The use of drones for recreational impact monitoring of public lands

by

Kristen D. Sikorsky

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Major Professor
Dr. Ryan Sharp

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Abstract

A significant increase in visitation to protected lands, such as wilderness areas, parks, and wildlife refuges, has been observed across the board, from the smallest of state parks to some of the largest national parks in the world. This rise in use has prompted concerns that visitation is degrading the plants, soils, water, and wildlife these areas were established to protect. The Interagency Visitor Use Management Framework (IVUMF) provides guidance to professionalize the process for the continued preservation of natural conditions and processes in protected natural areas and the sustained administration of high-quality recreational experiences. At the core of the IVUMF is the need to measure indicators and thresholds to both provide sound rationale on which to base new management decisions as well as measure the efficacy of enacted decisions over a long period of time. As public land managers seek to increase the implementation of simple and cost-effective methods to collect indicator and threshold data to address environmental and visitor experience concerns, drones may be the logical next step. This study analyzes the outcome of using a drone to formulate thresholds for two selected indicators, visitor-created trails and vegetation loss, in a newly established Kansas state park, Little Jerusalem Badlands. Up to a 42% loss in vegetation is already being observed in key areas of Little Jerusalem, as well as the formation of visitor created trails after the first three months of park opening consistent with the previously studied curvilinear rate of impact to a site. These results confirm the need for a simplified and reliable method to monitor a variety of environmental indicators in protected areas over the long-term to aid land management agencies in decision-making to reduce recreational impacts.

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In addition, I would like to thank my committee members, Dr. Jessica Fefer and Dr. Katherine Nelson. The work of both wonderful individuals inspired me to utilize multidisciplinary techniques to solve problems, from tracking down additional source material to the final challenges of my data analysis. Thank you both for supporting my endeavors through your own passions and ideas.

Besides the influential individuals at Kansas State University, I would also like to thank Matthew Bain and Laura Rose Clawson of The Nature Conservancy. I owe a sincere amount of gratitude to each of you for the many hours you have both spent checking on my progress and keeping me updated during the park creation process. Your genuine enthusiasm to protect Little Jerusalem Badlands and the rest of Smoky Valley Ranch is extremely apparent and instilled in myself a love for the prairie even as a Rhode Island native. I have no doubts that both of you will continue to serve as Kansas' foremost stewards of conservation.

Chapter 1 - An Introduction to Drones as Tools for Conservation

Introduction

A worldwide spike in visitation to protected natural lands, such as wilderness areas, parks, and wildlife refuges, has prompted concerns that a surge in visitation is degrading the plants, soils, water, and wildlife these areas were established to protect (Marion, Leung, Eagleston, & Burroughs, 2016). Managers of protected areas rely on cost-effective and innovative solutions to address threats to biodiversity and the visitor experience. Historically, land managers have chosen to address resource impacts utilizing a model of "carrying capacity," determining a maximum level of allowable use and setting direct management actions to keep visitor use at or below this determined threshold (McCool & Cole, 1998; Manning, 2011). However, decades of research have revealed that the solution to resource impact issues is exceedingly complex, linking the disciplines of recreation ecology, social science, environmental biology, and management to provide a thorough research-based solution. A multipart framework, developed in 2016, drew inspiration from the concept of carrying capacity and past frameworks (Such as Limits of Acceptable Change, Visitor Experience and Resource Protection, ect.) to provide a systematic basis to address managerial decision-making needs in public lands: The Interagency Visitor Use Management Framework (IVUMF). This framework relies on a diverse array of management strategies and actions, often termed a "management toolbox," for resolving visitor impact problems (Figure 1.1). This "toolbox" includes strategies such as restoration ecology, professional development of visitor management staff, modifying visitor behavior, increasing resource resilience, and many others (Interagency Visitor Use Management Council, 2016). The IVUMF provides additional guidance to professionalize the process for the continued preservation of natural conditions and processes in our protected natural areas and the sustained administration of high-quality recreational experiences. It is intended to provide a process that is legally defensible, transparent, meets all law and policy requirements regarding public land management, and ensures agency accountability in managerial decisions and actions (Marion et al., 2016). It is currently applied by the Bureau of Land Management, the National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, National Oceanic and Atmospheric Administration, and U.S. Army Corps of Engineers to assist in managerial decisions for the administration of public lands retained by each agency (Interagency Visitor Use Management Council, 2016).

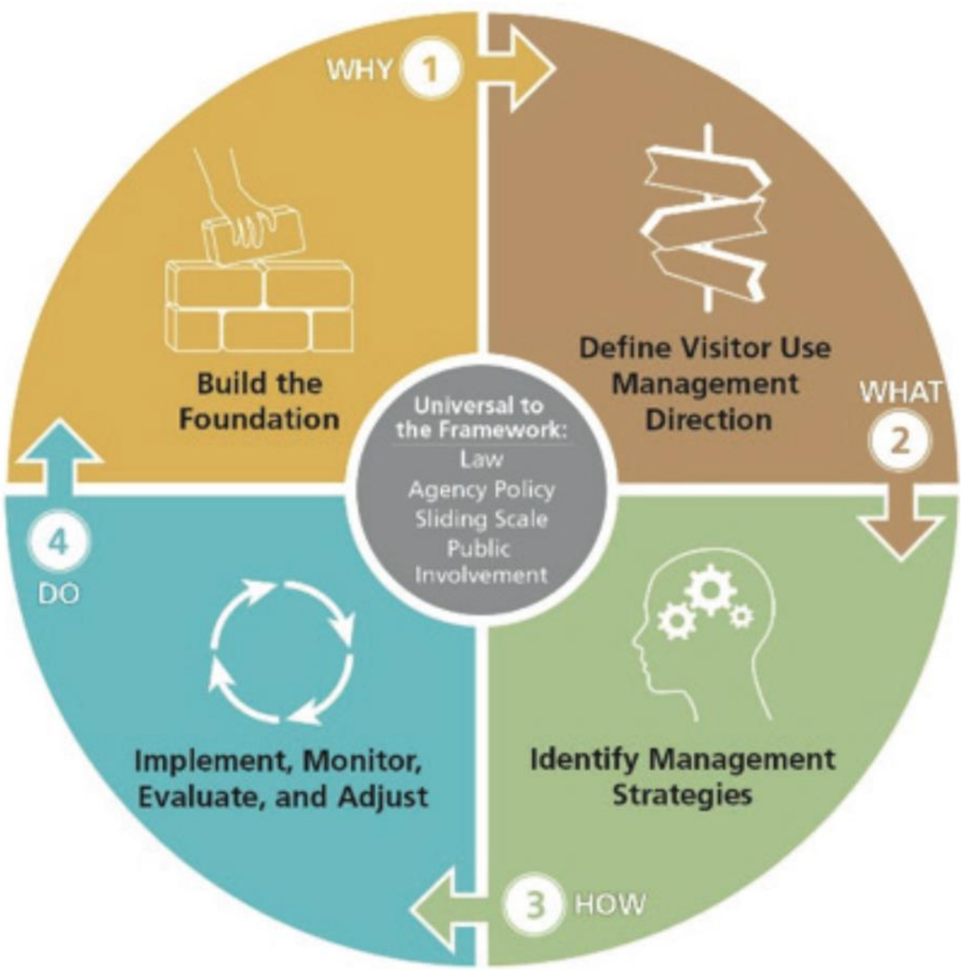

Figure 1.1 An introductory diagram detailing the four major steps of the Interagency Visitor Use Management Framework.

The framework is divided into four major elements: (1) Build the foundation, (2) Define visitor use management direction, (3) Identify management strategies, and (4) Implement, monitor, evaluate, and adjust. In step one, the project need is clarified, and the area of interest is defined before assessing current conditions and developing a plan of action. Step two identifies desired conditions, appropriate visitor activities, facilities, and services, then selects indicators and establishes thresholds. Step three compares the existing conditions to the desired conditions, then identifies management efforts and a monitoring strategy to help achieve the desired conditions. Lastly, step four implements the decided management actions, then conducts ongoing monitoring to evaluate the effectiveness of the management actions and adjust the strategy should the need arise (Interagency Visitor Use Management Council, 2016). At the core of the IVUMF is the need to measure indicators and thresholds to both provide sound rationale on which to base new management decisions as well as measure the efficacy of enacted decisions over a long period of time. Indicators are a type of experiential attribute that can be measured to track changes in conditions, whereas thresholds are minimally acceptable conditions associated with each indicator (Manning, 2011; Marion et al., 2016). For example, when collecting indicator data to maintain an existing hiking trail system against wear, the indicator may be trail depth in inches and the threshold may not exceed three inches of added depth to the original trail level. Indicators and thresholds are defined in step two of the framework, and are utilized in every step thereafter, including long-term monitoring in step four. Thus, indicators must be simple to measure in order to provide agencies with the flexibility required for long-term monitoring to ensure management decisions remain effective. If indicator data is too resource-intensive to gather, necessitates confusing methodology to collect, or entails special training or certification of staff to measure, the long-term monitoring required by the IVUMF may not be carried out, thus reducing the overall success of the framework to make sound decisions to address threats to public lands. Striking a balance between recreational quality and ecological integrity is of the highest concern to land managers, thus, taking the correct type of management action is key to accomplishing this goal (Schwartz, Taff, Lawhon, & Vanderwoude, 2018).

Traditionally, monitoring trails and ecological conditions of protected areas relied on time-consuming methods which generally required intensive field sampling by trained park staff or contracted organizations. Field workers would directly measure ecological conditions such as trail depth and width, proliferation of visitor created trails, vegetation trampling, campsite formation, vegetation loss as a result of visitor use, and other manmade impacts such as littering (Ancin-Murguzur, Munoz, Monz, & Hausner, 2019). These indicators are important to manage not only for the conservation of natural resources and wildlife within protected areas, but also to ensure a high-quality recreational experience for visitors. While these methods for monitoring recreational impacts can be very precise, they often rely on prior knowledge of which indicators are most important to monitor, as well as highly skilled individuals to carry out data collection efforts and the following analysis (Ancin-Murguzur, Munoz, Monz., Fauchald, & Hausner, 2018). Traditional fieldwork monitoring efforts would often fall to the wayside due to the significant commitment of time required to conduct field sampling, especially if park staff were responsible for data collection. Recreational impact monitoring may not take precedence over the day-to-day responsibilities of park managers and staff, as more pressing challenges occurring within the protected area may cause this step of the IVUMF to seem unimportant in the grand scheme. Economic and logistical constraints of traditional fieldwork may result in temporally and spatially sparse data, leading to ineffective management of protected areas and hindering ecological conservation efforts ((Ancin-Murguzur et al. 2019; Manning 2011; Stynes 1994).

