EXAMINING THE EFFECTIVENESS OF CITIZEN SCIENCE IN WILDLIFE CONSERVATION

By

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DEDICATION

This thesis is dedicated to all things keeping Arizona wild.

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ABSTRACT

"I'm not doing this for the recognition, I am just proud to be a part of this project and contribute to jaguar conservation."

- *Citizen science volunteer in Arizona*

The purpose of this research was to develop, implement, and evaluate a citizen science program to survey and monitor for jaguars (*Panthera onca*) and ocelots (*Leopardus pardalis*) within key mountain ranges in southwest Arizona. I had three main objectives: 1.) develop and implement a citizen science program to train participants with little or no knowledge of wildlife conservation, 2.) identify program effectiveness in comparison with experts in terms of the quality of data gathered and the financial and administrative costs/benefits, 3.) understand what creates an effective citizen science program and how it can be replicated in the future.

This research examined the efficacy of using citizen science as a tool to connect the public and scientific community through education and a research-based project. A network of citizen scientists were provided extensive education and training by field experts to participate in jaguar and ocelot monitoring in southern Arizona. The scale and scope of this project is unprecedented in the citizen science literature; participants drove and hiked off-trail monitoring wildlife cameras monthly for a minimum of one year in extremely rugged backcountry conditions in the mountains near the U.S./Mexico border. Citizen science participants were challenged by terrain, weather, and border issues during their time on this project. Despite these challenges, our group of nine citizen scientists successfully downloaded and sorted 28,637 photos from 22 cameras at 14 monitoring sites over 12 months. They logged a total of 327 hours of fieldwork including driving, hiking, and performing camera maintenance. After finishing a site visit, citizen scientists also sorted photos identifying wildlife, logging approximately 109 hours of data organization. In addition, 100% of our citizen scientists adhered to our protocols that we tested and implemented in the field over a one-year period. Citizen scientists continue to monitor remote wildlife cameras in the rugged mountainous regions of this southern Arizona study area.

Citizen science is often criticized because of skepticism from the scientific community regarding data integrity, quality control, and potentially biased data. This research aimed to exam the data integrity of citizen scientists by comparing it to the data analyzed by experts. When comparing

the ability of citizen scientists and field team experts in sorting and correctly identifying wildlife, I found strong positive correlations between the levels of data quality. These high positive correlations indicate that, with training, citizen scientists are capable of accurately identifying wildlife from camera data nearly as well as the field team experts, and can be an excellent surrogate for experts.

Connecting volunteers to the natural landscape through hands-on science research has the potential to create many positive experiences. Citizen science can increase participant's knowledge of science, build trust and foster understanding, and can create a more informed public. Despite these benefits, data integrity is the most important aspect of research and data collected by non-scientists remains heavily scrutinized. Collaboration amongst professionals, educators, program designers, and data managers is necessary to ensure that project goals are achieved while maintaining scientific integrity. Continuing to examine citizen science programs is important to advance the field of citizen science and foster meaningful relationships between the public and scientists. This study provided a unique opportunity to use non-scientists to augment data collection and assessment in the scientific workplace to advance jaguar and ocelot conservation. We strongly believe that citizen scientists remain an underutilized resource for helping scientists collect and analyze data in a climate of reduced funding and increasing need for long-term monitoring.

Chapter 1. Research Objectives

Research Introduction

Citizen science is an increasingly popular method of education and outreach to include the public as participants in scientific research. Citizen science is a collaborative tool that creates a nexus between professionals and the public and can increase the validity of public participation and benefit experts (Bonney et al., 2009). According to Whitelaw et al. (2001) citizen science is

> *"a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track, and respond to issues of common community concern. Citizen science refers to research collaborations between scientists and volunteers, particularly (but not exclusively) to expand opportunities for scientific data collection and to provide access to scientific information for community members. Citizen science typically involves projects where volunteers partner with scientists to answer real-world questions, and can be a program that enlists the public in collecting data across an array of locations over long spans of time."* (Whitelaw, 2001, 410).

Citizen science creates opportunities for interested participants and the local community to contribute to research through direct training, education, and data collection. Carr (2004) notes that, "Because local people are often the best placed to take action on local issues, they can complement, extend, refine, monitor, or initiate conventional science and do so with an ethic of care." Creating experiences where interested citizens can contribute to scientific research and influence decisions in a positive way is a goal of citizen science projects. Carr (2004) goes on to say that, "Science is a process of inquiry, not a process of exclusion. Therefore, it is as much the purview of those who practice it outside governments, corporations, and universities, as it is for those inside science institutions. Indeed there are many circumstances in which local people produce results that enhance, contest, verify, contradict, or otherwise relate to agency/academic scientists." Citizen science provides investment from the scientific and policy community into local and national values by engaging interested participants through training, education, and direct contribution to scientific research.

Through a cooperative effort between the University of Arizona (UA), United States Geological Survey (USGS), and the United States Fish and Wildlife Service (USFWS), a research team was assembled to develop and implement a citizen science program to survey and monitor for jaguars

(*Panthera onca*) and ocelots (*Leopardus pardalis*) within the U.S. portion of the Northwestern Recovery Unit (NRU). The UA conducted a multi-year surveying and monitoring effort (*Jaguar Surveying and Monitoring in the United States* contract number: F11PXO5778) for jaguars and ocelots in southern Arizona and New Mexico from 2012 - 2015. One of the goals for this project were to establish effective survey and monitoring methods, and use these methods to document jaguars and ocelots along the U.S.-Mexico border. A component of this project was also to develop, implement, and analyze a citizen science program for long-term monitoring of jaguars and ocelots within the U.S. portion of the NRU. Long-term monitoring is a necessary and valuable component of any study, particularly when monitoring wildlife species and/or evaluating ecosystem change over time. Frequently there is little funding allocated to continue long-term monitoring. As a result of inconsistent funding, citizen science has become an effective and popular strategy for engaging trained participants in data collection and analysis.

Problem Statement

A limitation in much wildlife research is that monitoring is conducted only in a portion of a species range, resulting in models that do not encompass the range of abiotic and biotic conditions encountered by the species. Data derived across the range of a species is necessary to model the impact of broadly distributed factors (Elith et al., 2009). Mammals are especially difficult to monitor due to their distribution, lack of specific calls, and avoidance of humans (O'Connell et al., 2006). The jaguar and ocelot monitoring team initiated a landscape-scale camera monitoring project with the intent of documenting and modelling notoriously cryptic and rarely seen species. "Camera traps have been used successfully for landscape scale surveys, returning photographs that are easily quantified and verified as biodiversity records. Typical camera projects have dozens or a few hundred locations sampled by paid field staff. Single projects often lack sufficient detections of rare species and only by pooling multiple projects together can analysis be conducted" (McShea et al., 2015).

The *Jaguar Surveying and Monitoring in the United States* project was an ambitious three-year project located across a large spatial area of the southwest. The primary method used to detect jaguars and ocelots were through motion-sensor trail cameras that passively monitored wildlife activity in the area. 250 camera sites with paired or single cameras were set and monitored throughout Arizona and New Mexico within the NRU (Culver et al., 2016). “One of the greatest modern challenges to ecologists is to provide mechanistic explanations for the local abundance of a given species” (McGill, 2010; McShea et al., 2016). Monitoring wildlife through remote photography is one method to overcome this challenge. “Remote photography can be less time consuming, costly, and invasive than traditional research methods for many applications. However, researchers should be prepared to invest time and money troubleshooting problems with remote camera equipment and recognize the limitations of data collected with remote photography equipment” (Cutler and Swann, 1999). Citizen scientists can augment camera monitoring projects to increase the geographic area of the study sites, monitor cameras, and assist and support field researchers.

Despite the potential positive aspects of using citizen science for large-scale camera monitoring, little published data exists regarding the efficacy of these types of monitoring programs and how these programs can aid researchers and land managers. Citizen science camera monitoring projects must demonstrate effective program design, data management, and effective training and education of participants to collect data at a level acceptable to experts. High quality data is the foundation of scientific research, without evidence examining the integrity of data collected by citizen scientists these types of programs will not provide value to scientific research. The scale and scope of this project is unprecedented in the citizen science literature; participants monitored wildlife cameras for neotropical felid occurence in extremely rugged backcountry conditions in mountainous areas near the U.S./Mexico border. This research provided qualitative and quantitative analyses of data collected by citizen scientists participating in a large-scale camera monitoring project and examined program development, education and training, database management, and overall program success.

Study Objectives

My thesis research aimed to help close the gap between data produced by citizen scientists and the scientific and decision-making communities. As part of this research, I and my colleagues developed a citizen science program to survey and monitor for jaguars and ocelots in Arizona.

The citizen science program consisted of a phased approach to train and build capacity of citizen scientists comprised of individuals from a range of socio-demographic communities. The program included a strong emphasis on education, jaguar and ocelot conservation, and extensive training of field-based techniques, including how to collect, download, verify, and analyze scientific data. The goal of this study was to research, evaluate, and characterize the program and evaluate success based on:

> <u>Objective 1.)</u> Develop and implement citizen science program, including characterization of:
>
> - a.) how participants are selected
> - b.) how field data collection activities are organized
> - c.) how field data is processed and stored
> - d.) train participants with little or no knowledge of camera monitoring projects
>
> <u>Objective 2.)</u> Identify program effectiveness in comparison with experts in terms of the quality of data gathered and the financial and administrative costs/benefits, including:
>
> - a.) effectiveness in comparison to field experts in terms of the quality of scientific data gathered and the financial and administrative costs/benefits.
> - b.) how successfully participants followed all necessary protocols
>
> <u>Objective 3.)</u> Understand what creates an effective citizen science program and how it can be replicated in the future, including:
>
> - a.) whether citizen science data was used successfully in this project
> - b.) how this experience can translate into other projects
> - c.) what are the tangible and intangible benefits of citizen science

Citizen science participants were trained in wildlife identification, ecosystem functioning, conservation, land management, and scientific data collection methods. We tested the accuracy and reliability of citizen science produced data to determine the integrity of data collection and assessment by comparing them to a team of experts.

Incorporating citizen scientists into the jaguar and ocelot surveying and monitoring project created several challenges including study design, data integrity, data management, and training and organization. A quantitative assessment of citizen science data versus expert data was compared to analyze the correlation and assess data integrity. The objectives of this project were intended to extend beyond the timeframe of this research. The goals of training and implementing this program were to increase community awareness of and participation in wildlife conservation, continue building relationships between research teams and the local community, and continue surveying and monitoring for jaguars and ocelots after the UA contract had ended with a group of trained citizen scientists.

Research Limitations

Although this study successfully accomplished its intended objectives, several factors limited the scope of the research. This study was designed as part of a larger project (*Jaguar Surveying and Monitoring in the United States* contract number: F11PXO5778). The contract for the citizen science team began one year after the implementation of the monitoring project. Because our team began later, many months of coordination with the monitoring team regarding project protocol, timelines, and funding were necessary. This loss of time pushed back our intended timeframe and program implementation. The monitoring project and citizen science program were on different timelines and this affected our ability to build the second phase of citizen scientists. Our team relied heavily on the monitoring project because we needed to use the equipment purchased by the team. Throughout this project, all camera sites were chosen and set by field team members. During training, citizen scientists were taught how to set cameras and the principles of where to set cameras to capture the best photo data (such as finding animal trails, previous jaguar sites, water sources, etc.). Despite this training all camera sites were chosen and set by field team members; this prevented comparison analyses in the abilities of trained citizen scientists to identify high quality camera sites. Other factors affecting this program were confidentiality issues regarding access to sensitive information about endangered species and personal property. Despite wanting to build a robust citizen science program, selection of participants was highly vetted to maintain control of confidentiality. The long-term goal of this program – to build a network of trained citizen scientists – was limited by the resources and timeframe of the larger jaguar and ocelot monitoring project.

Chapter 2. Introduction and Background

Jaguars and ocelots in the United States

The region known as the Madrean Archipelago in the southwestern United States and northwestern Mexico is one of the most biologically diverse and ecologically vulnerable regions in the United States (Cordova et al., 2007). It crosses the boundary between two nations and is influenced by two major climatic regimes: tropical and temperate. This area is ecologically diverse and home to possibly four species of native wild cats. Two felid species, the bobcat (*Lynx rufus*) and puma (*Puma concolor*) are common throughout the region. The other two neotropical species; jaguar (*Panthera onca*) and ocelot (*Leopardus pardalis*), reach their northern limit in the border regions (Haynes et al., 2005). The low density and solitary nature of these neotropical cats means little is known about their population size, range, or habitat in this region (Grigione et al., 2007). "The conservation of populations at the periphery of a species range is now considered extremely important to the long-term survival of endangered species; therefore, conservation of jaguars in the northernmost portion of their range (i.e., the borderlands population) deserves attention equal to or greater than that of core populations" (Abbitt et al., 2000; Channell et al., 2000; Johnson et al., 2007, McCain et al., 2008). Neotropical felid populations living in the northern reaches of their habitat face many challenges including rapid urbanization and border security activities which potentially threaten to alter the spatial habitat structure of these species (Flesch et al., 2010) making it important to identify and pursue opportunities to monitor these felid populations in the border region.

Based on credible historical accounts, 62 jaguars have been recorded in the southwest since 1900 (Brown et al., 2000). Historically, jaguars ranged as far north as the Grand Canyon in Arizona but were considered close to extirpation in the U.S. in the last half of the 20th century (Brown et al., 2001). In 1996, the first photographs of a jaguar since 1986 were captured in southern Arizona; this photographic evidence reinvigorated conservation efforts in the U.S. to protect these cats (Brown et al., 2001; Haynes et al., 2005; McCain et al., 2008). After this evidence, the Arizona Game and Fish Department (AZGFD) and New Mexico Game and Fish Department (NMGFD) began working with other agencies and private individuals to begin development of a management strategy for jaguars in the U.S. (Van Pelt, 2002). The increased management efforts prompted the USFWS to list the jaguar as an endangered species under the Endangered Species Act (ESA) in 1997. Despite the ESA listing and increased research, little was known about the status, distribution, and ecology of jaguars in the border regions (McCain et al., 2008).

Historically, ocelots have ranged into the southwestern United States. As of 2015, there are fewer than 60 ocelots in Texas with most individuals documented in the Laguna Atascosa National Wildlife Refuge and surrounding ranches (Grigione et al., 2007; Hilary Swarts *unpublished data* 2015). The last documented sighting in Arizona was in 1964 in the Huachuca Mountains (Girmendonk, 1994). Ocelots have been protected by a mandate of the AZGFD since 1970 (Grigione et al., 2007). In 2009, one ocelot was photographed in Cochise County, Arizona and another in 2011 in the Huachuca Mountains, Arizona, the first verifiable evidence of ocelots in Arizona in over 50 years.

The verified presence of these neotropical felids in the southwestern U.S. resulted in the development of a combination of new research and policies. Despite both species listed as endangered under the U.S. ESA and Mexican legislation (NOM-059-2001), little was known about the ecology, habitat use, and movement patterns of jaguars and ocelots in the borderlands, which made it difficult to manage for these species (Hatten et al., 2003; Grigione et al., 2007). The lack of information about these species in the border regions led to the assumption that jaguars observed in Arizona and New Mexico were not residents of the United States, but young dispersing transients (Boydston et al., 2005; Rabinowitz, 1999; McCain et al., 2008) coming from the resident population in Mexico (United States Fish and Wildlife Service, 2006). As evidence began to indicate that these U.S. cats were residents (likely non-breeding residents; Karanth et al. 2014), scientists and conservationists began working in the border region to study the distribution and status of each species (Grigione et al., 2007).

In March 1997, the AZGFD and NMDGF entered into a Conservation Agreement with federal, state, and local partners to contribute to jaguar conservation in Arizona and New Mexico. The Conservation Agreement contained two main components: 1.) development of a Conservation Assessment, which describes the status of jaguars in the United States 2.) reduce/eliminate threats in Arizona and New Mexico that might prevent expansion of the current range and distribution of the jaguar (Van Pelt, 2006). A main objective of the Conservation Agreement was to identify potential jaguar habitat in Arizona and New Mexico, focus conservation efforts, and identify opportunities for habitat management. A subcommittee was established to develop habitat suitability criteria for jaguars in Arizona, New Mexico, and northern Mexico, and produce maps identifying potential jaguar habitat. The habitat suitability maps identified southeastern Arizona including Santa Cruz, Pima, Cochise, and Graham Counties as the best habitat for jaguar populations (Hatten et al., 2003). At this time, no such planning has been developed for ocelot populations in the Arizona, New Mexico border regions.

The presence of jaguars and ocelots in the border regions created new opportunities for research and conservation. A combination of federal, state, and local research and conservation organizations began focusing on studying these neotropical felids. Some of these groups included: 1.) Borderlands Jaguar Detection Project which partnered with the Wildlife Conservation Society to conduct track surveys, hair snares, collect scat, and place wildlife cameras along the U.S.- Mexico border, 2.) Border Cats Project which used wildlife cameras, track surveys, and DNA analysis of scat and hair to gather baseline data on native felids in four National Park Service sites in southeastern Arizona, 3.) Sky Island Alliance Tracking Program which trained volunteers to document tracks and signs of pumas, bobcats, jaguars in potentially critical wildlife corridors to document wildlife use of corridors and valuable habitats, 4.) Defenders of Wildlife Bordercats Working Group which included track surveys, wildlife cameras, and interviews combined with sightings to create a database and held an expert mapping workshop to develop an outline of high priority areas and corridors for each species (Haynes et al., 2005). The goal of these projects and others served to assess the status and provide information about wild cats in the border region.

Private citizens and endangered species

The most recent sightings of jaguars, and ocelots, have been in the ecologically diverse U.S.-Mexico border region. Jaguars and ocelots range across different nations and habitat types, including the Sky Islands in the southwestern U.S. which also provide habitat for many of the region's other large carnivores such as black bears (*Ursus americanus*) and mountain lions (*Puma concolor*) (Sanderson et al., 2002; Atwood et al., 2011). In this same area the human population is increasing as documented in a 2005 analysis showing Pima County, Arizona to be losing one acre of desert every two hours to sprawl and development (The Conservation Fund, 2005). This increasing urbanization has created human-wildlife conflict. "Over the last century, the jaguar's range has been reduced to approximately 46% of its historic (pre-1900) range" (Sanderson et al., 2002). Increased activity along the U.S.-Mexico border including illegal immigration, construction of immigration deterrents including fences, roads, and towers, and increased human presence has contributed to human-wildlife conflict. According to Sanderson et al. (2002), "Jaguars range across many nations and habitat types, making international cooperation a necessity for jaguar conservation." The borderlands where jaguars reside exist in a mosaic of federal, state, and private landownership making it even more difficult to undertake multi-jurisdictional coordination and planning.

The increasing pressures on this region due to population growth and international tensions have created a complex situation when working with endangered species. The USFWS has relied on the U.S. ESA to conserve rare and endangered species on all lands, including privately owned property (Fisher, 1996; Wilcove et al., 1996) under the assumption that listing endangered species under the Act will help protect their populations and habitats (Brook et al., 2003). Unfortunately, in an increasingly litigious environment an ESA listing does not always ensure the safety of a species. The wide variety of organizations and researchers participating in jaguar and ocelot conservation in the border regions created an increasingly complex situation with many stakeholders. Jaguar distribution patterns suggested that southeast Arizona was the most likely area for future jaguar occurrence in the U.S. and a hotspot for conservation (Hatten et al., 2003). This area is made-up of National Parks, National Forests, State Trust lands, tribal, and private properties whose owners and managers may have differing opinions of habitat designation and management of endangered species. Conflict and mistrust between federal land agencies, conservation agencies, and private landowners has the potential to stall progress and discourage species conservation (Brook et al., 2003).

Studies have shown that landowners are wary of participating in endangered species research because of the assumption that data collected could be used to regulate their property and because many owners do not trust the government or conservation organizations (Brook et al., 2003). Collaborating with all landowners in the borderlands is necessary, especially when working with wide-ranging animals such as jaguars and ocelots. Often, small-scale conservation efforts over narrowly defined areas have not succeeded in stemming the extirpation of wide-roaming species such as jaguars and ocelots (Weber et al., 1996). According to Brook et al. (2003), "Private property owners' actions play a critical role in determining to what extent species conservation goals will be met. In the U.S. more than 90% of federally listed species have some habitat on non-federal land, and 37-50% depend entirely on nonfederal land." Collaboration amongst all stakeholder groups can improve the amount and type of information shared because it provides an opportunity to learn about conservation from experts, and gives experts insight into private property owners' knowledge (Brook et al., 2003). Collaborative processes increase perceived control for all parties involved, which can lead to decision-making processes that are perceived as fair (Tyler et al., 1992). Designing a process which involves all potential stakeholder groups is vital to long-term conservation efforts for wide-roaming species such as jaguar and ocelot which move and live within the complex ownership matrix of the border region.

Public participation

Providing citizens and stakeholders a forum to come together to discuss and plan land management issues with experts and public land staff is important to make effective decisions. Public participation is one method to provide this level of collaboration. According to Steelman et al. (1997), "Public participation is an ambiguous term that means many different things to many different people." The basic goal of public participation is to give citizens a voice in policy and planning decisions. Steelman et al. (1997) goes on to say that, "Public involvement is viewed as an unassailable good, for public deliberation and participation are keystones in our democratic culture. Public involvement can contribute to the creation of more informed policy, provide a normative justification for governance, and foster social, psychological, and political empowerment." Decision-making and policy planning has become more democratized as public participation has become a normal part of the process.

