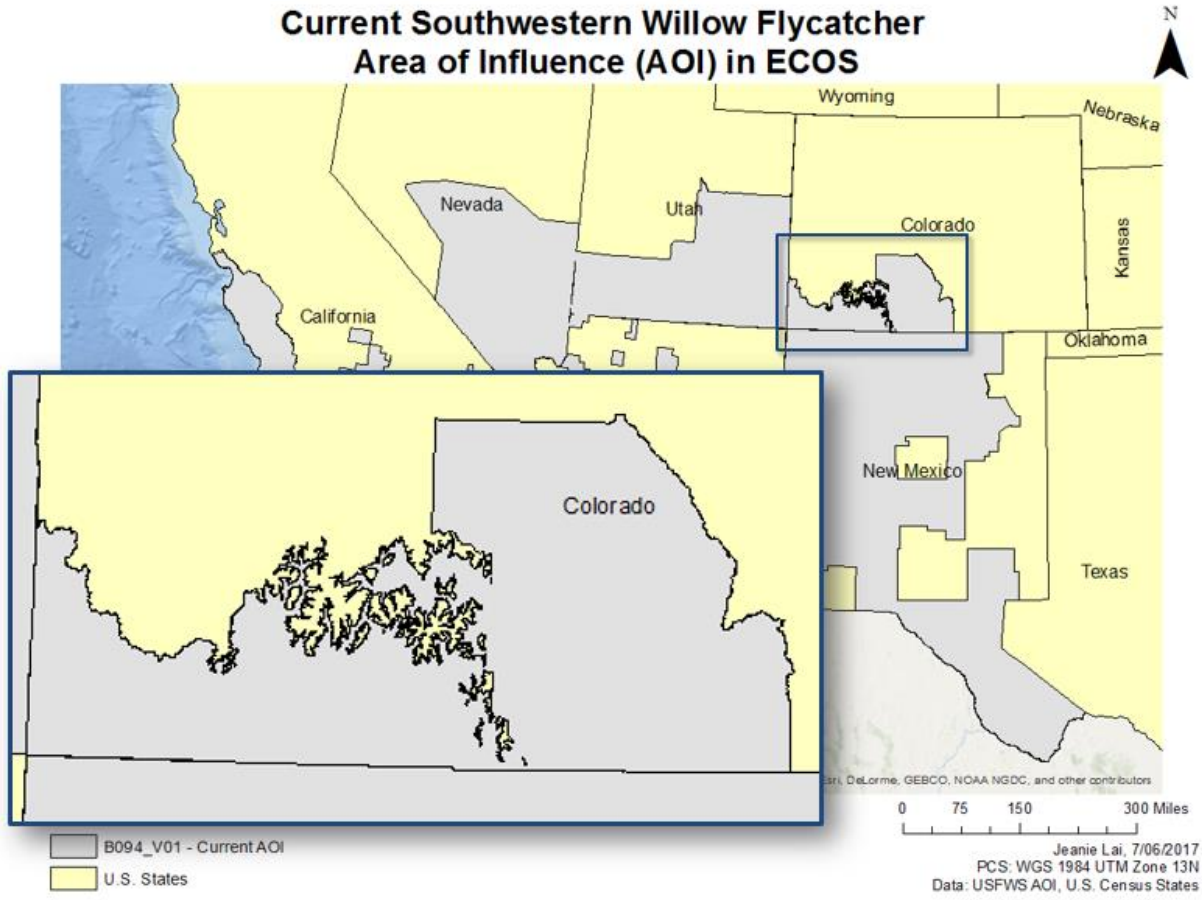

Figure 3. The current flycatcher AOI in ECOs.

In order to understand the spatial habitat occupied by the SWWF, I compiled hardcopy SWWF field survey results spanning from 1994 to 2016. I then digitized presence points to provide a geographic reference for SWWF presence. Digitizing flycatcher sightings allowed for a more fine tuned refinement of the AOI. For each SWWF presence point, I noted the date, witness, number of birds sighted, description, source, habitat, site name, county, state, and survey start and end time in the attribute table. 296 SWWF observations were digitized, including some additional points outside of Colorado. As illustrated in **Figure 4**, SWWF exists primarily in the southwestern region of CO.

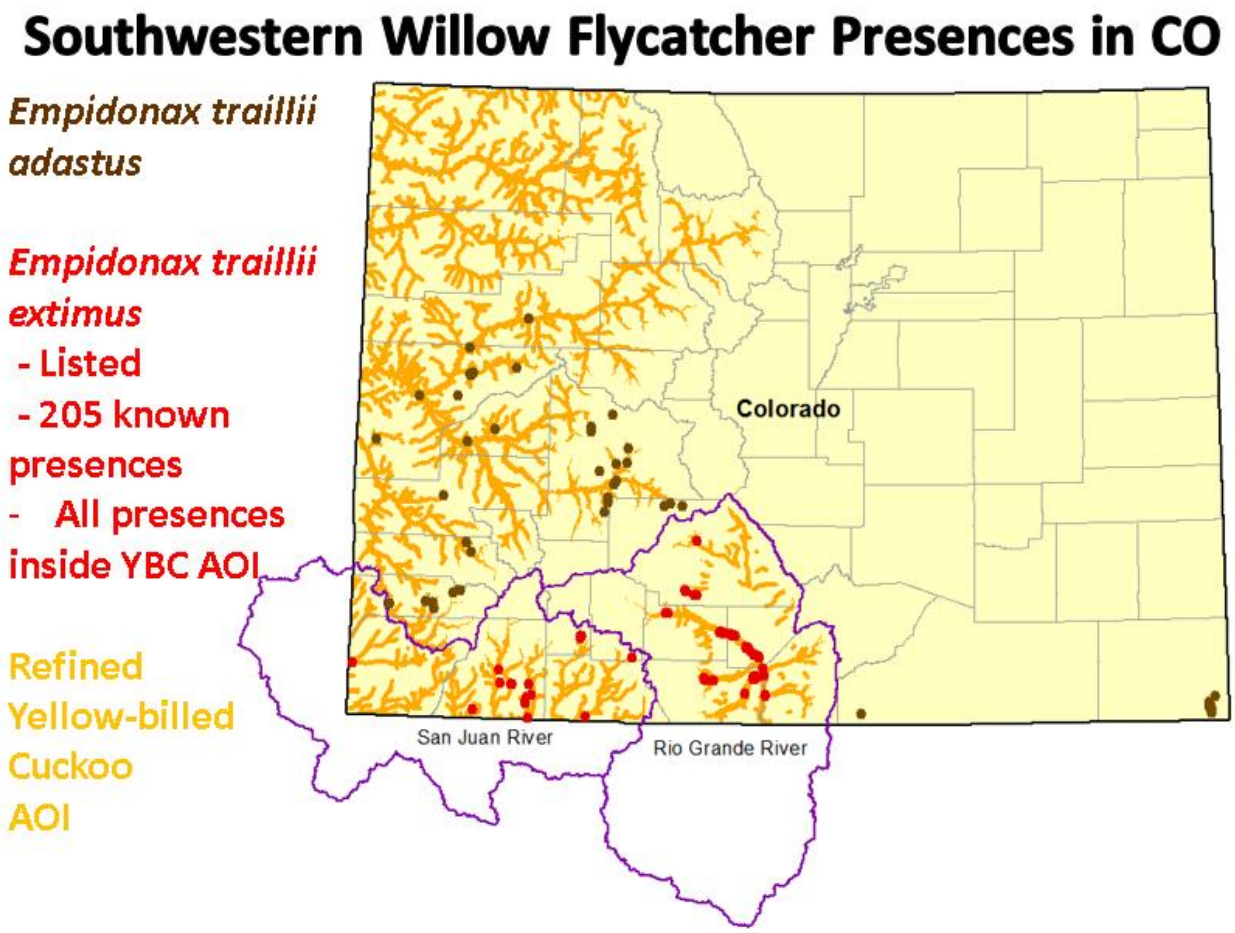

Figure 4. SWWF presences in CO.

