A GAP ANALYSIS OF BIODIVERSITY RESEARCH IN ROCKY MOUNTAIN NATIONAL PARK: A PILOT STUDY ON SPIDERS

FINAL REPORT

By

ATBI/BIOBLITZ SWAT TEAM

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Executive Summary

Research on biodiversity and the relationship between organisms is imperative to establish management practices for the conservation of protected areas. The E.O. Wilson Biodiversity Foundation (EOWBF) formed our team of four Duke University students as the first of many ATBI/BioBlitz SWAT teams to travel to protected areas and develop approaches to conduct All Taxa Biodiversity Inventory (ATBI) and BioBlitz that can inform their conservation. Upon arrival at Rocky Mountain National Park (RMNP), we conducted data mining to determine major gaps in the understanding of biodiversity inventories. We used available species lists from research conducted in the Park to ensure that the National Park species database, NPSpecies, contains the most up-to-date information. Our team added 645 species of plants and fungi to the database through this process. After completing this gap analysis, we identified spiders as the subject of our field study.

This document consists of five sections. The first section provides background information about RMNP. We discuss the extreme elevational gradient and variety of habitat types that occur in the park. These major physical and biological processes have motivated three hypotheses to study spiders. We hypothesize that spider species richness: (1) is higher during night sampling than day sampling; (2) decreases as elevation increases; and (3) is higher in riparian zones.

The second section describes our methods of gap analysis and focus on one taxonomic group, spiders, for our field study. We conducted a pilot analysis of spider biodiversity, to identify as many species in the Park as possible and to relate their occurrences to environmental variables. Specimens were collected from three non-wilderness sites in RMNP at three times of the day (morning, afternoon, and night), over a span of ten days (July 16 - 25, 2014). The three sites represented a range of elevations (2,398 - 2,923 meters) and habitats. We also conducted a mini-BioBlitz with 6 citizen participants using the same collecting protocol.

Third, we present our results and model analyses. Over 300 spider specimens were collected in the field survey, 157 of which were identified and documented, representing 15 families and 51 species. The remaining specimens were juvenile and it

is very difficult to identify them to species level. The Denver Museum of Nature and Science (DMNS) served as a repository and provided accurate specimen identification. After identification of the specimens, we conducted an analysis of what species occurred throughout the different habitats and sampling times. A Joint Species Distribution Modeling (JSDM) analysis was applied to provide a model fit, a cluster analysis, as well as the relationship of certain species to environmental variables such as elevation and sampling time.

Next, we discuss the implications of our results and the recommendations we have for the park. Our first hypothesis was not supported in our data. We found similar numbers of species in diurnal and nocturnal sampling. Our second hypothesis was not consistent with our data. The site with the lowest elevation had the highest number of specimens collected. However the trend did not continue in the next two sites of increasing elevation. The third hypothesis was consistent with our data. The highest number of specimens was found at the riparian zone.

Finally, we make conclusions regarding potential contributions from our ATBI/BioBlitz SWAT team. Cost-effective methods were utilized and evaluated for future spider research. We propose a more thorough spider survey in RMNP that can better inform management of the Park by providing information about spider diversity, abundance, function, and how spiders can be used as ecological indicators. We also recommend more mini-BioBlitz activities within the park system. These activities can provide valuable data to biodiversity research as well as connect people to nature in profound ways. Our hope is that there will be a consistent presence of ATBI/BioBlitz SWAT teams in National Parks to inform future research decisions and prioritize biodiversity gap research.

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Introduction

Our knowledge of species diversity is growing, but perhaps not fast enough to keep up with extinction. Of the estimated 9 million species on Earth, only 14% of the terrestrial species and 9% of the species in the ocean have been catalogued (Mora et al. 2011). Many species have gone extinct without our knowledge of their existence. A recent study suggested current global extinction rates to be 1,000 times higher than natural background extinction rates, and may further increase in the future (De Vos et al. 2014). Larger organisms tend to be much better known and studied than small creatures. For example, even though there have been 145,000 recorded soil microorganisms, the number of existing soil species is significantly higher than this number described (Brussaard et al. 1997). Soil species represent a variety of life forms, such as bacteria, algae, nematodes, microscopic insects, fungi, earthworms, and spiders (Ingham et al. 1985; Moldenke & Lattin 1990). Biodiversity at the species level is poorly understood because of a lack of research (Juslén & Sirkiä 2013). Indeed, the gap in our understanding and the need for conservation require an urgent increase in biodiversity research.

Protected areas on public and private lands are important refugia for various life forms in diverse ecosystems. Assessing gaps in biodiversity research in protected areas, particularly national parks, can help us identify threatened species, target vulnerable habitats, track changes in the ecosystems, anticipate risks of extinction, improve conservation within park boundaries, and inform biodiversity protection in broader landscapes. The E.O. Wilson Biodiversity Foundation (EOWBF) has been established to expand our understanding of biodiversity on earth and "foster a knowing stewardship of our world through biodiversity research", and thus to sustain the ecosystems around the world as well as our own livelihoods (E.O. Wilson Biodiversity Foundation). In partnership with the EOWBF, Discover Life in America (DLiA), and Rocky Mountain National Park (RMNP), we sought to communicate the urgent need for taxonomic information about existing biodiversity by piloting a study at RMNP. There was a necessity to illustrate potential problems associated with a lack of information on species diversity, abundance, and interrelationships within RMNP. In order to acquire baseline biodiversity information, we worked with RMNP to synthesize existing species information through data mining and fieldwork to identify current gaps in biodiversity research. Identification of gaps in the current species inventory could help prioritize the use of limited resources on key species and management areas.

The simplest measure of species diversity is a count of the number of species (MacArthur 1965). By referencing the National Park Species database (NPSpecies) and previous research done in the park, we conducted a comprehensive review of all species present in RMNP. Using this review we were able to identify gaps in biodiversity inventory. Our approach to inventory species in various ecosystems was inspired by All Taxa Biodiversity Inventory (ATBI) (Discover Life in America 2015) and BioBlitz (National Geographic 2015). Due to the underrepresentation of arthropods in the order Araneae in NPSpecies and their integral role in ecosystems, we chose a field study focused on spider inventory. We aimed to gather information about the distribution and ecology of spiders in RMNP, which will provide baseline knowledge for future research on the role of spiders as biological indicators to measure ecosystem health.

This document consists of five sections. The first section provides background information about RMNP and major physical and biological processes in effect that motivated our hypotheses to study spiders. The second section describes our methods of gap analysis and focus on one taxonomic group, spiders, for our field study. Third, we present our results and model analysis. Next we discuss the implications of our results and the recommendations for the Park. Finally we make conclusions regarding potential contributions from our ATBI/BioBlitz SWAT team.

Background

Established a hundred years ago on September 4, 1915, RMNP covers 415 square miles of protected mountain terrain and contains various ecosystems such as riparian, montane, subalpine, and tundra zones (Beidleman et al. 2000; National Park Service). RMNP is home to a variety of species within the high south-central continental divide. The extreme topographic relief supports a unique community of plants, animals, and microorganisms that make it an ideal place to conduct scientific research (Mast et al. 1990; Benninger-Truax et al. 1992; White et al. 1998). Vertebrates and vascular plants in RMNP are well studied and documented (ROMO Biodiversity Symposium 2014). However, even in these well-known taxa, there are many unanswered questions regarding their roles and functions. Initiating a long-term ecological inventory and monitoring program will enable the Park to manage future anthropogenic impacts and the biological effects of a changing climate. It is important to maintain an updated record of all species inventoried in the park. A comprehensive record of all taxa is fundamental to identify the often overlooked groups, such as smaller invertebrates.

Spiders, order Araneae, are one of the most abundant and diverse groups of organisms in terrestrial ecosystems (Foelix 2011). They are taxonomically rich at species, genus, and family levels and occupy a wide variety of niches, representing different ecological specializations (New 1999). Worldwide, about 40,000 species of spiders have been catalogued, representing about one-fourth of the total estimated number of species (Jiménez-Valverde & Lobo 2007). In North America, about 3,500 species of spiders are known (Levi et al. 2002). In RMNP, there was very little information on the distribution and diversity of spiders since there was only one spider species on record in NPSpecies originally. Spiders were one of the major gaps in the biodiversity inventory for potential field study.