The public has not always had such freedom in the policy process. The public was formally granted access to the planning and decision-making processes with the passing of the Administrative Procedures Act (APA) of 1946. This law mandated that all federal agencies follow certain protocol when developing policy, notifying the public and other agencies of their intentions, requesting public information, distributing information to the public, and receiving comments from the public and other agencies. Legislation in the 1960s and 1970s including the National Environmental Policy Act (1969), Coastal Zone Management Act (1972), and the National Forest Management Act (1976) opened federal land management decisions, which included public hearings and comment periods to allow citizens input into the natural resource policy-making process (Steelman et al., 1997). Federal land agencies are required to complete a plan that guides the activities of management decisions, considers the desires of interested parties, educates individuals about management decisions, and solicits information on the publics' desires (Gericke, 1994). This process is meant to be an effective forum for citizens to communicate with the different levels of government and express their concerns and preferences for decisions being made at a public or national level.

Cupps (1977) suggests that, "Public participation is desirable because it increases the representativeness and responsiveness of our administrative and political institutions, heightens citizens' sense of political efficacy, and acts as an important check on the abuse of administrative discretion." Public participation can improve the legitimacy of the decision-making process and build capacity to engage in the policy process, which leads to better results in terms of environmental quality and other social objectives (Dietz et al., 2008). All citizens have the right to establish their opinions and values; formal public participation has provided a new dimension to decision–making. According to Cupps (1977), "Citizen advocates have sought to place basic personal and moral issues and values at the center of political discourse, introducing "quality of life" considerations… into public policy." Mandating public participation as a required step in the planning process has made citizen groups effective at spreading their message and influencing political action.

Creating public-professional partnerships that are transparent, produce high quality data, and create trust between the public and decision-makers is important to maintain the values of public participation. Effective and informed public participation can be a powerful way to influence management decisions. Henning (1987) states that, “The general orientation of the greater majority of the public is toward values which form the basis for their nontechnical concerns and interests. In this sense, the general public can act very effectively to teach decision makers about environmental values and concerns.” Public participation is effective and can bring issues of morality and ethics to decision-makers. Public participation that is proactive and coordinated optimizes the ability to determine legitimate public concerns and reach sound decisions.

While public participation has provided a voice for citizens, it has also created controversy. Despite many forms of legislation requiring public participation, Congress has not been explicit regarding how public input should be handled (Steelman et al., 1997). Without specific protocol, participation can result in an automatic or uneducated majority that can be very dysfunctional to political and administrative systems. A chief complaint is of the overdramatization, hyperbole, and shrillness which some citizen groups present their case (Cupps, 1977). Since the implementation of the public participation process, federal agencies have faced high levels of dissatisfaction which has resulted in a high number of appeals (Gericke, 1993). The appeals process is costly and time-consuming. According to the U.S. Forest Service,

> *“The bottom line is that our appeals process has evolved so that it is not the simple, quick, informal process that the Forest Service originally intended it to be. Instead, it has become a significant generator of paperwork and a time consuming, procedurally onerous, confrontational, and costly effort”* (Robertson, Chief, USDA Forest Service, 1991).

Resolving conflicts created through the public participation process can stall progress, diminish funds, and create distrust amongst all involved.

Public participation has created opportunities and problems within the policy-making process. While public participation can bring nontechnical concerns into the conversation, it does not always benefit the process or create new tools to resolve issues. Brook et al. (1997) states that, "Usually flowing from legislative mandates, non-binding direct public input provisions often fail to give bureaucratic agencies specific direction in how to handle public input or conduct public processes." Democratizing decision-making has created progress but has also allowed anyone, even those who bring uneducated and disruptive discourse, into the process. Ensuring the continued progress and contributions to collaborative decision-making processes will require changing the current conditions of poorly monitored content created by participants. Beyond public hearings and meeting groups, public participation has the ability to involve interested citizens through high levels of education, training, and participation to contribute to the process in meaningful new ways. Through the development of citizen science programs, experts may be able to train participants to develop data that has high integrity and follows scientific protocol which will educate participants and allow effective contributions to the decision-making process.

Citizen Science

What is citizen science?

Citizen science is a collaborative tool that creates a nexus between professionals and the public that can increase the validity of public participation while benefitting scientific knowledge (Bonney et al., 2009). Citizen science is ideally not the traditional "scientists using citizens as data collectors" but instead, "citizens as scientists" (Dickinson et al., 2012). Citizen science creates opportunities for interested participants and the local community to voluntarily contribute to research through direct training, education, and data collection. Carr (2004) notes that, "Because local people are often the best placed to take action on local issues, they can complement, extend, refine, monitor, or initiate conventional science and do so with an ethic of care." Creating experiences where interested citizens can contribute to scientific research and influence decisions in a positive way is often a goal of citizen science projects. Carr (2004) goes on to say that, "Science is a process of inquiry, not a process of exclusion. Therefore, it is as much the purview of those who practice it outside governments, corporations, and universities, as it is for those inside science institutions. Indeed there are many circumstances in which local people produce results that enhance, contest, verify, contradict, or otherwise relate to agency/academic scientists." Citizen science provides investment from the scientific and policy community into local and national values by engaging interested participants through training, education, and direct contribution to scientific research.

History

Citizen science is a term with multiple origins but was coined independently in the U.S. during the mid-1990's by Rick Bonney (currently the Director of Public Engagement in Science at the Cornell Lab of Ornithology) (Riesch et al., 2014). While the term "citizen science" is relatively new, the principles of non-scientists contributing to scientific pursuits exists throughout history. Silvertown (2009) states, "The rise of science as a paid profession is a relatively recent phenomenon, dating from the later part of the 19th century. However, citizen scientists have never disappeared. Today, most citizen scientists work with professional counterparts on projects that have been specifically designed or adapted to give amateurs a role, whether for the educational benefit of the volunteer themselves or for the benefit of the project." Examples of amateurs and non-professionals contributing and advancing science exist throughout history. "This includes individuals such as Benjamin Franklin (printer, diplomat, politician, and kite flyer) and Charles Darwin who accompanied Captain Robert FitzRoy on the *Beagle* as a companion, not as a professional naturalist" (Silvertown, 2009). Large-scale citizen science projects also exist throughout history. Krasny et al. (2005) states that, "In 1900, the American Museum of Natural History's ornithologist, Frank Chapman, initiated the Christmas Bird Count (CBC) as an alternative to regular holiday bird-shooting contests; this project popularized ornithological monitoring in the United States and is now run by the National Audubon Society." At the end of the 19th century, one of the first monitoring projects began when volunteers submitted rainfall and temperature data to the National Weather Service (Firehock et al., 1995).

Throughout history, vast amounts of data and progress have been possible through the participation of engaged members of the public. Citizen science continues to contribute to scientific research and societal needs today. "Citizen scientists now participate in projects on climate change, invasive species, conservation biology, ecological restoration, water quality monitoring, population ecology and monitoring of all kinds" (Silvertown, 2009). On September 30, 2015 John P. Holdren, Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy, issued a memorandum to the heads of executive departments and agencies titled “Addressing Societal and Scientific Challenges through Citizen Science and Crowdsourcing.” This memorandum had two main objectives, 1.) outline principles that agencies should apply to ensure future use of citizen science that leads to greatest value and impact, 2.) directs agencies to identify a coordinator for citizen science and create a project database to be accessible to the public to improve collaboration within and across agencies. Citizen science also benefited from the Office of Management and Budget (OMB) which issued memorandum M-15-16 titled “Multi-Agency Science and Technology Priorities for the FY 2017 Budget” which encourages agencies to incorporate and support citizen science programs within federal agencies (Holdren, 2015). Federal support of citizen science increases validity of these programs and creates public investment in research.

Benefits of citizen science

<u>Economics</u>

One element affecting the rising popularity of citizen science is the economic benefits and incentives to scientists and government agencies. According to Silvertown (2009), “A factor driving the growth of citizen science is the increasing realization among professional scientists that the public represents a free source of labor, skills, computational power, and even finances.” Many government agencies face cutbacks in funding and staffing; despite these cutbacks, gathering data is still necessary for decision-making processes (Conrad et al., 2013). The reality of limited financial resources for data collection has created a growing need to devise programs that are both cost-effective and capable of fulfilling multiple objectives (Tulloch et al., 2013). Citizen science programs can provide the necessary people and skills to aid researchers and continue data collection. Citizen science and crowdsourcing projects can enhance scientific research and address societal needs, while drawing on previously underutilized resources. Researchers at the University of Washington analyzed 338 citizen science projects from around the world and estimated that the in-kind contributions of 1.3–2.3 million citizen science volunteers to scientific research have an economic value of up to $2.5 billion per year (Holdren, 2015). The economic benefits from citizen science programs include cost savings, an increased field staff, and flexibility to work outside of office-hours (Whitelaw et al., 2003).

Universities and scientists also benefit from collaborating with citizen science networks. Many funding sources now require some form of education or outreach. Funders such as the National Science Foundation now require every grantholder to undertake project-related science outreach as a form of public accountability. According to Silvertown (2009), “If we want to continue to spend taxpayer’s money, it is in scientists’ own interest to make sure that the public appreciates the value of what they are paying for.” Holdren (2015) states that these grant requirements, “Provide hands-on learning in science, technology, engineering, and mathematics (STEM), and connecting members of the public directly to Federal agency missions and to each other.” Requiring this form of outreach has the potential to engage people through citizen science to work together on shared objectives. Agencies and universities can help build cooperative relationships that increase awareness of problems, strengthens existing institutions, and builds new social networks (Bliss et al., 2001).

Engaging large groups

Beyond economics, citizen science projects are beneficial because they engage affected populations and create learning experiences by generating knowledge, inquiry, and place-based experiences. Benefits to professionals and participants overlap because learning, data, and results constitute a sharable public good (Triezenberg et al., 2012). Citizen science benefits experts and policy-makers by creating a large group of trained and engaged participants. This process creates new opportunities for professionals by expanding the potential for spatial research and supplementing localized research programs (Dickinson et al., 2012). Through the combination of historical data and assembly of a large and dispersed volunteer group of citizen scientists; opportunities exist for research at huge spatial and temporal scales (Dickinson et al., 2012).

Dickinson et al. (2011) state that, “Omnibus surveillance of multiple species throughout a region has an important role to play as a first line of attack; it can illuminate unexpected or even counterintuitive patterns and trends as the starting point for intensive, targeted monitoring or theoretically driven research.” Citizen science is often the only practical way to achieve the geographic extent required to document ecological patterns and address ecological questions at scales relevant to species range shifts, migration patterns, disease spread, broad-scale population trends, changes in national and state policy, and impacts of environmental processes (Tulloch et al., 2012). Wildlife cameras are a relatively new technology that can encompass the spatial and temporal challenges of landscape level research. As the technology of wildlife cameras has increased, researchers have utilized remote cameras to study phenomena that are difficult to address through traditional research methods of observation or capture (Cutler and Swann, 1999). Citizen science programs are an ideal method to monitor large-scale wildlife camera projects. Wildlife camera studies can be used to analyze a variety of important ecological concerns including presence-absence, population size, ecology, behavior and more (Cutler and Swann, 1999). Wildlife camera monitoring also has the potential to be used in citizen science programs because participants consider it a rewarding activity (McShea et al., 2015). The increasing amount of technology and data available to the public creates citizen science programs which are more sophisticated, and demand for these highly trained volunteers is increasing.

The rapid advancements in technology have created opportunities for participant contribution to scientific research, informal knowledge sharing, and information access. As the production of information transforms, technology can provide opportunities for citizens to participate in activities formerly exclusive to experts (Connors et al., 2012). Many challenging problems span spatial scales and impact diverse groups; addressing these challenges requires monitoring, efficient data collection, and increased communication and cooperation between experts and the public (Connors et al., 2012). Engaging the public as citizen scientists can help address these issues. Citizen science creates opportunities for understanding processes occurring at broad geographic scales and on private lands, which are impossible to sample extensively with traditional field research models (Dickinson et al., 2011). Through proper outreach and training, citizen scientists can be engaged across broad geographic regions and target diverse and invested communities. A strength of citizen science programs is the collection of data at regional, national and even continental scales (Devictor et al., 2010). Dickinson et al. (2012) notes that, “While some data can be obtained with satellite images and other remote-sensing technologies, others can be acquired only through the involvement of massive research teams like those assembled by citizen science.” Trained citizen scientists can expand the collection of data while presenting little cost to experts. The opportunity of engaging an invested public can continue current studies and provide opportunities for future research.

Bridging science and society

Citizen science engages the public beyond simply volunteering; it provides training to approach research through scientific methods. Citizen science programs are based on a framework that links citizens and scientists together, allowing the implementation of a complete scientific approach (Devictor et al., 2010). Because of its participatory nature, citizen science can elevate public understanding of and support for science, the environment, and technology (Dickinson et al., 2012). Studies have shown that participants in citizen science programs demonstrate greater scientific knowledge, skills, and positive attitudes toward science than the general public (Newman et al., 2012). Bonney et al. (2009) state that, "The educational value of contributory citizen science projects continues to be assessed, studies have shown that the experience of collecting data for use by professional scientists is highly motivating, fosters scientific knowledge, and provides opportunities for interacting with members of likeminded communities within local environments; this deeper involvement results in increasingly robust learning outcomes." Experts that provide training and insight into scientific methodologies can create transparency between the public and research institutions.

Creating transparency was a major goal of enacting public participation legislation; by creating transparency and an opportunity to learn the goals and protocol of scientific research, citizen science can generate support for continued research by understanding the scientific process. Citizen science programs that engage the local community can strengthen scientific capacity and inclusiveness of local decision-making, which can create an effective means of forming peer-to-peer networks with the potential for augmenting impacts through social learning (Dickinson et al., 2012). According to Bliss et al. (2001),

> *"The problems with which communities grapple are seldom easily categorized as either ''social'' or ''environmental,'' nor are they simply environmental problems with a human dimension. Rather, they are extraordinarily complex, with ecological, social, economic, political, and ethical dimensions. Those citizens working to improve their communities are often in a better position to comprehend the complexity of the issues than are specialists in any particular field."* (Bliss et al., 2009, 161)

Citizen science engages the public in the scientific process and in addressing societal needs. Federal agencies and nongovernmental organizations have mobilized millions of people to accomplish scientific work through citizen science programs (Holdren, 2015). By engaging the public through citizen science, experts can help the public understand the benefits, justify costs, and gain support of their research.

Newman et al. (2012) suggests that, “Today’s cyberinfrastructure investments in metadata, attribution, standardization, interoperability, and data curation and preservation will increase the value of citizen science datasets, not only for scientific research but also for decision support, education, outreach, and improved scientific literacy.” Engaging citizen scientists to collect and monitor information can result in participants becoming the best allies of managers and stakeholders in setting large-scale research (Devictor et al., 2010). Krumpe et al. (1997) suggest that, “Experiential knowledge can inform the planning process of what issues and questions are socially relevant and the political acceptability of alternatives. It may complete gaps in knowledge about specific places and its presence may increase the quality of discussion.” The technology now exists for people to create data and scientists and other decision-makers to utilize this information. Going forward, if researchers want to capitalize on a distributed network of volunteer geospatial data producers, then they must focus attention in the new social network of geo-information production (Coleman et al., 2009). To advance science and education, expanded efforts are necessary to garner support and recognition of citizen science as a discipline. Through effective outreach, training, and engagement, researchers can create citizen science programs to effectively address research questions at unprecedented scales.

Citizen science has the ability to engage participants through experiential education and can provide them the skills and education necessary to impact scientific and social change. According to Holdren (2015), “Through citizen science, the American public are contributing their talents and creativity — as well as insights gained from a wide range of backgrounds and real-life experiences — to help agencies and researchers answer questions related to urgent real-world problems. These projects contribute to a more informed citizenry engaged in public service, a foundation of America’s democratic system of government.” In a study analyzing the attitudinal changes of citizen science participants, researchers found that individuals showed no statistically significant change in their attitude toward the environment after participating in a citizen science program. However, the results suggested that even before participating, respondents were already highly concerned about the environment, a finding which indicates the specificity of the population interested in participating in projects such as citizen science (Brossard et al., 2005). Engaging citizens who are interested in a particular topic and providing them education, training, and the chance to affect future management and research creates a powerful connection between the public, researchers, and policy-makers. Public support for environmental issues and conservation can be increased by building social capital (social capital is measured in levels of trust, harmony, and cooperation) (Schwartz, 2006). Social capital is increased through activities that lead to volunteer engagement, agency connection, leadership building, problem-solving, and identification of resources which can lead to a more educated community and creation of a stewardship ethic (Whitelaw et al., 2003 and Cooper et al., 2007). As citizen science programs continue to grow, the stewardship ethic formed through participation in citizen science will grow and spread across communities.

Challenges of citizen science

Data integrity

Despite the opportunities that exist within citizen science, some experts remain doubtful of data integrity and the scientific value of results produced by these programs. Despite the advantages for both professionals and community members, citizen science still faces many challenges. Issues for citizen science include data integrity, data fragmentation, and lack of participant objectivity (Whitelaw et al., 2003). The origin, quality, and reliability of large datasets can be confusing, resulting in individuals using poor or insufficient data that can have serious scientific, social, and political consequences (Flanagin et al., 2008). Data integrity is the foundation of scientific protocol, and the use of data collected by citizen scientists has the potential to create some challenges. According to Engel et al. (2002), "Using biological assessments performed by volunteers for the authorized purposes of regulatory and natural resource agencies is a matter that should not be taken lightly. There can be important outcomes of these activities, some of which would not be desirable. The consequences of inaccurate volunteer biological monitoring may be worse than not making any official use of volunteer data." Despite efforts, it can remain difficult to convince people responsible for creating data to provide adequate documentation (Elwood et al., 2012). Some experts question data integrity because they believe volunteered data can be biased and is less about scientific data accuracy and more about which information, opinion, or perspective people believe (Flanagin et al., 2008). Data integrity is vitally important in creating usable and reliable scientific results. Disregarding citizen science produced data based on data integrity can begin to affect other areas of the project including the loss of interest by volunteers, participant objectivity, inconsistent funding that causes data fragmentation, and accuracy of data collection (Bliss et al., 2001). Most participants join these projects because they are interested in the environment and their community and want to contribute their time and efforts to aid in research.

<u>Acceptance by the scientific community</u>

While citizen science offers many benefits to both scientists and volunteers; data integrity, scientific protocol, and long-term effectiveness are still questioned by researchers and decision-makers. Bliss et al. (2001) states that, "An underlying tension involves questions of the relative legitimacy of science-based knowledge, indigenous knowledge, and the mystique of academic professionalism." A challenge in using public participation to understand and inform scientific issues is addressing problems that embrace traditionally disparate knowledge systems (Quinn et al., 2005). Data produced by individuals with no background in the academic traditions associated with the research has prompted concern among professionals about credibility because of the uncertainty regarding who is responsible for information and whether it is credible (Flanagin et al., 2008). In 2009, the United States Environmental Protection Agency (EPA) identified over 900 citizen science projects in the United States (Loperfido et al., 2010). Despite huge investments to fund these projects and the time put forth by volunteer citizen scientists, there is hesitation from the scientific community to use this data in science-based decision-making.

Citizen science programs have increased the number of non-professionals participating in research, which has blurred the lines between experts and non-experts. "An early concern regarding citizen science data was observer quality, that is, skill of participants compared to professional biologists. Like ecological field assistants, citizen scientists vary in ability, experience, and type of training" (Dickinson et al., 2010). Despite the successful contributions of citizen scientist programs, some scientists remain skeptical whether citizen monitoring activities can reliably detect and adequately characterize ecological processes (Brossard, 2012). Continually questioning the validity and integrity of citizen science data can limit its influence on management and policy decisions (Gillett et al., 2011). Testing citizen science programs to validate the quality of the data collected is necessary to ease underlying skepticism (Brossard et al., 2012). The public's roles and skills, including knowledge, experience, and organizational capabilities, should be acknowledged and used in any system that aims at strengthening the capacity to manage sustainability for human well-being (Conrad et al., 2008). Despite highly successful citizen science programs, further research and evidence showing high quality of data integrity, protocol, and results collected by citizen science programs, are necessary. Advancing the acceptance of citizen science programs by the scientific community will only happen through continued efforts to analyze programs and implementing successful programs as well as by follow-up programs that validate them through repeatability.

Chapter 3. Research Methods

Methods

The UA has conducted a multi-year surveying and monitoring effort (*Jaguar Surveying and Monitoring in the United States* contract number: F11PXO5778) for jaguars and ocelots in southern Arizona and New Mexico from 2012-2015. The purpose of this work was to establish effective survey and monitoring methods, and use these methods to document jaguars and ocelots along the U.S.-Mexico border.

This project established and implemented a non-invasive system for detecting and monitoring jaguars and ocelots. The study area incorporates most of the mountainous areas north of the U.S.-Mexico international border and south of Interstate 10, from the Baboquivari Mountains in Arizona to the Animas Mountains in New Mexico. The two primary methods used for detection were motion-sensor cameras, and genetic testing of large carnivore scat collected in the field. Wildlife was not captured, radio-collared, baited, or harassed during this project. Additional data including weather, vegetation, and geographic information system (GIS) data were collected to analyze in conjunction with the photo data. The results of this study are intended to aid and inform future management and conservation practices for jaguars and ocelots in this region (Culver et al., 2016).