According to experts, at this time the *extimus* SWWF subspecies is what is listed, and *extimus* is currently defined to be inside the San Juan and Rio Grande River basins. That region consists of the subspecies of focus as opposed to the *adastus* subspecies, which reside outside of the San Juan and Rio Grande River basins. Upon identifying the *extimus* species, there are 205 known sighting areas. Relating those presences to the available Yellow-Billed Cuckoo (YBC)'s refined AOI, all presences were located inside that YBC AOI. This perhaps insinuated similarities in habitat requirements of the YBC and SWWF.

After completion of digitization, the next step was to collaborate with expert biologists who worked in depth with the flycatcher species, Creed Clayton, Ph.D. and Terry Ireland of the

Grand Junction sub-field office. I traveled to Grand Junction to discuss and establish the refinement process for the flycatcher AOI. These essential meetings established the model for refining the SWWF AOI. Three main criteria were identified in the refinement process. First, the AOI was limited to Colorado's boundaries because Colorado is the state of focus. Secondly, the AOI was limited to the Rio Grande and San Juan basins where the listed *extimus* subspecies is found. Third, the AOI was limited to elevations less than 11,000 ft. The flycatcher observation recorded at the highest elevation was just less than 11,000 ft. **Figure 5** summarizes the refined AOI product based on the established model. In green, this polygon shapefile summarizes the updated Section 7 consultation range information of the SWWF in CO, based on the documented observations and literature between 1994 to 2016. This AOI contains all 205 known SWWF occurrences in CO defined to be *extimus* – the listed species. **Figure 6** compares the newly refined AOI with the current unrefined AOI. The comparison shows the eastern portion of the refined AOI to be more detailed and covering of less AOI space, serving to minimize false positives in Section 7 consultations.

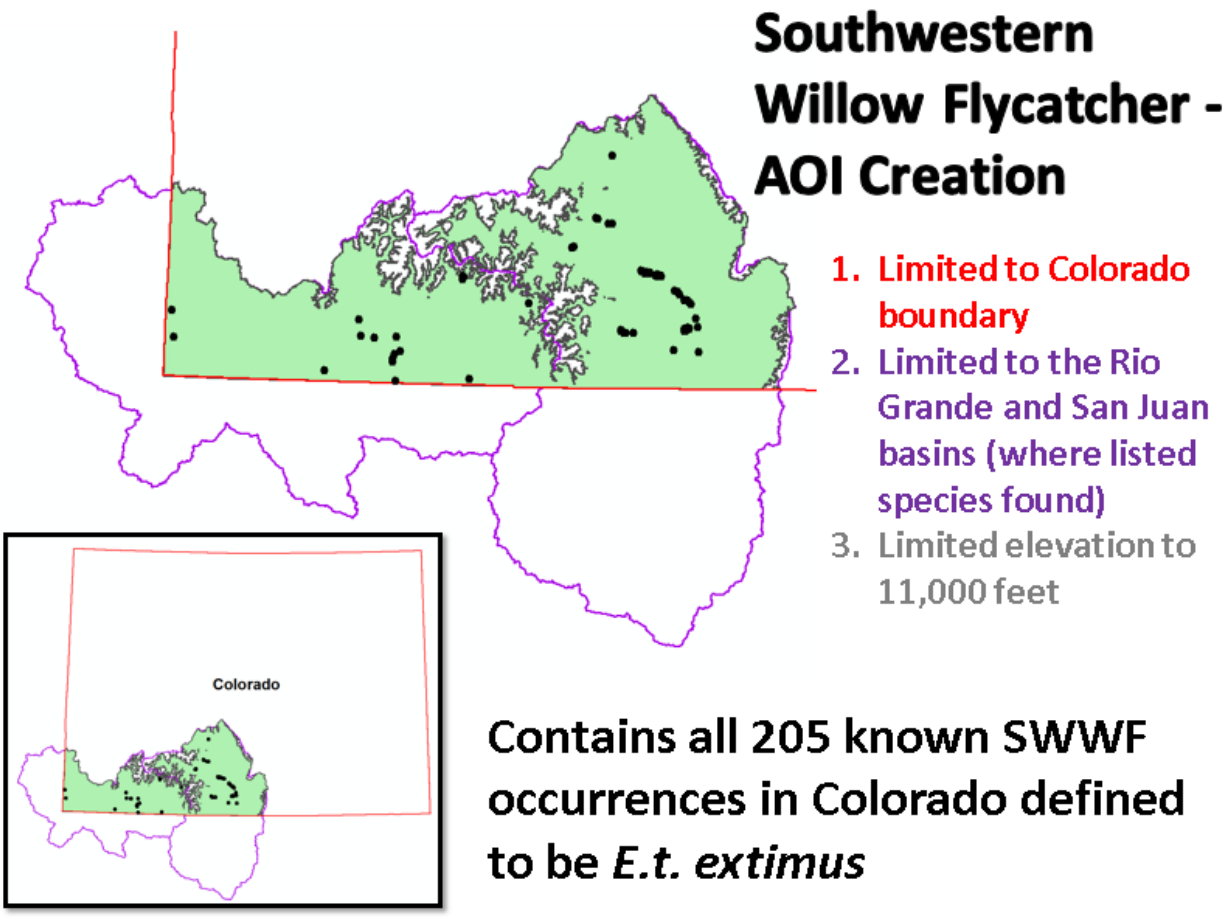

Figure 5. Refined SWWF AOI using established model.