Although these methods, if conducted properly, may lead to conditional data conducive to effective management of recreational impact, the need for a simplified and reliable method to monitor a variety of environmental indicators over the long-term is clear.

Drones offer a straightforward and low-cost option to rapidly and systematically observe natural phenomena at high spatio-temporal resolution. Because of this, drones have recently become a major trend in wildlife research and management and have been hailed as ushering in a new era of remote sensing (Horcher & Visser, 2019). This is largely due to the flexibility of drones to carry a wide variety of sensors and devices, such as compact thermal vision cameras, hyperspectral sensors, and laser scanning such as LiDAR. Even sensors to measure physical variables, such as humidity and temperature, can be installed onto medium-size drones and larger with relative ease. These devices can be attached to consumer grade drones and provide professional mapping solutions at a fraction of the cost of traditional photogrammetric techniques, such as high-speed photography or remote sensing. Many protected areas are already employing drones for a wide variety of uses such as search and rescue, documentation of illegal logging and mining, wetland management, anti-poaching, invasive species monitoring, marine litter detection, and research purposes (López & Mulero-Pázmány, 2019). Drones can even be utilized by non-specialists, as many consumer models are made to be simple to operate, leading to a momentous increase in the acquisition of both qualitative and quantitative environmental and spatial data in recent years (Sabella, Viglianisi, Rontond, & Brogna, 2017).

Following the IVUMF, indicator data must be repeatedly collected to ensure management actions are continuing to effectively work to solve problems well after management strategies are implemented. For protected areas with limited staff, limited monetary resources, or with a majority volunteer workforce, collecting indicator data to provide conditional updates to managers often falls to the wayside (Manning 2011; Stynes, 1994). As a result, actions taken to protect resources and provide high-quality visitor experiences may not be as effective as if a constant monitoring effort were in place to give feedback. Drones may have a future in recreational impact research, specifically to collect this required indicator data for long-term monitoring. As public land managers seek increasingly more simple and cost-effective methods to collect indicator and threshold data to address environmental and visitor experience concerns, drones may be the logical next step (Ancin-Murguzur et al., 2019). Drones can be utilized by management and researchers in parks to quantify vegetation loss over a large square area, provide a time-driven model of erosion rates, offer an aerial view of visitor-created trails, display accurate pictorial visitor counts that maintain anonymity, and many more. As drones are enormously flexible in the type of measuring tools they are capable of equipping, the type of data collected is only limited to the availability of various sensors and cameras. Equipment included in the methodology for other types of study, such as wildlife counts, could be repurposed for use in recreational impact monitoring. For example, the compact thermal vision cameras commonly used in drone-driven breeding bird surveys may be repurposed to quantify visitor dispersion and use rates in a protected area. LiDAR, commonly used to characterize vertical forest structure or shrubs, could also be used to quantify vegetation trampling along a recreational trail system. Much of the required methodology for recreational impact monitoring already exists in other areas of research that have previously adopted the use of drones and would only need to be slightly altered to fit the monitoring strategies employed by public land managers.

Potential Limitations

Data Collection and Data Analysis

Despite the advantages drone use provides, it also presents several limitations. Although the cost of drones and related surveying equipment continues to decrease, the up-front investment required to purchase a consumer model drone may pose a challenge for some land management agencies. Partnerships with other organizations, such as universities and extension programs, may alleviate some or all the initial costs related to purchasing drone systems through the utilization of grants or borrowing equipment from partnering organizations. These partnerships may also remedy concerns of complex training required to fly a drone for data collection or data analysis methods, which may utilize various software or methods to sort and evaluate the collected data and use the results to assess conditional changes. While minimal training was required to fly the Typhoon H utilized in this study, models of drone above consumer-level may increase in complexity, requiring special training or licensing to operate. If a complex model is required, partnerships with organizations who have staff already proficient in the required operation procedures would mitigate the need for additional agency staff training or resource input. Necessary licensing also varies by geographic location, as some countries may require licenses to fly even consumer-level drones while others may require no licensing at all for recreational or research applications. In the United States, the Federal Aviation Administration requires a small UAS pilot’s license to operate drones weighing less than 55 pounds for research purposes. However, newly introduced legislation to the U.S. congress in 2019 proposes the elimination of licensing requirements to operate a small UAS for research uses, potentially simplifying the process and making this methodology more accessible to protected area managers in the future. The intricacy of the drone and associated equipment will depend on the monitoring needs of each specific public land management agency or protected area. The methodology described in this study is designed to be widely accessible in a variety of public land settings, thus, the challenges encountered while operating the Typhoon H in Little Jerusalem Badlands State Park may not reflect the challenges faced in monitoring efforts conducted in other protected areas.

The limits of the equipment, including the drone and add-on sensors, are based on the landscape composition and type of monitoring conducted. For example, the use of a drone for quantifying visitor-created trails as described in this study may not be applicable in areas with dense tree cover or drastic elevation changes, such as mountainous areas. The same holds true for measuring indicators and thresholds associated with vegetation loss. Ecosystems in northern latitudes which experience drastic seasonal vegetation changes may yield false significant results simply based on the succession of seasonal ground cover from cooler temperature months to warmer. To alleviate this, monitoring may take place yearly rather than seasonally, with photopoints only being assessed during the same time each year to determine accurate vegetational loss associated with recreational use rather than seasonal change. Depending on the model of drone, high winds or heavy rain may also prevent flight from taking place entirely. The Typhoon H may only fly in winds below 40 miles per hour and cannot be exposed to extreme moisture. Fog may also adversely affect the quality of captured images. Disruptions to data collection may be limited by selecting data collection frequencies which avoid times of the year known for poor weather and scheduling data collection flights to coincide with clear local weather forecasts.

Legal and Social

Legal limitations may be a point of concern as this method involves the collection of photographic data within protected areas experiencing various rates of public visitation. Legal limitations must be addressed prior to the start of data collection. Independent state or regional laws often govern drone use relating to any purpose, whether that purpose is recreational, commercial, or research. The participating agency conducting data collection flights must be aware of any local laws which regulate the type of drones permitted to fly, restricted air space, distance from urban centers, or photography privacy regulations. Additional restrictions may apply to land managed by federal or state agencies. Many protected areas, such as National and State Parks, prohibit the use of drones for recreational purposes and set a strict permitting process for research applications. Research permits may be required for data collection within these areas, which may pose a challenge for agencies or organizations unfamiliar with the permitting process. Research permits occasionally must be renewed yearly rather than upon conclusion of the project, presenting additional hurdles for long-term monitoring efforts as outlined by the IVUMF.

The social implications of utilizing drones for protected area monitoring may pose the largest challenge to implementing scientifically robust methodology. Depending on the type of indicator and threshold data being collected, drone use may pose a privacy risk to visitors and employees within protected areas. Drones often instill a fear of confidentiality violations in individuals who spot an aircraft overhead. This fear may incite visitors to question the decisions of protected area managers to allow flight in a public land, even if the drone in question is not equipped with cameras. Conversely, individuals may question why a drone is flying in an area where visitors are not permitted fly their own aircraft for recreational purposes. Special care should be taken to interpret the purpose of the drone to concerned visitors and staff, as well as ensure no unlawful personal information is collected. Visitors and staff should be educated on the value of the data collected to aid in making managerial decisions that reduce recreational impact to the site. If the drone is equipped with a camera, flight missions should be planned to coincide with periods of low visitation and at an altitude where individual features cannot be distinguished. FAA guidelines in the United States mandate that it is unlawful to operate small UAS directly above any individual. Extra caution must be taken when indicator and threshold data is based on visitation rates or visitor dispersion, as this type of data often includes visitors within each photograph. However, as there is no assumption of privacy within many types of protected area, the managing agency ultimately has the final say as to the level of personal data collected during monitoring efforts.

Chapter 2 - Manuscript

Introduction

A worldwide spike in visitation to protected natural lands, such as wilderness areas, parks, and wildlife refuges, has prompted concerns that a surge in visitation is degrading the plants, soils, water, and wildlife these areas were established to protect (Marion, Leung, Eagleston, & Burroughs, 2016). Managers of protected areas rely on cost-effective and innovative solutions to address threats to biodiversity and the visitor experience. Historically, land managers have chosen to address resource impacts utilizing a model of "carrying capacity," determining a maximum level of allowable use and setting direct management actions to keep visitor use at or below this determined threshold (McCool & Cole, 1998; Manning, 2011). However, decades of research have revealed that the solution to resource impact issues is exceedingly complex, linking the disciplines of recreation ecology, social science, environmental biology, and management to provide a thorough research-based solution. A multipart framework, developed in 2016, drew inspiration from the concept of carrying capacity and past frameworks such as Limits of Acceptable Change and Visitor Experience and Resource Protection (Marion et al., 2016) to provide a systematic basis to address managerial decision-making needs in public lands: The Interagency Visitor Use Management Framework (IVUMF)(citation). This framework relies on a diverse array of management strategies and actions, often termed a "management toolbox," for resolving visitor impact problems (Figure 2.1). This "toolbox" includes strategies such as restoration ecology, professional development of visitor management staff, modifying visitor behavior, increasing resource resilience, and many others (Interagency Visitor Use Management Council, 2016). The IVUMF provides additional guidance to professionalize the process for the continued preservation of natural conditions and processes in our protected natural areas and the sustained administration of high-quality recreational experiences. It is intended to provide a process that is legally defensible, transparent, meets all law and policy requirements regarding public land management, and ensures agency accountability in managerial decisions and actions (Marion et al., 2016). It is currently applied by the Bureau of Land Management, the National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, National Oceanic and Atmospheric Administration, and U.S. Army Corps of Engineers to assist in managerial decisions for the administration of public lands retained by each agency (Interagency Visitor Use Management Council, 2016).