My research project worked closely with the field monitoring research team to develop a program that incorporated citizen science volunteers into the larger monitoring project. The citizen science program was designed as a phased approach to train and build capacity of citizen scientists comprised of individuals from a range of socio-demographic communities (urban/rural, students, community members, and more). The program included a strong emphasis on education, jaguar and ocelot conservation, and extensive training on field-based techniques, including how to collect, download, verify, and analyze scientific data. The citizen science program built on the three-year UA jaguar and ocelot monitoring study.

Development of the first citizen science training workshop began in the fall of 2013. Members of the education and outreach, field monitoring, and citizen science teams for the various jaguar studies began weekly meetings to discuss and plan the implementation of a citizen science component to the study.

Citizen scientists worked under several permits obtained by the monitoring team and all participants were required to adhere to the rules and regulations of these permits (Appendix pages I-IV). The USFWS Performance Work Statement states:

> "*Information gathered with funding from this project is confidential and not for public release without the approval of USFWS. The contractor will maintain the confidentiality of all data collected under this project, including, but not limited to, any information relating to threatened and endangered species survey and detection locations. Data will be shared with the USFWS, the Arizona Game and Fish Department, and the New Mexico Department of Game and Fish only for the purposes of implementing the Endangered Species Act. Access to location information will be restricted unless required by the Freedom of Information Act, Public Records Law, or court order. Private property owners will have access to the information for all listed species locations on their own properties."*

All citizen science participants including volunteers and staff were required to adhere to the protocol regarding all wildlife. Detections of listed species were reported to the jaguar monitoring team within 24 hours who would contact the USFWS, and through them, the respective state wildlife agency, Department of Interior (DOI), Border Patrol, the land management agencies (if applicable), and the private landowner or grazing lease permittee.

Selection

The sensitive nature of this project due to location information of endangered species, confidentiality agreements, and working within federal partnerships made proper selection of citizen scientists very important to the citizen science research team and the field monitoring team. A protocol (Appendix B Figure 3-2.1b) was developed which outlined mandatory requirements for all potential citizen science participants. The minimum requirements for consideration were: 1.) access to a 4WD vehicle, 2.) ability to hike five miles over rough and uneven terrain, 3.) willingness to engage in public outreach, 4.) commitment of one year to the citizen science program and, 5.) attendance at weekend training workshop. All potential citizen scientists involved in the first phase of the project were required to participate in all aspects of the monitoring project including fieldwork, data processing, and data analyses. Members of the citizen science team and field team had experience working with volunteers on other camera monitoring projects in the area and reached out to individuals whom they believed may be interest in participating in this project. Individuals interested in participating as a citizen scientist were required to submit a request with references to the citizen science volunteer coordinator. Applicants were reviewed and accepted/denied by the citizen science research team.

Individuals accepted as a citizen scientist were additionally required to adhere to mandatory protocols and agreed to maintain project confidentiality. This project worked under several permits including USFWS (Appendix A Figure 3-1.1a) , Forest Service (Appendix A Figure 3-1.1a2), and Arizona State Land Department (Appendix A Figure 3-1.3a). Each agency has different reporting requirements in terms of scheduling, camera location mapping, and field activity coordination. The fieldwork schedule was dependent on permits and scheduling was adapted to address permit delays or other influences on project timeline (Culver et al., 2016). All non-UA participants were required by the University to register as a Designated Campus Colleague (Appendix A Figure 3-1.4a).

A stratified sampling method was used to select citizen scientists from a range of stakeholders in the study area to ensure a representative sample. These included UA students, retired volunteers, and those working for non-profits. Their ages ranged from 18 to 75. Most individuals selected had participated in other camera monitoring projects or were aware of the ongoing monitoring project.

Training

In April 2014, nine citizen scientists and 13 others (including research team, experts, and invited guests) attended a three-night, two-day intensive workshop at the Florida Station at the Santa Rita Experimental Range. Appendix B Figure 3-2.2b is an outline of the workshop agenda.

Experts in the field of tracking, jaguar ecology, conservation genetics, and database management were assembled to teach citizen scientists during the workshop.

Day one of the workshop began with an overview of the objectives of the citizen science and monitoring projects. The focus of this day was to familiarize participants with proper field technique to process data and remain safe in backcountry locations. Citizen scientists were given hands-on practice with all equipment used in the field including trail cameras, locks, and GPS devices. Tracking basics were also taught to help citizen scientists identify tracks and scat samples in the field. After teaching citizen scientists about all equipment needed to monitor trail cameras, participants were broken into small groups and each team was accompanied by an expert with experience monitoring trail cameras and received hands-on experience going through the entire process of setting and monitoring trail cameras. Day two consisted of a practicum for all participants which used GPS devices to navigate to a camera that had been placed around the Florida Station and went through the entire process of monitoring cameras including: recording all necessary information, changing batteries, checking and replacing SD cards, and properly mounting and setting the trail camera. The SD cards collected during the practicum were then loaded onto a computer and we began instruction of data processing. Susan Malusa, University of Arizona and member of the monitoring research team, taught citizen scientists data processing and analysis. Citizen scientists were provided with flashdrives that had been loaded with the file hierarchy used for data processing. These steps are explained in detail below.

During May 2014, citizen science teams were assigned transects and accompanied by a field expert and citizen science coordinator on their first site visit to ground-check citizen scientists on protocol, field safety, and ability to monitor field cameras. A protocol guide was provided to each participant (See Appendix B Figure 3-2.3b). Each citizen scientist team received continuous feedback in the field from the accompanying professional scientist, who assessed the accuracy of observations and monitoring methods. After certification of training was completed, citizen scientists were assigned to a route and site (for the remainder of the next 12 months) which they performed monthly monitoring, downloaded data, changed camera batteries, sorted images from the camera survey, and reported any evidence of jaguar or ocelot presence. Citizen scientists began unsupervised field checks with their assigned teams in June 2014.

Study Area

This study was conducted throughout the Arizona portion of the NRU, a mix of urban, rural, and ranching communities. The southern Arizona landscape (specifically Pima, Santa Cruz, and Cochise counties) provides a unique area to design and implement a citizen scientist program because it has a diverse group of stakeholders including a strong ranching community and a diverse urban and rural population. These counties, as well as Hidalgo County in New Mexico, are a part of the U.S. portion of the NRU for the jaguar (Figure 1). Fieldwork was confined to mountain ranges throughout southern Arizona and New Mexico which encompassed portions of land within the U.S. National Forest, National Park Service, Bureau of Land Management, Arizona and New Mexico State lands, and some private ranches. The study area was predefined by the USFWS in their Request for Proposals to encompass the area where jaguars are most likely to currently occur in the U.S. (Culver et al., 2016).

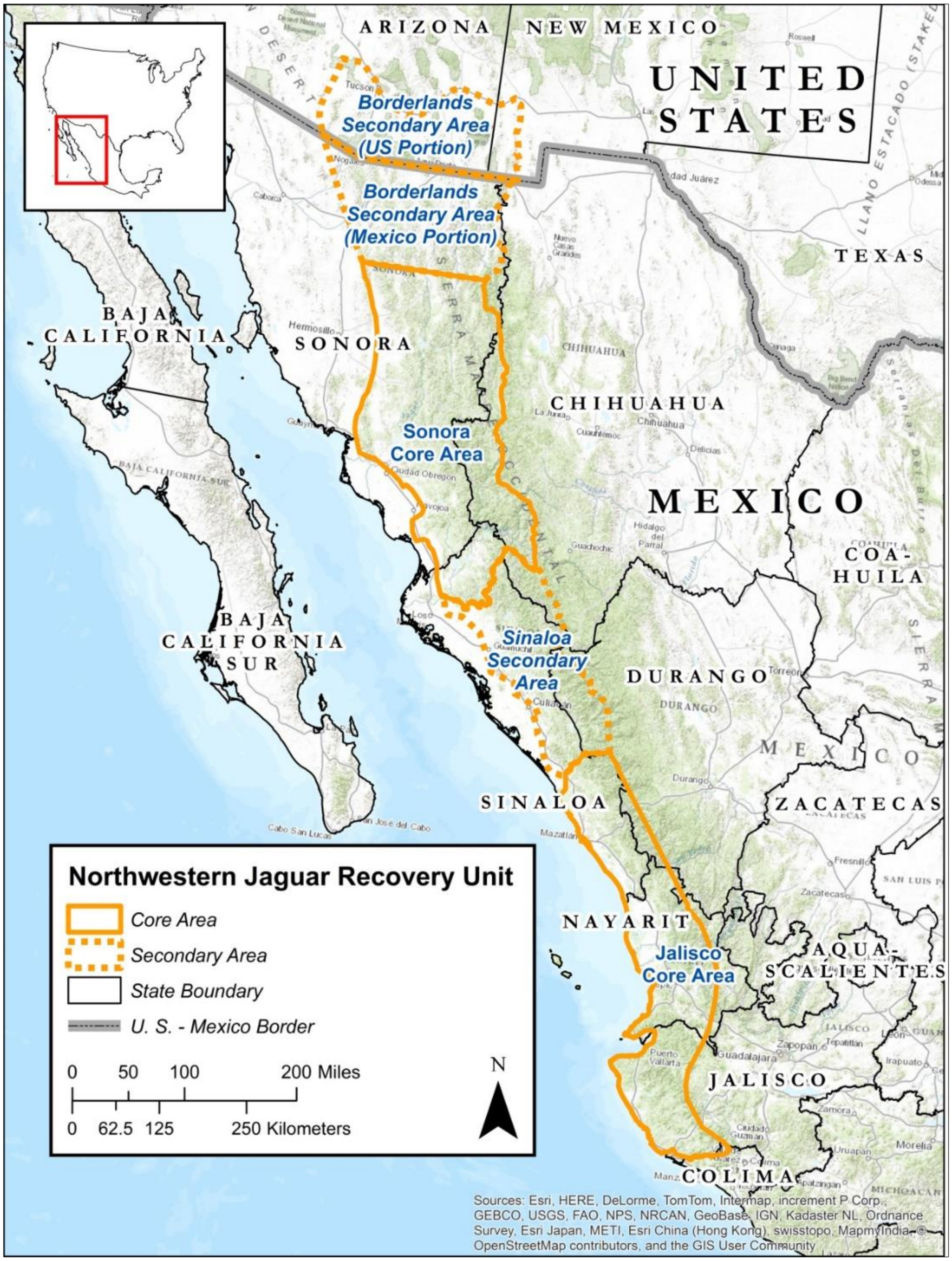

Figure 1 – Map of the Northwestern Recovery Unit (NRU) of the jaguar (modified from Sanderson and Fisher 2013). This citizen science program was conducted throughout the Arizona portion of the NRU. See the Recovery Outline for the Jaguar (U.S. Fish and Wildlife Service 2012) for a description of the NRU, as well as the Core and Secondary Areas.

The citizen science research team worked closely with the field monitoring team to identify which mountain ranges were the most important to expand monitoring efforts for jaguar and ocelot detections. Sites were chosen based on the need for additional research sites proposed by the monitoring research team. All citizen science study sites were located in the Huachuca Mountains in Cochise County, AZ and Santa Rita Mountains in Santa Cruz County, AZ. Both mountain ranges are characterized as Madrean Sky Islands, with biotic communities consisting of shrub and grassland at lower elevations, oak woodlands at mid-elevations, and Madrean evergreen woodlands at higher elevations (Brown, 1994). Topography of both mountain ranges vary from low elevation desert flats and steep canyons to high-elevation coniferous forests and meadows (Culver et al., 2016).

The Huachuca Mountain sites are located in Cochise County, AZ within the Coronado National Forest approximately 70 miles (110 km) south-southeast of Tucson, AZ, with a maximum elevation of 9,466 feet (2,885 m). This area is owned primarily by the USDA Forest Service (Coronado National Forest) (41%), U.S. Army (Fort Huachuca) (20%), and private land (32%). Annual precipitation increases with elevation, averaging from 15 inches at lower elevations to 20 inches on peaks. Average daily temperatures during the study ranged from 89.2°F (31.7°C) in July 2014 to 34.5°F (1.39°C) in December 2014 (NOAA, Western Regional Climate Center). Based on 2010 census data, human population density of Cochise County, AZ was 21.3/mile^2 and housing density was 9.6/mile^2 (http://quickfacts.census.gov accessed 29 Feb 2016).

The Santa Rita Mountain sites are located in Santa Cruz County, AZ within the Coronado National Forest approximately 40 miles (65 km) southeast of Tucson, AZ, with a maximum elevation of 9,453 feet (2,881 m). Annual precipitation increases with elevation, averaging from 10 inches at 2,900 feet to 20 inches at 4,300 feet. Average daily temperatures during the study ranged from 96.1°F (35.6°C) in June 2014 to 36.5°F (2.5°C) in December 2014 (NOAA, Western Regional Climate Center). Based on 2010 census data, human population density of Santa Cruz County, AZ was 38.3/mile^2 and housing density was 14.6/mile^2 (http://quickfacts.census.gov accessed 29 Feb 2016).

Research sites were chosen for each team based on accessibility, ruggedness, and hiking/driving distance. Figure 3-7 displays each citizen science field monitoring location.

Data Collection and Field Safety

Camera transects were monitored by citizen science teams every calendar month for one year. Each team was provided equipment to properly maintain trail cameras that included rechargeable AA batteries, battery charger, SD cards, camera remote (for ScoutGuard SG565©), keys, extra cable and lock, GPS unit, and protocol/safety booklet. All new camera sites were set during the initial site visit by the field expert accompanying citizen science teams.

To ensure that safety was prioritized, a system to maintain communication and coordination was implemented prior to camera checks. Citizen scientist teams were requested to schedule site visits two weeks in advance with the citizen science coordinator and provide the monitoring route, day, time of entry, and expected return. The coordinator would give this information to the monitoring team so proper land agencies, U.S. Customs and Border Protection, and private landowners could be notified in advance. On the day teams were monitoring sites they were required to send a message via call, email, or text when leaving to check study sites and when the team exited the field.

Citizen science teams drove to the general area of camera locations using four-wheel drive vehicles and accessed remote camera sites by hiking (four-wheel recreational vehicles or horseback were permitted). Each team provided vehicle information including make, model, color, and license plate number which was stored in a spreadsheet and provided to necessary agencies and landowners. Citizen science teams consisted of two or more individuals and were not permitted to perform fieldwork alone. A list of emergency numbers (Appendix B Figure 3-2.4b) was distributed in the event that a citizen scientist needed help. U.S. Customs and Border Protection points of contact were informed every 2-3 weeks with field work locations, camping locations, vehicles, primary mode of transport (park and hike, ATV, horse/mule), and dates. Citizen scientists were trained to operate two types of motion-sensor trail cameras; the Covert Deuce© and ScoutGuard SG565©. Once sites were selected, cameras were mounted on natural structures such as trees and stumps. Cameras were housed in tamper-proof boxes designed for the camera by the manufacturer and locked and secured to the supportive structure using a cable lock. No ground disturbance took place. Because the cameras detect motion and heat, branches or vegetation were trimmed to avoid false triggering of cameras. Some site locations began with setting paired cameras facing each other so that the target animal would walk between them. Additionally, paired cameras: 1) allow both sides of an animal to be photographed to identify individuals; 2) maximize the higher detection rate related to paired cameras than a single camera (primarily because animals can walk behind one camera and still be photographed by the opposing camera); and 3) have the advantage of a second camera serving as a backup if one is nonfunctional (Culver et al., 2016). We maintained a spreadsheet of all cameras used in the project to track the status and condition of the cameras as they were set in the field, maintained, damaged, or no longer functional.

While checking cameras, photographs were viewed in the field using the on-board viewing capabilities of the Covert Deuce© or ScoutGuard SG565© cameras. Viewing photographs in the field allowed teams to evaluate if the camera was functioning properly and if the aiming point or location should be adjusted to obtain better results. Batteries were checked and replaced monthly and memory cards removed and replaced with a blank card. Memory cards were labeled with site name, which camera of the pair, date, time, number of photos, and then taken from the field to be downloaded to a computer and processed.

Teams were required to view all photos within 24 hours of collecting SD cards to monitor data for the presence of jaguars and ocelots. If a jaguar or ocelot were detected, a process to begin the detection notification protocol was required (Appendix B Figure 3-2.5b). The notification process began with an email to the citizen science coordinator; an email labeled DETECTION with the attached photo was sent in the first email followed by a second email with the site code and GPS coordinates. The citizen science coordinator immediately sent both emails to Sue Malusa. Specific details of each jaguar or ocelot detection were immediately communicated to USFWS, as well as the respective state wildlife agency, the landowner/land management agency, and Border Patrol. GPS coordinates or place-name location of jaguars and ocelots were kept confidential to outside entities. Only the date and mountain range were released to outside sources, via USFWS.

Data Processing

Software developed by J. Sanderson was employed to process picture files, which included DataOrganize, DataAnalyze, MyRenamer, UpdateInput, CreateInput, and CorrectInput (Harris et al., 2010). The program ReNamer, which automatically relabels each file with the unique date and time the photo was taken, was also utilized. Species observed in photographs were identified by trained team members and photographs were sorted by team members into hierarchical folders labeled as follows: location / species / #-of-individuals. A more detailed description of the process is available online (http://www.smallcats.org/CTA-executables.html).

We followed the same data sorting process that the monitoring research team had developed. Each citizen scientist was given a flashdrive loaded with their assigned sites and the folder structure to organize photos. This structure consisted of a file with folders of common species names which contained subfolders representing group size. The folders were organized as: Badger, Bats (all bats (Chiropterans)), Bear, Birds (all birds excluding turkeys, *Meleagris gallopavo*), Bobcat, Coati, Cottontails (*Sylvilagus audobonii* and *S. floridanus*), Cow, Coyote, Dog, Fox, Ghost (no animal present in frame), Human, Jackrabbits (*Lepus californicus* and *L. alleni*), Jaguar, Javelina, Lizards (all lizards (Lacertids)), Mule Deer, Ocelot, Opossum, Puma, Raccoon, Ringtail, Rodents (all non-Sciurid rodents (Rodentia)), Skunks (*Mephitis mephitis, M. macroura*, *Conepatus leuconotus*, and *Spilogale gracilis*), Snakes (all snakes (Serpentes)), Squirrels (*Sciurus variegatus* and *S. arizonensis*), Test (photo of team member checking cameras), Turkey, Unknown (animal in frame but could not be determined), White-tailed Deer. Depending on the analyses, some groups were omitted from analysis due to relative rarity and lack of species-level identification.

Two systems were used to collect data from citizen science teams. 1.) The team monitoring cameras in the Santa Rita Mountains contacted the volunteer coordinator to collect flashdrives after data had been renamed and sorted along with the SD cards with raw images. The flashdrives and SD cards were brought to UA and given to the monitoring team data manager Sue Malusa. The SD cards with raw images were then given to the monitoring field team member in charge of the Santa Rita Mountain Range to process and sort. 2.) The teams monitoring cameras in the Huachuca Mountains would mail flashdrives after data had been renamed and sorted along with the SD cards with the raw images to monitoring team leader Jack Childs. Mr. Childs would process and organize the data from the SD cards collected by citizen science teams.

Data Analysis

The data collected by citizen science teams was added to the same database as the monitoring field team. Because citizen science data was added to the ongoing monitoring project, data integrity was extremely important. A system of quality assurance and quality control (QA/QC) was developed to ensure that data entering the system from citizen scientists met the standards of the field team. A quantitative assessment of citizen scientists' ability to recognize wildlife when compared to field team experts was used to evaluate the sorted camera data (photos) and assess the degree to which citizen scientists could accurately identify wildlife species and individuals as compared to professional biologists.

Citizen science teams were required to process and organize data collected at their study sites and after this process, send the sorted data and raw data on the SD cards to the monitoring field team member in charge of their site. During the timeframe of the monitoring study (April 2012-June 2015) all raw data from SD cards collected by citizen scientists was re-processed and re-analyzed by field team members and added to the database. All data was stored and backed-up on a UA server. Each citizen science team had a designated field expert to determine their route, monitoring sites, and QA/QC their data. When the expert received the data, he or she also sorted the raw images. This allowed a direct comparison of the citizen scientists' ability to correctly identify individual species to that of field team experts.

Two citizen science groups (A and B) were selected from among our first nine citizen scientists to represent the similarities and differences between highly trained volunteers and those with less experience to field team experts. These citizen science groups were chosen because they represented opposite ends of the spectrum of volunteer types involved in this project. Group A was a team of two retirees with an extensive background volunteering on camera survey projects. Group A had ample resources to aid them including time, backcountry knowledge, and a 4WD vehicle. The dates of the data sampled for Group A were September-December of 2014. Group A had four camera sites located in the Huachuca Mountains. Group B was a team of three college students majoring in wildlife biology. This group had limited knowledge about camera surveys before starting the program and little free time outside of their university and work schedules. The dates of the data sampled for Group B were May-November of 2014. Group B had three camera sites in the Santa Rita Mountains. A subset of data was chosen for each group to represent the entirety of data gathered by citizen scientists. The dates for each group were chosen because these were the timeframes that field team experts sorted the same set of photos, allowing a direct comparison between citizen scientists and field team experts, as well as the data integrity and efficacy of using trained volunteers to perform these tasks to be determined.