Spiders can serve as ecological indicators, a taxonomic group whose presence or absence provides information about ecosystem health (Blandin 1986). These indicators can be used in various circumstances, such as to evaluate the biodiversity of an area, or to investigate the effects of changes that management decisions have on a habitat (Maelfait and Hendrickx 1998). Surveying the composition of spider assemblages in an ecosystem can also yield important information about the trends of change within the ecosystem. Spiders have been found to indicate the recovery of an ecosystem after disturbances such as single or repeated fires in the Swiss Alps (Moretti et al. 2002). There is also evidence that spiders can demonstrate the effects of habitat fragmentation, which can suggest future conservation efforts (Maelfait & Hendrickx 1998).

Several factors in the ecosystem are related to spider biodiversity. In previous studies, differences in spider assemblages have been found when samples were taken diurnally and nocturnally (Green 1999; Coddington et al. 1996). In another example, Jiménez-Valverde and Lobo (2007) compared two spider families in ecosystems with different climates, topographies and vegetation variables and they suggested that climate variables such as maximum temperature had a significant impact on spider species richness in the Mediterranean region and spider diversity increased with vegetation complexity (Jiménez-Valverde & Lobo 2007). According to Downie et al. (1995) spider assemblages varied across elevations in northern England. They also stipulated that invertebrate populations were important to study the effects of disturbance (Downie et al. 1995). Finally, a correlation between riparian zones and increased spider abundance has been shown, as spiders utilized aquatic insects as a major food source (Marczak & Richardson 2007).

The previous studies summarized above motivated the following hypotheses that we aimed to address with our field study:

(1) Spider species richness is higher during night sampling than day sampling;
(2) Spider species richness decreases as elevation increases; and
(3) Spider species richness is higher in riparian zones.

Methods

The field component of our biodiversity gap analysis in RMNP spanned from June 1st to August 2nd. The first part of our gap analysis was to determine which species were well documented and which were underrepresented in existing biodiversity inventories. NPSpecies was one of our major sources of reference. It documents all the taxa found in national parks in the United States. We used NPSpecies to generate a list of already documented species specific to RMNP and we found a total of 2,942 species originally in the Park. Building from this list, we carried out comprehensive data mining and searched for existing species lists that had not been incorporated into NPSpecies by previous studies in RMNP. In addition, we consulted 15 researchers and managers in RMNP about unpublished and on-going research that can be added to the database. We added a total of 645 species through this process, which is a 22% increase from the original species number, representing taxa of plants, lichens, and other fungi.

The findings from this comprehensive review allowed us to identify several taxonomic gaps in RMNP biodiversity inventory such as ants, wasps, bees, soil microorganisms, bats, clams, and spiders. To determine the taxa to focus on for our field survey, we had to take into account the constraints of our timeline, available resources for equipment, training, and identification. With all these considerations, we decided that spiders represented the best opportunity to maximize the utility of our time and resources.

The initial background study identified spiders as a gap in research. There was a single entry, the Western Black Widow Spider (*Latrodectus hesperus*). The *Symbiota Collection of Arthropods Network* (SCAN) was used to conduct this data mining and we added existing entries to NPSpecies. Many of the specimens were dated as far back as 1962 and there were no records of spider studies conducted within the Park in the recent past. We designed and executed a spider field study that aimed to inventory as many spider species as possible, which resembles the rationale of ATBI (DLiA 2014; Parker & Bernard 2006; White et al. 2000). In addition, the temporal aspect of field surveys is crucial to adequately represent the spider assemblages in an area. Both diurnal and nocturnal sampling are required as many spiders are active only at night. Most studies use a combination of different methods to capture the diversity of spider populations in different microhabitats, such as manual collecting, pitfall traps and vacuum samples (Green 1999). In compliance with our research permit to study spiders in RMNP, we used manual collecting methods that do not involve placing man-made objects in natural environments (Appendix C).

The methods used for spider collection were modeled after the *Colorado Spider Survey Handbook*, created by Dr. Paula Cushing at the Denver Museum of Nature and Science (DMNS) (Cushing 2014). Surveyors collected spiders in clear, plastic vials. Our team aimed to collect only adult specimens, as juveniles cannot be definitively identified to species level. However, it was very difficult to differentiate between adult and juvenile spiders in the field. Each transect has a total of one main vial filled with 75% ethanol to preserve the specimens, which were identified later in the laboratory. The geographic coordinates and elevation were taken for each site with GPS units. Field notes recorded the environmental information, such as weather and habitat conditions.

The four different collection methods that were applied to implement spider sampling are listed below:

1. *Sweep net method (look-up and look-down)*. The surveyor swept over the vegetation using a sweep net when walking in a relatively straight line through the transect, and collected spiders fallen in the sweep net into a vial.
2. *Beat sheet method*. The surveyor stretched a beat sheet (1 square meter, light-colored cloth) under the edge of a plant, and beat or shook the vegetation vigorously to make resident spiders fall onto the beat sheet, and collected the fallen spiders into a vial.
3. *Berlese funnel* extraction. The surveyor collected a quart-sized bag of leaf litter sample at each transect site and transported it back to the Berlese funnel. The surveyor placed the leaf litter sample on the screen inside the funnel and a vial with 75% ethanol under the funnel, and suspended a 25-watt bulb over the sample. Between 24 to 72 hours, the spiders and insects were collected from the vial with ethanol into which they were driven down through the end of the funnel.

4. *Casual* collecting. The surveyor collected spiders into a vial when encountering them at the transect. This involved flipping over rocks, leaf litter, and logs.

Methods 1, 2, and 4 utilized manual collecting and we attempted to only collect mature individual spiders. Method 3 was used to collect ground-dwelling spider species and minimized bycatch as an alternative to the pitfall trap method.

For our field study, we chose three sites in the non-wilderness areas within RMNP for a comparative study of spider biodiversity in three ecosystems: McGraw Ranch (average elevation: 2,400 m), Lily Lake (2,745 m), and Hidden Valley (2,920 m). McGraw Ranch is in the dry Montane Life Zone with riparian vegetation and grassland ecosystems containing various spider habitats (Beidleman et al. 2000). Lily Lake is a once disturbed area of 469 acres in the upper Montane Life Zone with willow-aspen grove and lodgepole pine forest surrounding the lake and has been added to RMNP since 1990 (Beidleman et al. 2000). Hidden Valley is in the Subalpine Life Zone with moist Engelmann spruce and Subalpine fir ecosystem that resemble boreal ecosystems seen further north in Canada (Beidleman et al. 2000).

The three sites were surveyed at three time periods within a day: morning, afternoon, and night during July 16-25. The morning sample started between 8:30 and 10:15 am; the afternoon sample started between 5:00 and 7:00 pm; and the night sample started between 9:45 and 10:45 pm. The timeframes were scheduled to account for the daily afternoon thunderstorms. Each transect was surveyed for one hour, which only included periods of active sampling, and we used all four collecting methods. Each site was sampled six times in total, including two repetitions for each of the above time frames.

An extra sample was collected with the aid of local citizen scientists, as a Mini-BioBlitz activity. Four children in elementary and middle school and two adults were recruited to participate in this activity. A thirty-minute training was followed by a one-hour sampling period. The same collecting protocol described above was observed. The group sampled the McGraw Ranch site in the morning and the specimens collected through this process were included as one of our samples. (For detailed methods see Appendix B)

Finally, we performed casual collecting to capture spiders outside of the scheduled sampling periods, labeled as sample “Casual Collection.” There were a total of 20 samples, with eighteen samples as part of the survey design and two samples from the mini-Bioblitz activity and casual collection in McGraw Ranch.

Before analyzing the variation of spider species, identification to species level was required. The dichotomous key in two publications by the American Arachnological Society (AAS): *Spiders of North America: An Identification Manual* and *Common Spiders of North America* was used to identify the spiders to the family level. A team of identification volunteers in DMNS aided our team in identifying the specimens to the species level. Most specimens identified are adult specimens, although some juveniles were also identified. To expedite the process to fit our project timeline, the volunteer team ceased analyzing the juveniles, as most of them cannot be identified to the species level. The DMNS serves as a repository for the collected spider specimens.