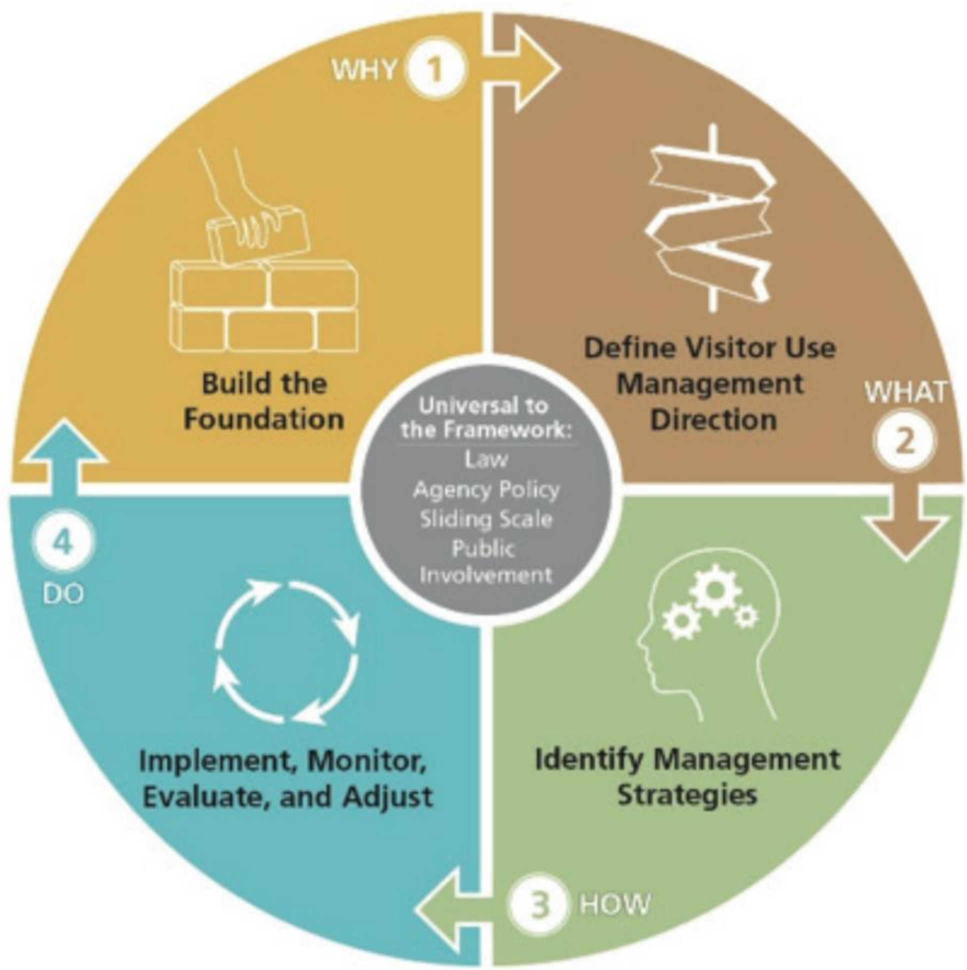

Figure 2.1. An introductory diagram detailing the four major steps of the Interagency Visitor Use Management Framework.

The framework is divided into four major elements: (1) Build the foundation, (2) Define visitor use management direction, (3) Identify management strategies, and (4) Implement, monitor, evaluate, and adjust. In step one, the project need is clarified, and the area of interest is defined before assessing current conditions and developing a plan of action. Step two identifies desired conditions, appropriate visitor activities, facilities, and services, then selects indicators and establishes thresholds. Step three compares the existing conditions to the desired conditions, then identifies management efforts and a monitoring strategy to help achieve the desired conditions. Lastly, step four implements the decided management actions, then conducts ongoing monitoring to evaluate the effectiveness of the management actions and adjust the strategy should the need arise (Interagency Visitor Use Management Council, 2016). At the core of the IVUMF is the need to measure indicators and thresholds to both provide sound rationale on which to base new management decisions as well as measure the efficacy of enacted decisions over a long period of time. Indicators are a type of experiential attribute that can be measured to track changes in conditions, whereas thresholds are minimally acceptable conditions associated with each indicator (Manning, 2011; Marion et al., 2016). For example, when collecting indicator data to maintain an existing hiking trail system against wear, the indicator may be trail depth in inches and the threshold may not exceed three inches of added depth to the original trail level. Indicators and thresholds are defined in step two of the framework, and are utilized in every step thereafter, including long-term monitoring in step four. Thus, indicators must be simple to measure in order to provide agencies with the flexibility required for long-term monitoring to ensure management decisions remain effective. If indicator data is too resource-intensive to gather, necessitates confusing methodology to collect, or entails special training or certification of staff to measure, the long-term monitoring required by the IVUMF may not be carried out, thus reducing the overall success of the framework to make sound decisions to address threats to public lands. Striking a balance between recreational quality and ecological integrity is of the highest concern to land managers, thus, taking the correct type of management action is key to accomplishing this goal (Schwartz, Taff, Lawhon, & Vanderwoude, 2018).

Traditionally, monitoring trails and ecological conditions of protected areas relied on time-consuming methods which generally required intensive field sampling by trained park staff or contracted organizations. Field workers would directly measure ecological conditions such as trail depth and width, proliferation of visitor created trails, vegetation trampling, campsite formation, vegetation loss as a result of visitor use, and other manmade impacts such as littering (Ancin-Murguzur, Munoz, Monz, & Hausner, 2019). These indicators are important to manage not only for the conservation of natural resources and wildlife within protected areas, but also to ensure a high-quality recreational experience for visitors. While these methods for monitoring recreational impacts can be very precise, they often rely on prior knowledge of which indicators are most important to monitor, as well as highly skilled individuals to carry out data collection efforts and the following analysis (Ancin-Murguzur, Munoz, Monz., Fauchald, & Hausner, 2018). Traditional fieldwork monitoring efforts would often fall to the wayside due to the significant commitment of time required to conduct field sampling, especially if park staff were responsible for data collection. Recreational impact monitoring may not take precedence over the day-to-day responsibilities of park managers and staff, as more pressing challenges occurring within the protected area may cause this step of the IVUMF to seem unimportant in the grand scheme. Economic and logistical constraints of traditional fieldwork may result in temporally and spatially sparse data, leading to ineffective management of protected areas and hindering ecological conservation efforts (Ancin-Murguzur et al., 2019; Manning, 2011; Stynes, 1994). Although these methods, if conducted properly, may lead to conditional data conducive to effective management of recreational impacts, the need for a simplified and reliable method to monitor a variety of environmental indicators over the long-term is clear.

Drones offer a relatively simple and low-cost option to rapidly and systematically observe natural phenomena at high spatio-temporal resolution. Because of this, drones have recently become a major trend in wildlife research and management and have been hailed as ushering in a new era of remote sensing (Horcher & Visser, 2019). This is largely due to the flexibility of drones to carry a wide variety of sensors and devices, such as compact thermal vision cameras, hyperspectral sensors, and laser scanning such as LiDAR. Even sensors to measure physical variables, such as humidity and temperature, can be installed onto medium-size drones and larger with relative ease. These devices can be attached to consumer grade drones and provide professional mapping solutions at a fraction of the cost of traditional photogrammetric techniques, such as high-speed photography or remote sensing. Many protected areas are already employing drones for a wide variety of uses such as search and rescue, documentation of illegal logging and mining, wetland management, anti-poaching, invasive species monitoring, marine litter detection, and research purposes (López & Mulero-Pázmány, 2019). Drones can even be utilized by non-specialists, as many consumer models are made to be simple to operate, leading to a momentous increase in the acquisition of both qualitative and quantitative environmental and spatial data in recent years (Sabella, Viglianisi, Rontond, & Brogna, 2017).

Following the IVUMF, indicator data must be repeatedly collected to ensure management actions are continuing to effectively work to solve problems well after management strategies are implemented. For protected areas with limited staff, limited monetary resources, or with a majority volunteer workforce, collecting indicator data to provide conditional updates to managers often falls to the wayside (Manning 2011; Stynes, 1994). As a result, actions taken to protect resources and provide high-quality visitor experiences may not be as effective as if a constant monitoring effort were in place to give feedback. Drones may have a future in recreational impact research, specifically to collect this required indicator data for long-term monitoring. As public land managers seek increasingly more simple and cost-effective methods to collect indicator and threshold data to address environmental and visitor experience concerns, drones may be the logical next step (Ancin-Murguzur et al., 2019). Drones can be utilized by management and researchers in parks to quantify vegetation loss over a large square area, provide a time-driven model of erosion rates, offer an aerial view of visitor-created trails, display accurate pictorial visitor counts that maintain anonymity, and many more. As drones are enormously flexible in the type of measuring tools they are capable of equipping, the type of data collected is only limited to the availability of various sensors and cameras. Equipment included in the methodology for other types of study, such as wildlife counts, could be repurposed for use in recreational impact monitoring. For example, the compact thermal vision cameras commonly used in drone-driven breeding bird surveys may be repurposed to quantify visitor dispersion and use rates in a protected area. LiDAR, commonly used to characterize vertical forest structure or shrubs, could also be used to quantify vegetation trampling along a recreational trail system. Much of the required methodology for recreational impact monitoring already exists in other areas of research that have previously adopted the use of drones and would only need to be slightly altered to fit the monitoring strategies employed by public land managers.

Drones could significantly reduce the workload related to the long-term collection of indicator and threshold data, as well as extend both the spatial and temporal range of data collection. Flights conducted at relevant time intervals increase monitoring opportunities and support a robust data collection method to back managerial decisions. Although, on the surface, the use of drones for recreational monitoring may seem complicated, drones will bolster the efficacy of the IVUMF for indicator and threshold monitoring, thus granting land managers valuable data at a fraction of the cost of traditional photogrammetric techniques and with minimal pilot training required. As drone technology advances each year, the cost of such equipment is expected to continue to decrease, while add-on technology such as LiDAR becomes readily available for a wider range of configurations and uses.