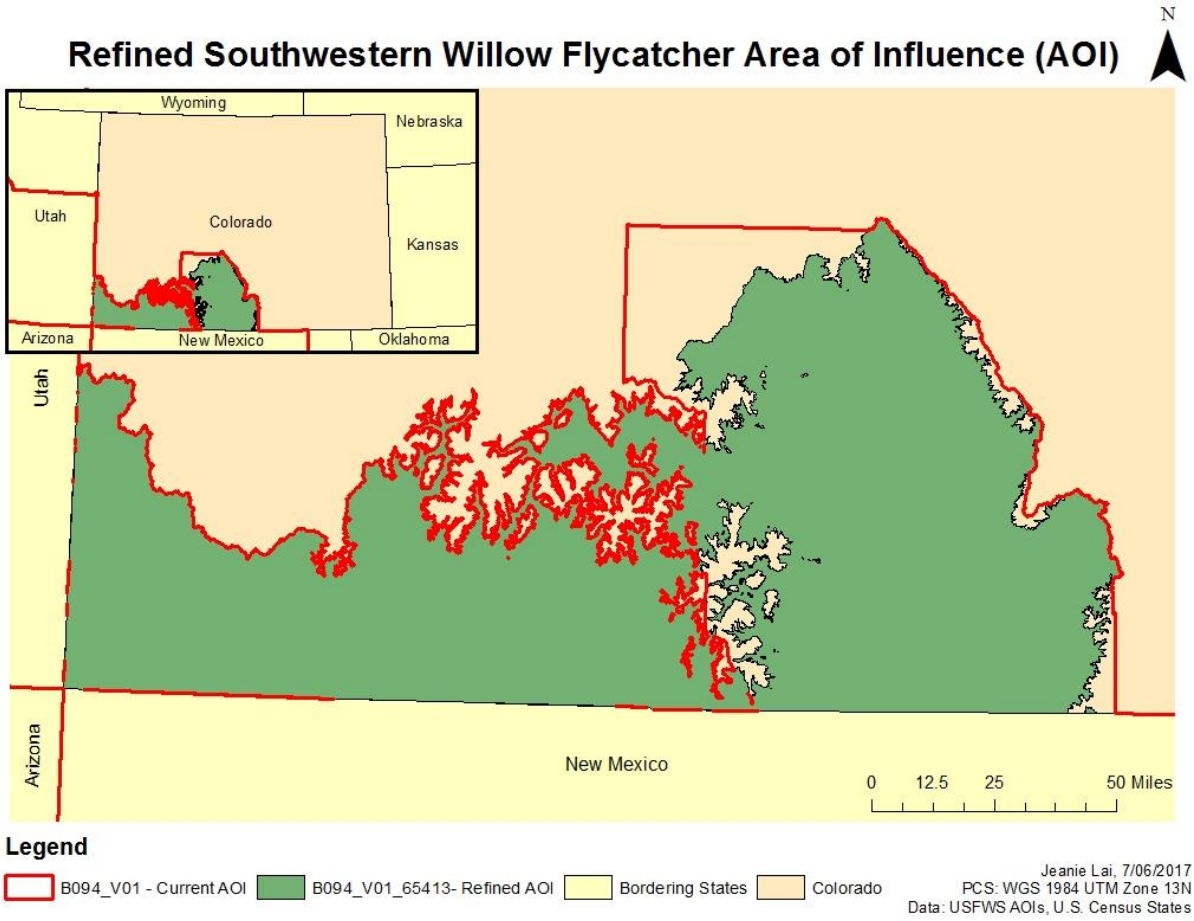

Figure 6. Comparison of the newly refined SWWF AOI with the current unrefined AOI.

Task 2 - Greenback Cutthroat Trout

The second species I researched was the Greenback Cutthroat Trout (*Oncorhynchus clarki stomias*)– Colorado's state fish. Currently, this trout is listed as threatened. Because this trout experienced a rapid decline in the 1800s, its original distribution remains unknown (ECOS). Its population is jeopardized due to hybridization, competition with non-native fish, overharvesting, and other detrimental effects (ECOS). Through collaboration with expert biologists (Creed Clayton, Ph.D. and Amy Crittenden) of the Grand Junction field office, I updated the Greenback Cutthroat Trout database by identifying green verses blue lineage streams in Colorado based on a 2012 genetic characterization survey study conducted by Colorado Parks

and Wildlife (CPW). The green lineage cutthroat trout is treated as a listed fish for Section 7 consultation purposes. Identification of green lineage stream locations facilitates Section 7 consultation and conservation. In the longer run, if this fish becomes formally listed, having its streams identified aids in targeting larger scale recovery actions such as protection, reclamation, etc. **Figure 7** illustrates the identification of green verses blue lineage streams of the Greenback Cutthroat Trout. On July 17, 2017, I helped reintroduce the trout into Herman Gulch and Denver Post covered the story (http://www.denverpost.com/2017/07/18/greenback-cutthroat-trout-transplanted-to-native-habitat/). In hopes of higher survivability of released trout, fish introduced this year were bigger and hardier compared to the previous year's release.

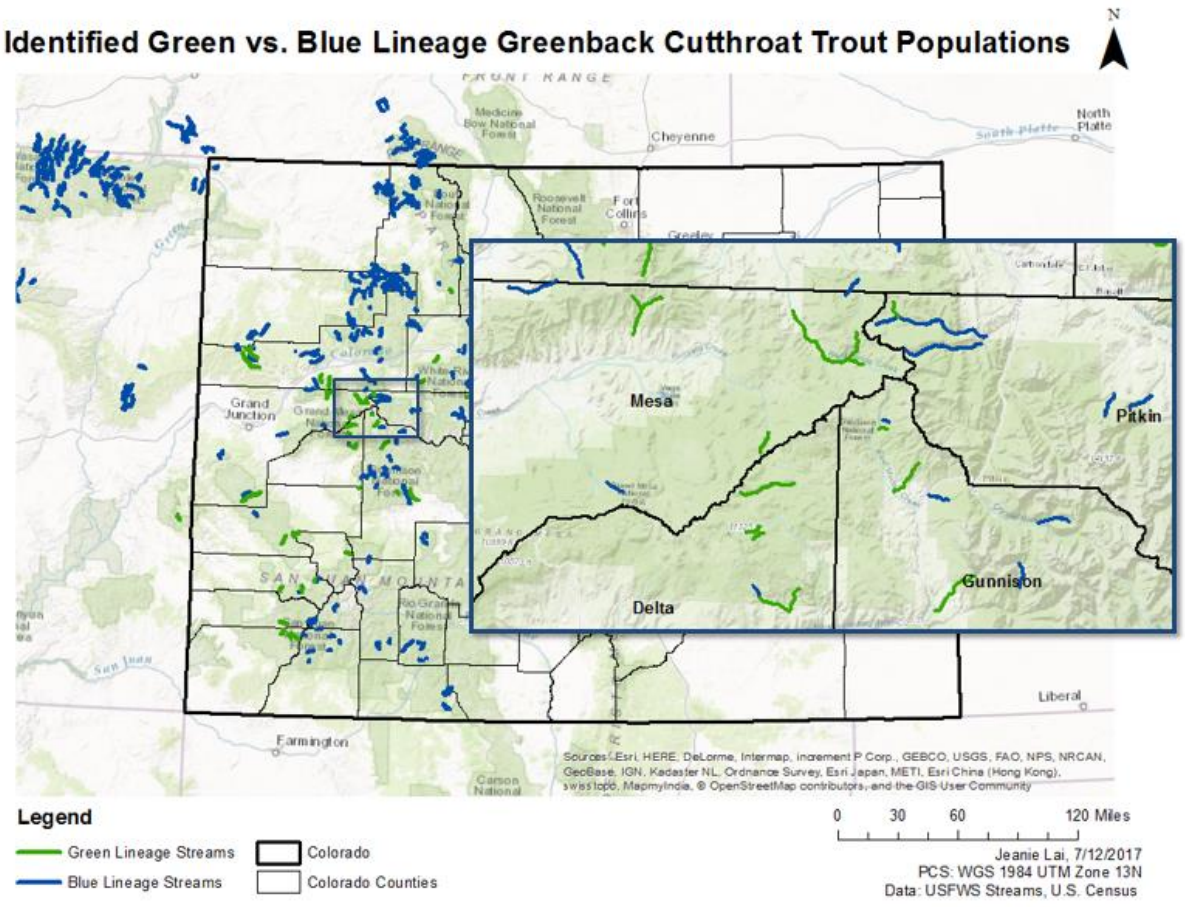

Figure 7. Identification of green verses blue lineage streams of the Greenback Cutthroat Trout.