Data analysis was conducted using the Joint Species Distribution Modeling (JSDM) method (Clark et al. 2014). The JSDM is a single model for the prediction of the distribution of multiple species simultaneously, taking into account both species occurrence and abundance, as well as environmental variables. Compared to the traditional species distribution models, JSDM accounts for species interactions such as competition and mutualism. Our analyses include a fitting to the model, a cluster analysis, and probability density analyses.

Results

Over 300 spider specimens were collected in the field survey, 157 of which were identified and documented, representing 15 families and 51 species. The remainder of the specimens were juvenile, making it difficult to identify them to the species level. A characterization of specimens in three sites is shown in Table 1. Thirteen juvenile specimens were identified to the species level. The three most abundant families sampled were Lycosidae (23% of the total specimens collected), Clubionidae (13% of the total), and Theridiidae (13% of the total). The only one species present in all three sites was *Dictyna cebolla* of the Dictynidae family (Appendix A). The mini-BioBlitz activity yielded 15 species identified.

All the specimens collected were through manual collecting methods (methods 1, 2, and 4). The Berlese funnel extraction (Method 3) did not yield any spider specimens from the leaf litter on the ground.

Upon further research, we found 59 species on record in RMNP that were deposited in the DMNS (Appendix A). Of these 59 species added to NPSpecies through the data mining process, 8 were found in our study. This means our field study added 43 novel species entries to the Araneae records in RMNP.

Table 1. Taxa characterization of specimens in three sites

Study Site	**Number of Specimens**	**Number of Families**	**Number of Species**
McGraw Ranch	102	13	36
Lily Lake	31	9	13
Hidden Valley	24	8	16

The JSDM was used to analyze our species data. First, the model fit was applied to determine the model could predict our field data (Figure 1). The trend line produced by the model fits the observed species abundance shown in the box plot of all samples, meaning the model can be used to analyze our data with high confidence.

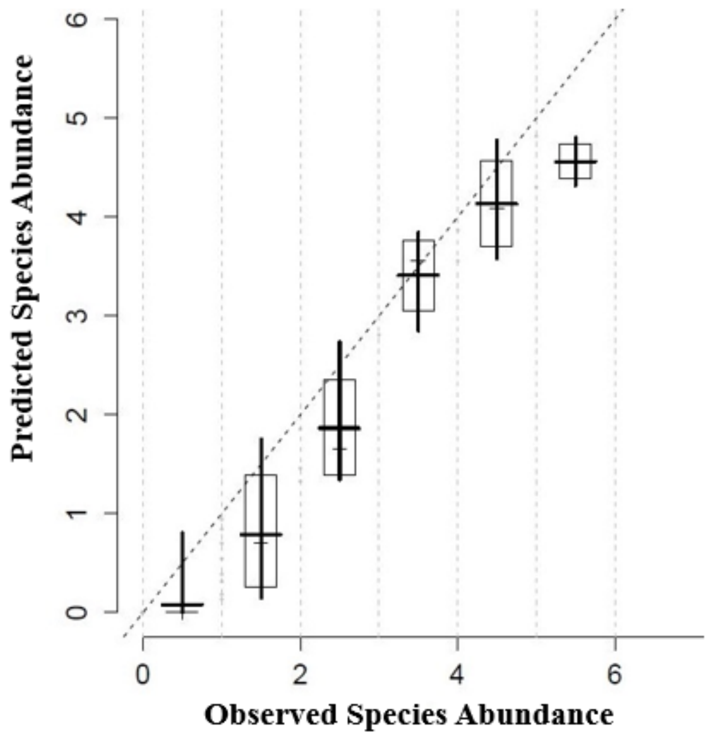

Figure 1. Model Fit of Species Abundance. Predicted species abundance data agrees with observed data. Box and whisker plots show 1 and 2 standard deviations.

We conducted a cluster analysis to understand the relationships between species based on all three environmental variables: elevation, sampling time, and habitat types (Figure 2). For example, the species in yellow color demonstrated the following characteristics: they all occurred in Hidden Valley, with the highest elevation, and at night; they represented five families, Amaurobiidae, Araneidae, Dictynidae, Linyphiidae, and Lycosidae. All but one species in the red color occurred in McGraw Ranch, the site with the lowest elevation, and in the afternoon; this group represented five families, Lycosidae, Salticidae, Tetragnathidae, Theridiidae, and Thomisidae and it shared only one family with the yellow group. There is very little similarity between these groups. This classification provided an initial investigation into the relationship between species.

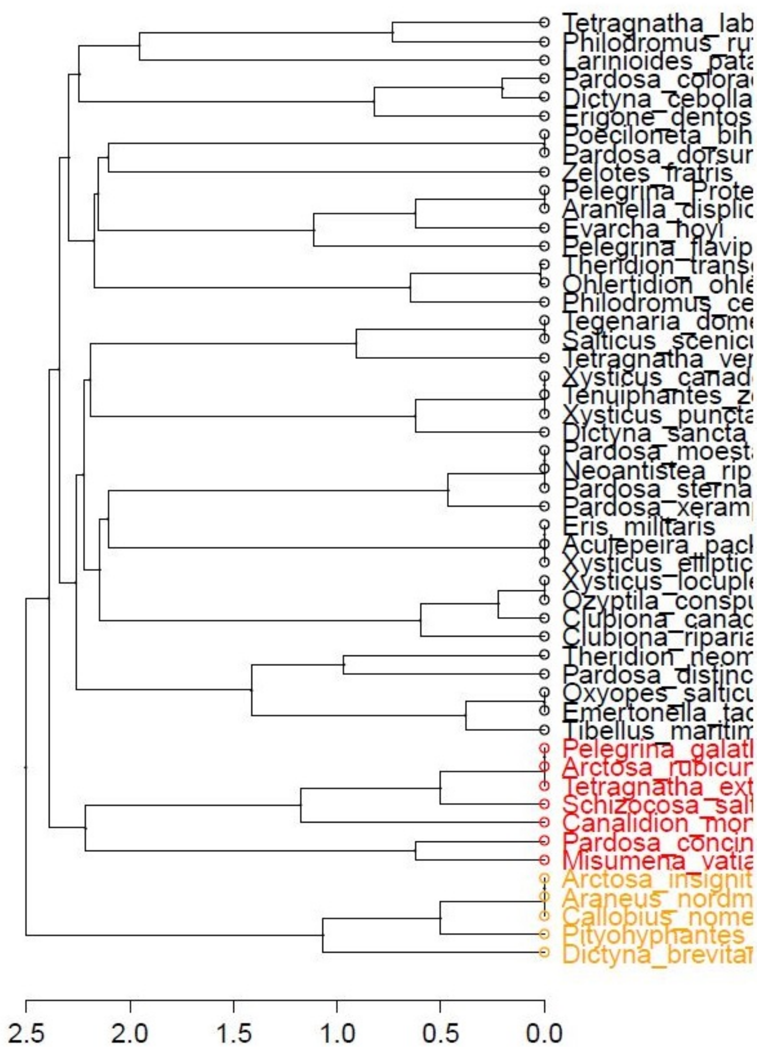

Figure 2. Cluster Analysis of Species responses to environmental variables. The same color represents species that are similar to each other based on responses to elevation, sampling time, and habitat types.

Another aspect of using the JSDM method is to understand the relationship between species and environmental variables. Probability density functions can be used to show the rate of change in species abundance (the number of specimens for each species) with the changes in various environmental variables such as elevation (Figure 3) and sampling time (Figure 4 and Figure 5). The three species shown in these figures, *Pardosa distincta*, *Clubiona riparia*, and *Tetragnatha laboriosa*, belong to the three most abundant families (Lycosidae, Clubionidae, and Theridiidae) described above, respectively. They were the only species that showed any trend with elevation or sampling time using JSDM. The other 48 species did not show any trend due to the small sampling size. Because of this lack of data, JSDM method cannot be used to answer our three hypotheses. However future research can use this model to predict more robust trend of species distribution in the Park.