This study aims to assess the feasibility of adopting a consumer-level drone for collection of indicator data for the monitoring of recreational impacts in line with the Interagency Visitor Use Management Framework. Designed as a "proof of concept," this study analyzes the outcome of using a drone to detect visitor-created trails and vegetation loss in a recently designated Kansas state park to aid land management agencies in decision-making to reduce recreational impacts. The use of drones for recreational impact monitoring presented in this study is one of the first applications for this purpose in the United States (Ancin-Murguzer et al., 2019), may be the first-time drones have been utilized with this intent within a state park, and is likely the first time this methodology has been employed in a newly established park to collect thorough baseline data prior to park opening. This method is designed for use in parks and protected areas across the world to provide a long-term recreational impact monitoring protocol in line with the IVUMF which does not burden protected area managers nor their staff and provides key conditional data to aid in managerial decision making.

Literature Review

In past recreation impact research, managers have relied on guesswork, personal experience, or intuition alone to make management decisions (Hammit, Cole, & Monz, 1998). However, an effective monitoring program must be developed with specific objectives in mind and a rigid, scientifically-sound data collection must be utilized to provide accurate indicator and threshold data for the support of managerial decisions (Manning, 2011). Photopoints, or photographs repeatedly captured from the same location, have long been utilized to measure recreation impact, sometimes to only enhance systematic field data, and other times to convey site conditions not quantifiable with field measurements (Hammit et al., 1998). In the case of comprehensive areas, landscape-level assessment is often highly relevant for managing the impact of land-use change and other drivers on the landscape (Ancin-Murguzur et al., 2019). This type of assessment allows for an in-depth analysis of an ecosystem of interest, including identification of locations of high ecological value, co-occurrence of multiple ecosystem services, and spatial tradeoffs and synergies. Landscape-level assessment generally utilizes digital photo analyses for measurements such as plant cover or high-resolution remote sensing of vegetation cover, as digital photography is cost-effective and maximizes the area of field sampling within a short period of time. The photographs are then analyzed using software such as Sample Point or VegMeasure to detect rare plant species, indications of wildlife, evidence of recreational use, or other disturbances (Ancin-Murguzur et al., 2019; Sivanpillai & Booth 2008). Although typically conducted with a wide-angle lens digital camera mounted on a tripod, this method can be converted to incorporate aerial drone photography to increase the spatial area of field sampling and thus be more efficient for monitoring recreation impact in large swaths of protected areas. When utilized to systematically provide data according to the indicator monitoring protocol recommended in the IVUMF, landscape-level assessment with drone photography could greatly increase the amount of data collected and efficiency of data collection to better manage protected areas for long-term recreational use.

The last decade has seen a “boom” of drone use for conservation purposes, with applications being divided into two categories: Research applications and direct conservation applications (Sandbrook, 2015). Under the research category, drones have been utilized to provide data useful for conservation efforts, such as wildlife counts or monitoring of biological features important for ecosystem function (Marris, 2013). Drones have been endorsed for ecological research because of the flexibility of sensors and equipment available, their affordability, ease of use, and safety (Horcher & Visser, 2004). Examples include forest biodiversity measurements, bird counts, and algal bloom monitoring. For direct conservation purposes, drones have typically been used for law enforcement and monitoring illegal activities (Ornes, 2014), although future use may include beneficial ecosystem services such as aerial seed dispersal (López & Mulero-Pázmány 2019). Despite their flexibility and potentially wide use of applications, drone use in the conservation sector has been largely experimental and dominated by research applications. However, conservation organizations and public land management agencies, such as the World Wildlife Fund (WWF), have been increasingly pursuing scientific developments which will allow drone technology to be adapted for direct conservation action. In 2012, WWF received a Google Global Impact Awards Grant for $5 million dollars to develop a remote aerial survey system to increase the detection and deterrence of poaching in Asia and Africa (WWF, 2014). As technological advances continue and conservation organizations begin to actively consider how to incorporate drone use to help carry out their missions, it is extremely likely the use of drones in conservation will rapidly increase over the next decade for both research and direct conservation purposes.

Although drones have been a popular topic in a broad range of recent scientific publications, drone use for recreational impact monitoring has been severely understudied compared to other fields. López & Mulero-Pázmány (2019) conducted a literature review to address a gap in knowledge regarding benefits that drones could bring to fostering effectiveness in conservation work and assisting with managerial decisions. A comprehensive literature search on drones in conservation up to October 2nd, 2018 was conducted mainly utilizing Google Scholar, providing a total of 256 studies. Of these, 99 describe applications that were accomplished in terrestrial and marine protected areas, according to the Protected Planet database. Studies were classified into five distinct areas of applications: "wildlife monitoring and management"; "ecosystem monitoring"; "law enforcement"; "ecotourism"; and "environmental management and disaster response." Of these categories, wildlife monitoring and management, ecosystem monitoring, and environmental management and emergency response were among the best represented in prior publications. Ecotourism and law enforcement remain unexplored, with ecotourism being the subject of only two of the 256 published studies (Figure 2.2). For use in ecotourism research, drones have been proposed for recreational and educational purposes, to document natural monuments and cultural sites, social research, and visitor surveillance. However, drone operations are susceptible to endanger wildlife, compromise the tourist experience, or in the case of accidents, lead to pollution or wildfires in sensitive areas due to the presence of toxic and flammable components. López & Mulero-Pázmány (2019) advised to be cautious in the face of a growing demand to incorporate drones into ecotourism services and continue working on a set of consensual measures to minimize the potential drawbacks drones may bring to protected areas. Not without founded reasons, an overly restrictive and indiscriminate regulatory framework arguing privacy and safety issues is currently limiting the applications of drones in the field of conservation (Leary, 2017). Once the use of drones has proven feasible in many different fields of application, López & Mulero-Pázmány (2019) mentioned it would be of interest that research focuses on methods to produce a set of ecological indicators in line with established monitoring frameworks (Such as the IVUMF).

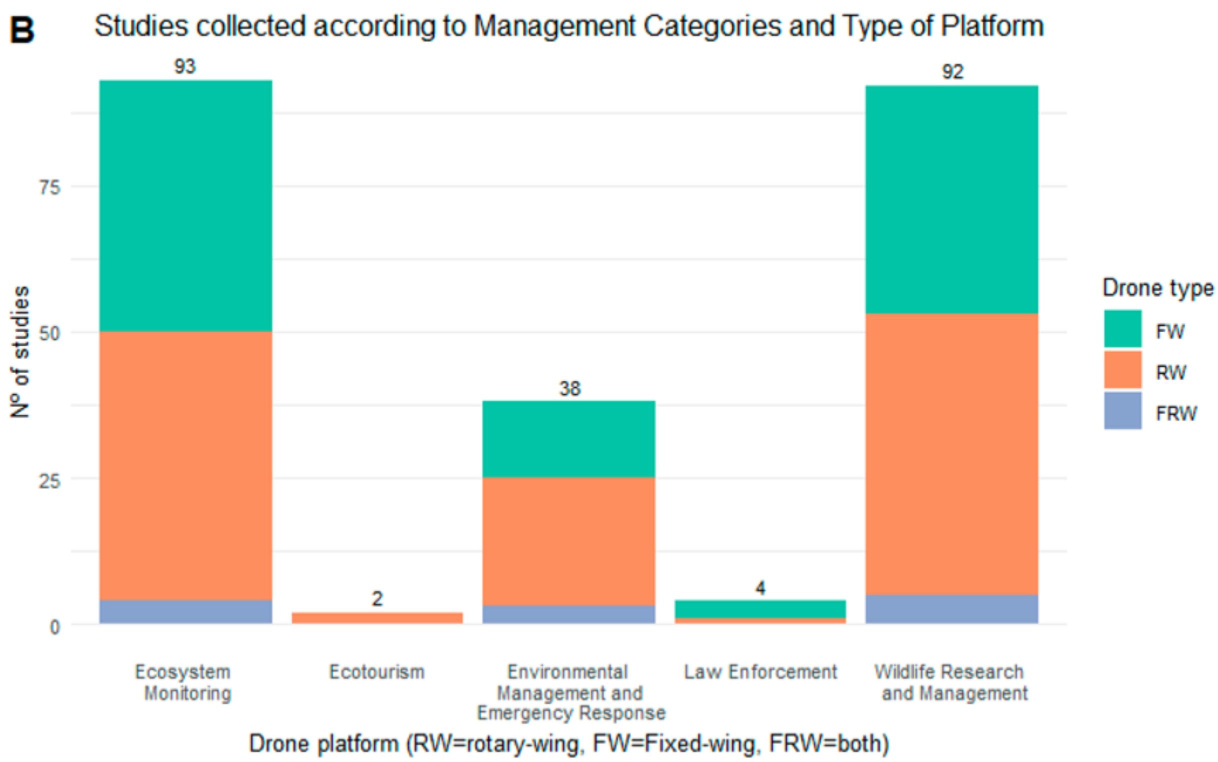

Figure 2.2 A graph representing the number of publications related to drone use in each of the five categories adapted from López & Mulero-Pázmány (2019) in their literature review of drones in conservation.

To date, the only published instance of drones being utilized as a tool to measure recreational impacts takes place in a low-visitation national park located in south-central Norway (Ancin-Murguzer Munoz, Monz, & Hausner, 2019). A consumer-level drone was utilized to collect baseline data in an area of Jotunheimen National Park where new tourist facilities will be established. Visitor-use patterns and common visitor impacts, such as trail condition, vegetation structure, visitor-created trail proliferation, trampling, and other trail impacts were measured utilizing drone photography. The results collected from each drone photopoint were then compared to data collected by means of traditional methods of measuring these impacts, in this case, on the ground field sampling. Data collection took place in August 2017 and August 2018. The drone measurements were carried out in the same frequency and location as the traditional measurements to compare the variability between both methods. Photopoints were selected based on 17 trail sampling transects where trail width and elevation were measured to the closest millimeter, then captured within the drone images. The resulting images were processed to produce an orthophoto, an aerial photograph created by assembling multiple photographs into a map-like image with a consistent scale. OpenDroneMap, an open-source photogrammetric website, processed the resulting 711 images into a continuous orthophoto. The updated orthophoto was then converted to a digital surface model (DSM) in ArcGIS. Divergence between the traditional trail measurements (width and depth) and DSM at each of the 17 sampling locations was determined utilizing a t-test, whereas vegetation loss, addition of manmade structures, and wildlife cues were determined only with a visual inspection of both orthophotos. Divergence between trail width measurements was negligible, whereas divergence between depth measurements was consistently 1.05cm. Drone measurements had a low error rate compared to traditional measurements, thus, Ancin-Murguzer et al. (2019) determined that drones are a more flexible tool for monitoring human impacts and vegetation changes than traditional methods. However, the method utilized in this study requires ample knowledge of flight path programming, image processing, ArcGIS map creation, and statistics, reducing its effectiveness as a long-term monitoring tool for park management. It is unlikely that park staff would have prior knowledge of the techniques utilized to collect the data utilizing precise transects, process the images into a usable orthomap and DSM, and conduct the required statistical analysis. On top of this, vegetation loss was not actually quantified, but instead based on visual inspection only. In protected areas where vegetation change may be negligible due to low visitation, visual inspections may not be enough to make informed managerial decisions. Coupling drone use with the indicator and threshold monitoring requirements presented in the IVUMF may yield a more facile sampling method which can be conducted by staff with minimal training.