Task 3 - Colorado Hookless Cactus

The third listed species I did AOI refinement research on was the threatened Colorado Hookless Cactus (*Sclerocactus glaucus*). This barrel shaped cactus is relatively small, ranging from 1.2 to 4.8 inches tall with exceptional plants as tall as 12 inches (ECOS). The cactus is present on alluvial benches (soil deposited by water) along the Colorado and Gunnison Rivers and their tributaries (ECOS). **Figure 8** displays the current AOI of the Colorado Hookless Cactus in ECOs. This cactus occupies the western region of Colorado. However, there is a gap in the AOI that should not be there as cactus is present in that gap.

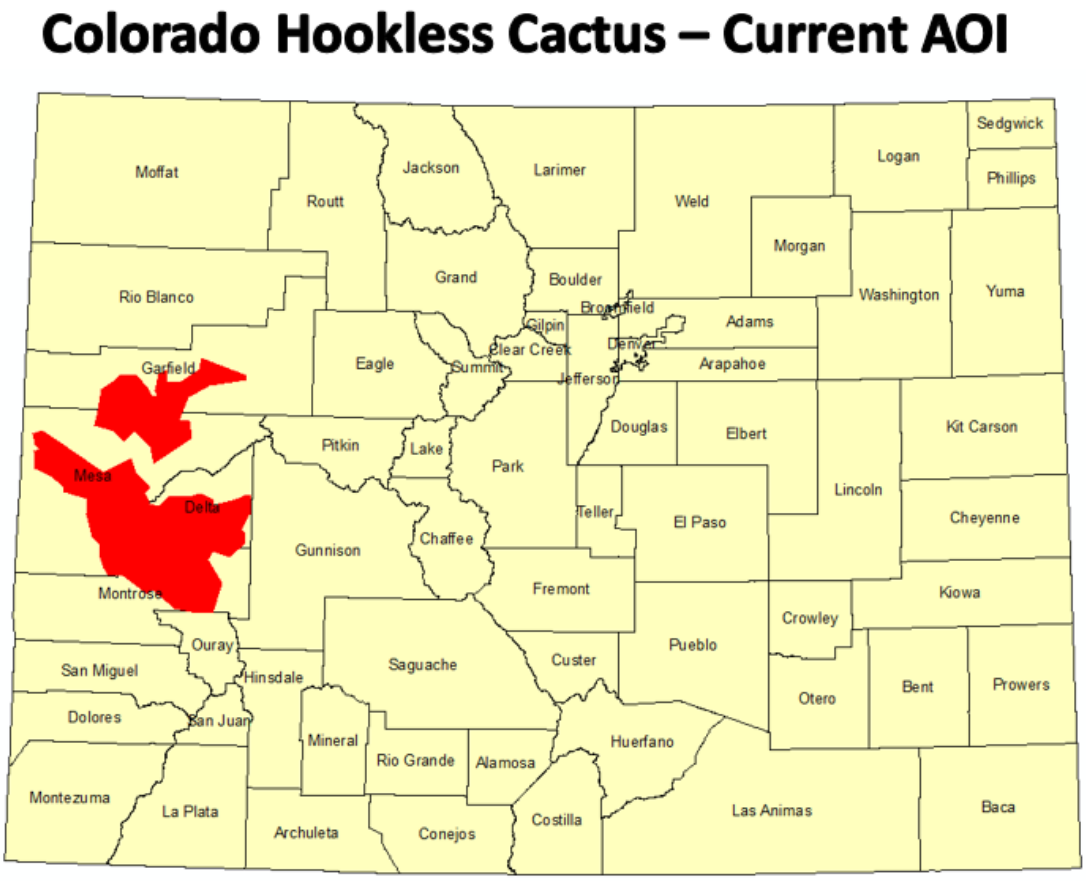

Figure 8. Current AOI of the Colorado Hookless Cactus in ECOs.

In 2017, Karin Decker of Colorado State University (CSU)'s Colorado Natural Heritage Program (CNHP) produced an updated suitable habitat model for the Colorado Hookless Cactus using a variety of factors, such as precipitation, elevation, snowfall, etc. Illustrated in **Figure 9**, this updated model is a combination of both the North and South sub-models delineating probable suitability of habitat for the cactus and serves as a guide for refining the cactus AOI. The red outline is the current unrefined AOI. This provides a clear comparison between the unrefined AOI and the CNHP's habitat model.

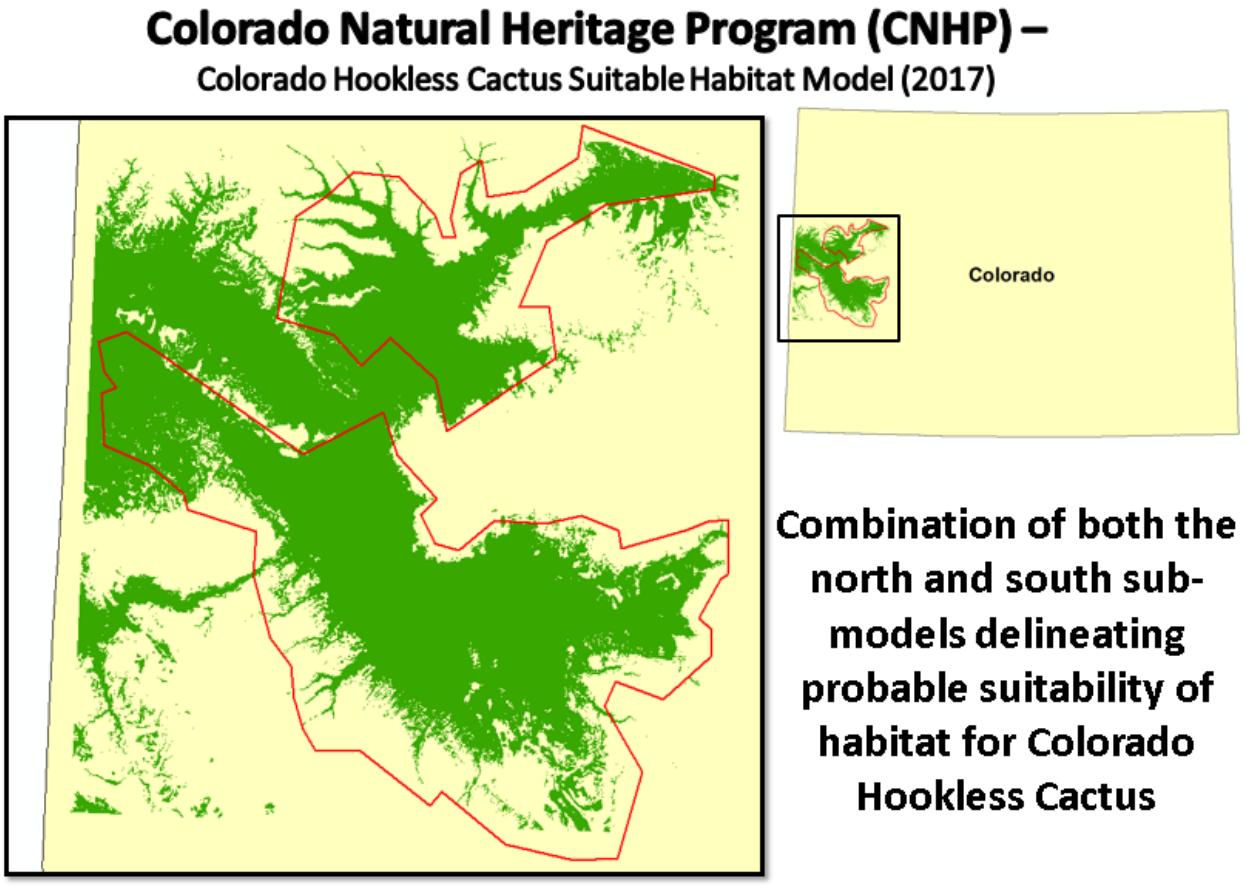

Figure 9. Comparison of the unrefined AOI and CNHP's habitat model.