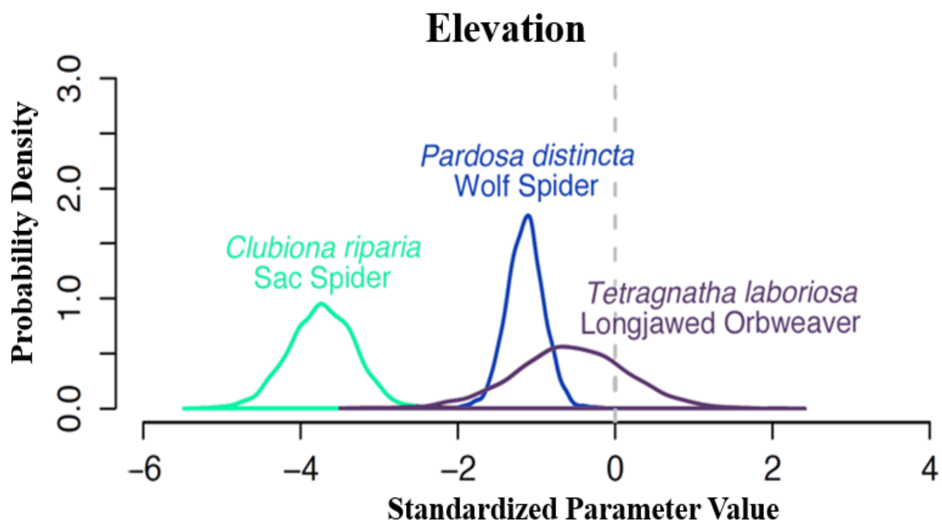

Figure 3. Sensitivity to the Elevation Gradient. *Clubiona riparia* tends to occur at low elevation relative to the other two species. *Tetragnatha laboriosa* is the most ambiguous since it spreads across zero value and has a low peak.

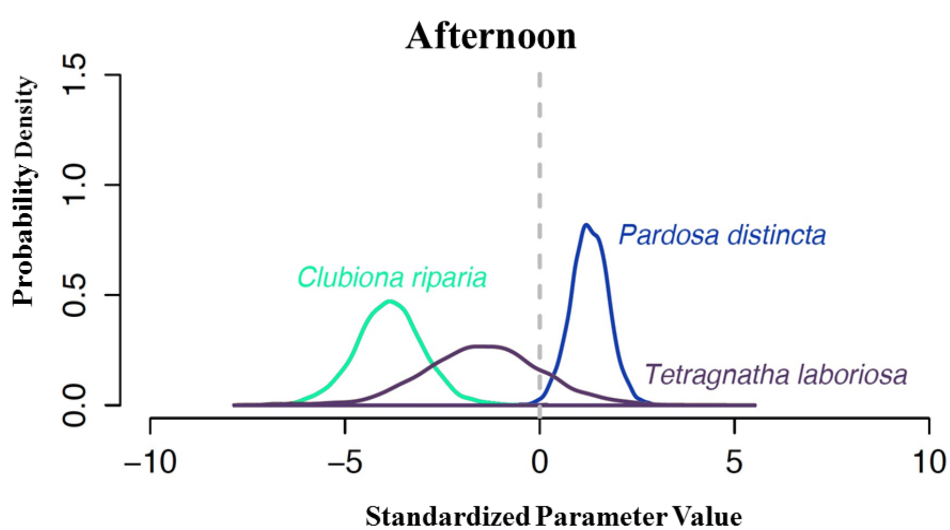

Figure 4. Sensitivity to Sampling Time - Afternoon. Positive values means *Pardosa distincta* is most often encountered in the afternoon. *Clubiona riparia* is more likely to occur in the morning.

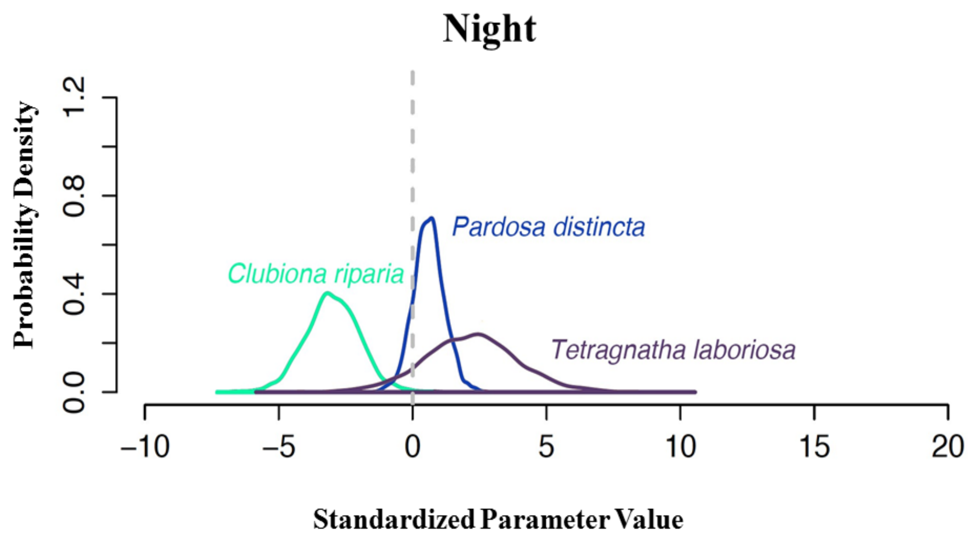

Figure 5. Sensitivity to Sampling Time - Night. Positive values mean that *Pardosa distincta* and *Tetragnatha laboriosa* are more likely to occur at night than in the morning. *Clubiona riparia* is more likely to occur in the morning. More confidence is shown with *Pardosa distincta* than with *Tetragnatha laboriosa* because the former species has a higher peak.

Species identified during the morning, afternoon, and night sampling yielded almost identical numbers of species (Figure 6). The night and afternoon samples both contained 24 species and morning contained 23. The species that were collected only at night represent 8 families and 11 species (Appendix X). This is not consistent with our original hypothesis that nocturnal sampling would yield more species.

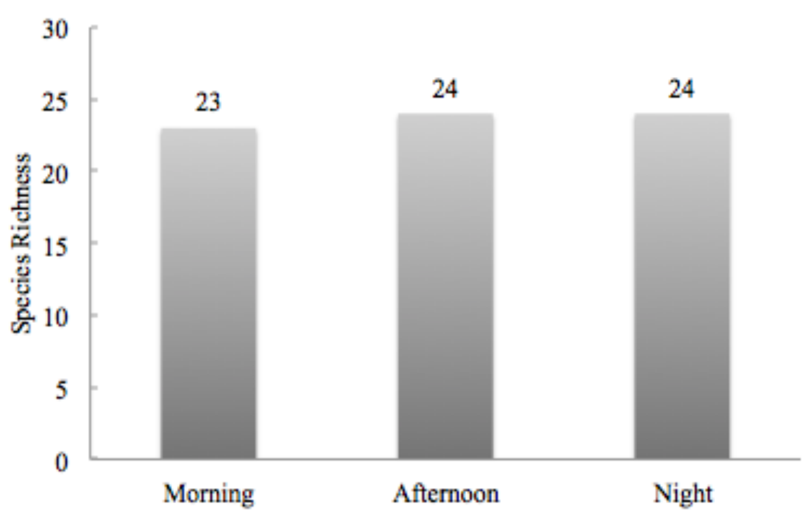

Figure 6. Spider Species Richness plotted across Morning, Afternoon, and Night.

As seen in Figure 7, the majority of our species occurred at McGraw Ranch (36) and the least at Lily Lake (13). McGraw Ranch was the riparian site with the lowest elevation at 2,400 m. This trend follows our hypothesis that there would be greater species richness in the riparian zone. However, our elevation hypothesis is inconclusive as Lily Lake and Hidden Valley had relatively similar species richness.