Data comparison was conducted through a random selection of dates from the citizen science groups and compared to the corresponding months of the experts' data. We deferred to the data from the field team experts as the correct version of the data sorting process. After photo data was analyzed in the ReNamer program, and all errors resolved, photos were analyzed and placed in the file hierarchy and delivered to the UA for backup on a server. I would compare citizen science data to expert data after analyzing both datasets through software programs used by the survey and monitoring teams. The first step was to analyze data in the program DataOrganize to identify and correct all errors and organize data. This program creates two files including AllPictures.txt and InputTemp.txt which are necessary to continue analyzing data. After these files are created, DataAnalyze is the last step in the analyses procedure that produces the analysis file Output.txt. DataOrganize uses the first and last pictures to set the start and stop dates for each camera trap. Only camera locations and species listed in the input file are used in the analyses. DataAnalyze uses AllPictures.txt, Input.txt, and the library file pg.dll to produce a full analyses of the photo data. The file InputTemp.txt is saved as Input.txt and DataAnalyze is run to produce the Output.txt which completes the analyses (Harris et al., 2010). The Output.txt file contains a comprehensive analyses of the data processed and analyzed by citizen scientists and experts. Appendix D Figure 3-4.1d contains an example of parts of the Output.txt used in analyses. I was able to compare the Output.txt files of the citizen scientists and experts to analyze the efficacy of citizen science data compared with an expert.

DataAnalyze application was used to analyze all photos (Harris et al., 2010). This program uses a timeframe of 60 minutes to distinguish individual photos by the time associated with the re-named images. For all of our analyses, we used a Pearson's correlation analysis that uses a coefficient normally denoted as r, a statistical value that measures the linear relationship between two variables. It ranges in value from +1 to -1, indicating a perfect positive or negative linear relationship, respectively, between two variables, with 0 representing no correlation between the variables. In our analyses, we measured the correlation between citizen scientists and our field team experts in accurately identifying wildlife species, including wildlife identification, species presence-absence, and species richness. The direct comparison of citizen scientists versus field team experts permitted a quantitative assessment of their abilities, acquired through our training, reflecting the degree to which they could accurately identify and document wildlife from camera photos, thereby providing a direct measure of the quality of the data they collected.

The group of nine citizen scientists downloaded and sorted more than 28,637 photos from 22 cameras at 14 monitoring sites over 12 months. Appendix D Figures 3-3.2d and 3-3.3d contain a breakdown of the total number of species analyzed for each citizen science camera and summary of all citizen science data. Citizen scientists logged a total of 327 hours of fieldwork including driving, hiking, and performing camera maintenance. After finishing each site visit, citizen scientists also sorted photos, logging approximately a total of 109 hours of data organization.

A combination of 14 Covert Deuce© and ScoutGuard SG565© cameras were stationed at selected monitoring sites. Monitoring sites included areas within the Santa Rita and Huachuca Mountains in southern Arizona. Cameras were stationed at areas along probable carnivore routes including riparian corridors, drainages, stock tanks, animal trails, former jaguar/ocelot detection locations, and trail intersections. Habitats surveyed by citizen science cameras included Madrean evergreen woodland, oak-pine forest, and areas with a deciduous riparian forest component. To determine if there were differences in wildlife identified by field team experts compared with Group A and

Group B we examined 252 photos collected and sorted by Group A from four monitoring sites between September 2014 and December 2014, and 590 photos collected and sorted by Group B from three monitoring sites between May 2014 and November 2014, with the same photos as sorted by field team experts.

Data comparison

The most important aspect throughout this project was to ensure that data integrity collected by citizen scientists would be collected and analyzed at a level acceptable to field team experts. Data integrity was analyzed through comparisons of species data from each Output file including total species present, species percentage, presence-absence, and species richness. The best way to represent data integrity is to ensure that the species present at each monitoring site were properly identified and categorized, the comparison of total species present allowed an analysis of this metric. A second, species-only analysis (with "Ghost" and "Test" images removed; "Ghost" images are photos with no identifiable species in the frame and "Test" images are photos of the field team experts or citizen scientists checking the sites) was conducted to examine citizen scientist versus expert data analysis. To determine species presence-absence detected by field team experts vs. Group A and Group B, we compared 134 species photos analyzed by Group A over four monitoring sites for four months and 252 species photos analyzed by Group B over three monitoring sites for six months with the same photos as analyzed by field team experts. Species richness was measured between field team experts vs. Group A and Group B through a comparison of 252 species photos analyzed by Group A over a four month period and 590 species photos analyzed by Group B over a seven month period with the same photos as analyzed by field team experts.

All photos captured during the project were saved, including images with no species in the frame. Photos without a discernible animal in the frame were assigned to a folder labelled "Ghost". Ghost images can be caused by improper setting of camera sensitivity, radiated heat, and the movement of vegetation caused by wind. Comparing the total number of Ghost images between experts and citizen scientists allows an assessment of the accuracy of citizen scientists to identify wildlife in a frame. Photo data may not have the entire animal in the frame because the camera is not triggered quickly enough and contains a small part of the animal in the edges of the frame. I compared the total number of Ghost images between experts and citizen scientists to understand if citizen scientists are capable of accurately detecting an animal, or part of an animal, in photo data.

Cost analysis

Limited financial resources for data collection has created a growing support for developing citizen science programs. Researchers often need programs that are cost-effective and capable of producing high quality data. Citizen science programs can provide the necessary people and skills to aid researchers and continue data collection. Comparing the cost between using only paid employees and citizen scientists is necessary to justify which option is best suited for a project. A cost comparison was performed to analyze program success. The cost comparison was conducted using General Service Administration (GSA) rates for the cost of employing a field biologist versus citizen scientists. The GSA is an independent agency of the U.S. government that helps manage and support the basic functioning of federal agencies including, transportation, wages, per diem, and more (per diem was included for a generalized cost comparison model, but per diem was not a direct cost of the jaguar monitoring study). All comparisons are made with GSA rates for Tucson, Arizona fiscal year 2014. This comparison is not a comprehensive analysis; it does not show costs associated with employees (examples including background check, hiring process, benefits, etc.) nor does it have every cost associated with a citizen science program (examples including room rental for training, food, equipment, etc.). This comparison only includes the cost of fieldwork and data analyses between citizen scientists and experts.

Chapter 4. Results, Discussion, and Conclusions

Results

Data collected by citizen scientists

From May 2014 to May 2015, a total of 14 citizen science camera monitoring sites were set throughout the study area, including 11 in the Huachuca Mountains and 3 in the Santa Rita Mountains. For each camera site, the general location description, Universal Transverse Mercator (UTM) coordinates, and Zone for each camera survey site are provided in Appendix C Figure 3-3 page XIII .

Quantitative assessment of data collected

Wildlife identification analyses

To determine if there were differences in images analyzed by field team experts versus Group A and Group B, I compared the same dataset from each group (Figures 4-1.1 and 4-1.2). All photos collected and sorted by Group A and Group B were highly correlated with those sorted by field team experts (r=0.9991 for Group A and r=0.9968 for Group B). Eight inconsistencies (3.2% of all photos) were detected between Group A and the field team experts [this includes differences in the "Ghost," "Bird," "Bear," "Coyote," "Fox," and "Unknown" folders]. Group B had 74 inconsistencies (12.5% of all photos) detected, [this includes differences in the "Squirrels," "Human," "Bear," "Fox," "Test," "Skunks," "White-tailed Deer," "Lizards," "Coati," "Birds," "Coyote," "Unknown," "Rodents," "Cottontail," and "Mule Deer" folders].

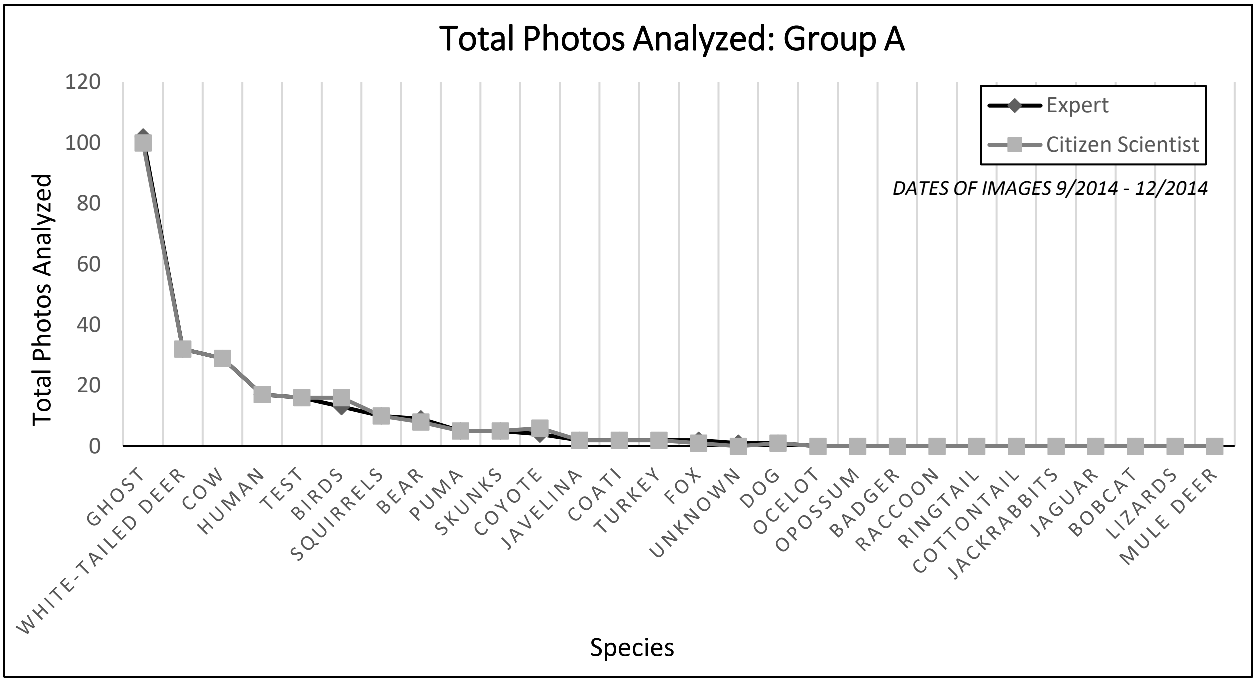

Figure 4-1.1 – Comparison of the amount of photos analyzed between field team experts and citizen science Group A. Each species is represented in the graph with the corresponding total number of images sorted by the field team experts or citizen scientists (R-value=0.9991).

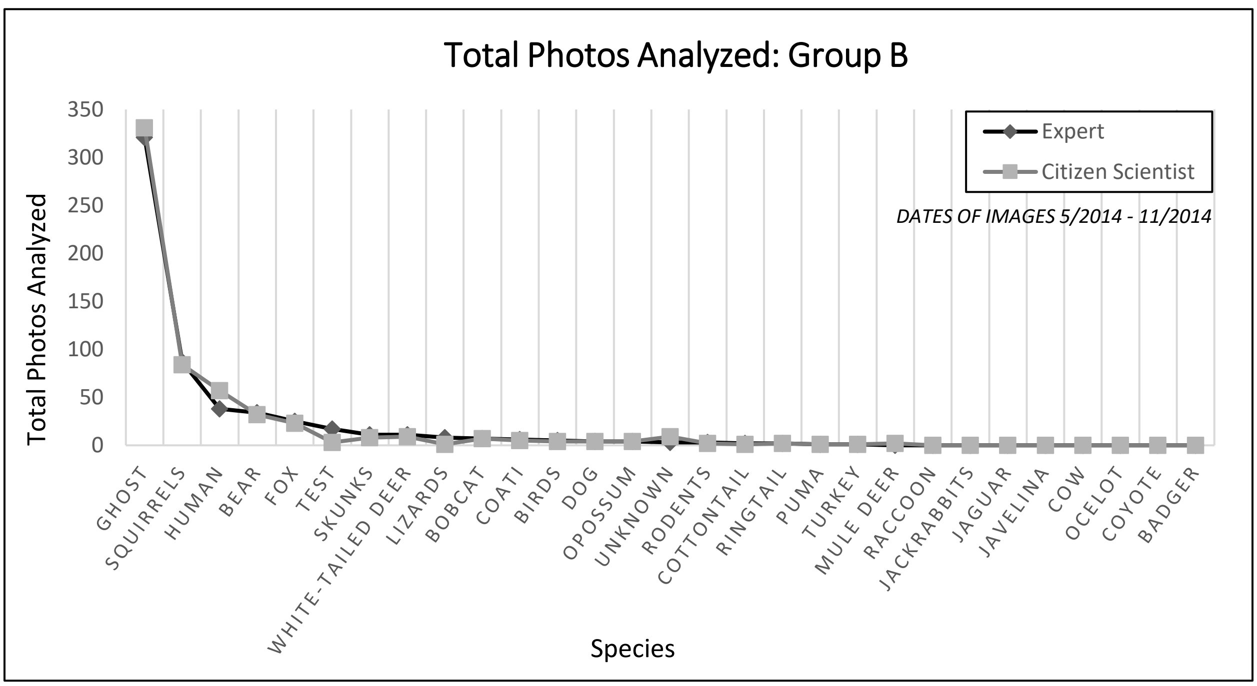

Figure 4-1.2 – Comparison of the amount of photos analyzed between field team experts and citizen science Group B. Each species is represented in the graph with the corresponding total number of images sorted by the field team experts or citizen scientists (R-value=0.9968).

Species percentage of total photos analyzed showed a high correlation between photos collected and sorted by Group A (134 species-only photos) and Group B (252 species-only photos) and those collected and sorted by field team experts ($r=0.9945$ for Group A and $r=0.9723$ for Group B). Eight inconsistencies (6.0% of species-only photos) were detected between Group A and the field team experts, which included discrepancies in the "Bird," "Bear," "Coyote," "Fox," and "Unknown" species image folders. For Group B, 36 inconsistencies (14.3 of species-only photos) were detected, including "Squirrels," "Human," "Bear," "Fox," "Skunks," "White-tailed Deer," "Lizards," "Coati," "Birds," "Unknown," "Rodents," "Cottontail," and "Mule Deer." Additionally, the R-value for Group B was lower because this group incorrectly put images of the field team experts or citizen scientists checking the sites in the "Human" folder rather than the "Test" folder, which accounts for the disparity of images in those categories (Note that "Test" is included in Figure 4-2.1 to show this disparity).

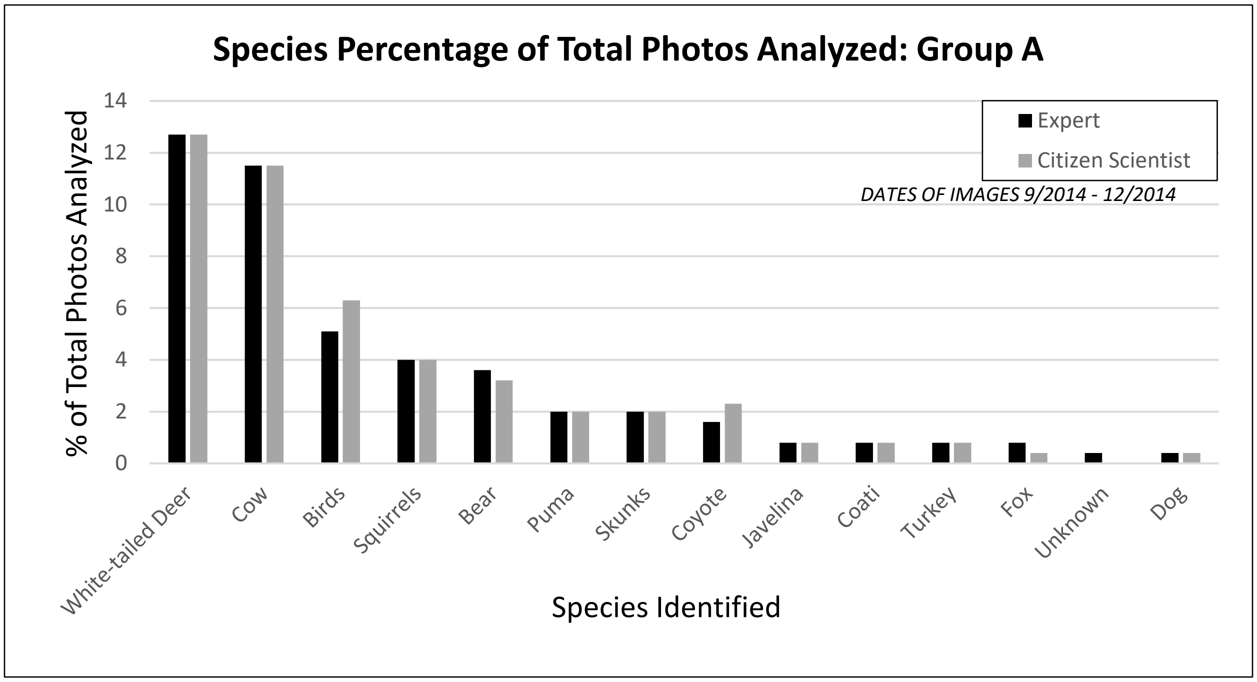

Figure 4-2.1 – Comparison of the representation of species identified at camera sites by percentage between field team experts and citizen scientists in Group A (r-value= 0.9946).

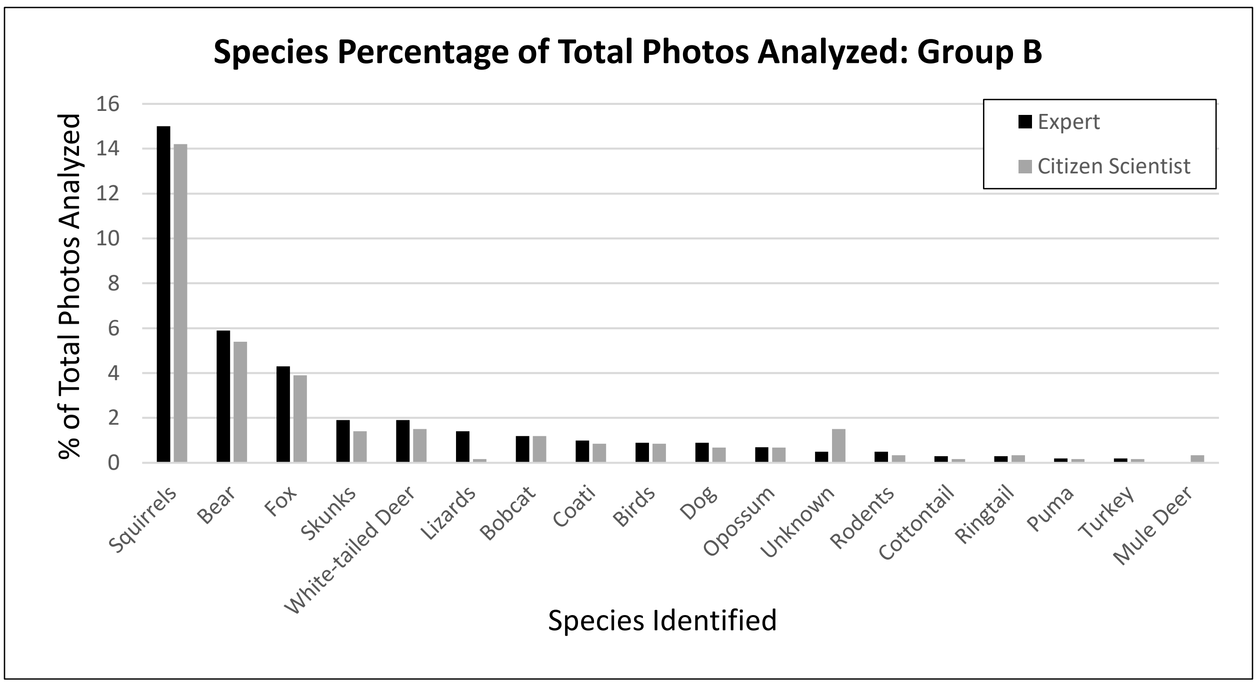

Figure 4-2.2 – Comparison of the representation of species identified at camera sites by percentage between field team experts and citizen scientists in Group B. (r-value= 0.9928).