In conjunction with Grand Junction's Creed Clayton, Ph.D., a model for refinement of the Colorado Hookless Cactus was established. First, I buffered all potentially suitable habitats (scores 1-4) in the 2017 probability model by 1000 m to account for potential indirect effects

from nearby projects to the Colorado Hookless Cactus and its pollinators. Separately, I then buffered the Colorado Hookless Cactus observations by 10 km to include unsurveyed areas beyond the known occupied range. Next, both buffers were intersected to develop the initial cactus AOI—all suitable habitats within 10 km of any current or historical Colorado Hookless Cactus observation. I then adjusted the boundary between *S. glaucus* and *S. parviflorus*. Displayed in **Figure 10** are all cactus points of *glaucus*, the listed subspecies. The colors correspond to the two different varieties of *glaucus* that have been identified. To finalize the cactus AOI, a boundary on the western edge of the buffer intersect was adjusted to account for areas occupied by *S. parviflorus* – a neighboring, unlisted cactus species identified by differing genetics than the *S. glaucus*. At this time, areas west of Broadway and north of Monument Rd. are determined to contain *S. parviflorus*, and hence, were left out of the AOI range for the Colorado Hookless Cactus (*S. glaucus*).

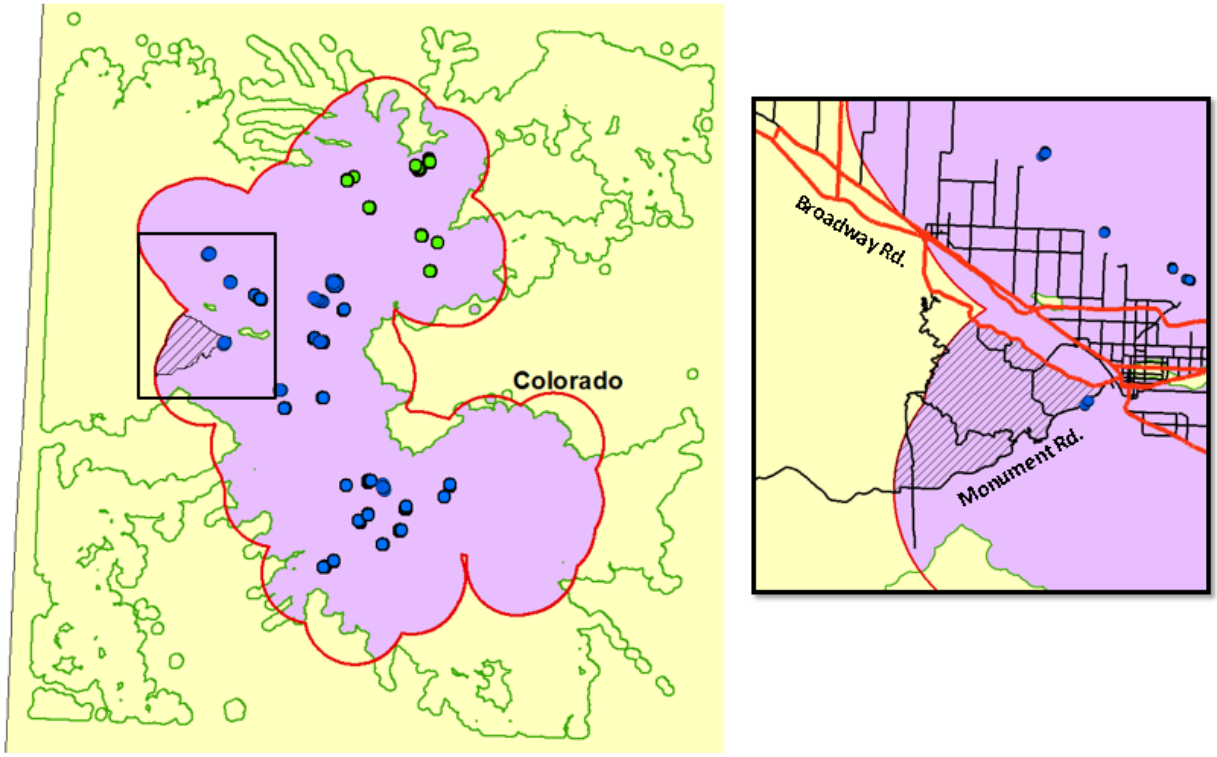

Figure 10. Boundary adjustment between *S. glaucus* and *S. parviflorus*.

Figure 11 illustrates steps of the model taken to refine the Colorado Hookless Cactus AOI. This is a polygon shapefile summarizes the current Section 7 consultation range map for the Colorado Hookless Cactus, *Sclerocactus glaucus*. **Figure 12** compares the final refined Colorado Hookless Cactus AOI overlaid with the current unrefined AOI. The gap from the unrefined AOI is now closed to accurately pinpoint that there is *glaucus* from north to south of the AOI extent.