Materials and Methods

Research Site

Little Jerusalem Badlands State Park in Logan County, Kansas is a recently established state park co-managed by The Nature Conservancy and the Kansas Department of Wildlife, Parks, and Tourism (Figure II). This 330-acre stretch of land was deeded to The Nature Conservancy (TNC) by the preceding landowner who stipulated that the land must be opened to the public for as long as it is owned by TNC. This area is ecologically unique, home to the largest Niobrara Chalk formation in Kansas with a fossil record dating back 85-million years. The ecosystem adjacent to the Niobrara formations is a native shortgrass prairie of great natural and landscape value. As 80% of Kansas' shortgrass prairie has been converted to other uses, mainly agricultural, the preservation and proper management of Little Jerusalem is of the utmost importance to conservation. The 100-foot towering chalk spires attract many specialized flora and fauna species not found anywhere else in the region including Black-footed ferret (*Mustela* *nigripes*), Ferruginous hawks (*Buteo regalis*), Cliff swallows (*Petrochelidon pyrrhonota*), Great Plains wild buckwheat (*Polygonum convolvulus*), and many more.

Figure 2.3 The Niobrara Chalk formations of Little Jerusalem Badlands State Park.

The property also maintains a high level of historical value. Native American use dates back thousands of years, as one of the newly established park trail systems passes a buffalo jump utilized by native tribes (Hill Jr., 1996). Settlers traveling west during the period of westward expansion would often stop on the property to gather the standing water that collects in the eroded canyons, many of whom left personalized carvings in the walls of the chalk spires. For the past several generations, the property had been in the possession of the same family of cattle ranchers who had interchanged Little Jerusalem into their seasonal grazing rotation. Not only does the site serve important ecological and historical functions, but Little Jerusalem is also a key resource for outdoor recreation. Kansas is comprised of 98% privately owned land; thus, it is important to maintain this public resource for the enjoyment of the American people. Collectively, the ecosystem value, presence of specialized wildlife species, natural resource importance, and historical significance make proper management of Little Jerusalem Badlands a momentous concern. Proper management will ensure minimal negative impact to these individual resources and to the site overall.

The management plan of Little Jerusalem Badlands State Park is approved and upheld by both The Nature Conservancy and the Kansas Department of Wildlife, Parks, and Tourism. Only indirect management is utilized to limit negative impacts to the ecosystem, such as chalk erosion and vegetation loss, and focuses on keeping visitors on three specific trails around the rim rather than allowing access into the canyons through the use of interpretive signage. However, vehicle entrance to the site is controlled by an automatic gate system which allows visitation at any time from dusk until dawn every day of the year. Local law enforcement patrols the site only periodically and no full-time personnel have been hired, leaving a lot of room for recreational impact to ensue as a result of uncontrolled use. Basic infrastructure necessary to qualify Little Jerusalem as a state park, such as restrooms, a parking lot, educational signage, an ADA-accessible hiking trail, and a rim trail system were constructed between 2018 and 2020. Both cooperating agencies have expressed the desire to keep the area "as natural as possible," with very little unnecessary recreational infrastructure to be installed even in future years. The area will continue to be utilized for grazing into the foreseeable future at the request of the previous landowner. Much concern was focused on the environmental impact allowing visitors into the park would have on the landscape and resident flora and fauna. Little Jerusalem Badlands had seen its fair share of visitation, mostly by the local community, and was not in pristine condition at the time of acquisition. Prior visitation and current trespassing, coupled with historic and future grazing on site, are both important factors to be accounted for when analyzing indicator data. The park opened to the public in October 2019.

Study Design

The primary study objectives were to document baseline ecological conditions prior to park opening and develop an effective monitoring protocol to continue after visitation began while obtaining "proof of concept" that drones may be a viable tool to conduct long-term monitoring. Methodology for continuous indicator monitoring following the standards of the IVUMF was designed to continue indefinitely following the conclusion of this study, relying on a simple yet effective data collection method which could be conducted by park staff without additional training. The primary concerns of the two land management agencies were the proliferation of visitor-created trails and vegetation loss as a result of visitor use. Both visitor created trails and vegetation loss are crucial management concerns, as they often contribute significantly greater impacts to protected area resources than the use of formal trails (Hockett, Marion, & Leung, 2017). This is especially true at Little Jerusalem, as the Niobrara chalk formations erode at a higher rate than most other substrates, leading to increased levels of impact as a result of vegetation loss and informal trails. The unique capacity to collect data prior to park opening allowed for the observation of impacts in real-time and enabled us to not only determine the severity of damage to the resource, but also the rate of occurrence. We sought to provide park managers with a precise approach in line with the robust IVUMF that would allow for data-driven management to reduce ecological impacts caused by the two selected indicators. Drone data collection began in January 2019 seeking to collect recurrent photographs of six “key” monitoring locations on a monthly basis.

Drone Photography

The drone used for this study was the Yuneec Typhoon H, a hexacopter-style model capable of up to 25 minutes of flight and up to a mile of flying distance between the drone and its pilot (Figure 2.4). The factory-installed camera captures 12 megapixel still images and 4k video with a 360-degree range of motion. No additional drone add-ons nor upgrades to the airframe were necessary for data collection, although compact thermal cameras and LiDAR may be promising tools for future monitoring efforts. Registration of the aircraft with the Federal Aviation Administration (FAA) as well as an FAA Part 107 small UAV license were required to operate the aircraft. Although the required Part 107 license is currently a barrier to ease of practical implementation, the Drone Integration and Zoning Act of 2019, introduced to the senate in October 2019, would remove the federal licensing requirement for research purposes and grant individual states a greater level of control over zoning authority in respect to unmanned aircraft systems (United States Congress, 2019). Permission to fly was obtained from the Kansas Department of Wildlife, Parks, and Tourism, as Little Jerusalem Badlands is now officially classified as state land. Kansas State University also has its own Unmanned Aircraft Systems Policy which requires all drone flights operated on Kansas State property or for any university-sponsored event (such as research) to receive approval from the university, thus, this methodology is also authorized by Kansas State University.

Figure 2.4 A Yuneec Typhoon H hexacopter drone, the same model utilized in this study.

This model of drone has many autonomous flight capabilities, including flying to specific GPS points and elevations, an “orbit mode” for getting a better look at large landmarks, and a follow mode where the aircraft autonomously follows behind the pilot. These options are what made this model so desirable for recreational impact research. The pilot can program a flight path while operating the aircraft, and the drone will save the GPS coordinates and elevation and fly the same path whenever necessary.

Based on recommendations from the responsible land-management agencies, six key monitoring locations were selected across the site. These locations possessed notably fragile elements that managers were concerned about, or they were areas that were expected to be heavily populated that may tempt visitors to travel off the official trail system. Locations of critical importance included three overlooks at the end of each of the trails (Life on the Rocks Trail overlook, Rim Trail overlook, and Oil Pad overlook), a bridge structure gapping a canyon along the Rim Trail, that may entice visitors to climb down, a ramada structure where all three trails began and ended, and a large chalk slab inscribed with names and dates back to the 1840s deemed the “inscription wall” (Figure 2.5). The inscription wall was the only monitoring location located a far distance away from the trail system but concerns of vandalism in this area were especially high due to the historical value of this setting. Two sets of photographs were taken of each site: A “profile photo” at a fixed elevation and GPS point at each location for site identification purposes, and an overhead photo of each location to examine vegetation loss and visitor-created trails both utilizing the GPS-controlled autonomous flight system (Figure 2.6).