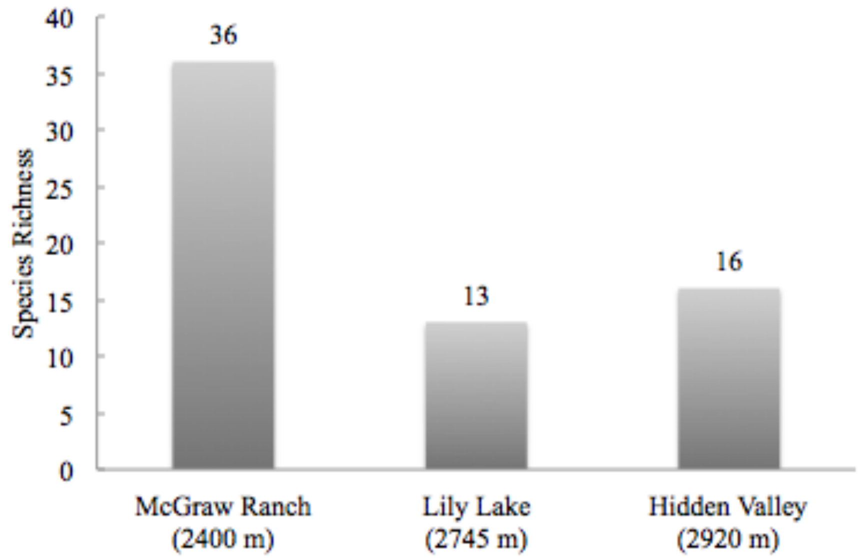

Figure 7. Species Richness at each sampling site.

Discussion

Our team added 102 new spider species to the RMNP database, through the data mining and field survey methods, allowing for a greater understanding of spider diversity in the Park. Our ten-day sampling period yielded a relatively small number of samples, and therefore we were unable to make statistically significant conclusions from the data. There were, however, interesting trends in our data that could be used to inform future studies in spider diversity, abundance, and ecology. We used the JSDM as an initial investigation into the interrelationships between species and their interactions with environmental variables. Future studies with larger data samples can use this model to predict more robust trends in species distribution of spiders.

The three different time frames yielded about the same number of species. This refutes our original hypothesis that more species could be collected at night, as most spider species are nocturnal (Stowe 1978). Nearly half of the species were found during both day and night sampling. One explanation for this could be that our team sampled at two time periods during the day but only one time period at night. This was mostly due to safety and logistical reasons. Another possible impact on the number of species collected was the difficulty of casual collection at night. The limited lighting most likely led to a decrease in the casual collecting at night (Green 1999).

Our initial hypothesis that species richness would decrease with increasing elevation was not reflected in the data. While McGraw Ranch had the most species collected and had the lowest elevation, Lily Lake had a lower species count than the highest elevation site, Hidden Valley. A much larger range of elevations will need to be sampled to be able to identify patterns in differences in spider assemblages at various elevations in RMNP. Habitat type is also a major factor that may confound the effects of elevation (McCain et al. 2010).

McGraw Ranch accounted for the majority of species (70.6%) that were collected. This site represented a riparian montane ecosystem, with tall grasses and ample ground cover. This was a primary habitat for spiders, and one that had been previously predicted to yield many specimens by Dr. Cushing at DMNS (Cushing, pers.

comm.). There were also two extra samples collected from McGraw Ranch, one during the mini-BioBlitz activity and one from Casual Collection we collected around our cabins. This could have inflated the number of species collected from the McGraw Ranch site. We were able to collect a limited number of specimens from Lily Lake and Hidden Valley. These samples may have had more juvenile specimens and therefore they were not represented in our data. In different ecosystems, the spiders might have been at different stages in their lifecycle. This difference in species richness could also have been due to previous disturbance and current restoration projects. Lily Lake was added to RMNP in the 90's to prevent a proposed residential development and in 1992 Hidden Valley was restored from a previous ski resort to maintain native vegetation and aquatic habitat (Kloepfer 2002; Kingsbury 2002).

Overall, our team faced many challenges when designing our survey. We received preliminary training in spider collection methodology, but we were limited in our survey design areas, timeline, and methods. We could only select sites that were in non-wilderness areas in the Park as there was a long process to obtain a permit to sample in wilderness areas. As 95% of RMNP is designated wilderness (National Park Service), we had very little flexibility in terms of the types of habitat and elevation. Our timeline did not allow for a long permitting process and this is a major consideration for future spider surveys that may be conducted in RMNP. There were also numerous rules and regulations that had to be followed because of the protected status of the territory. Some of these included restrictions on the use of pitfall traps or other installations of any kind that might greatly impact the outcome of our spider study.

We also faced challenges during the sampling process. After repeating transects at the same site, we noticed a decrease in the amount of specimens collected. A decision was made to move the transects 10 meters away from the initial transects. This might have impacted the repeatability of our experiment because the survey regime changed during the process. Weather was a major factor throughout our time at RMNP. The Park is affected by nearly daily afternoon thunderstorms, which posed issues regarding safety while sampling. In addition, after the rain, the sweep nets and beat sheets became inundated with moisture and collection produced fewer specimens.

Despite these constraints, due to our short sampling period (10 days), we were not allowed the flexibility with our sampling time.

One of the highlights of our time at RMNP was conducting a mini-BioBlitz with a group of participants ranging in age from children to adults. We explored the suitability of using citizen scientists to aid in conducting spider research in the Park. The group was trained for a short thirty-minute period and they were very adept at collecting spider specimens using our methods. They proved to be very successful, collecting 15 species for our final tally. This shows the validity of mini-BioBlitz in the collection of Arachnids, and provides a quick, cost effective way of adding to overall species lists (Appendix B). By creating activities to encourage children and adults to come to the park, it can foster a deeper personal connection with nature. Hopefully these activities will inspire future interests in species and biodiversity research in the park.

Our experiences from this pilot project could inform processes of future biodiversity gap analysis in the Park. Throughout our spider survey, we were able to identify and document 102 spider species in RMNP, a significant improvement from the one spider species documented at the beginning of our study. We recommended the Park to conduct more robust studies of the distribution and ecology of spiders. A comprehensive study, spanning 2-3 years, across all localities, during all times of the day, and that takes place over the entire collecting season, would lead to a thorough understanding of spider biodiversity in the park. For example, to determine the relationship between spider distribution and the elevational gradient, a future study should include the same habitat type at different altitudes. Future research that utilizes complementary collecting methods could lead to a more complete picture of spider assemblages. New studies can also investigate the differences in spider diversity in wilderness and non-wilderness sites. Furthermore, there is potential to examine the impact of the Elk & Vegetation Management Plan on spider biodiversity. Implemented in 2008, this plan has been a major development in RMNP the conservation toolkit. Spiders may serve as indicators to evaluate the success of a variety of conservation tools outlined in this plan, such as fencing and vegetation restoration (National Park Service).

Conclusion

A major theme throughout our project is that it is important to identify and learn about what life forms are present in order to conserve and protect its biodiversity. Our most meaningful contribution was to have developed a process through which gaps in biodiversity research can be addressed in national parks. A species database is useful to determine the diversity of organisms within national parks. It is imperative to document all species inventories generated by biodiversity research in the Park on the NPSpecies database.

The pilot spider survey we conducted in RMNP was the first concerted effort to study spider biodiversity within the Park. Spiders were identified as a gap in the Park's species database and they perform crucial ecological functions. We added 102 species to the RMNP database through data mining and a field survey. The survey design we utilized can be improved and adapted for future spider studies in RMNP and other national parks.

Biodiversity research is crucial to improve conservation management in protected areas. The results of our study suggest that prioritizing biodiversity research in resource stewardship practices in national parks can help us better understand and conserve the species within them. This pilot study accomplished its goal through scientific research, outreach, and communication to convey the relevance of biodiversity to the decision makers at the Park and to the general public. Our experience also suggests that non-expert researchers can coordinate resources in a cost effective and timely manner to significantly improve the knowledge of biodiversity. We hope our pilot study will lead to a constant presence of ATBI/BioBlitz SWAT teams that are in National Parks around the world. These teams can conduct ATBI research and further the initiative by the E.O. Wilson Biodiversity Foundation to catalogue all species on the planet.