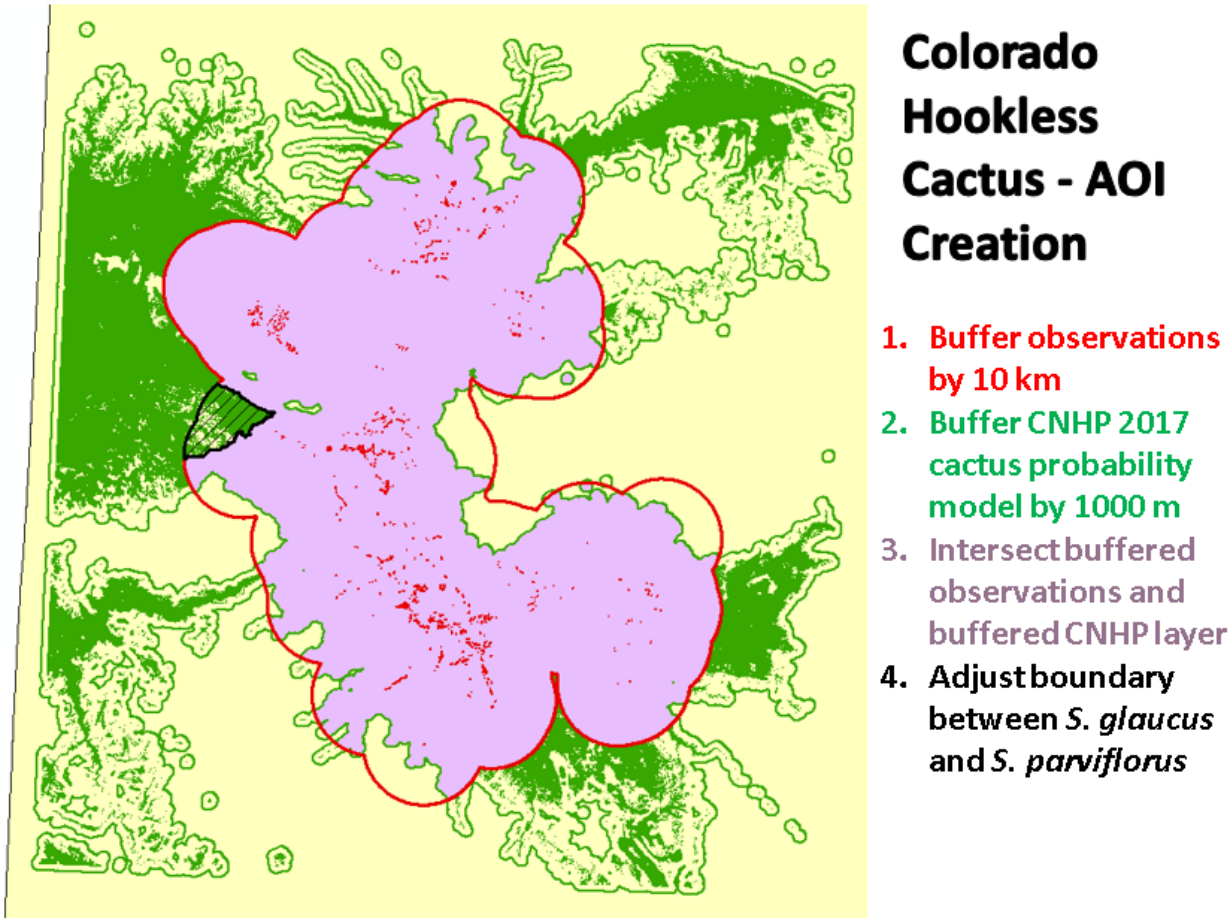

Figure 11. Refined Colorado Hookless Cactus AOI using established model.

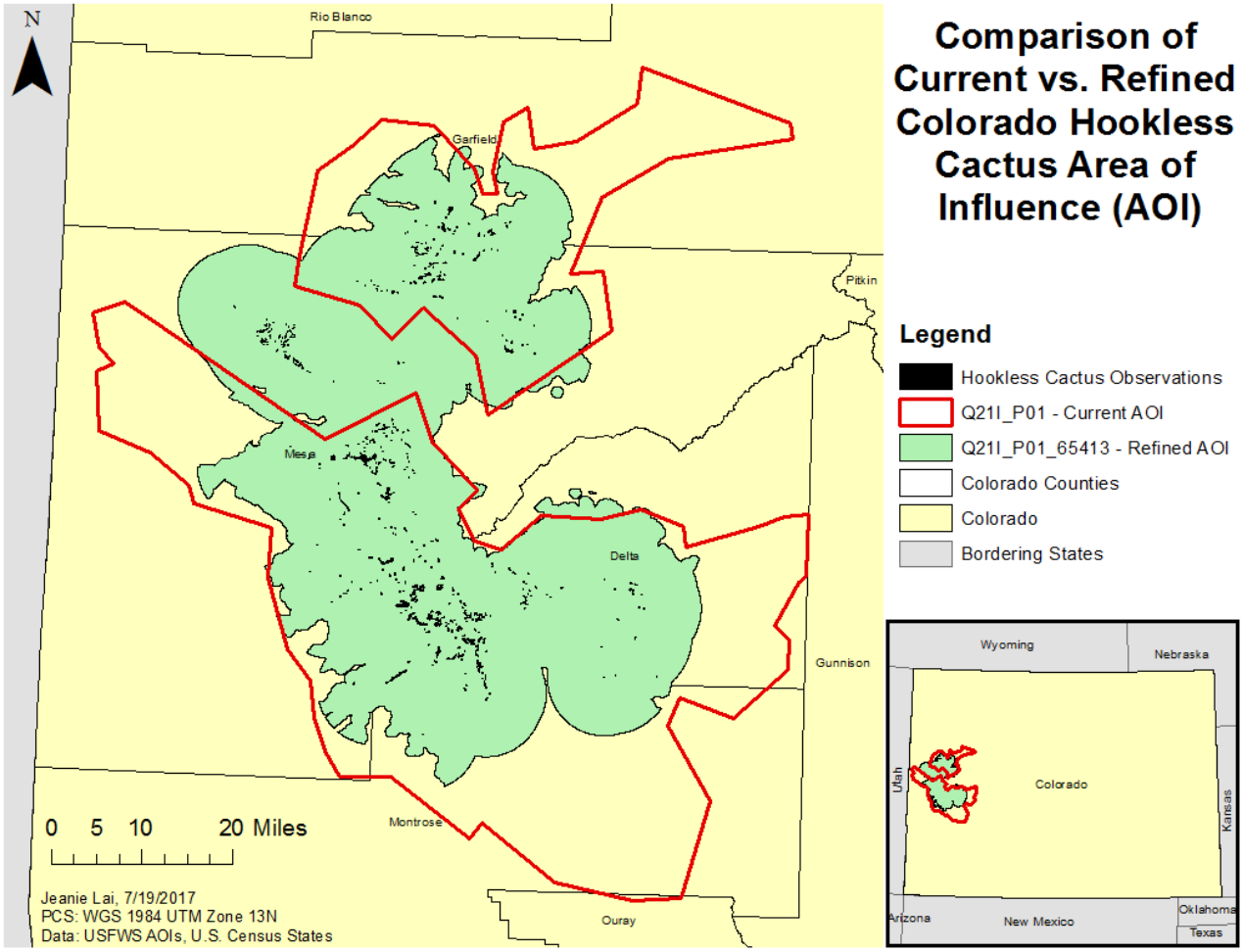

Figure 12. Comparison of the newly refined cactus AOI with the current unrefined AOI.

Task 4 - Preble's Meadow Jumping Mouse

The last listed species I worked on was the threatened Preble's Meadow Jumping Mouse (PMJM), tasked with creating a conservation potential map of this species. Preble's mouse inhabits well-developed riparian habitats with adjacent relatively undisturbed grassland communities (ECOS). They regularly use uplands at least as far out as 100 meters beyond the 100-yr flood plain, and have limited dispersal (ECOS). Given I was nearing the end of my fellowship timeframe; I did not have much time to consult with the project leads regarding my

progress and results. This work serves as preliminary grounds for future conservation potential mapping methodologies.

Figure 13 displays the weights and factors used to create the PMJM conservation potential map. The factors incorporated were elevation, mouse observations, land cover, streams, and non- vs. critical habitat. I reclassified those data layers with values 1 to 10, with higher values denoting higher conservation importance. Reclassified higher conservation areas were that of lower elevation, higher PMJM density, woodland & scrubland land covers, distances less than 300 ft. of 100 yr. flood plain wetlands, and designated critical habitats. Critical habitats and PMJM densities carried the highest weights. Next, land cover followed by streams and elevation.