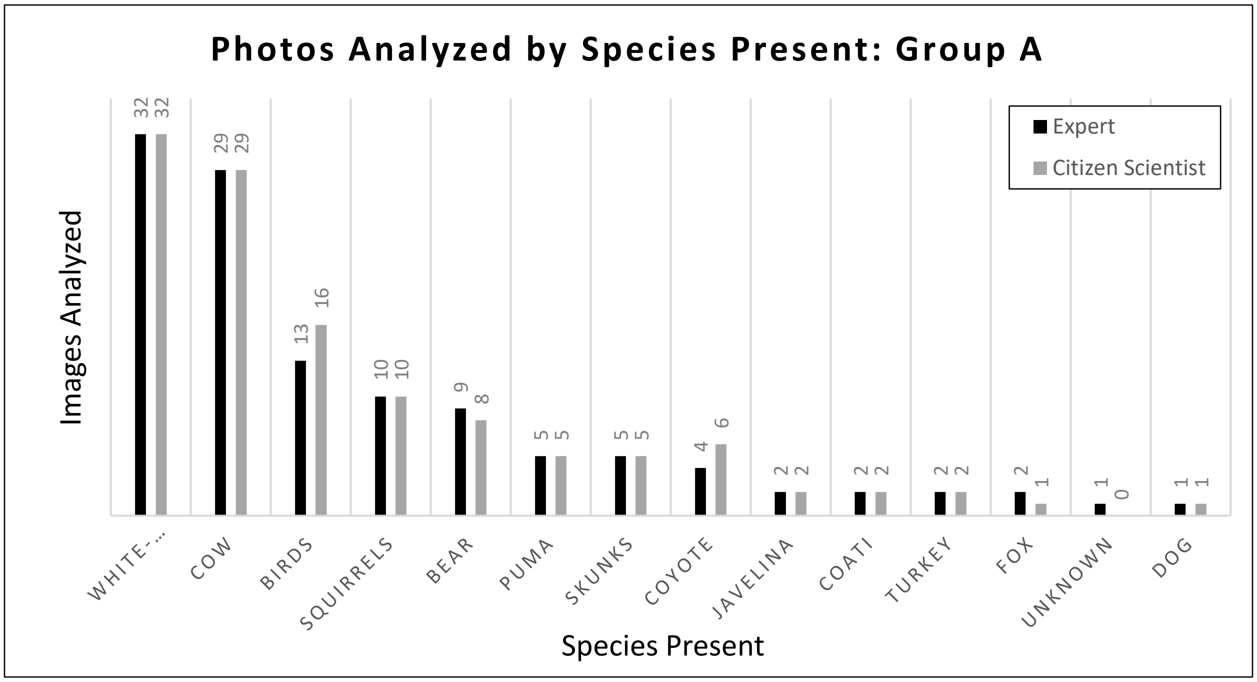

Figure 4-3.1 – Comparison of the total amount of photos of species represented at the sites over the timeframe sampled between field team experts and citizen scientists in Group A. Animal species not present at the sites were not included. (r-value= 0.9944)

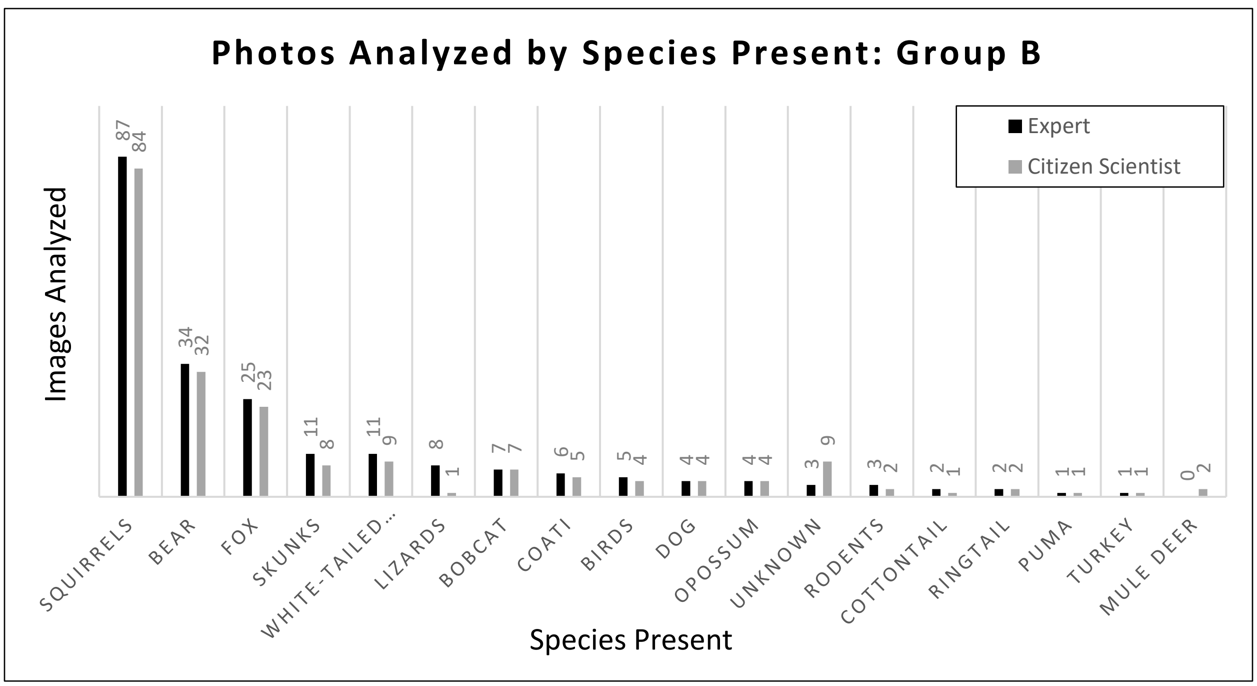

Figure 4-3.2 – Comparison of the total amount of photos of species represented at the sites over the timeframe sampled between field team experts and citizen scientists in Group B. Animal species not present at the sites were not included. (r-value= 0.9928)

<u>Presence-absence analyses</u>

Species presence-absence were compared between citizen scientists and experts (Tables 1 and 2). All species photos analyzed by Group A and Group B were highly correlated with those analyzed by field team experts (r=0.9723 for Group A and r=0.9945 for Group B). Of the few inconsistencies detected between field team experts and Group A and Group B, two discrepancies were found between Group A and field team experts (“Squirrels” and “Unknown”), and three discrepancies were found between Group B and field team experts (“Bear,” “Mule Deer,” and “Skunks”).

Presence-Absence Matrix: Expert and Citizen Scientist Group A								
Species	Site 1		Site 2		Site 3		Site 4	
Badger	0	0	0	0	0	0	0	0
Bear	1	1	0	0	1	1	0	0
Birds	1	1	1	1	1	1	1	1
Bobcat	0	0	0	0	0	0	0	0
Coati	0	0	1	1	0	0	1	1
Cottontail	0	0	0	0	0	0	0	0
Cow	1	1	1	1	0	0	0	0
Coyote	1	1	0	0	0	1	1	1
Dog	0	0	0	0	1	1	0	0
Fox	0	0	0	0	1	1	0	0
Human	1	1	1	1	1	1	1	1
Jackrabbits	0	0	0	0	0	0	0	0
Jaguar	0	0	0	0	0	0	0	0
Javelina	1	1	0	0	0	0	0	0
Lizards	0	0	0	0	0	0	0	0
Mule Deer	0	0	0	0	0	0	0	0
Ocelot	0	0	0	0	0	0	0	0
Opossum	0	0	0	0	0	0	0	0
Puma	1	1	0	0	1	1	1	1
Raccoon	0	0	0	0	0	0	0	0
Ringtail	0	0	0	0	0	0	0	0
Skunks	1	1	1	1	1	1	0	0
Squirrels	1	1	0	0	1	1	0	1
Turkey	0	0	1	1	0	0	0	0
Unknown	0	0	0	0	1	0	0	0
White-tailed Deer	1	1	1	1	1	1	1	1

Table 1 – Comparison between the presence-absence of species analyzed by the field team experts (light gray) and citizen scientists of Group A (dark gray) (r-value=0.9723).

Presence-Absence Matrix: Expert and Citizen Scientists Group B						
Species:	Site 1		Site 2		Site 3	
Badger	0	0	0	0	0	0
Bear	1	1	1	1	1	0
Birds	0	0	1	1	0	0
Bobcat	1	1	1	1	0	0
Coati	1	1	1	1	0	0
Cottontail	1	1	0	0	0	0
Cow	0	0	0	0	0	0
Coyote	0	0	0	0	0	0
Dog	1	1	1	1	0	0
Fox	1	1	1	1	0	0
Human	1	1	1	1	1	1
Jackrabbits	0	0	0	0	0	0
Jaguar	0	0	0	0	0	0
Javelina	0	0	0	0	0	0
Lizards	0	0	1	1	0	0
Mule Deer	0	0	0	0	0	1
Ocelot	0	0	0	0	0	0
Opossum	0	0	1	1	0	0
Puma	1	1	0	0	0	0
Raccoon	0	0	0	0	0	0
Ringtail	0	0	1	1	0	0
Rodents	0	0	1	1	0	0
Skunks	0	0	1	1	1	0
Squirrels	1	1	1	1	0	0
Turkey	0	0	1	1	0	0
Unknown	1	1	1	1	0	0
White-tailed Deer	1	1	1	1	1	1

Table 2 – Comparison between the presence-absence of species analyzed by the field team experts and citizen scientists of Group B. (r-value=0.9945).

Species richness analyses

Species richness as detected by field team experts vs. Group A and Group B were analyzed (Tables 3 and 4). All species photos analyzed by Group A and Group B were highly correlated with those analyzed by field team experts (r=0.9850 for Group A and r=0.9808 for Group B). The inconsistencies detected between field team experts and Group A and Group B regarding species richness, 20 (7.9%) discrepancies were found between Group A and field team experts over four monitoring sites and 101 (17.1%) discrepancies were found between Group B and field team experts over three monitoring sites.

Species Richness by Month: Expert and Citizen Scientist Group A										
Species	Sep		Oct		Nov		Dec		Total	
Bear	3	2	0	0	6	6	0	0	9	8
Birds	5	6	2	2	6	8	0	0	13	16
Coati	0	0	1	1	1	1	0	0	2	2
Cow	23	23	6	6	0	0	0	0	29	29
Coyote	1	2	0	0	3	4	0	0	4	6
Dog	1	1	0	0	0	0	0	0	1	1
Fox	1	1	0	0	1	0	0	0	2	1
Human	7	7	1	1	9	9	0	0	17	17
Javelina	1	1	1	1	0	0	0	0	2	2
Puma	2	2	1	1	2	2	0	0	5	5
Skunks	2	2	1	1	1	1	1	1	5	5
Squirrels	4	4	0	0	6	6	0	0	10	10
Turkey	2	2	0	0	0	0	0	0	2	2
Unknown	0	0	0	0	1	0	0	0	1	0
White-tailed Deer	20	20	3	3	9	9	0	0	32	32
Total pictures	72	73	16	16	45	46	1	1	134	136
Species richness	13	13	8	8	11	9	2	2	NA	NA

Table 3 – Comparison between species richness analyzed by field team experts (light gray) and citizen scientists Group A (dark gray) (r=0.9850).

Species Richness by Month: Expert and Citizen Scientist Group B																
Species	May		Jun		Jul		Aug		Sep		Oct		Nov		Total	
Bear	7	7	15	14	5	5	1	0	0	0	1	1	5	5	34	32
Birds	0	1	3	3	2	0	0	0	0	0	0	0	0	0	5	4
Bobcat	1	1	3	3	1	1	0	0	1	1	1	1	0	0	7	7
Coati	0	0	2	1	1	1	2	2	0	0	1	1	0	0	6	5
Cottontail	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	1
Dog	0	0	0	0	0	0	3	3	1	1	0	0	0	0	4	4
Fox	3	3	3	3	0	0	0	0	0	0	8	6	11	11	25	23
Human	1	6	7	12	11	11	3	6	8	11	8	10	0	1	38	57
Lizards	2	0	1	1	0	0	0	0	0	0	0	0	5	0	8	1
Mule Deer	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
Opossum	0	0	3	3	1	1	0	0	0	0	0	0	0	0	4	4
Puma	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Ringtail	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Rodents	2	1	1	1	0	0	0	0	0	0	0	0	0	0	3	2
Skunks	1	1	4	4	4	2	0	0	1	1	1	0	0	0	11	8
Squirrels	17	24	26	26	23	15	0	0	0	0	2	1	19	18	87	84
Turkey	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
Unknown	1	3	1	2	1	1	0	2	0	1	0	0	0	0	3	9
White-tailed Deer	2	2	4	4	2	0	0	0	1	1	2	2	0	0	11	9
Total pictures	39	51	74	78	54	41	9	13	12	16	24	22	40	35	252	256
Species richness	11	11	14	14	12	11	4	4	5	6	8	7	4	4	NA	NA

Table 4 – Comparison between species richness analyzed by field team experts (light gray) and citizen scientists Group B (dark gray) (r=0.9808).

Comparison of Ghost Images

A comparison of "Ghost" images (images with no discernible species in the frame) between citizen scientist Group A and B and experts were analyzed (Figure 4-4.1 and 4-4.2). Ghost images analyzed by field team experts and citizen science Group A were highly and positively correlated with an r value of 0.9994. Ghost images analyzed by field team experts and citizen science Group B were highly and positively correlated with an r value of 0.9999.

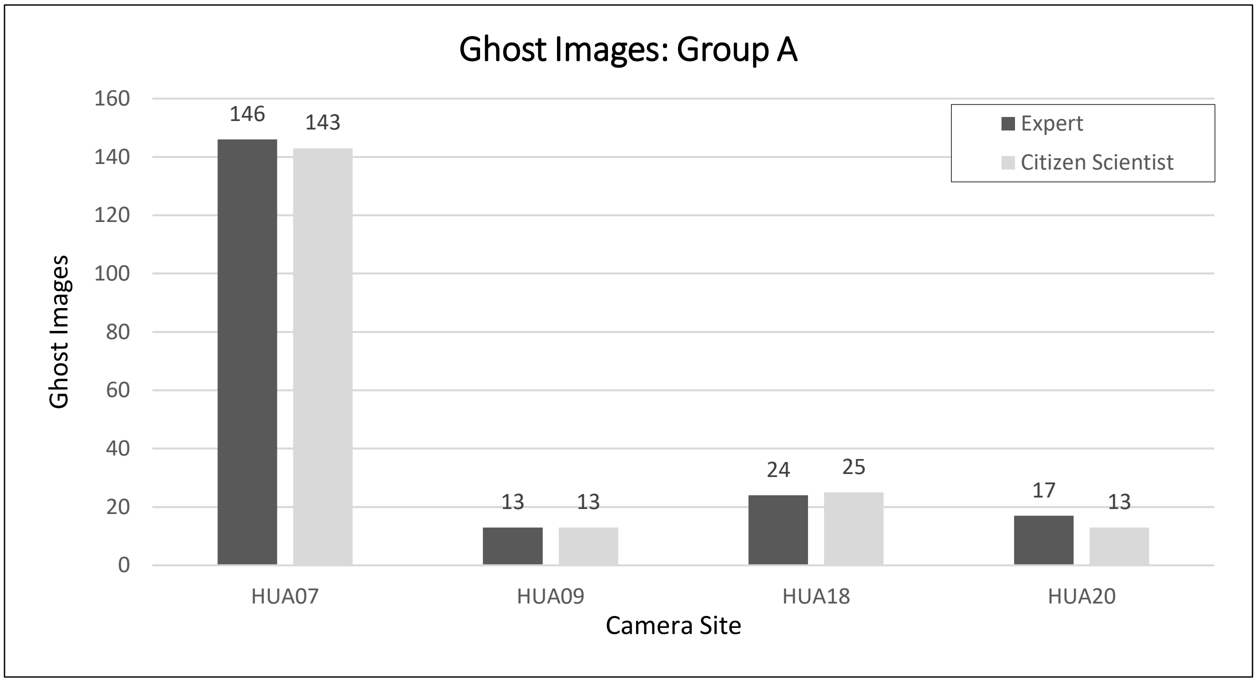

Figure 4-4.1 – Comparison of Ghost images analyzed by field team experts and citizen scientists Group A. (r= 0.9994)

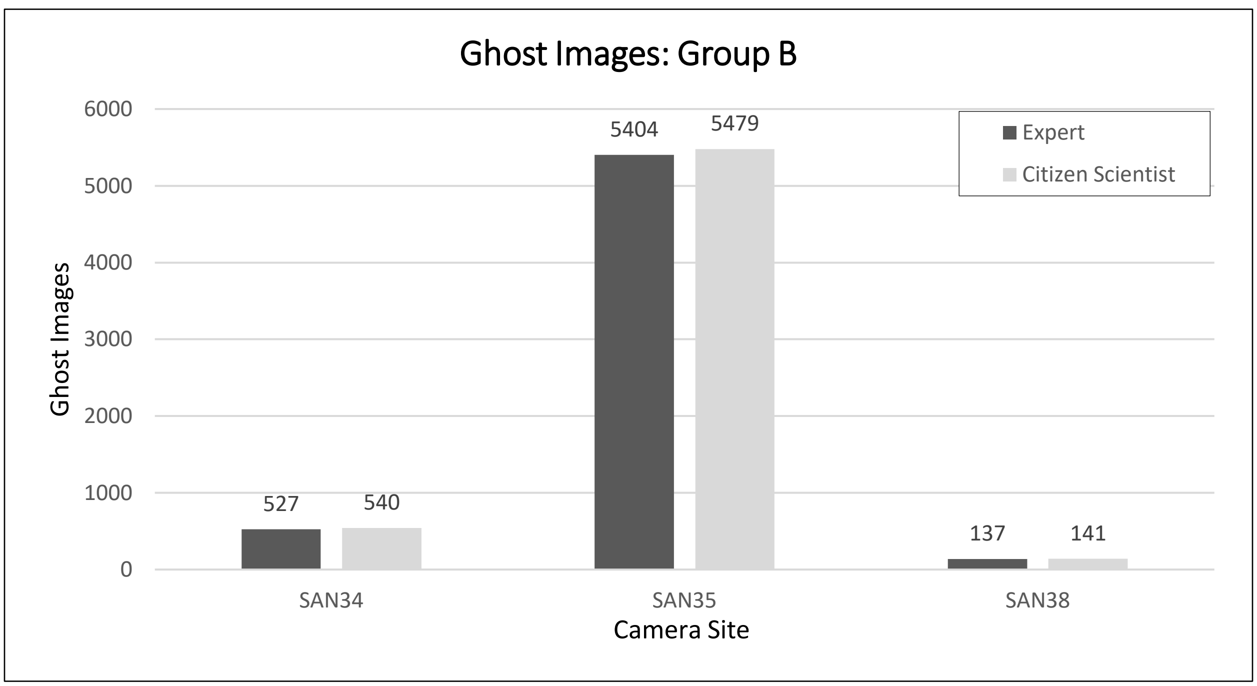

Figure 4-4.2 – Comparison of Ghost images analyzed by field team experts and citizen scientists Group B. (r= 0.9999)

Cost Analyses

A cost analysis was conducted to examine the financial costs between a citizen science program and the employment of field experts. Per diem was not part of the field monitoring staff compensation but was used as a point of comparison for general purposes. One citizen science team saved an average of $394.32 per month; with four citizen science teams, this resulted in a total savings of $18,927.36 for the year.

Assumptions (average time over one month)	
Avg. time/costs based on citizen scientist	
Roundtrip driving time	3 hours
Roundtrip mileage	122 miles
Hours in the field	6 hours
Hours sorting data	10 hours
Total hours	19 hours

Table 5- cost assumptions based on averages reported by citizen scientists.

Cost	Employee	Citizen scientist	Savings
Average salary	$16.95/hour *	$0	**$322.05**
Gas ***	$0.19/mile (government vehicle)	$3.20- $3.29 **	**$16.27**
Per Diem	$51/day	$0	**$51**
Incidental Expenses	$5/day	$0	**$5**
Total			**$394.32/month**

Table 6- All numbers are based on an average of times reported by citizen scientist. Drive time, hiking, and time sorting photos is highly variable between groups.
* Based on USFWS GS-5 (midlevel) Biological Science Technician
** Based on 2014 gas prices in Tucson, AZ (www.gasbuddy.com)
*** Based on 2014 Dodge RAM 1500 (average mileage 24 mpg)

Discussion

My results suggest that citizen scientists provided with effective training can collect and analyze wildlife camera photo data at a level comparable to expert field biologists. Results were significantly and positively correlated for all variables measured. The sampling design compared the ability to analyze data with experience level (nonprofessional vs. professional). These results are consistent with other studies which suggest that nonprofessionals can effectively collect and analyze data from wildlife cameras (McShea et al., 2015; Crooks et al., 2008; Cooper et al., 2007; Newman et al., 2003).

Discrepancies between citizen science and expert data were greatest for Ghost images but were not statistically significant. Data discrepancies may have resulted from misclassifications by experts because they were sorting a much higher total volume of photo data than citizen scientists, from citizen scientists or experts misclassifying an image, or simply the inability to determine the object in the photo. Discrepancies in the data analyzed by field team experts vs. Group A and Group B may be due to several factors including data may not indicate incorrect analysis, Group A and B may have sorted images differently but necessarily incorrectly as compared to experts. An example of this is that Group B sorted "Test" images under the folder "Human" while the field expert sorted this data under "Test". It is important to make it clear in the education and training portions of the project to clarify how certain images should be filed. Another factor creating discrepencies may be that some images were copied and put in multiple folders (e.g., an image of a horse with a rider may have been copied and put into "Horse" folder and "Human" folder, resulting in two copies of the same photo). Another factor may be that field team experts and Groups A and B may not have sorted the images the same way (e.g., Group A or B sorted an image as Unknown and an expert was able to distinguish the object in the photo as the correct animal species).

An additional factor may be based on analyses conducted of all images by the DataAnalyze application we used to analyze all photos. This program uses a timeframe of 60 minutes to distinguish individual photos by the time associated with the re-named images, meaning that if images were put in different folders by Groups A and B and field team experts, the program could have counted different numbers of photos over a sequence of images due to different time periods associated with how the images were sorted.

The purpose of this project was to develop, implement, and evaluate a citizen science program to survey and monitor for jaguars and ocelots within the U.S. portion of the NRU. McShea (2015), has suggested, "Variation in the abundance of animals affects a broad range of ecosystem processes. However, patterns of abundance for large mammals, and the effects of human disturbances on them are not well understood because we lack data at the appropriate scales." The scale and coordination of the monitoring project was conducted at a macroscale to meet landscape level spatial data needs. Culver et al. (2016), claim that, "There are no precedents that we know of for such an intensive research project conducted in this region on such a large geographic scale across such a complex matrix of stakeholders and jurisdictional entities.” The citizen science program helped expand the spatial and temporal scale of the jaguar and ocelot monitoring project by engaging interested and dedicated citizens who successfully monitored wildlife cameras distributed throughout the southern Arizona landscape. A large dataset of photos of an extensive variety of wildlife across the study area has been amassed by the jaguar field team and citizen scientists. This data has the ability to provide a remarkable understanding of the mammalian biota (and in some cases avian and herpetofauna) of this region and yields one of the most comprehensive region-wide analyses of a wildlife community to date (Culver et al., 2016).