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Appendix A: Spider Species Lists from Data Mining and Field Survey

I. Spider species list from data mining

Table 1. Spider Species List from Data Mining

Family (14)	Species (59)
Agelenidae	*Agelenopsis utahana*
Araneidae	*Aculepeira carbonarioides*
Clubionidae	*Clubiona kulczynskii*
Corinnidae	*Castianeira*
Dictynidae	*Dictyna brevitarsa*
	Dictyna crosbyi
	Dictyna volucripes
	Emblyna phylax
	Emblyna uintana
Gnaphosidae	*Callilepis eremella*
	Gnaphosa borea
	Gnaphosa muscorum
	Haplodrassus chamberlini
	Haplodrassus eunis
	Haplodrassus hiemalis
	Haplodrassus signifer
	Micaria coloradensis
	Micaria constricta
	Micaria pulicaria
	Sergiolus montanus
	Zelotes fratris
	Zelotes puritanus
Hahniidae	*Neoantistea gosiuta*
Linyphiidae	*Allomengea dentisetis*
	Erigone aletris
	Erigone blaesa
	Erigone dentigera
	Erigone hypenema
	Grammonota gentilis
	Idionella tugana
	Incestophantes lamprus
	Tachygyna haydeni
	Tunagyna debilis

Lycosidae	*Alopecosa aculeata*
	Hogna frondicola
	Pardosa coloradensis
	Pardosa concinna
	Pardosa distincta
	Pardosa fuscula
	Pardosa groenlandica
	Pardosa mackenziana
	Pardosa modica
	Pardosa moesta
	Pardosa ourayensis
	Pardosa uintana
	Pardosa uncata
	Pardosa yavapa
Philodromidae	*Thanatus altimontis*
	Thanatus coloradensis
Salticidae	*Habronattus altanus*
	Pelegrina flavipes
	Pelegrina proterva
	Talavera minuta
Theridiidae	*Enoplognatha intrepida*
	Steatoda hespera
Thomisidae	*Xysticus benefactor*
	Xysticus discursans
	Xysticus montanensis
Titanoecidae	*Titanoeca nivalis*

II. Spider species list from field survey

Table 2. Spider Species List from ATBI Field Survey

Family (15)	**Species (51)**
Agelenidae	*Tegenaria domestica*
Amaurobiidae	*Callobius nomeus*
Araneidae	*Aculepeira packardi*
	Araneus nordmanni
	Araniella displicata
	Larinioides patagiatus
Clubionidae	*Clubiona canadensis*
	Clubiona riparia

Dictynidae	*Dictyna brevitarsa*
	Dictyna cebolla
	Dictyna sancta
Gnaphosidae	*Zelotes fratris*
Hahniidae	*Neoantistea riparia*
Linyphiidae	*Erigone dentosa*
	Pityohyphantes cristatus
	Poeciloneta bihamata
	Tenuiphantes zelatus
Lycosidae	*Arctosa insignita*
	Arctosa rubicunda
	Pardosa coloradensis
	Pardosa concinna
	Pardosa distincta
	Pardosa dorsuncata
	Pardosa moesta
	Pardosa sternalis
	Pardosa xerampelina
	Schizocosa saltatrix
Oxyopidae	*Oxyopes salticus*
Philodromidae	*Philodromus cespitum*
	Philodromus rufus
	Tibellus maritimus
Salticidae	*Eris militaris*
	Evarcha hoyi
	Pelegrina flavipes
	Pelegrina galathea
	Pelegrina proterva
	Salticus scenicus
Tetragnathidae	*Tetragnatha extensa*
	Tetragnatha laboriosa
	Tetragnatha versicolor
Theridiidae	*Canalidion montanum*
	Emertonella taczanowskii
	Ohlertidion ohlerti
	Theridion neomexicanum
	Theridion transgressum
Thomisidae	*Misumena vatia*
	Ozyptila conspurcata

	Xysticus canadensis
	Xysticus ellipticus
	Xysticus locuples
	Xysticus punctatus

III. Summary of spider families across time

Table 3. Spider Sample Family Occurrence across Time

Family	**Morning**	**Afternoon**	**Night**	**Casual**	**Grand Total**
Agelenidae				1	1
Amaurobiidae			1		1
Araneidae	1		10		11
Clubionidae	16	1	4		21
Dictynidae	7	4	2		13
Gnaphosidae		1			1
Hahniidae		1			1
Linyphiidae	1	4	5		10
Lycosidae	7	19	7	3	36
Oxyopidae			1		1
Philodromidae	4	1	4		9
Salticidae	4	2	1	1	8
Tetragnathidae	4	3	9	1	17
Theridiidae	10	5	5		20
Thomisidae	2	2	3		7
Grand Total	**56**	**43**	**52**	**6**	**157**

IV. Summary of Spider family across study sites

Table 4. Spider Sample Family Occurrence across Three Study Sites

Family	**Hidden Valley**	**Lily Lake**	**McGraw Ranch**	**Grand Total**
Agelenidae			1	1
Amaurobiidae	1			1
Araneidae	2	7	2	11
Clubionidae			21	21
Dictynidae	4	1	8	13
Gnaphosidae		1		1
Hahniidae			1	1
Linyphiidae	7	1	2	10
Lycosidae	3	1	32	36
Oxyopidae			1	1
Philodromidae	1	4	4	9
Salticidae		1	7	8
Tetragnathidae		6	11	17
Theridiidae	3	9	8	20
Thomisidae	3		4	7
Grand Total	**24**	**31**	**102**	**157**

V. Statistics of spider samples by family

Table 5. Spider Sample Composition by Family

	Family	Number of specimens	% of specimens	Number of species	% of Species
	Agelenidae	1	1%	1	2%
	Amaurobiidae	1	1%	1	2%
	Araneidae	11	7%	4	8%
	Clubionidae	21	13%	2	4%
	Dictynidae	13	8%	3	6%
	Gnaphosidae	1	1%	1	2%
	Hahniidae	1	1%	1	2%
	Linyphiidae	10	6%	4	8%
	Lycosidae	36	23%	10	20%
	Oxyopidae	1	1%	1	2%
	Philodromidae	9	6%	3	6%
	Salticidae	8	5%	6	12%
	Tetragnathidae	17	11%	3	6%
	Theridiidae	20	13%	5	10%
	Thomisidae	7	4%	6	12%
Sum	**15**	**157**	**100%**	**51**	**100%**

Appendix B: Mini-BioBlitz Techniques

Spider Mini-BioBlitz Activity: Methods and Discussion

Prepared by the ATBI/BioBlitz SWAT Team from Duke University

Introduction

The national parks offer wonderful opportunities for the public to connect with nature and become inspired by science. A technique that has been used successfully to increase awareness and interest in natural systems is BioBlitz. Originated from citizen science programs, which have helped the participants think critically and scientifically in other areas of their lives (Bonney & Dhondt 1997; Trumbull et al. 2000; Krasny & Bonney 2005; Brossard et al. 2005), BioBlitz proves to be a powerful participatory method to invite citizens to conduct research and connect with nature. We demonstrated the importance of biodiversity research in Rocky Mountain National Park through hosting a Mini-BioBlitz spider workshop. Initially we hypothesized that participants would effectively learn the methods of spider collection and collect mature specimens within three hours. We found our efforts to be successful, as demonstrated by the students' enthusiasm and success at collection. This activity suggested mini-BioBlitz as a valid tool to conduct biodiversity research in a national park.

Methods

Participant Recruitment

A successful mini-BioBlitz activity needs an adequate number of participants with enthusiasm. We aimed to find children and teenagers in order to test if our collection methods were understandable and practical to be applied by a younger audience. Fortunately, the Park has formed a positive relationship with local teachers with potential interested participants. Our activity took place on July 24, 2014, from 9 am to 12 pm. We designated McGraw Ranch site as our focal transect because of its large number of spiders, adequate and convenient parking, and access to training facilities such as a conference room and picnic table.

Items provided by organizers:

- Sweep Nets
- Beat Sheets
- Dry Vials
- Wet Vials
- Sunscreen
- Drinking Water

Items prepared by participants:

- Water bottles
- Bug spray
- Hat
- Long pants/shirt sleeves

- Access to bathrooms
- Information sheet
- Magnifying glasses

Participant Training

When the participants arrived, we first introduced and oriented them to the place and facilities they could use. Then we conducted a 30-minute training session, introducing our project, the importance of spiders in an ecosystem, and sampling methods. First we introduced the rationale for participating in a mini-BioBlitz activity like this. Three major questions we asked our citizen participants were: (1) What is biodiversity? (2) Why are spiders important to the ecosystem? and (3) How is biodiversity research conducted in the park? An information sheet was provided to each individual with relevant spider facts (Appendix B-1).

Another important part of our program was to demonstrate the critical permitting process to research in the park. We presented our permit and explained our site selection in non-wilderness area, our manual collection methods to prevent establishing man-made installations in the park. The procedure was important to stress for a successful and compliant collecting in the Park.