Weights & Factors

Reclassified Factor Values

1 (Low Conservation Potential) **10** (High Conservation Potential)

25%	Non-critical habitat	Critical habitat
25%	Lower PMJM Density (obs/km^2) – Census tract level	Higher PMJM Density
20%	Western Great Plains Shortgrass Prairie & Others	Western Great Plains Riparian Woodland and Shrubland
15%	Distances > 300 ft. of 100 yr. flood plain wetlands	Distances < 300 ft. of 100 yr. flood plain wetlands (counties of Arapahoe, Boulder, Douglas, El Paso, Jefferson, Larimer, Teller, Weld)
15%	Higher elevation	Lower elevation

Figure 13. Weights and factors used to create the PMJM conservation potential map.

Figure 14 displays the current range of the Preble's mouse in CO. Its range is in northern, central CO. **Figure 15** displays the final conservation potential map of the Preble's mouse, a visualization of where high and low conservation potentials lie. In the western range of more mountainous areas, there is low conservation potential as opposed to the eastern range. This conservation potential map of PMJM was created using the factors of critical habitat (25%), PMJM density (obs./km sq.) (25%), land cover (20%), & elevation (15%), & streams (15%). Each factor was reclassified with pixel values 1 - 10, where higher values equated to higher conservation potential.

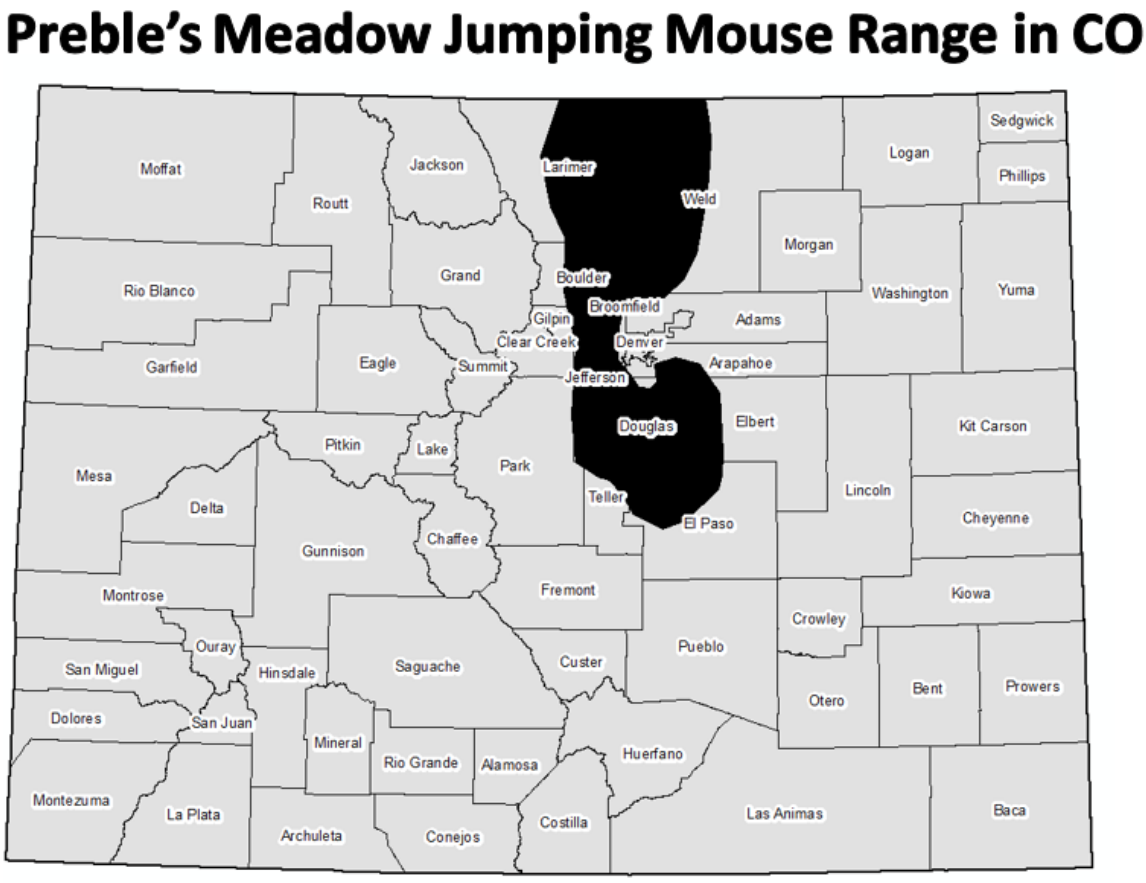

Figure 14. Current range of the Preble's Meadow Jumping Mouse (PMJM) in CO.

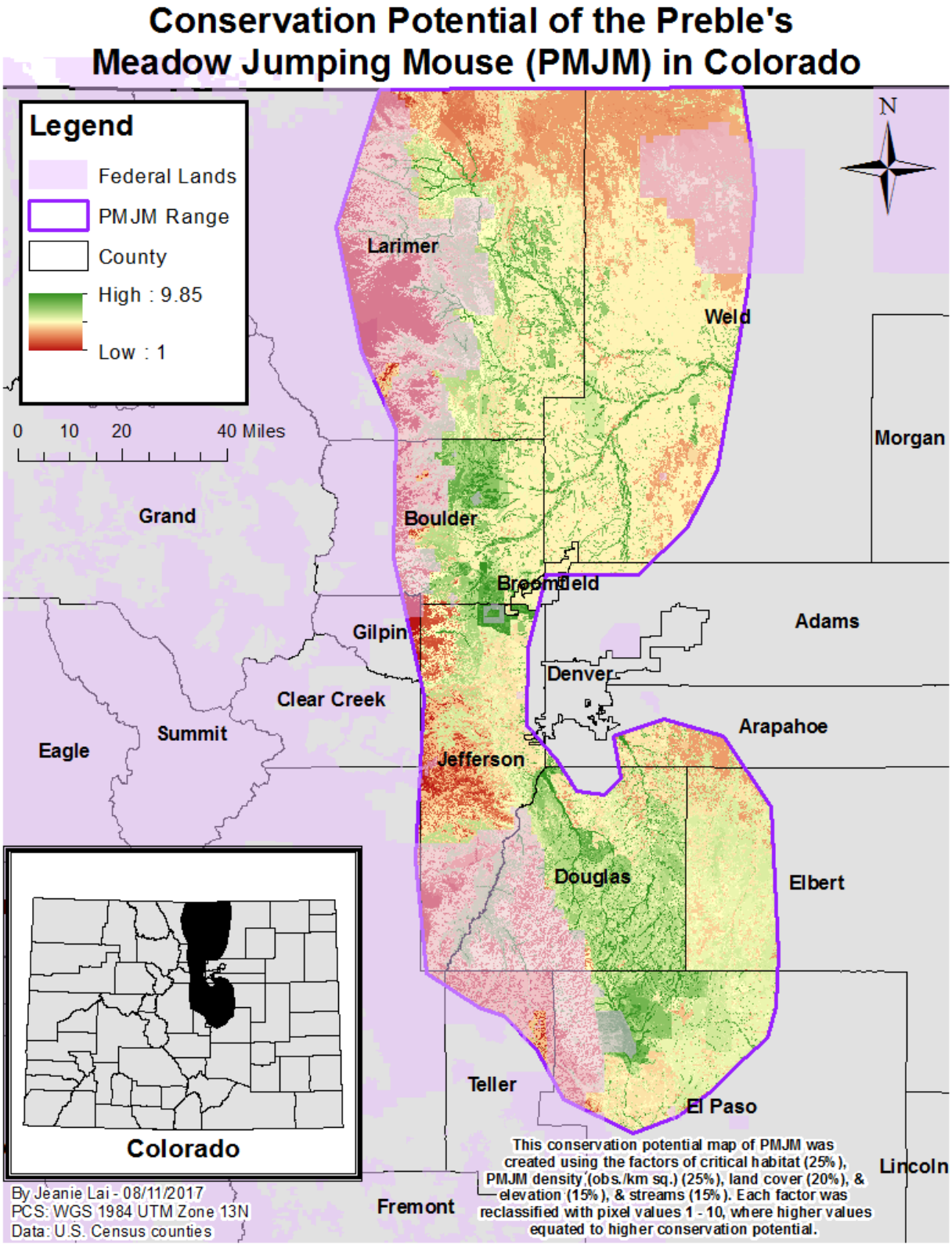

Figure 15. Final conservation potential map of the Preble's mouse.