This study also provided an opportunity to use and study non-scientists to augment data collection and assessment to advance jaguar and ocelot conservation. As discussed in Chapter 2, there are concerns about citizen science programs because of data integrity, ability to follow scientific protocol, and credibility. Comparing citizen science teams to field team experts in their ability to accurately identify wildlife species and analyze photo data provides a measure that evaluates those differences. The high positive correlations that I found are strong evidence that Group A and Group B can be excellent surrogates for field team experts. These results will strengthen the lack of published data regarding the efficacy of citizen science in large-scale camera monitoring programs by demonstrating that data accuracy and integrity can be performed by trained citizen scientists at a level comparable to field experts.

The goal of this research was based on three main objectives: 1.) develop and implement citizen science program, 2.) identify program effectiveness in comparison with experts in terms of the quality of data gathered and the financial and administrative costs/benefits, 3.) understand what creates an effective citizen science program and how it can be replicated in the future. Through a series of training, analyses, and feedback, I feel we have successfully accomplished each objective established in Chapter 1.

Objective 1.) Develop and implement citizen science program

A citizen science program was successfully developed and implemented (refer to Chapter 3 for full program description) and citizen scientists were trained that had little or no prior experience with trail cameras. The participation of field experts as educators and trainers during the training portion of this program was integral in teaching participants who had little or no experience working on camera monitoring projects. The hands-on field training and continued communication with field team experts created a deeper understanding of all the required protocols and the program continually adapted as citizen scientists gained a deeper understanding the project. It is necessary to train experts alongside citizen scientists. While experts may be an authority in their respective fields, it is important that they understand the scope, limitations, and expectations of the citizen science program. Hands-on training is equally important for experts because this will help them understand how citizen scientists interpret training and let experts understand how to effectively communicate with these participants.

Another aspect of program success was adherence to the mandatory guidelines developed for participation: 1.) commitment to one year, 2.) check cameras once every calendar month, 3.) adhere to all confidentiality rules, 4.) process and analyze all data, 5.) report all jaguar and ocelot detections. We had a 100% success rate in citizen scientist retention and many participants continue to monitor wildlife cameras on this same project, and have added additional monitoring routes to this day, despite the project funding coming to an end. Through training and continuous feedback, we were able to teach all participants the protocol for proper field practices, data processing, and data analyses. Two citizen science teams (one team in the Santa Rita Mountains and one team in the Huachuca Mountains) documented an ocelot at a camera site. Both teams complied with protocol and successfully reported the ocelot detection to the UA.

Objective 2.) Identify program effectiveness in comparison with experts in terms of the quality of data gathered and the financial and administrative costs/benefits

The evaluation portion of this study addressed two main objectives: 1.) can trained citizen scientists be as effective and efficient in the pursuit of quality scientific data gathered and analyzed, identifying and documenting wildlife observations from camera data as accurately as field team experts, 2.) identify the financial costs and benefits of incorporating a citizen science program.

The findings of this study concluded that citizen scientists could be trained to identify and document wildlife in remote settings with a high degree of confidence and accuracy. The analyses revealed a strong positive correlation between citizen science teams Groups A and B and field team experts when analyzing the total number of individual wildlife identified ($r=0.9991$ for Group A and $r=0.9968$ for Group B) and the species identified in photos ($r=0.9945$ for Group A and $r=0.9723$ for Group B). These high positive correlations indicate that citizen scientists were well trained and able to identify wildlife from camera data nearly as well as the field team experts. Engel et al. (2002) suggest that, "Volunteer monitoring protocols must be analyzed in detail and compared with appropriate statistical techniques to confirm that they reach the same conclusions as the professional protocols. Without such rigorous validation studies, professional biologists will always be skeptical, and justifiably so, about the results of volunteer biological monitoring programs".

The presence-absence and species richness analyses highlighted the importance of identifying and sorting the correct animal species to maintain data integrity in measuring and understanding the distribution of species across the landscape. The presence-absence analyses allowed a cursory comparison between the species identified at each monitoring site by the field team experts and Groups A and B of the citizen science teams. These analyses showed which species were detected at the monitoring sites and if citizen scientists were able to properly analyze photos to represent all species. The results indicated that the citizen scientists' ability to sort photos is highly correlated to that of the field team experts, as demonstrated by the high R-value scores ($r=0.9723$ for Group A and $r=0.9945$ for Group B). While presence-absence does not indicate species abundance or density, I chose this measure because it provides a quantitative analysis to measure and understand the distribution of species across the landscape.

Species richness aids in measuring and understanding the distribution of species across the landscape. This estimate measured the total number of individual animals that field team experts and Groups A and B of the citizen scientists were able to identify by month. The correlation between the field team experts and Groups A and B was high (r=0.9850 for Group A and r=0.9808 for Group B), which indicated that citizen scientists may be able to correctly identify and categorize species images similar to that of a field expert.

Analyzing photo data is very tedious and requires a high level of attention to detail, especially when sorting through thousands of images. Ghost images can cause complacency when sorting photos due to the high volume of images with no animal in the frame. A windy day is capable of producing thousands of images on one camera with few or no animal images, due to the movement of vegetation. Comparing Ghost images between experts and citizen scientists can determine if citizen scientists are capable of maintaining the level of focus and accuracy necessary when analyzing and processing scientific data. Analyzing Ghost images aids in understanding the abilities of citizen scientists to accurately process data is sufficiently robust for scientific applications.

The cost comparison between citizen scientists and experts in this project was not a comprehensive cost analysis. Couvet et al. (2008) note that, “The relevance of citizen monitoring systems depends on their relative costs and benefits compared with professional systems. The comparison must take account of financial costs, the social legitimacy of the results, and the maintenance of the network over years.” This project benefited from the generosity of interested individuals who donated a training space (Florida Research Station in the Santa Rita Experimental Station), provided training and expertise at no cost, and the partnership and resources between UA and USFWS. The costs measured in this project including average gas/mileage, salary, and GSA field expenses resulted in a savings of $394.32/month for every citizen science team monitoring camera routes. This results in an overall savings of roughly $18,927.36 for one year of monitoring. As discussed in Chapter 2, government and research monitoring often experiences funding shortages and financial difficulties. While it is necessary to retain professionals to support a program, citizen scientists provide a means to augment field support and provide high quality data collection with reduced costs.

Objective 3.) Understand what creates an effective citizen science program and how it can be replicated in the future

Through the process of selecting and training citizen scientists during the development and implementation portion of the study, citizen scientists provided valuable feedback from which I gained insight into structuring trainings and protocols. Programs must be adaptable to provide sufficient guidance for different team compositions and demographics (Newman et al., 2003). While the protocols and guidelines developed apply only to the particular participants from which our sample was drawn and to the circumstances in which they worked, I found significant generalizations regarding the functioning of any citizen science program. Every citizen science program will have unique programmatic requirements but the following guidelines are necessary procedures which aided in the success of this program.

<u>Recruitment, marketing, and retention</u>

Although audiences can be identified and targeted through different forms of media; tapping into existing groups or partner organizations is particularly effective. Working closely with specific target audiences and matching the project activities to what the target audience finds rewarding can identify interested participants (Dickinson et al., 2012). Identifying groups such as civic groups, neighborhood organizations, non-profit environmental protection groups, outdoor hobby/recreation groups, retirement communities, and after-school programs can help amplify participation through targeted outreach.

Retention not only eases demands on the infrastructure to market and recruit, it is an essential requirement for adaptive management, which requires not only longitudinal data but also iteration. Retention can create a core group of participants with advanced levels of experience, providing local leadership and resulting in collection of more reliable data. A long-term commitment to the project can also create more cost-effective training. Volunteer retention requires treating participants as professionals by informing them how they are impacting conservation, recognizing them for their efforts, and matching monitoring protocols to the interests and skills of the volunteers (Whitelaw et al., 2003). Retaining participants requires consistent support, including rapid response to questions and suggestions as well as online resources for communication among participants. Email listservs and online discussion boards are important for participants to discuss the project as part of a community.

Training

Recruiting through local partners or providing online resources for neighborhood networks can help increase the efficiency of project transfer, providing support for individuals who are interested, but might not feel confident in their ability to teach themselves. Training media can be written (printed or online) tutorials, video, animation, and person-to-person. While all of the training provided was necessary to facilitate understanding the scope of the project, the most important aspect was practical field training and data analyses. Field time between experts and citizen scientists allowed hands-on experience and generated questions gained from a new level of understanding. This aspect of training also provided citizen scientists with the ability to observe and learn about proper field techniques including organization, preparedness, and safety. Hands-on experience aided citizen scientists in the data analyses aspect of the project. Providing support and assistance to participants using the data analyses programs to understand the software helped them learn and understand these programs. Different levels of training are necessary for every program. This project required citizen scientists to be proficient at every level of the program (field and data) to reduce the coordination otherwise necessary. While training is time consuming, many volunteers can be trained simultaneously which is a more cost-effective method for increasing participation in wildlife conservation.

Data collection and organization

Collecting huge amounts of *ad hoc* observations does not necessarily deliver good science, and merely managing information is not enough. Adequate program design, data collection, and field methods are necessary in successful citizen science projects (Couvet et al., 2008). Unless meaningful results with sufficient analytical power are produced, then volunteer efforts will have been wasted (Newman et al., 2003). Designing an effective system for data collection, analyses, and organization is necessary before beginning fieldwork. Important considerations include cyberinfrastructure requirements that include data standardization, providing tools to collect and process data, securing terabyte-scale data storage, integrating mechanisms that ensure data standards and quality, meeting the user experience and usability needs of both citizen scientists and experts, and managing a volunteer workforce (McShea et al., 2015).

Institutional capacity of the central organization will largely determine the data collection, reporting, and archiving scheme. Data can be reported on a variety of paper forms, including worksheets, scan forms using optical mark recognition (OMR) or optical character recognition (OCR), and a variety of online data submission forms, either created with purchased software or custom built. Statistical issues of error, bias, and effort are important to the design of citizen science projects. To minimize detection error and observer error, researchers can explicitly estimate detection probability for survey methods and use indices that incorporate (or methods that standardize) observer effort.

Professional partnerships

The success of the citizen science project was dependent on investment from the field experts and other members of the monitoring team. Team members dedicated resources, time, and expertise to ensure the proper training and success of this project. Citizen scientists had direct and open communication with experts throughout the span of the project. Experts provided much support and aided in the success of the citizen science program. While the citizen science team members created this program, it would not have succeeded without the support of professionals, investment from the UA and USFWS, and others who donated time and resources to this project. Citizen science benefits and is enhanced by strong and supportive professional partnerships; the goal of these programs is not to replace professionals but supplement field capability and data collection.

According to citizen science experts (Bonney et al., 2009),

> *"A successful citizen science project requires a development team comprising multiple disciplines. A researcher is required to ensure the project's scientific integrity, to develop protocols that will lead to the collection of quality data, and to analyze and publish the data after they are collected. An educator is required to explain the project's importance and significance to participants, to pilot- and field-test protocols with potential participants, to develop clear and comprehensive project support materials, and to ensure appropriate participant feedback. A computational statistician or information scientist is needed to develop both the database infrastructure and the technology*

> *required to receive, archive, analyze, visualize, and disseminate project data and results. An evaluator is needed first to ensure that the project begins with measurable objectives, and second to gather data to assess project success based on those objectives, both during and after project implementation."*(Bonney et al., 2009, 979)

While these suggestions for the basic infrastructure of a successful program require multiple staff members, it is not necessary for every program to hire staff to fill these roles. Strong professional partnerships established at the beginning of the program can help facilitate project goals. Citizen science support now exists in multiple forms; many non-profits and government agencies have a professional citizen science component and many online resources exist for program design, implementation, and support. "Small groups or organizations that do not have internal access to all disciplines can partner with other organizations or adapt national citizen science projects for use at local or regional scales" (Bonney et al., 2009). New citizen science projects can turn to these professionals and resources to help launch programs without spending time and resources duplicating the basic method for successful program design

<u>Funding</u>

Citizen science programs, like any other research and monitoring, requires consistent funding. Programs and projects require professional skills and support, basic supplies, training, database management, and more. Adequate long-term funding is essential to establish and maintain citizen science programs. A lack of funding can cause data fragmentation and inconsistent standards. It is critical to ensure project funding costs are built into budget development of projects and programs (Bliss et al., 2001). Citizen science projects should be self-sustaining and not rely on large sums of money or staffing from one sector. Projects should have long-term goals and a system to evaluate the project as needed (Firehock et al., 1995). Dickinson et al. (2012) notes that, "Strategic collaborations and partnerships may be necessary to garner the resources and participant base required to sustain projects over the long term." Understanding the full range of materials and staffing necessary to implement and maintain a citizen science program should be reviewed prior to any planning or recruitment.

A limitation of this project was the lack of program budget. The budget did not have sufficient funding to cover supplies, training including facility costs, materials, and food, or to compensate professionals for their time. This limited our ability to produce and procure materials necessary for the project. The expert monitoring team shared supplies and purchased necessary equipment for the citizen science project which was hugely beneficial to the success of the project. Without a good working relationship with the expert monitoring team, the citizen science program would not have neem successful. Collaboration with partners and outside organizations can help reduce costs and provide support, but a sufficient amount of funding is necessary to effectively build and operate a citizen science project.

Summary

I believe the success of the citizen science program was based on a combination of factors. First, constant feedback through informal and formal surveys allowed the citizen science team to refine and improve protocols and match citizen scientists' abilities with appropriate routes and monitoring sites, contributing to a high degree of compliance with the protocols. Second, the protocol that evolved from training sessions enabled citizen scientists to follow an easily comprehended and implemented set of field procedures and data downloading, sorting, and analyses methods. Third, a direct comparison between field team experts and Group A and Group B demonstrated that the quality of data processed by both groups was highly correlated with the data processed by field team experts and allowed us to assess data integrity issues. Finally, the strong collaboration and communication between the Group A and Group B and field team experts regarding their experience and expertise, knowledge of wildlife and conservation education, and advanced data management skills contributed to the success of using citizen scientists to collect and analyze wildlife data. I believe and conclude that the high positive correlations that were identified in the data analyses provide strong evidence that citizen scientists such as those represented in Group A and Group B can be excellent surrogates for field team experts to collect and analyze wildlife data from remote cameras.

Recommendations

I believe that future assessments of data for wildlife cameras should include data analyzed from both citizen and professional scientists, in addition to a collection of images, in order to distinguish methodological differences from various levels of experience. A larger sample size of citizen scientists is necessary to allow for a more thorough statistical analyses between nonprofessionals and professionals. If discrepancies between the datasets were chiefly due to misclassifications, then additional training may be required so that citizen scientists are sufficiently familiar with an array of photos. Desirable modifications to the training protocol may include reducing subjectivity in the data classifications by better defining software standards and observing and classifying more data during training. Education and training are also essential for non-data related aspects of a successful program. The training workshop created an open and collaborative environment between citizen scientists and experts. Individuals came together as a team through goals developed throughout the training and an understanding of the overall project goals. Creating a bond between participants will strengthen retention and increase the overall effectiveness of the program. I believe that a well-developed training workshop where participants formed a relationship with other citizen scientists and experts contributed significantly to the success of this project.

Funding is a major limiting factor to most research; securing funding prior to project planning is necessary to accomplish tasks including training, material procurement, and staffing. Yarnell et al. (2003) states, "Effective program management requires sufficient staff resources to deal with the volunteers, manage data, secure funding, and generate information products. Without the necessary financial and technical support, and feedback mechanisms, volunteer-based monitoring programs are unlikely to last." Citizen science should not be an afterthought to fulfill obligations of a grant as participants are volunteering a valuable resource in the form of their time to participate in real scientific research. Designing and implementing a well-designed program allows volunteered time to go towards meaningful research and can benefit participants, staff, and communities.

Conclusions

This research has provided insight into the structure and maintenance of a complex citizen science wildlife monitoring program. Study objectives 1, 2, and 3 were fulfilled through a literature review, months of development, trial-and-error, feedback, and constant analyses through every phase of the project. The support of the expert monitoring team was an essential partnership in the success of this program. The citizen science approach focused on reviewing all data analyzed by citizen scientists and comparing it to the same dataset analyzed by experts, which ensured that I could identify where citizen scientists struggled with the process, correct mistakes, and produce high quality data. The citizen science team has had high success at retention, and citizen scientists continue to monitor 62 cameras despite project funding ending and are still adding new cameras as needs arise. This research has demonstrated that citizen scientists are capable of contributing data at a level comparable to experts in a large and complex wildlife conservation project, and are proven to be dedicated and committed to a project. Data collected and analyzed by trained citizen scientists contributed to the USFWS analyses of wildlife throughout the Arizona portion of the NRU and provided an increased level of understanding about neotropical felids in the southwestern United States.

Despite some data discrepancies between experts and citizen scientists, trends in community level attributes of species present, species percentage, presence-absence, and species richness derived from the citizen science data presented similar trends to those obtained by professional scientists. Analyzing data collected by wildlife cameras is tedious and time consuming. One camera is capable of taking thousands of photos, multiply that by another three or four cameras and the time necessary to accurately analyze data can become extremely difficult for a team that is volunteering their time. It is critical that goals and objectives are assessed and that citizen science teams receive constant support and feedback. The citizen science coordinator was responsible for providing this necessary feedback and support in the form of answering questions in a consistent and timely fashion, relaying information and questions to appropriate experts, and keeping citizen scientists updated throughout the project. Field team members were also necessary in supporting citizen scientists. Field team experts were available to meet, confer, and provide assistance to citizen science teams regarding field and data questions. This support created an open and collaborative environment between the different project teams, citizen scientists, and experts and contributed to the overall success of the project. Reducing and eliminating discrepancies could be achieved through further refinements of the classification system and training protocol could improve the accuracy of wildlife photo monitoring. Modest adaptations of protocol could make the project design applicable for use in other locations and for other species and project goals.

Proper training and education can teach citizen scientists to collect and analyze wildlife camera data at a level comparable to professional field biologists. Monitoring is a structured and repeatable process of observing and recording something over time and is an essential component of an iterative management cycle. Citizen science ecosystem monitoring should be goal-oriented, structured, and repeatable (Yarnell et al., 2003). Maintaining an ongoing and successful project requires a combination of professional and volunteer participants. Citizen science does not replace the roles of professional field biologists; rather, it augments the staff of perpetually underfunded agencies, universities, and other research organizations that are required to manage and monitor natural resources with limited financial means. As Culver et al. (2016) suggest, "Wildlife research is usually conducted to guide management practices and conservation programs. However, it is too often done without fully recognizing and accommodating the social matrix in which wildlife studies are conducted. If management and conservation efforts are to succeed, they must be accepted socially, culturally, and politically by a critical mass of the public, particularly those who may be affected by the research." Citizen science can help provide this critical mass of the public to continue and support this work. Citizen science provides the centralization required to implement conservation programs, study the outcomes, and manage landscapes in a coordinated way that could generate measurable positive impacts at meaningful scales (Cooper et al., 2007).

Carr (2004) states that citizen science, "encourages practitioners to act. In local places, it is frequently the same few people who notice a problem, recognize the implications of acting on or ignoring it, design the research, collect the data, analyze those data, and act on the results. It is in this last stage, of acting on the results, that the significance of having community scientists is most noticeable." Citizen science could be the impetus, the critical mass of people necessary in order to accomplish this work. Carr (2004) goes on to say that, "We need community science because the ownership of both the process and the results can lead to more direct, immediate, effective on-the-ground changes. Stakeholder and public involvement programs are designed around this principle. Ownership of the question, the process, results, and interpretation may all lead community scientists to act in a cyclical process of planning, acting and reflection." This project was able to bring a diverse group of Arizona citizens together who were interested in contributing to wildlife conservation. Many environmental issues are extremely complex and affect social, economic, and political issues. These issues are best addressed through multiparty initiatives such as citizen science.

The citizen science program described in this thesis, could easily be adopted by natural resource managers, researchers, private landowners, and land management agencies, to monitor wildlife communities and assess environmental management initiatives. Citizen science engages the energy, knowledge, and commitment of local volunteers to gather scientific information that can increase the capacity of government agencies to make informed management decisions. These programs also build an element of public participation into decision-making. The participation of community members can facilitate partnerships with other organizations, gain acceptance by the community, and put pressure on managers and decision-makers (Yarnell et al., 2003). Continuing the partnership between citizen scientists, government agencies, and universities has the possibility to enhance relationships and build trust within the southern Arizona community.

These partnerships are especially helpful when dealing with contentious environmental and land management issues. Federal, state, and private dealings with endangered species are often controversial and complicated; this includes the issue of jaguar and ocelot in Arizona. Data collected on neotropical felid occurrences, habitat, and status is necessary to provide information to land managers. Urban development, habitat loss, connectivity, and genetic isolation are all potential threats to jaguar and ocelot populations in the U.S. (Haynes et al., 2005). The political and environmental issues of endangered species in Arizona is complicated by federal and state agencies, private industry, non-profit groups, and private citizens. Creating programs such as the citizen science jaguar and ocelot monitoring project seeks to connect interested citizens with these issues and create a scientifically valid way for them to become involved and contribute to these issues.