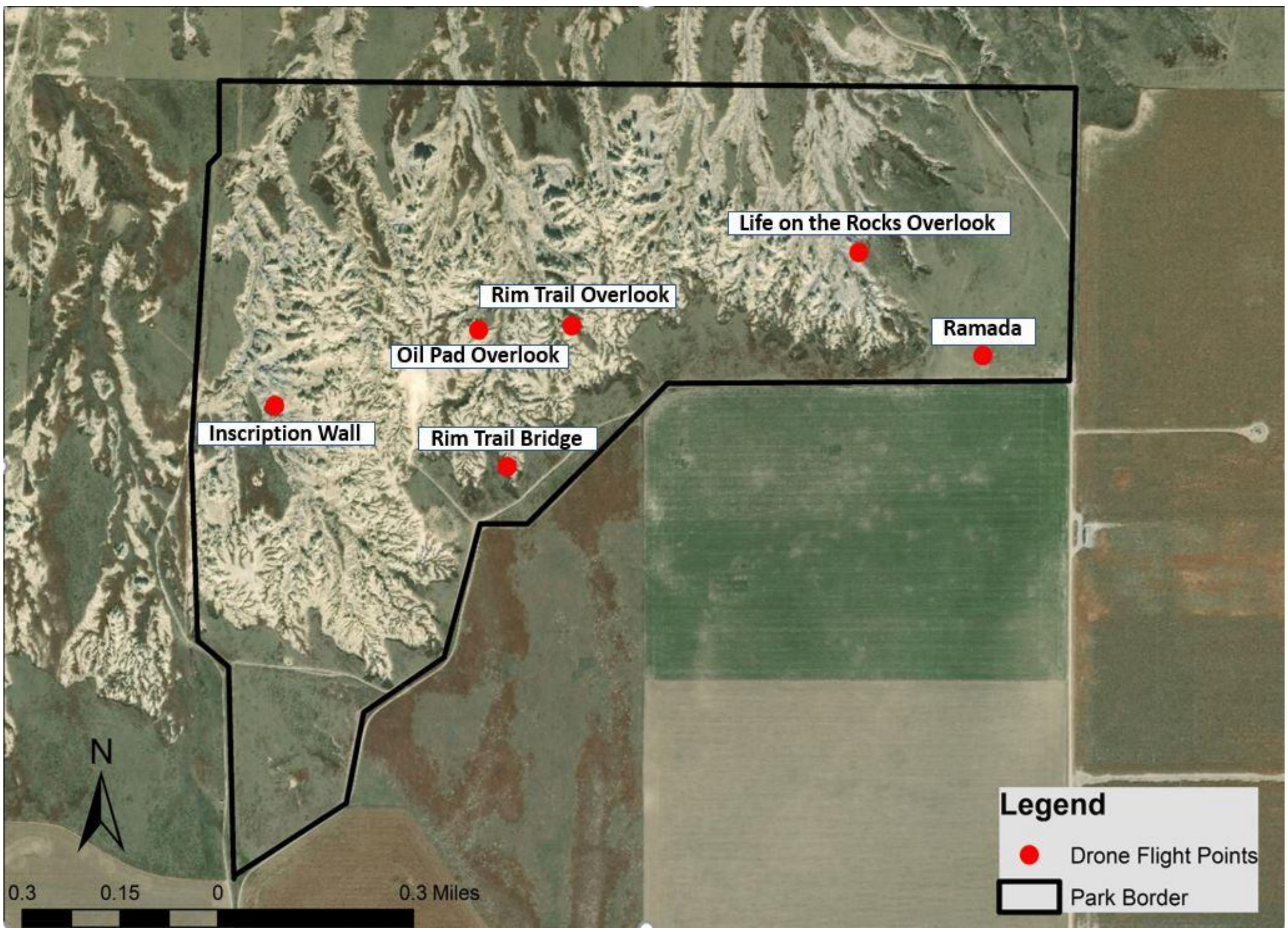

Figure 2.5 A map of Little Jerusalem Badlands State Park denoting all six “key locations” selected for long-term drone monitoring of vegetation loss and visitor created trails.

Figure 2.6 (Top) An overhead photo of the Inscription Wall. (Bottom) A "profile photo" of the inscription wall.

Data Analysis

Vegetation loss was quantified utilizing SamplePoint, a free program which facilitates vegetative cover measurements from aerial imagery by superimposing a systematic array of crosshairs which target single image pixels (Booth, Cox, Meikle, & Zuuring, 2008; Breckenridge & Dakins, 2011; Sivanpillai & Booth, 2008). These pixels are then classified by means of user-defined categories, and data is saved automatically to an Excel spreadsheet. The program presents a scientifically-sound method for quantifying vegetation loss from repeat drone photo points from month-to-month, while maintaining ease of use and simple interpretation of results.

The SamplePoint program is pre-configured with default "buttons," selection options which allow for the classification of pixels in the aerial images via user identification. The Little Jerusalem monitoring protocol utilizes five custom buttons specific to this project to classify the sample pixels: Visitor, trail, manmade, bare, and vegetation. The visitor button will be used to define pixels in which visitors are present rather than the natural topography. Similarly, the trail button is selected to define a pixel which is sampled along the official designated trail system captured in locations such as the overlooks or Rim Trail bridge. Manmade is a classification which may be used to identify a pixel contained by a manmade object such as an interpretive sign, bench, trash can, or other manmade structure. The bare and vegetation buttons are the two most important classifications, used to define a pixel contained by a patch of bare ground or a pixel which is composed of vegetation. The custom buttons are an extremely important part of measuring the vegetation loss indicator, as the default buttons prepacked with SamplePoint are not conducive to a park setting. Luckily, creating a new button file is a simple process and allows for modification of this method to better suit individual protected areas. A grid size of 10x10

(100 sample points) was selected based on vegetation quantification methods utilized in previous studies (Booth, Cox, Meikle, & Zuuring, 2008; Sivanpillai & Booth, 2008).

Visitor created trails, due to their various structures and appearances based upon the amount of light in the aerial photograph, vegetative cover, connection to the official trail system, and severity were examined via visual inspection of the overhead and profile photographs. However, it is important to note that although methodology exists to classify existing trails into qualitative trail condition classes (Marion, Leung, & Nepal, 2006), a comprehensive search of existing literature could not provide a qualitative system to identify newly formed visitor created trails. For the purposes of this study, the trail must be connected to the official trail system to be considered a visitor created trail. Visitor-created trails were identified based on several types of visual evidence such as tread width, trail sinuosity, or the presence of bare ground (Leung, Newburger, Jones, Kuhn, & Woiderski, 2011). The total number of visitor created trails in each photograph was counted monthly.

Results

Vegetation Loss

A total of 139 aerial images were captured between January 2019 and February 2020. To address the focus of this study, assessing visitor created trails and vegetation loss, analysis of the photos included all overhead photographs from January 2019, nine months before the park opened to the public, to February 2020, five months following park opening. September 2019, one month prior to park opening, was selected as the "baseline" month to provide original vegetative cover for comparative analysis of the months following park opening. The data is consistent for each month within this span besides November 2019, as the monthly drone flight could not be conducted due to insufficient weather conditions which were not conducive to FAA approved safe flight operations.

No significant vegetation loss was observed between January 2019 and September 2019, as Little Jerusalem had not yet been opened for public visitation, thus, no severe impacts were observed prior to September. The original percentage of vegetation cover was measured for each of the six sites based upon the analysis of September's overhead photographs one month prior to the introduction of permitted recreational use. This original percentage was then used as a baseline to calculate vegetation loss as a result of recreational use in the months following park opening. The baseline percentage was then designated as 100% original vegetative cover for each site, and a total percentage of loss was calculated from this value. Table 2.1 designates the total amount of vegetation lost at each of the six locations.

Vegetation loss following park opening was observed in all six selected monitoring locations, but severity differed between sites (Figure 2.7). The locations noted to have undergone the highest percentages of vegetation loss following park opening were the three trail overlooks, the Oil Pad overlook, Rim Trail overlook, and Life on the Rocks Trail overlook. The greatest loss occurred at the Oil Pad overlook, a site with 52% vegetative cover in September which decreased to only 30% vegetative cover by February, just four and a half months after park opening. This was a total loss of 42.3% of the original vegetative cover from the first month of analysis to the last (Table 2.1). The two other overlooks also suffered severe vegetation losses, with the Rim Trail overlook losing 28% of its total vegetation and the Life on the Rocks trail overlook losing 37.93%. Both the Rim Trail and Life on the Rocks overlooks feature physical barriers to deter visitors from traveling off the designated trail system and into the chalk formations. The Oil Pad overlook is the only overlook without a barrier and has seen the greatest vegetation losses around the adjacent formations as a result.

The three photopoints not located along trail overlooks, the Rim Trail Bridge, Ramada, and Inscription Wall did not undergo significant vegetation loss as a result of recreational use. The Ramada lost the greatest amount of vegetation of the three non-overlook photopoints, decreasing by 8.82% of the site's original baseline vegetative cover. However, the ramada area underwent significant construction between June and July, causing a large amount of vegetative trampling around the site of the ramada. The loss observed following June 2019 is likely a combination of trampling by construction vehicles and increased visitation to the park. The Inscription Wall lost 3.57%, while the Rim Trail bridge lost only 2.7% of the original baseline vegetation present at each site. None of these results were significantly larger than zero, reinforcing the suspicion that the moderate climate of western Kansas would not induce seasonal vegetation loss that may effect month-to-month comparision.

Regions such New England or other areas of the United States which do undergo extreme seasonal temperature fluxuations may not be suitable for a month-to-month analysis, but may require only annual measurements to reduce false significance caused by seasonal vegetation loss. The only noted seasonal changes at Little Jerusalem were the slight browning of vegetative cover during the late fall into winter as well as light snowfall into the winter months. Although vegetative color change did not effect the ability to distinguish bare ground from vegetation within SamplePoint, snow cover posed a significant challenge as areas of the image were covered. To mitigate this, months where snow cover blocked areas of vegetation within the photograph were compared to the prior month of data. As SamplePoint places the crosshairs in the exact same location within the photograph every time, trends in vegetative loss could be observed month-to-month and compared over time. However, in the future, it may be beneficial to conduct annual monitoring rather than month-to-month analysis selecting months where snowfall is a nonfactor to collect data.