Fellowship Responsibilities Summary

My accomplished tasks supports USFWS' mission of working collaboratively to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of people. I successfully refined AOIs of the Southwestern Willow Flycatcher and Colorado Hookless Cactus in Colorado. Refining AOIs aids USFWS in reducing unnecessary efforts and time spent due to false-positives (indicating species present when in reality, species is not present), and thus, increases USFWS efficiency in future Section 7 consultation processes. All refined AOIs were formatted and updated into the IPaC System. The IPaC system serves as a powerful decision-guiding tool facilitating action agencies to outline activities that consider potential effects to listed species and their habitats. During my time with USFWS, I also had the opportunity to produce GIS products for other listed species, such as the Greenback Cutthroat Trout and the Preble's Meadow Jumping Mouse. My GIS, research, and communication skills used to produce accurate GIS products of species aids USFWS in tackling conservation efforts of listed species.

CHAPTER 4: INTERNSHIP ASSESSMENT

Learning as a Fellow

My summer fellowship with USFWS provided an impactful and meaningful learning experience. In addition to learning about the mission, structure, and operations of USFWS, I partook in one of the many important tasks within Region 6's Branch of Decision Support that allow USFWS's mission come into fruition. The mission of USFWS is to conserve and protect our nation's unique fish, plant, and wildlife species and habitats in which benefit people today and of future generations. This dynamic federal agency operates on a national scale to forego

conservation efforts of endangered or threatened species. From collaboration with lead scientists as a GIS Technician, I experienced how pertinent GIS and data analysis is to supporting conservation management efforts of USFWS. With my fellowship role and responsibilities, I gained exposure to one sector within USFWS focused on data decision support.

Skills in Practice

My graduate level education at Clark University has been pivotal to my growth in GIS knowledge. With Clark's versatile courses available to students covering various GIS topics and applications, Clark provided a holistic strengthening of essential basics in GIS understanding and theory to aid in successful completion of my fellowship tasks. Specific skills learned at Clark aiding my fellowship tasks included advanced analytical vector GIS tools for spatial data creation, management, and analysis and multi-criteria decision-making. Remote sensing knowledge and skills also were useful for understanding the important role of remotely sensed imagery in conservation project analysis within USFWS. I did not specifically work with remote sensing applications in my job responsibilities, but through shadowing other decision support USFWS offices, I gained exposure to projects involving remote sensing. For instance, upon shadowing the Habitat and Population Evaluation Team (HAPET) team in Bismarck, North Dakota, I learned about the use of airplanes to produce aerial imagery to assess wetland quantity and conditions of the Prairie Pothole region over time. With Clark's GIS education, I learned how to produce, manage, and format spatial data accurately to be used in vast GIS analysis applications, such as multi-criteria decision mapping of listed species.

Beyond the skills provided my Clark GIS education, skills obtained during my fellowship consisted most importantly of interpersonal skills while I applied GIS to complete my job tasks. The GIS technical skills base is essential to fulfilling duties within the Branch of Decision

Support. However, in order to be completely successful in this fellowship, interpersonal skills were crucial to producing my GIS products given the need of adequate communication with expert scientists to map ranges for the listed species accurately for the public to utilize. This communication ability is also important given the large scale of USFWS's operations. Upon correspondence with expert scientists of listed species, I increased my skills of species ecological understanding, where decision-making using ecological knowledge to represent species ranges spatially required a high level of confidence and awareness when applying scientific expertise. Holistically, during my fellowship, I improved my interpersonal skills of leadership, independence, strategic thinking/critical thinking and problem solving, and effective oral and written communication skills. In addition, this fellowship provided many opportunities for me to gain exposure to multiple stakeholders, navigate organizational levels, demonstrate a high degree of autonomy and personal responsibility, and produce and present work products to key decision makers.

Closing Thoughts

Reflecting on my experience with USFWS, my fellowship experience was in line with my course of studies at Clark University and overall, my career goals beyond Clark University. Before attending Clark University, my background was in environmental science and GIS applications. With a devotion to public service, I am fervidly interested and invested in meaningful work that supports conservation efforts of our nation's natural resources. My experience at USFWS allowed me apply my environmental science and GIS knowledge to produce spatial data aiding in conservation efforts of listed species on a national scale. Clark University's GISDE program provides balance in covering environmental topics and GIS applications and theory. My fellowship experience has influenced my course selection for my

remaining semesters at Clark University and my career path beyond Clark University. Upon completion of my fellowship, I now see my interest in understanding environmental processes grow as I scope out coursework and skills benefiting my interest in a career supporting natural resource conservation.

Given my fellowship experience, I conclude with a strong recommendation to consider being a fellow of the prestigious USFWS's Directorate Fellows Program for the summer for those students interested with a natural resource background interested in a career of natural resource conservation. This fellowship program gives students a great opportunity to learn about USFWS's mission and operations and to network with many experienced and seasoned employees of USFWS. Ultimately, this valuable summer opportunity allows students to consider strongly if a career with USFWS within DOI is a desirable career path after degree obtainment.

CHAPTER 5: CONCLUSION

I started my journey as a Master's GIS for Development and Environment student at Clark University in fall 2016. Fast forward to past the halfway way mark of my Clark tenure, I am filled with appreciation for the resourceful Clark faculty and staff in GIS teaching and skill preparation that tremendously aided in my obtainment of a summer fellowship position in USFWS's Directorate Fellows Program. As a fellow this summer, I gained valuable insight on USFWS's mission and ways in which dedicated USFWS employees apply their skills and expertise to fulfill USFWS's mission.

My fellowship experience was an excellent and balanced combination of GIS application, environmental knowledge, and expert scientist guidance. I refined spatial AOI products for listed species onto USFWS's IPAC system, which serves as a powerful decision-guiding tool

facilitating action agencies by outlining activities that consider potential effects to listed species and their habitats. Refining AOIs aids USFWS in reducing unnecessary efforts and time spent due to false-positives (indicating species present when in reality, species is not present) and vice versa. AOI refinement and other decision support tasks comprise of GIS, research, and communication with field biologists to generate accurate species data increasing efficiency of USFWS species conservation operations. I absolutely recommend this fellowship opportunity with USFWS to those dedicated to a career of natural resource conservation for the benefits of people today and of future generations.

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