Despite the numerous studies showing the high data quality and positive benefits of citizen science, criticism and doubt still linger. Data quality issues are not unique to citizen science, issues of poor data quality must be identified and a validation system developed as a component to any monitoring program (Dickinsen et al., 2010). Although this project produced high quality data and received strong support from the monitoring team, USFWS, and UA; some individuals stalled the implementation of sending citizen scientists into the field and created multiple setbacks that altered the intended structure of the program. Lack of communication and delayed participation into the larger project created unnecessary complications that could have been mitigated by immediate involvement of the citizen science team in the planning process. These challenges were frustrating and complicated but aided the team in refining project design and protocols which facilitated building a successful program. If citizen science programs are carefully analyzed, modified, and validated professional biologists and others in regulatory and natural resource agencies should accept the results, be confident about using them, and be grateful for the assistance" (Engel et al., 2002).

Program Future

With little fanfare, nine original and now 17 citizen scientists continue to monitor over 60 cameras in southern Arizona mountain ranges. Despite no financial support and little logistical support, this group continues to grow despite these setbacks. These individuals contribute hundreds of hours planning, hiking, driving, and analyzing data to ensure the continuation of productive scientific contribution to jaguar and ocelot conservation. Bonney et al. (2009) suggest that, "Projects with long-term and intensive engagement of public members or those that result in visible environmental changes have been associated with participant actions such as future engagement in projects or involvement in agencies that manage resources." We will continue to pursue funding and try to maintain and grow the efforts of this project. The citizen science team hopes to continue providing valuable scientific information and maintaining our objectives set forth in the beginning of program planning.

McCallie et al. (2009) states,

> *"As individuals, communities, and societies, our understanding of and response to science are shaped by the cultures and contexts in which we live, work, and play. This means that understandings of and responses to science are deeply informed by knowledge and perspectives from non-science domains, such as senses of ethics and morality, visions for society and future generations, and drives to explore and explain the unknown. Therefore, to address complex scientific questions and controversies in a way that fosters responsible and appropriate scientific*

> *knowledge production and decision making, we must create opportunities for an exchange of knowledge, ideas, and perspectives that involves the participation of all aspects of society—publics, scientists, and decision makers. This exchange can help create well-informed, empowered publics who are better equipped to contribute to our understanding of the world and to responsible decision making."*
> (McCallie et al., 2009, 11)

While citizen science creates valuable data, it also has the potential to change individuals who become involved. Citizen science projects not only augment and enhance the scientific process, but also address other societal needs while drawing on untapped resources — the skills, dedication, and ingenuity of participants (Holdren, 2015). "In community science, nature and neighborhood are both nurtured, and neither can be disentangled from an ethic of care for a specific place" (Carr, 2004). Participants can become empowered by citizen science through the development of new skills, and increased awareness of the cultural relevance of science and how it affects their communities. If one of the goals is behavioral change, then conservation-related citizen science projects should incorporate active learning and approaches that reinforce the participants' belief that their behavior can contribute to the conservation effort (Jordan et al., 2011). Creating an ethic of care for science, conservation, and communities can be achieved through a well-executed citizen science program that produces high quality results which can be used in research and decision-making.

I hope that the future of this program creates a mutual learning environment for participants and scientists, empowers those who dedicate their time to this project, increases the awareness and importance of wildlife conservation, and recognizes the importance of multiple perspectives in issues spanning environmental, scientific, and political boundaries. People who participate as citizen scientists are individuals busy with jobs, families, and other hobbies, but have found an issue that motivates them to contribute their most valuable asset; time. Researchers and decision-makers need to respect the contributions of citizen scientists and support these programs by trusting the data produced, thus increasing its validity within scientific communities and creating legitimacy in data collected by citizen scientists.

APPENDIX A
FIGURE 3-1.1a
USFWS PERMITS

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

FEDERAL FISH AND WILDLIFE PERMIT

2. AUTHORITY-STATUTES
16 USC 1539(a)

REGULATIONS
50 CFR 17.22

50 CFR 13

1. PERMITTEE

UNIVERSITY OF ARIZONA
[illegible] 4TH STREET
BIOSCIENCES EAST, [illegible]
TUCSON, AZ [illegible]
U.S.A.

3. NUMBER
TE[illegible]-1 AMENDMENT

4. RENEWABLE: YES / NO
5. MAY COPY: YES / NO

6. EFFECTIVE: [illegible]
7. EXPIRES: [illegible]

8. NAME AND TITLE OF PRINCIPAL OFFICER
MELANIE CULVER
PRINCIPAL INVESTIGATOR

9. TYPE OF PERMIT
NATIVE ENDANGERED SP. RECOVERY - E WILDLIFE

10. LOCATION WHERE AUTHORIZED ACTIVITY MAY BE CONDUCTED
ON LANDS SPECIFIED WITHIN THE ATTACHED SPECIAL TERMS AND CONDITIONS
ARIZONA, NEW MEXICO

11. CONDITIONS AND AUTHORIZATIONS:

A. GENERAL CONDITIONS [illegible]

B. THE VALIDITY OF THIS PERMIT IS ALSO CONDITIONED UPON STRICT OBSERVANCE OF ALL APPLICABLE FOREIGN, STATE, LOCAL, TRIBAL, OR OTHER FEDERAL LAW.

C. [illegible]

D. Your permit has been amended. The terms and conditions set forth in the most recent permit, dated January 1, 2012, and any previous amendments or renewals are hereby superseded by this document.

E. Acceptance of this permit serves as evidence that Permittees agree to abide by the "General Conditions for Native Endangered and Threatened Wildlife Species Permits" (copy attached).

F. Acceptance of this permit serves as evidence that Permittees agree to abide by all conditions stated. Terms and conditions of this permit are inclusive. Any activity not specifically permitted is prohibited. Please read through these conditions carefully as violations of permit terms and conditions could result in your permit being revoked or denial of a new permit when the current one expires. Violations of your permit terms and conditions which contribute to a violation of the Endangered Species Act (ESA or Act) could also subject the Permittee to criminal or civil penalties.

G. Disposal, transplant, or release of live wildlife/plants or plant parts taken or held under the terms of this permit, unless specifically authorized, requires prior written approval by the species' lead U.S. Fish and Wildlife

ADDITIONAL CONDITIONS AND AUTHORIZATIONS ALSO APPLY

12. REPORTING REQUIREMENTS
ANNUAL REPORT DUE: [illegible]

ISSUED BY
TITLE
ASSISTANT REGIONAL DIRECTOR - ECOLOGICAL SERVICES

DATE
[illegible]

APPENDIX A
FIGURE 3-1.2a
USFS PERMIT

Authorization ID: SUP0116
Contact ID: UA_WILDCAT_RESEARCH
Expiration Date: 12/31/2015
Use Code: 422

FS-2700-4 (10/09)
OMB No. 0596-0082

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

SPECIAL USE PERMIT

Authority: ORGANIC ADMINISTRATION ACT, June 4, 1897

University of Arizona Wild Cat Research and Conservation Center, Biological Sciences East 325, University of Arizona, Tucson, AZ 85721 (hereinafter "the holder") is authorized to use or occupy National Forest System lands in the Coronado National Forest, subject to the terms and conditions of this special use permit (the permit).

This permit covers ± 2 acres in the Douglas, Nogales, and Sierra Vista Ranger Districts within various sections, townships and ranges, ("the permit area"). This permit issued for the purpose of: conducting non-invasive Jaguar monitoring by placing motion-sensor trail cameras at selected locations throughout the Douglas, Nogales and Sierra Vista Ranger Districts of the Coronado National Forest. Trail cameras may be mounted to trees in a manner that does not harm the tree. A list of gps coordinates and a map showing camera locations will be provided as cameras are located on NFS lands. The map and list will be updated quarterly if locations change. This permit also authorizes the collection of large carnivore scat for genetic analysis. If jaguars or other large cats are detected, the use of a specially trained scat detection dog is also authorized to aid in the collection of genetic material. Any sightings of jaguars or other large cats will be reported to the District Biologist or the permit administrator within 48 hours. An annual report, including positive and negative results, will be provided to the District Biologist or the permit administrator on the anniversary of the permit.

TERMS AND CONDITIONS

I. GENERAL TERMS

A. AUTHORITY. This permit is issued pursuant to Organic Administration Act of June 4, 1897 and 36 CFR Part 251, Subpart B, as amended, and is subject to their provisions.

B. AUTHORIZED OFFICER. The authorized officer is the Forest Supervisor or a subordinate officer with delegated authority.

C. TERM. This permit shall expire at midnight on 12/31/2015, approximately 4 years from the date of issuance.

D. RENEWAL. This permit is not renewable. Prior to expiration of this permit, the holder may apply for a new permit that would renew the use and occupancy authorized by this permit. Applications for a new permit must be submitted at least 6 months prior to expiration of this permit. Renewal of the use and occupancy authorized by this permit shall be at the sole discretion of the authorized officer. At a minimum, before renewing the use and occupancy authorized by this permit, the authorized officer shall require that (1) the use and occupancy to be authorized by the new permit is consistent with the standards and guidelines in the applicable land management plan; (2) the type of use and occupancy to be authorized by the new permit is the same as the type of use and occupancy authorized by this permit; and (3) the holder is in compliance with all the terms of this permit. The authorized officer may prescribe new terms and conditions when a new permit is issued.

E. AMENDMENT. This permit may be amended in whole or in part by the Forest Service when, at the discretion of the authorized officer, such action is deemed necessary or desirable to incorporate new

APPENDIX A
FIGURE 3-1.2a
USFS PERMIT

520 621 8801 SNRE U of A Tucson,AZ 02:10:38 p.m. 06-13-2012 1/1

Special Use Permit – SUP0218 University of Arizona Wild Cat Research

authorize the cutting of timber or other vegetation. Trees or shrubbery may be removed or destroyed only after the authorized officer or the authorized officer's designated representative has approved in writing and marked or otherwise identified what may be removed or destroyed. Timber cut or destroyed shall be paid for at current stumpage rates for similar timber in the Coronado National Forest. The Forest Service reserves the right to dispose of the merchantable timber to those other than the holder at no stumpage cost to the holder. Unmerchantable material shall be disposed of as directed by the authorized officer. Trees, shrubs, and other plants may be planted within the permit area with prior written approval of the authorized officer.

II. SUBMIT REPORTS. The holder shall provide the authorized officer with a copy of all reports and publications resulting from the project including theses, dissertations, articles, monographs, etc. The final report on work performed shall be submitted in two copies to the Forest Service no later than 1 year following the completion of the research.

This permit is accepted subject to the conditions set out above.

HOLDER: UNIVERSITY OF ARIZONA Wild Cat Research & Conservation Ctr.	U.S. DEPARTMENT OF AGRICULTURE Forest Service
By: M. Culver DR. MELANIE CULVER	By: Jim Upchurch JIM UPCHURCH
Title: Principal Investigator	Title: Forest Supervisor
Date: 6/13/12	Date: 6/25/12

According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond, to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0596-0082. The time required to complete this information collection is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and, where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call toll free (866) 632-9992 (voice). TDD users can contact USDA through local relay or the Federal relay at (800) 877-8339 (TDD) or (866) 377-8642 (relay voice). USDA is an equal opportunity provider and employer.

The Privacy Act of 1974 (5 U.S.C. 552a) and the Freedom of Information Act (5 U.S.C. 552) govern the

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APPENDIX A
FIGURE 3-1.3a
STATE LAND PERMIT

A. PUBLIC OR STATE TRUST LANDS GRAZING PERMITTEE:

Name ____

- Please coordinate with me about your field activities (Please select as many as apply):

  i. By phone ______ Phone number: ______________________________

  ii. By email _______ Email address: ______________________________

  iii. In person ______ Description (e.g. stop by ranch headquarters on way in, etc.):

  ____

- Ongoing coordination not necessary _____

B. PRIVATE LANDOWNER: Name ____

- Please coordinate with me about your field activities (Please select as many as apply):

  i. By phone ______ Phone number: ______________________________

  ii. By email _______ Email address: ______________________________

  iii. In person ______ Description (e.g. stop by ranch headquarters on way in, etc.):

  ____

- Ongoing coordination not necessary _____

I give my permission for you to conduct field activities (check one or both) ______ on my private land and/or ______ cross my private land to access other project areas:
______________________________________ Date: ____________________

APPENDIX A
FIGURE 3-1.4a
Designated Campus Colleague

DCC Type: Volunteer - Department	Start Date (MM/DD/YYYY): March 2015	Expiration Date (MM/DD/YYYY): 2015
Person Information		
(Legal) Last Name:	First Name:	EmplID (if known):
Date of Birth (MM/DD/YYYY):	Other Names Used (if any):	
Home Phone: ( )	Gender: (Check one) ☐ M ☐ F	Personal Email:
Mailing Address:		
1) Are you a minor (under age 18)? (Check one): ☐Yes ☒ No ***(MINORS ARE DEFINED AS INDIVIDUALS UNDER 18 YEARS OF AGE, IN ACCORDANCE WITH THE STATE OF ARIZONA CHILD LABOR LAWS ARS 23-232)*** *Minor and sponsor must attach the appropriate Program Participation form.	Have you previously: 2) Worked for the UA? ☐Yes ☐ No 3) Held a UA no-salary or DCC appointment? ☐Yes ☐ No 4) Enrolled as a UA student? ☐Yes ☐ No	
Citizenship		
5) Are you a US Citizen or Permanent Resident? ☐Yes ☐ No		
Visa Permit Data (complete if answer to citizenship question is "No")		
6) Citizen/Passport Country: Visa Status Date (MM/DD/YYYY):	Visa type: Visa Exp. Date (MM/DD/YYYY):	
Duties/Services Performed		
7) Are you collaborating or performing services in the US? ☒Yes ☐ No		
8) Are you collaborating on research activities with UA faculty or research scientist? ☒Yes ☐ No		
9) Brief (under 250 characters) description of duties: volunteer for UA Jaguar Field Survey Check camera functionality, change batteries, insert new memory card.		
Sponsor/DCC Building Information		
Sponsor's Last Name: Gimblett	Sponsor's First Name: Randy	Sponsor's EmplID: 06901736
Affiliate Institution:	Average weekly hours (*whole numbers only please)*:~~10-15/month	
UA title (Affiliate and Associates only):		
Building:	Room:	UA Directory Phone:

Security Sensitive Functions - *(For additional information please visit http://policy.arizona.edu/pre-employment-screening)*			
	Yes	***No***	***Comments***
10) Significant financial oversight responsibilities?		x	
11) Unsupervised contact with minors who are not enrolled students of the University?		x	
12) Unrestricted access to residence hall rooms?		x	
13) Role designated by Dean or Vice President as "security or safety sensitive"?		x	
14) Driving on university business in UA, rented, or personal vehicles?	x		
Import/Export - *(For additional information please visit http://orcr.vpr.arizona.edu/export-control)*			
	Yes	***No***	***Comments***
15) Access to ITAR Controlled data, technology, materials information, software or equipment?		x	
16) Access to EAR Controlled technology or encryption software code?		x	

	Yes	No	Comments
a. Has restrictions on the release of certain project information?	x		
(Import/Export - continued)	**Yes**	**No**	**Comments**
b. Has a publication or access and dissemination restriction?		x	
c. Has a military connotation or end-use?		x	
d. Is sponsored by a defense agency?		x	
e. Is related to space, missile technology, or biological/chemical weapons?		x	
f. Requires foreign national approval by sponsor or no foreign nationals are allowed?		x	
g. Involved in a project that has a technology control plan in place?		x	
h. Do you have a reason to believe the individual will need an export license?		x	
Specialized Training Required - *(For additional information please visit http://risk.arizona.edu/training/index.shtml)*			
	Yes	**No**	**Comments**
17) Working in a laboratory setting with any of the following:		x	
a. Bloodborne pathogens or other biological materials?		x	
b. Radioactive materials?		x	
c. Lasers or other non-ionizing radiation?		x	
d. Hazardous Chemicals		x	
18) Working in a non-laboratory setting with chemical or biological materials?		x	
19) Handling animals (living or deceased), animal tissues, fluids, or waste byproducts in a research setting.		x	
20) Performing work that requires protective equipment including respiratory and hearing protection?		x	
College of Medicine - *(For additional information please visit http://ahsc.arizona.edu/contracting)*			
	Yes	**No**	**Comments**
21) Participating in clinical teaching of medical students or residents? *If Yes, complete next question*		x	
a. Signed a preceptorship agreement through contracting office or associated with an institution that has an executed preceptor agreement on behalf of clinicians?		x	
Required Attachments			
For Affiliates: CV, [Affiliate Verification Form]()			
For Associates: CV			
For Grad Committee Members: CV or other rationale			
If Yes to #2: Copy of Visa Documents (do not attach—Please forward to Systems Control)			

APPENDIX B
FIGURE 3-2.1b
Volunteer Advertisement

Participate in jaguar and ocelot conservation

A partnership between the U.S. Fish & Wildlife Service and the University of Arizona has an exciting opportunity to volunteer as a **Citizen Scientist** in jaguar and ocelot conservation. Learn and work with experts in non-invasive sampling techniques including camera monitoring, tracking, and data analysis.

Contact

Research Assistant: Emily Reynolds

E-mail: eareynol@email.arizona.edu

Citizen Scientist Requirements:

- Ability to hike MINIMUM 5 miles over rough terrain
- Personal transportation and comfort on 4WD roads
- Commit to training workshop T.B.D (Feb 20-22)
- Commit to monitoring cameras every 30 days
- Adhere to strict safety and confidentiality protocol

University of Arizona
Wild Cat Research
& Conservation Center

Name: Emily Reynolds
E-mail: eareynol@email.arizona.edu

Name: Emily Reynolds
E-mail: eareynol@email.arizona.edu
Name: Emily Reynolds
E-mail: eareynol@email.arizona.edu
Name: Emily Reynolds
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Name: Emily Reynolds
E-mail: eareynol@email.arizona.edu

APPENDIX B
FIGURE 3-2.2b
Citizen Science Workshop Agenda

Jaguar Citizen Science Workshop Agenda
Date/Time: 4-6 April 2014
Location: Santa Rita Experimental Range

OBJECTIVE
To develop citizen scientists that are proficient in jaguar ecology and camera trap monitoring with great data integrity.

ROLES/RESPONSIBILITIES
Primary coordinator: Randy
Schedule coordinator & content: Aletris
Contact person: Emily
Classroom setup: Emily
Food set-up: All
Beverages: Randy
SRER: Mark

SCHEDULE
Friday

6:00 - 6:30	Participants arrive-given name tags & pre survey& waiver	Emily
6:30 - 7:00	Welcome, overview of project & housekeeping	Randy & Mark
7:00 - 7:15	Introductions by participants & staff	Aletris
7:15 - 7:45	Wild Cat Center Intro & Rancher Importance	Lisa
7:45 - 8:45	Dinner and refreshments	TBD
8:45 - ?	Refreshments & great conversation around the fire	Randy

Saturday

7:00 - 7:45	Breakfast buffet, coffee & tea	TBD
8:00 - 8:15	Pass out materials & daily overview	Randy
8:15 - 9:45	Jaguar Project Objectives/ Overview	Jack
9:45 - 10:00	Break	
10:00 - 11:45	Southern AZ Carnivore Ecology	Aletris
11:45 - 12:30	Spotted Cat Ecology	Jack
12:30 - 1:30	Lunch	TBD
1:30 - 2:00	Non-invasive sampling & scat collection	Melanie
2:00 - 2:30	Tracking basics	Aletris
2:30 - 3:00	Break & group photo	
3:00 - 4:30	Camera trap basics, setting & checking camera traps	Jack, Chris, Tom
4:30 - 5:00	Safety and hazards on the trail	Robert Fink
5:00 - 5:30	Transect options & select transect	Chris & Aletris
5:30 - 6:30	GPS basics & scavenger hunt	All
6:30 - 8:00	Dinner	TBD
8:00 - 8:30	Introduction to jaguar education project	Aletris
8:30 -	Campfire discussions and beverages	Randy

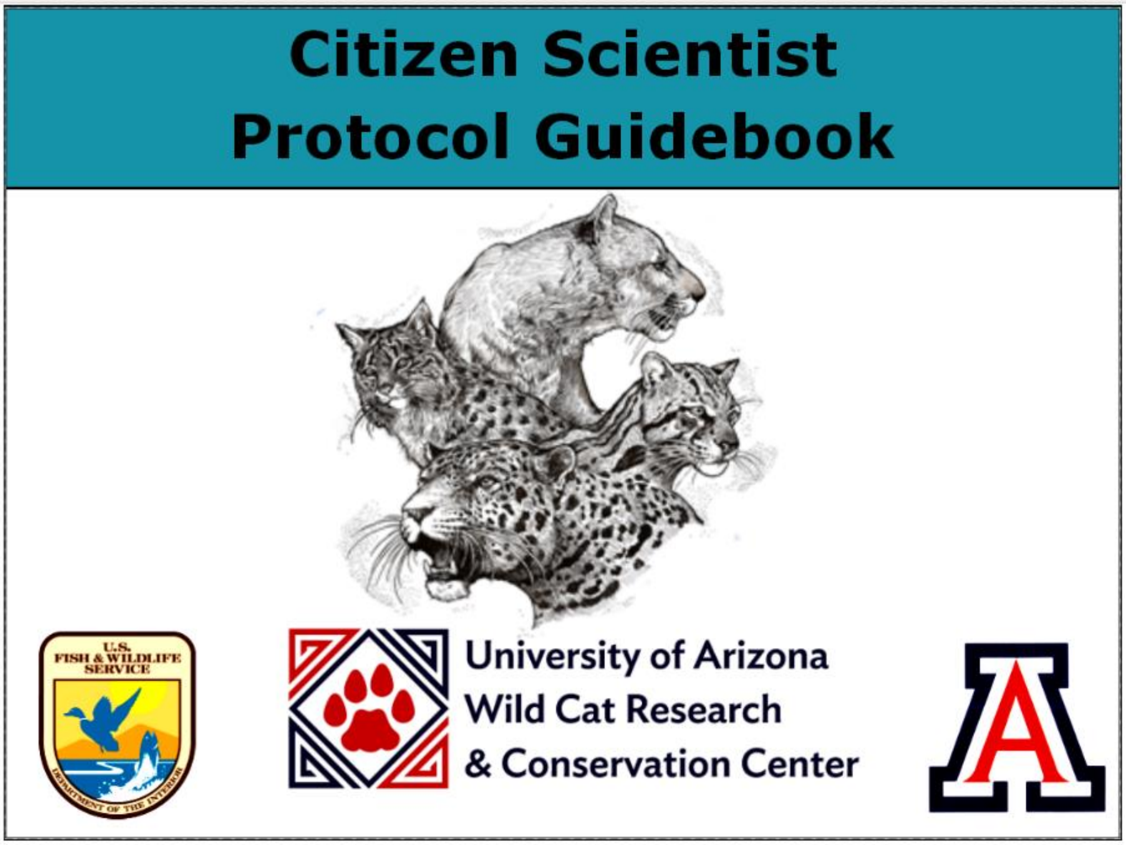
Sunday

7:00 - 7:30	Breakfast buffet	TBD
7:30 - 8:00	Check group camera trap and retrieving cards	Chris
8:00 - 9:30	Downloading and data sorting	Chris & Sue
9:30 - 10:00	Field protocol	Emily, Randy, Aletris
10:00 - 12:00	Field excursion, tracking, check camera	All
12:00 - 1:00	Lunch and cleanup	TBD
1:00 - 2:00	Wrap-up and adjourn and post survey	Emily and Randy

Confirmed Citizen Scientists March 2014:

Name	Affiliation (if any)
Ben Beal	UA
Edmund Priddis	Cochise College
Ethan Craig Wissler	UA
Tim Cook	Tucson Citizen
Bernice Isaacs	Tucson Citizen
Jene Isaacs	Tucson Citizen
Axhel Munoz	Pima County Education
Manuel Metzler	Cochise College

APPENDIX B
FIGURE 3-2.3b
Protocol and Safety Guidebook



APPENDIX B
FIGURE 3-2.4b
Emergency Contact Information

Safety is the most important aspect of this project. Your safety is top priority, if there is any reason you feel unsafe please do not proceed with field work.