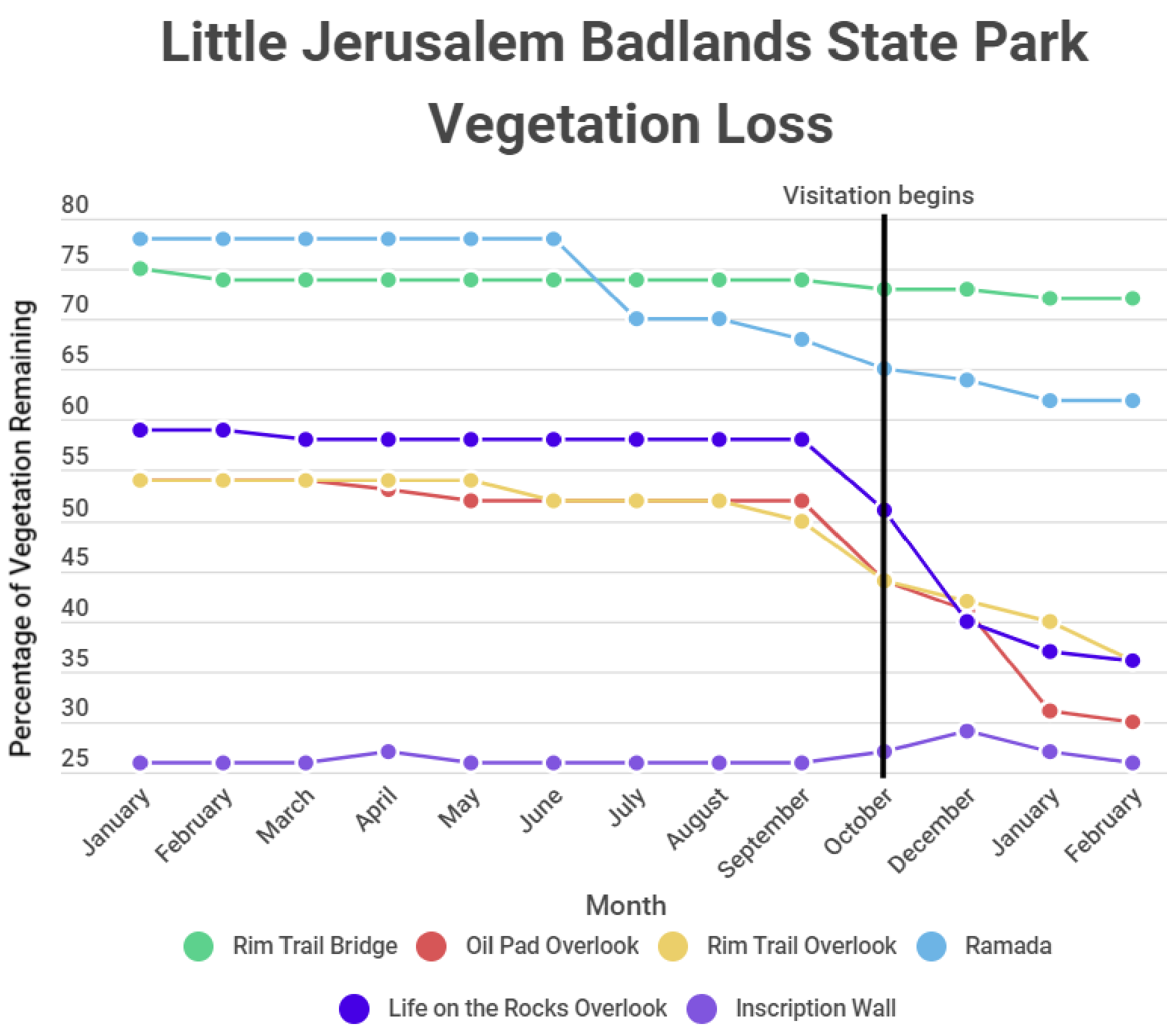

Figure 2.7 A graph detailing the total vegetation loss at each of the six drone flight locations between January 2019 and February 2020. Significant vegetation loss was observed following park opening in October 2019.

Location	Percent of Vegetation Lost Between September 2019 and February 2020
Rim Trail Bridge	2.70%
Inscription Wall	3.57%
Ramada	8.82%
Rim Trail Overlook	28%
Life on the Rocks Overlook	37.93%
Oil Pad Overlook	42.30%

Table 2.1 The percentage of vegetation lost from the original total cover observed at each flight location between September 2019 and February 2020.

Visitor Created Trails

The visual inspection of the aerial photographs allowed us to detect the formation of visitor created trails during the months following park opening. This method successfully identified not only one visitor created trail located at the Oil Pad overlook photopoint (Table 2.2) in the month of December, but also significant vegetation loss along the perimeter of the official trail system, suggesting that drone photography may also be useful in identifying trail containment issues, such as trail widening or increasing trail depth, as well as the proliferation of visitor created trails (Figure 2.8). Although we observed the formation of only a single defined visitor created trail, we detected linear patterns of vegetation loss at several monitoring locations which may indicate the early stages of future informal trail proliferation. This type of linear vegetation loss occurred more frequently at the three trail overlook locations where smoother gradients allowed visitors to more easily access the chalk formations. Visitor created trails are often created to access attractions of interest that are not connected to the official trail system, so management action to prevent propagation may be especially necessary in areas of the park where gradual descents into the formations are available.

Location	Number of Observed Visitor Created Trails in February 2020
Rim Trail Bridge	0
Inscription Wall	0
Ramada	0
Rim Trail Overlook	0
Life on the Rocks Overlook	0
Oil Pad Overlook	1

Table 2.2 The number of visitor created trails observed upon conclusion of data collection in February 2020, five months following park opening.

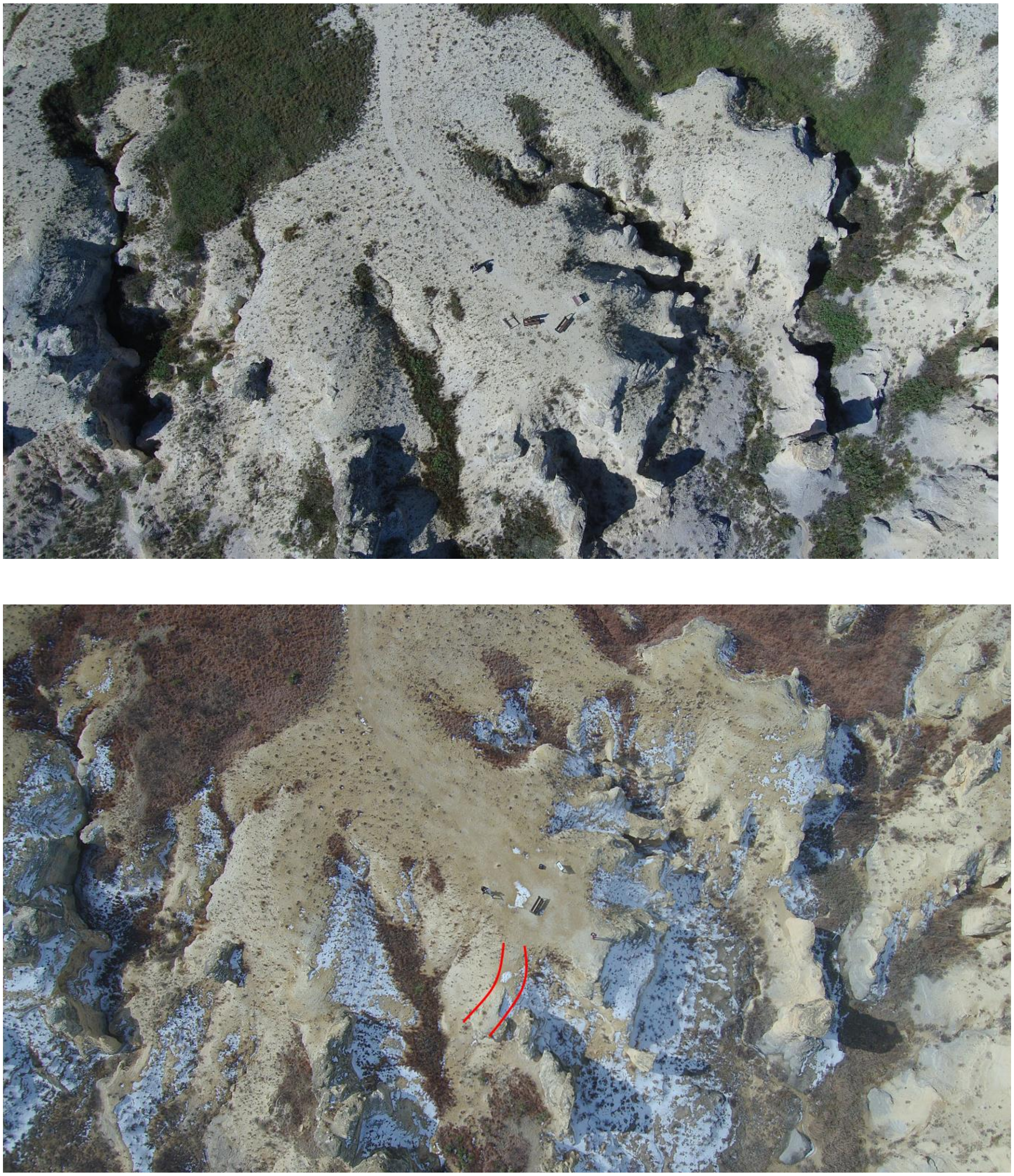

Figure 2.8 (Top) The Oil Pad overlook baseline photograph from September 2019, one month prior to park opening. (Bottom) The Oil Pad overlook in February 2020, five months after park opening. Notice the visitor created trail in the bottom left of the image, as well as significant widening of the designated trail between the two photographs.

Examining the Rate of Impact

The relationship between increasing recreational use of a site and the site's ecological condition is often described as curvilinear (Figure 2.9), with many studies finding that the majority of resource impact occurs at low to moderate recreational use with only marginal increases in impact occurring at higher levels of use (Manning, 2009; Monz, Pickering, & Hadwen, 2013). This extreme sudden impact is especially noticeable on undisturbed sites, as even small increases in the amount of initial use result on dramatic increases in impacts. The ability to collect baseline indicator data for vegetation loss and the creation of visitor created trails prior to park opening and subsequently observe impacts in real-time following park opening allowed us to explore not only the severity of these two impacts, but also the rate at which they occur. The results of this study suggest the occurrence of a curvilinear ecological response due to recreational impacts taking place at Little Jerusalem Badlands State Park. After just four months of permitted visitation, significant vegetation loss as well as the proliferation of visitor created trails were noted at severe magnitudes, with some locations losing between 25% and 45% of their original vegetative cover and many locations displaying future signs of multiple visitor created trails.

Previous literature detailing the curvilinear response to recreational use of a newly established site suggests that these impacts may decelerate in rate over time, but unfortunately, the ecological degradation already observed may be irreversible. This curvilinear relationship underpins strategies that seek to "confine" recreational use to designated trails. The confinement approach assumes that once a site is extensively disturbed, impacts will not change considerably despite substantial increases in use. Thus, confinement strategies, although they cannot reverse damage which has already occurred, may significantly reduce the overall area impacted by recreational use (Monz, Pickering, & Hadwen, 2013). A confinement strategy may be an effective management tool at Little Jerusalem based upon the curvilinear response suggested by the data collected.