Next, we demonstrated our spider collecting techniques. Two major methods were focused on and modeled by the participants. After they understood and felt comfortable about the techniques, we led them to the actual transect. The instructions for two collecting techniques, beat sheet and sweep net, are listed below.

Instructions for Two Collecting Methods

Beat Sheet: Place the sheet underneath the branch or plant of your choice. Use a stick to tap vigorously on the branch or plant. After 5 to 7 taps take a look at the sheet. Move quickly! Spiders will start to climb to the outside of the sheet, make sure to catch them before they are gone!

Sweep Net: Find a place in the grass or bushes that you have plenty of room. Swing the net like a golf club (swing hard!). After 5-7 “sweeps”, look carefully inside the net for spiders. You might have to shake it around or use your hand to sift through what you’ve caught.

Furthermore, we explained our efforts to collect only mature spiders by observing the specimens collected with magnifying glass in the field. Male and female spiders can be identified through their different genitalia features (Figure 1, Figure 2).

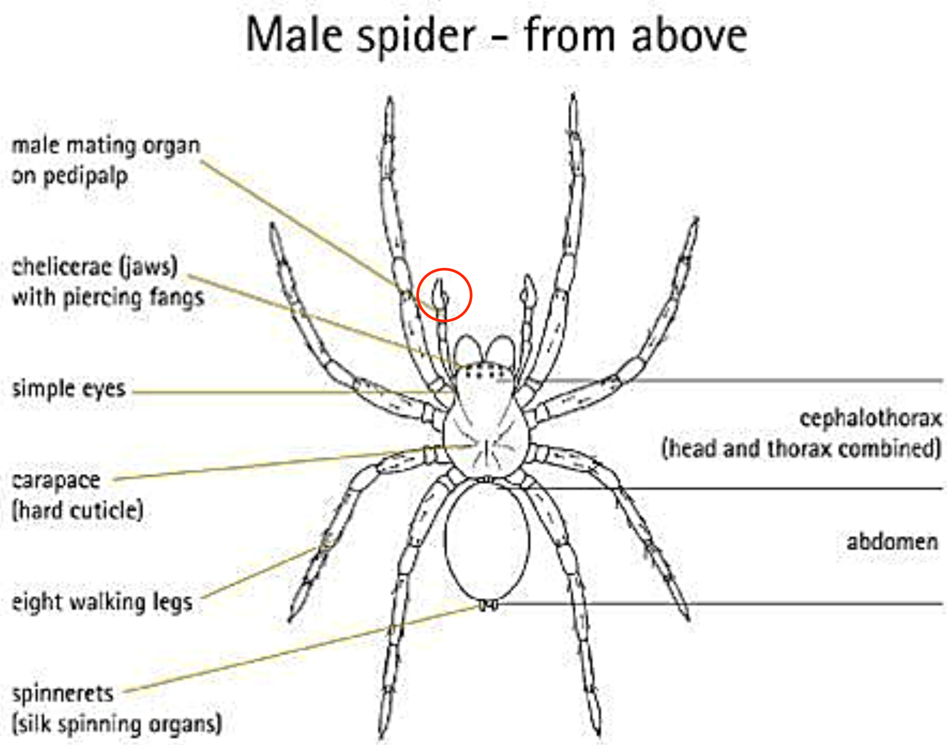

Figure 1. Male Spider viewed from above, showing external structures

This diagram shows a male spider. The adult males have a pedipalp (circled) that is enlarged and has distinctive structures. The pedipalps can be referred to as "boxing gloves". The immature male spiders have boxing gloves that are enlarged, but with no distinctive structures. This part can be seen using a magnifying glass. Adult males will lose their web-making capability. So if a male was found on a web, it was automatically classified as immature.

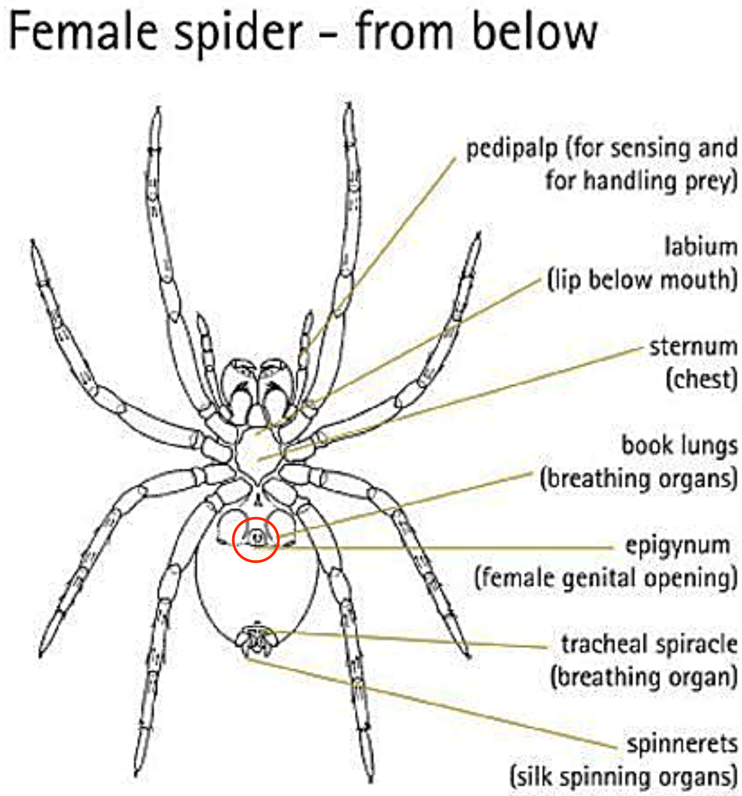

Figure 2. Female Spider viewed from below, showing external structures

Depicted above is a diagram of a female spider. The mature female spiders show an epigynum (circled) with distinctive structures. This is more difficult to see in a magnifying glass but is possible with practice. The epigynum in mature female specimens is black in color and shows a scelaritization (hardening of the tissue).

Sample Collection

To begin the spider survey, we explained the importance of correct labeling of samples. This sample that the participants collected would be included in our results, and therefore we illustrated the labeling procedure to the participants. We recorded site name, starting time, collector, and location. Then, we used a GPS unit to record the coordinates and elevation of the site. All information was recorded on 100% cotton paper with India ink, which was then put into our wet vial containing 75% ethanol. Each participant was given a dry vial to collect specimens, and a sweep net or a beat sheet based on their preference. We started the timer at 9:40 am, and explained that we would be collecting until 10:40 am, for one hour. Upon catching a spider in the dry vial, we would assist the participants to determine whether it was mature, and if so, transfer the specimen into the wet vial.

Identification and Follow-up

At the end of the hour, we reconvened in a nearby conference room. In order to demonstrate the process of the identification of spider species, we took out some specimens in magnifying vials. Groups of two were then provided a computer with pictures of spiders known to exist in Colorado. Each person was given a chance to identify about 4 to 5 spiders to families based on the visuals. This was a very rough identification. We explained that these results were just educated guesses and usually a microscope needed to be used to identify to a genus or species level.

With the help of the Denver Museum of Nature and Science, we are able to identify the specimens to species. We will be sending a list of spider species collected to all the participants. This will also provide a tangible result to their efforts. This is also to fulfill the mission that we show each specimen taken from the park for a specific purpose.

Discussion

Our mini-BioBlitz activity consisted of 4 children and teens aged 7 to 14 as well as two adults. We were pleasantly surprised at the efficacy of the participants' collecting. Within five to ten minutes of starting, we were seeing each person begin to catch spiders. Even those that initially expressed distaste for spiders actively participated in the collection and identification of specimens.

The transect site was chosen for the amount of spiders we had previously collected. We wanted the participants to have the greatest chance of catching spiders as possible. Our transect site at McGraw was located in a grassland and riparian ecosystem. Many different arachnid families were collected. The participants seemed enthusiastic when collecting and identifying the specimens.

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Mini-BioBlitz Information Sheet
Provided to participants during training

Spider Survey in Rocky Mountain National Park

What is Biodiversity?

- The various forms of plants, animals, and microorganisms that live in an ecosystem such as parks.
- This includes knowledge on where they live, how many there are of each species, and how they interact with other species in the park.
- Knowing this information will help the park identify priority conservation areas.