Emergency Contacts:

Arizona State Police
(520) 746-4500
6401 S Tucson Blvd
Tucson, AZ 85706

American Border Patrol
(520)-803-7703
2160 E. Fry Blvd. #426
Sierra Vista, AZ 85635

Pima County Sheriff
(520) 351-4600
1750 E Benson Hwy
Tucson, AZ 85714

Sierra Vista USFS Ranger District
520-378-0311
4070 South Avenida Saracino
Hereford, AZ 85615

Cochise County Sheriff
(520) 586-8150
126 W 5th St #2
Benson, AZ

Phi Cares (Helicopter Insurance)
1-888-435-9744
www.phicares.com

APPENDIX B
FIGURE 3-2.5b
Detection Protocol

<u>Detection Protocol</u>

All photos must be reviewed within *<u>24 hours</u>* of checking cameras.

If a jaguar or ocelot is detected:

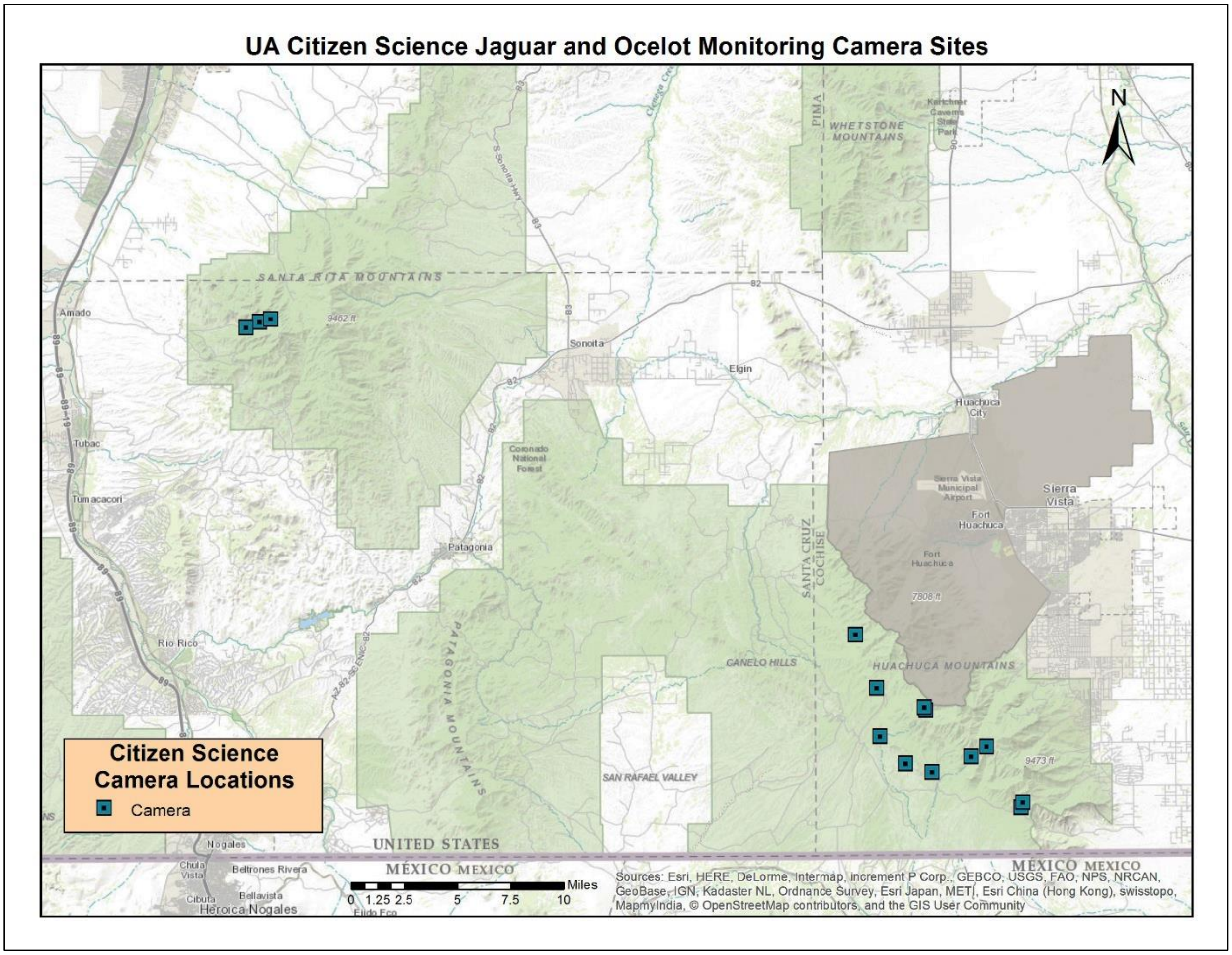
- Email Emily with subject line: *DETECTION* and attach the photo
- In a second email send the site ID name
- Call or text Emily alerting that you have sent an important email
- Emily will alert Sue Malusa

Never send a photo with the coordinates and site name in the same email.

Please honor the confidentiality of this project. Do not share photos or GPS coordinates of any sites associated with this project.

Contact for Emily:
eareynol@gmail.com
574-315-6306

APPENDIX C
FIGURE 3-3
MAP OF CS SITES



APPENDIX D
FIGURE – 3-4.1d
Output.txt File Example (Team B)

SITE CAMERA TRAP DATA (TEAM B)
Date: 2015 May 1
LOCATIONS 3

SAN34	SAN35	SAN38

SPECIES 29

Badger	Bear	Birds	Bobcat	Coati
Cottontail	Cow	Coyote	Dog	Fox
Ghost	Human	Jackrabbits	Jaguar	Javelina
Lizard	Mule Deer	Ocelot	Opossum	Other Rodent
Puma	Raccoon	Ringtail	Skunks	Squirrels
Test	Turkey	Unknown	White-tailed Deer	

This file contained: 6768 lines
Number of lines used in analysis: 6768
Reject file has 0 lines not used in analysis
Number of pictures processed = 6768
Number of pictures used in activity calculation = 1023
Number of independent pictures used in analysis = 590
Number of sequential pictures of same species at same location within a PERIOD = 6178
Number of days in camera trap program = 190
First picture: Year = 2014 Month = 5 Day = 18
Last picture: Year = 2014 Month = 11 Day = 23

SPECIES INCLUDED BUT NOT PHOTOGRAPHED OR ALL REJECTED

Badger	Jaguar
Cow	Javelina
Coyote	Ocelot
Jackrabbits	Raccoon

SPECIES RANKED BY NUMBER OF INDEPENTDENT PICTURES AND PERCENT OF TOTAL

Species	Total	Percent	Species	Total	Percent
Ghost	331	56.1017	Mule Deer	2	0.3390
Squirrels	84	14.2373	Other Rodent	2	0.3390
Human	57	9.6610	Lizard	1	0.1695
Bear	32	5.4237	Turkey	1	0.1695
Fox	23	3.8983	Cottontail	1	0.1695
Unknown	9	1.5254	Puma	1	0.1695
White-tailed Deer	9	1.5254	Raccoon	0	0.0000
Skunks	8	1.3559	Javelina	0	0.0000
Bobcat	7	1.1864	Cow	0	0.0000
Coati	5	0.8475	Coyote	0	0.0000
Birds	4	0.6780	Ocelot	0	0.0000
Opossum	4	0.6780	Badger	0	0.0000
Dog	4	0.6780	Jackrabbits	0	0.0000
Test	3	0.5085	Jaguar	0	0.0000
Ringtail	2	0.3390	Total pictures	590	100.00

CAMERA TRAP DAYS

Location	Start date	Stop date	Duration	First pic	Species
SAN34	2014 5 18	2014 10 26	162	2014 5 18	Ghost
SAN35	2014 5 18	2014 11 23	190	2014 5 18	Bear
SAN38	2014 5 18	2014 8 5	80	2014 5 18	Human

Camera trap days: 432

FOR EACH LOCATION TOTAL NUMBER AND PERCENT OF EACH SPECIES

Use independent picture

	SAN34		SAN35		SAN38	
Species	Total	Percent	Total	Percent	Total	Percent
Badger	0	0.00	0	0.00	0	0.00
Bear	3	1.43	29	8.92	0	0.00
Birds	0	0.00	4	1.23	0	0.00
Bobcat	1	0.48	6	1.85	0	0.00
Coati	1	0.48	4	1.23	0	0.00
Cottontail	1	0.48	0	0.00	0	0.00
Cow	0	0.00	0	0.00	0	0.00
Coyote	0	0.00	0	0.00	0	0.00
Dog	2	0.95	2	0.62	0	0.00
Fox	7	3.33	16	4.92	0	0.00
Ghost	131	62.38	153	47.08	47	85.45
Human	34	16.19	18	5.54	5	9.09
Jackrabbits	0	0.00	0	0.00	0	0.00
Jaguar	0	0.00	0	0.00	0	0.00
Javelina	0	0.00	0	0.00	0	0.00
Lizard	0	0.00	1	0.31	0	0.00
Mule Deer	0	0.00	0	0.00	2	3.64
Ocelot	0	0.00	0	0.00	0	0.00
Opossum	0	0.00	4	1.23	0	0.00
Other Rodent	0	0.00	2	0.62	0	0.00
Puma	1	0.48	0	0.00	0	0.00
Raccoon	0	0.00	0	0.00	0	0.00
Ringtail	0	0.00	2	0.62	0	0.00
Skunks	0	0.00	8	2.46	0	0.00
Squirrels	25	11.90	59	18.15	0	0.00
Test	1	0.48	2	0.62	0	0.00
Turkey	0	0.00	1	0.31	0	0.00
Unknown	1	0.48	8	2.46	0	0.00
White-tailed Deer	2	0.95	6	1.85	1	1.82
Total pictures	210	100.00	325	100.00	55	100.00

FOR EACH LOCATION AND MONTH TOTAL NUMBER EACH SPECIES

Use independent picture

2014

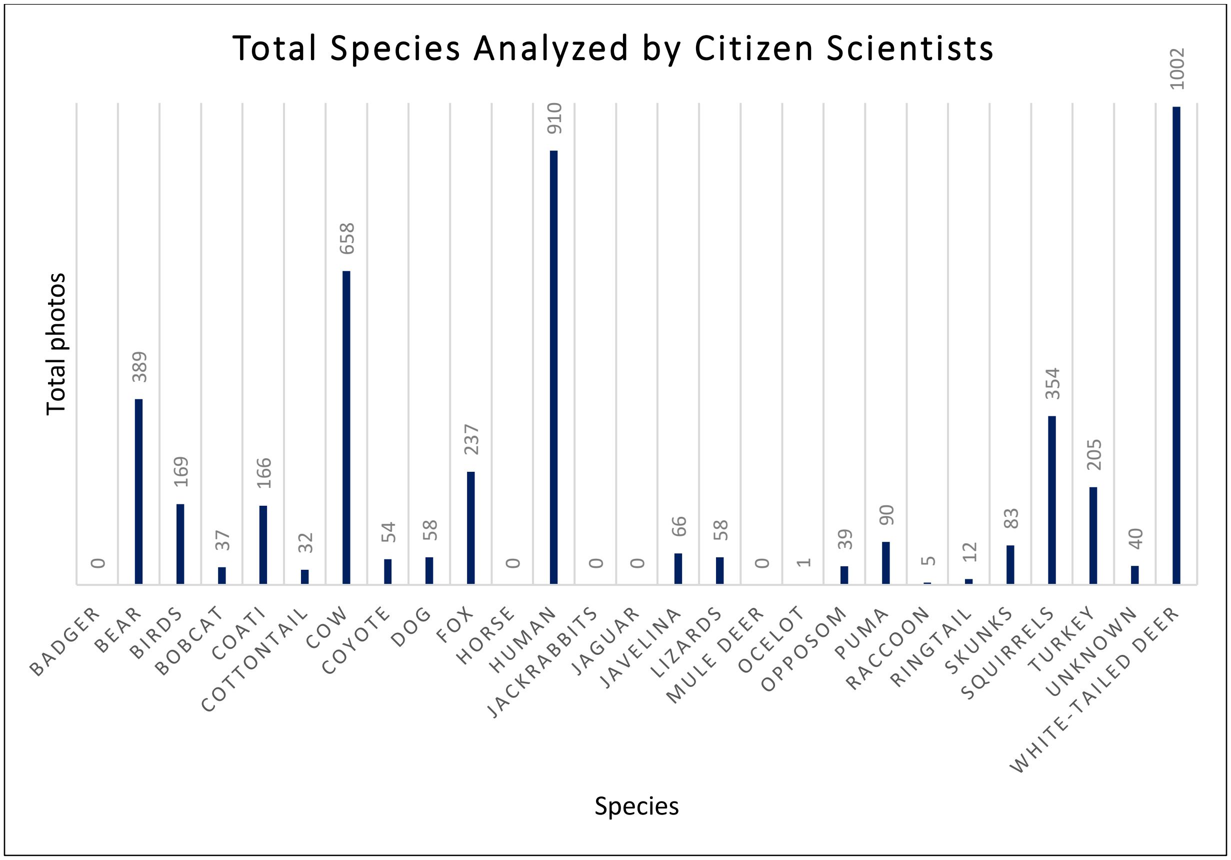
SAN34	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bear	0	0	0	0	0	2	1	0	0	0	0	0	3
Bobcat	0	0	0	0	0	1	0	0	0	0	0	0	1
Coati	0	0	0	0	0	0	1	0	0	0	0	0	1
Cottontail	0	0	0	0	0	0	1	0	0	0	0	0	1
Dog	0	0	0	0	0	0	0	2	0	0	0	0	2
Fox	0	0	0	0	1	2	0	0	0	4	0	0	7
Ghost	0	0	0	0	25	70	20	3	3	10	0	0	131
Human	0	0	0	0	3	7	6	3	8	7	0	0	34
Puma	0	0	0	0	0	1	0	0	0	0	0	0	1
Squirrels	0	0	0	0	5	6	14	0	0	0	0	0	25
Test	0	0	0	0	0	0	0	0	1	0	0	0	1
Unknown	0	0	0	0	0	0	0	1	0	0	0	0	1
White-tailed Deer	0	0	0	0	0	0	0	0	1	1	0	0	2
Total pictures	0	0	0	0	34	89	43	9	13	22	0	0	210
Total effort	0	0	0	0	14	30	31	31	30	26	0	0	162
Total/Total effort	0.00	0.00	0.00	0.00	2.43	2.97	1.39	0.29	0.43	0.85	0.00	0.00	1.30

SAN35	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bear	0	0	0	0	7	12	4	0	0	1	5	0	29
Birds	0	0	0	0	1	3	0	0	0	0	0	0	4
Bobcat	0	0	0	0	1	2	1	0	1	1	0	0	6
Coati	0	0	0	0	0	1	0	2	0	1	0	0	4
Dog	0	0	0	0	0	0	0	1	1	0	0	0	2
Fox	0	0	0	0	2	1	0	0	0	2	11	0	16
Ghost	0	0	0	0	25	21	33	2	10	34	28	0	153
Human	0	0	0	0	1	4	4	2	3	3	1	0	18
Lizard	0	0	0	0	0	1	0	0	0	0	0	0	1
Opossum	0	0	0	0	0	3	1	0	0	0	0	0	4
Other Rodent	0	0	0	0	1	1	0	0	0	0	0	0	2
Ringtail	0	0	0	0	2	0	0	0	0	0	0	0	2
Skunks	0	0	0	0	1	4	2	0	1	0	0	0	8
Squirrels	0	0	0	0	19	20	1	0	0	1	18	0	59
Test	0	0	0	0	0	1	0	0	0	1	0	0	2
Turkey	0	0	0	0	0	0	1	0	0	0	0	0	1
Unknown	0	0	0	0	3	2	1	1	1	0	0	0	8
White-tailed Deer	0	0	0	0	2	3	0	0	0	1	0	0	6
Total pictures	0	0	0	0	65	79	48	8	17	45	63	0	325
Total effort	0	0	0	0	14	30	31	31	30	31	23	0	190
Total/Total effort	0.00	0.00	0.00	0.00	4.64	2.63	1.55	0.26	0.57	1.45	2.74	0.00	1.71

SAN38	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Ghost	0	0	0	0	8	36	3	0	0	0	0	0	47
Human	0	0	0	0	2	1	1	1	0	0	0	0	5
Mule Deer	0	0	0	0	0	0	2	0	0	0	0	0	2
White-tailed Deer	0	0	0	0	0	1	0	0	0	0	0	0	1
Total pictures	0	0	0	0	10	38	6	1	0	0	0	0	55
Total effort	0	0	0	0	14	30	31	5	0	0	0	0	80
Total	0.00	0.00	0.00	0.00	0.71	1.27	0.19	0.20	0.00	0.00	0.00	0.00	0.69

DISTANCE (km) BETWEEN LOCATIONS
Minimum distance = 0.851 Locations: SAN34 SAN35
Maximum distance = 3.033 Locations: SAN35 SAN38
Average distance = 2.261

APPENDIX D
FIGURE – 3-4.2d
Summary of citizen science data



APPENDIX D FIGURE – 3-4.3b
Summary of citizen science data

Species	HUA10	HUA11	HUA19	HUA04	HUA05	HUA21	HUA23	HUA07	HUA09	HUA18	HUA20	SAN34	SAN35	SAN38
Badger	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bear	25	29	43	42	13	4	54	18	6	53	1	3	94	4
Birds	2	0	2	13	0	0	4	37	11	69	22	0	9	0
Bobcat	2	0	2	1	0	0	1	3	0	0	1	9	16	2
Coati	2	4	11	22	12	0	60	15	7	6	9	2	16	0
Cottontail	0	0	0	9	2	0	0	12	0	6	1	2	0	0
Cow	57	54	26	0	0	0	0	286	97	10	127	0	0	1
Coyote	0	1	0	0	1	0	0	21	4	0	27	0	0	0
Dog	5	3	0	2	5	0	0	2	0	22	1	4	14	0
Fox	18	8	17	18	19	0	4	35	4	21	16	28	49	0
Ghost	4274	1075	2086	2514	1654	8	199	1115	174	1500	107	669	6620	143
Horse	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Human	132	47	12	15	155	38	55	27	16	103	22	122	164	2
Jackrabbits	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jaguar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Javelina	2	1	0	40	2	0	2	15	0	4	0	0	0	0
Lizards	0	11	0	0	0	0	0	0	0	0	0	0	47	0
Mule Deer	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocelot	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Opposom	5	0	0	0	2	0	0	0	0	27	0	0	5	0
Puma	22	5	4	12	3	2	0	16	7	15	2	2	0	0
Raccoon	0	0	0	0	0	0	0	0	3	0	1	1	0	0
Ringtail	0	0	0	0	3	0	3	1	0	2	0	0	3	0
Skunks	3	1	3	2	6	0	0	6	3	27	3	0	27	2
Squirrels	9	14	13	39	4	0	2	33	2	9	6	37	186	0
Test	235	60	237	153	79	20	32	207	189	158	84	138	212	30
Turkey	24	15	21	0	20	0	0	0	33	79	9	0	4	0
Unknown	2	7	0	12	5	0	0	4	1	2	1	2	4	0
White-tailed Deer	30	65	60	78	298	10	43	87	29	205	67	9	16	5

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