Why are spiders important?

Spiders, order Araneae:

- Are one of the most abundant and diverse groups of organisms in terrestrial ecosystems
- Are native to every continent in the world except Antarctica
- Spiders have been used as ecological indicators to measure the health of an ecosystem
- Eat large amounts of insects, significantly controlling their population. They also kill other spiders, even their own species, which naturally controls their populations.
- Different birds, wasps, and mammals depend on spiders as a food source to survive.
- Humans have used spider venom to treat many diseases.
- Spider silk is the strongest natural material and has brought about many innovations in engineering.

What can you do?

Tell your friends how important spiders are! The next time you see a spider, think of it as a top predator in its ecosystem, and not a creepy, crawly arachnid.

Fun Spider Facts

- Daddy Longlegs are NOT spiders.
- The young spiders disperse by flight in the wind like the dandelions, a behavior called ballooning.
- A few spider moms carry the egg case with them until the young emerge. For example, wolf spiders carry the egg case attached to the special fingerlike structure called the spinnerets where silk is released.

Spider senses:

- Sense of touch - Spiders use their legs to “hear” the webs they are standing on or hairs to sense the movement in the air.
- Sense of smell - Spiders can sense the sexual perfumes called pheromones from as far as 1 meter, which is equal to a city block in human terms.
- Sense of vision- Have 6-8 eyes

Appendix C: Research Permit in Rocky Mountain National Park

United States Department of the Interior

NATIONAL PARK SERVICE
Rocky Mountain National Park
Estes Park, Colorado 80517

IN REPLY REFER TO:

N2219 (ROMO)

Ms. Casey Johnson
530 South LaSalle St.
Apt 3309
Durham, NC 27705

Dear Ms. Johnson:

This is in response to your request for permission to conduct research in Rocky Mountain National Park (ROMO) titled "Spider Biodiversity Survey in Rocky Mountain National Park". We have reviewed your research proposal and find the methodology will be essentially nondestructive to resources found in ROMO. Therefore, by copy of this letter, we are granting permission to carry out the research during the times and in the locations indicated in the enclosed research permit.

As a condition of conducting research within ROMO, we require that completion of an Investigator's Annual Report and a copy of your research be made available to the park. Please see your permit for additional conditions.

The permit itself will serve as an entrance pass for you and any co-investigators. Individual investigators should be prepared to show it at the entrance gate along with photo identification. You and your associates are also required to have a copy of the permit with you while in the field. Please keep us updated if your project team changes and we will gladly update your permit.

If you have further questions, please call Isabel Ashton. Isabel has been designated as the park contact for your project.

Sincerely,

~~Ben Bobowski~~ Acting
Chief of Resources Stewardship
Enclosures

SCIENTIFIC RESEARCH AND COLLECTING PERMIT Grants permission in accordance with the attached general and special conditions **United States Department of the Interior** **National Park Service** **Rocky Mountain**	**Study#: ROMO-00082** **Permit#: ROMO-2014-SCI-0047** **Start Date: Jul 11, 2014** **Expiration Date: Jul 29, 2014** **Coop Agreement#:** **Optional Park Code:**

Name of principal investigator:
Name: Casey Johnson **Phone:**507-210-0941 **Email:**casey.johnson@duke.edu

Name of institution represented:
Duke University

Co-Investigators:

Name: Sahil Chaini	**Phone:** 919-627-5554	**Email:** sahil.chaini@duke.edu
Name: Zhenzhen Chen	**Phone:** 540-429-9630	**Email:** zhenzhen.chen@duke.edu
Name: Jianyu Wu	**Phone:** 919-699-2472	**Email:** jianyu.wu@duke.edu

Study Title:
Spider Biodiversity Survey in Rocky Mountain National Park

Purpose of study:
1. To conduct a pilot study of spider biodiversity in three different life zones in Rocky Mountain National Park. We expect to survey for three different times each day during day and night.
2.Collect information in order to close a biodiversity research gap in Rocky Mountain National Park.

The proposed study sites are: McGraw Ranch, Lily Lake, and Hidden Valley areas. Each transect will be repeated six times, including diurnal and nocturnal sampling. Sampling methods will include using sweep nets, beat sheet collecting, casual collecting and a Berlese funnel. Researchers will avoid bycatch by using hand collection for all methods but the Berlese Funnel. This method will be used once at the end of the transect and will have minimal take. The survey will be conducted in non-wilderness areas but removed from the path so as not to disturb visitors. Surveyors will try to minimize the collection of individuals from each species and the focus will be on species diversity. A maximum of 1000 specimens will be collected, identified, and the Denver Museum of Nature and Science will serve as a repository.

Subject/Discipline:
Invertebrates (Insects, Other)

Locations authorized:
McGraw Ranch, Lily Lake, and Hidden Valley.

Transportation method to research site(s):
Vehicle access to trailheads, then foot access to each transect.

Collection of the following specimens or materials, quantities, and any limitations on collecting:
May collect up to 1000 spider specimens for identification purposes and curation

Name of repository for specimens or sample materials if applicable:

Repository type: Permanently retained in National Park Service collection, maintained in one or more non-NPS repositories identified in attached Appendix A (complete and submit an Appendix A for each proposed repository) (Denver Museum of Nature and Science (formerly Denver Museum of Natural History))
Objects collected:
Arachnids, order Araneae will be stored in glass vials containing 75% ethanol. The sample size will be no larger than 1,000 specimens. Over a two week period researchers will collect samples six times for each transect. The three collecting sites are: McGraw Ranch, Lily Lake, and Hidden Valley in Rocky Mountain National Park. These specimens will be sent to the Denver Museum of Nature and Science (DMNS). The small number of arthropods gathered using the Berlese Funnel method will be identified and preserved at DMNS. The DMNS will help researchers identify spider specimens to the species level.

Specific conditions or restrictions (also see attached conditions):
Please read these conditions carefully as they are legally binding. If you want to request a change in your permit conditions, please

contact your designated park permit lead.

This permit must be carried at all times by field staff while sampling within the park. The permit also acts as an entrance pass. Individual investigators should be prepared to show the permit and personal identification at the park gate and as requested by any park staff member.

Park regulations must be followed. Researchers are responsible for knowing and complying with all park and National Park Service regulations unless specifically exempted from a regulation below. A copy of the most recent Compendium is available upon request from the Park Dispatch Office ((970) 586-1204).

Entrance to closed areas is not permitted without specific permission. If you wish to enter a closed area to conduct research, please contact your designated park permit lead to discuss. Permission must be issued in writing by the Chief Ranger's Office.

Data Sharing. The permittee is required to submit an Investigator's Annual Report. Within five years of the expiration of the research permit, ROMO requires that the permittee provide copies of completed research products, including electronic or hard copies of all scientific publications and gray literature including theses, dissertations, photographs, all published and unpublished data sets, and field notes. A presentation to park managers may be requested upon completion of the project to explain the management implications of the completed work. The permittee signature on this permit indicates the researcher's concurrence with these requirements.

Protect rare plants and archeological resources. No rocks may be moved and no soil disturbed during this project unless specifically authorized by this permit.

Equipment installation and plot markers are not generally allowed. The permittee is not allowed to install equipment or plot markers of any kind unless specifically authorized in this permit.

Protect wilderness values. All collections must occur out of sight and sound of visitors to the maximum extent possible. Use of mechanized equipment in areas of the park managed as wilderness is not allowed.

Safety is the responsibility of the principal investigator and team. If advice is needed on routes or on conditions which might be encountered, researchers should contact the Backcountry Office ((970) 586-1242) or park research staff.

Recommended by park staff(name and title):

Isabel Ashton Director CDRLC

Reviewed by Collections Manager:

Yes ____ No ____

Approved by park official:

Isabel Ashton

Date Approved:

7/14/14

Title:

Chief, Resources Stewardship - Acting

I Agree To All Conditions And Restrictions Of this Permit As Specified
(Not valid unless signed and dated by the principal investigator)

Casey Johnson 7/14/14

(Principal investigator's signature) (Date)

THIS PERMIT AND ATTACHED CONDITIONS AND RESTRICTIONS MUST BE CARRIED AT ALL TIMES WHILE CONDUCTING RESEARCH ACTIVITIES IN THE DESIGNATED PARK(S)