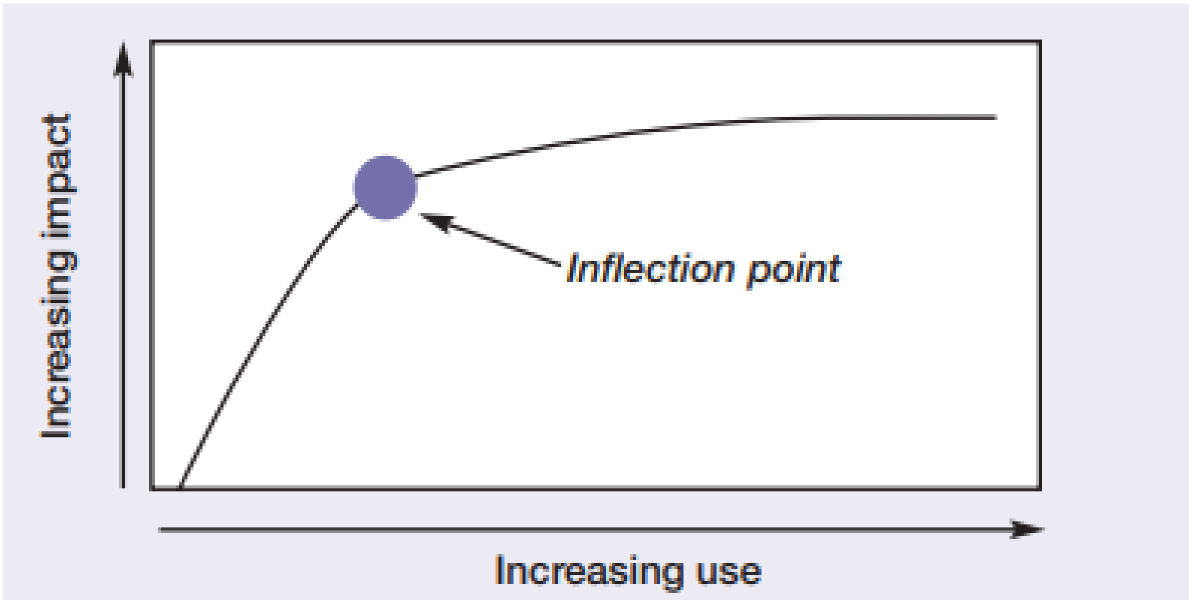

Figure 2.9 The curvilinear relationship between increasing recreational use of a protected area and the resulting ecological impact to that area.

Discussion and Conclusions

The Effectiveness of a Drone as a Conservation Tool

This study demonstrated that drones serve as a valuable tool in recreational impact monitoring, as they have the potential to significantly reduce the workload related to the long-term collection of indicator data yet still provide precise measurements of ecological conditions. Flights conducted at relevant time intervals increase monitoring opportunities and support a robust data collection method to back managerial decisions. The methodology utilized in this study was developed with park staff and managers in mind, designed to be easily applied in any protected area setting where visitation is permissible. When protected areas are open to the public, some impact to the resource is unavoidable. Any ecosystem exposed to anthropogenic activity will be impacted to some degree. Although ecological communities are often resilient systems with the ability to rebound following damage, continuous visitation to a site, such as use associated with recreational activity, may result in too small of a convalescence period for the resource to recover. This is especially true when studying previously undisturbed areas, as the curvilinear relationship between increasing use and the amount of observed impact often means even a small amount of initial use results in a dramatic impact to a site. Recreation ecology research as well as park managers collectively seek to reduce impacts to protected areas. However, when such severe impacts occur at an accelerated rate such as within this study, at what point do we deem certain areas of a site as “sacrificial,” and focus our efforts elsewhere? The curvilinear response to visitation has impacted areas of Little Jerusalem to the point where attempting to reverse the ecological damage may not be logistically nor economically viable. This study suggests that efforts should be focused on containing impacts rather than preventing them altogether, a feasible goal in the race against the curvilinear response.

Even robust systems may experience irreversible impacts associated with prolonged recreational use, but this concern is amplified when observing delicate ecosystems such as that of Little Jerusalem. Unlike ecosystems which may simply regrow following severe impact, such as forests or grasslands, the Niobrara Chalk formations of Little Jerusalem are finite structures. If erosion occurs as a result of visitor use, there is no way to build up the chalk once again to replace that which was lost. This makes long-term monitoring especially important at Little Jerusalem, as the future of the site relies on effective management to contain impacts. Collectively, the ecosystem value, presence of specialized wildlife species, natural resource importance, and historical significance make proper management of Little Jerusalem Badlands a momentous concern. Proper management will ensure minimal negative impact to these individual resources and to the site overall. The drone utilized at Little Jerusalem Badlands State Park has provided valuable ecological conditional data pertaining to the health of the park and will be a boon in guiding management actions in the park to prevent negative impacts as a result of recreational use.

Future Monitoring Challenges of Little Jerusalem Badlands

This methodology mitigated the time and logistical constraints of traditional fieldwork while still providing a robust dataset which accurately represented changes to the site as a result of recreational impact. In line with the IVUMF, monitoring will continue indefinitely to detect future changes to the site's ecology and gauge the effectiveness of managerial decisions to reduce or contain recreational impacts. Originally, this study set out to not only to provide baseline indicator data, but also establish thresholds for the two indicators studied at Little Jerusalem. The park, slated to open in early summer 2019, experienced delayed construction and did not open to the public until October. As data collection ended in February 2020, this only provided 5 months of data where visitation to the park was permitted, not nearly enough of a sample to establish thresholds based on IVUMF guidelines. A year of data collection or more following park opening would be sufficient to provide a more robust dataset on which to base thresholds for impact management. Future monitoring will focus on identifying the inflection point noted in the curvilinear pattern of impact, as well as utilizing previous literature and the desired ecological condition of Little Jerusalem Badlands to establish acceptable impact thresholds to pair with both indicators.

However, an effective monitoring tool does not always guarantee that a protected area will be better managed as a result. Little Jerusalem Badlands faces several unique challenges that may affect the way the property is managed. For example, as a stipulation of the land trust agreement that allowed the property to be opened to public visitation, the previous landowners requested that the property continue to be incorporated into a seasonal grazing rotation, introducing cattle several times a year. This adds another layer to the monitoring procedure, as impacts as a result of cattle grazing must be differentiated from impacts as a result of recreational use. Cattle grazing has altered the site's ecology for several generations, but the effects may be exacerbated if combined with recreational use as well. On top of this, policy and regulations also play a role in the success of monitoring and management techniques. Little Jerusalem Badlands allows leashed dogs along the established hiking trails amongst the property, but the lack of full-time staff to enforce rules may lead to unleashed dogs wandering off the established trail. Negative consequences as a result may include displacement of wildlife, which was a primary concern of the responsible management agencies. Another example is the ranger guided hiking program planned for future implementation. This program would allow visitors access into the chalk formations during ranger guided tours, increasing the area of impact outside of the contained trail system. Even if these three aspects increase the severity of impact, area of impact, and complicate the monitoring process, the regulatory fulfilments and offering of additional recreational opportunities may take precedence.

Limitations: Data Collection and Data Analysis

Despite the advantages drone use provides, it also presents several limitations. Although the cost of drones and related surveying equipment continues to decrease, the up-front investment required to purchase a consumer model drone may pose a challenge for some land management agencies. Partnerships with other organizations, such as universities and extension programs, may alleviate some or all the initial costs related to purchasing drone systems through the utilization of grants or borrowing equipment from partnering organizations. These partnerships may also remedy concerns of complex training required to fly a drone for data collection or data analysis methods, which may utilize various software or methods to sort and evaluate the collected data and use the results to assess conditional changes. While minimal training was required to fly the Typhoon H utilized in this study, models of drone above consumer-level may increase in complexity, additional training or licensing to operate beyond just the FAA required Part 107 license. If a complex model is required, partnerships with organizations who have staff already proficient in the required operation procedures would mitigate the need for additional agency staff training or resource input. Necessary licensing also varies by geographic location, as some countries may require licenses to fly even consumer-level drones while others may require no licensing at all for recreational or research applications. In the United States, the Federal Aviation Administration requires a small UAS pilot's license to operate drones weighing less than 55 pounds for research purposes. However, the Drone Integration and Zoning Act of 2019 proposes the elimination of licensing requirements to operate a small UAS for research uses, potentially simplifying the process and making this methodology more accessible to protected area managers in the future (United States Congress, 2019). The intricacy of the drone and associated equipment will depend on the monitoring needs of each specific public land management agency or protected area. The methodology described in this study is designed to be widely accessible in a variety of public land settings, thus, the challenges encountered while operating the Typhoon H in Little Jerusalem Badlands State Park may not reflect the challenges faced in monitoring efforts conducted in other protected areas.

The limits of the equipment, including the drone and add-on sensors, are based on the landscape composition and type of monitoring conducted. For example, the use of a drone for quantifying visitor-created trails as described in this study may not be applicable in areas with dense tree cover or drastic elevation changes, such as mountainous areas. The same holds true for measuring indicators and thresholds associated with vegetation loss. Ecosystems in northern latitudes which experience drastic seasonal vegetation changes may yield false significant results simply based on the succession of seasonal ground cover from cooler temperature months to warmer. To alleviate this, monitoring may take place yearly rather than seasonally, with photopoints only being assessed during the same time each year to determine accurate vegetational loss associated with recreational use rather than seasonal change. Depending on the model of drone, high winds or heavy rain may also prevent flight from taking place entirely. The Typhoon H may only fly in winds below 40 miles per hour and cannot be exposed to extreme moisture. Fog may also adversely affect the quality of captured images. Disruptions to data collection may be limited by selecting data collection frequencies which avoid times of the year known for poor weather and scheduling data collection flights to coincide with clear local weather forecasts.

Limitations: Legal and Social

Legal limitations may be a point of concern as this method involves the collection of photographic data within protected areas experiencing various rates of public visitation. Legal limitations must be addressed prior to the start of data collection. Independent state or regional laws often govern drone use relating to any purpose, whether that purpose is recreational, commercial, or research. The participating agency conducting data collection flights must be aware of any local laws which regulate the type of drones permitted to fly, restricted air space, distance from urban centers, or photography privacy regulations. Additional restrictions may apply to land managed by federal or state agencies. Many protected areas, such as National and State Parks, prohibit the use of drones for recreational purposes and set a strict permitting process for research applications. Research permits may be required for data collection within these areas, which may pose a challenge for agencies or organizations unfamiliar with the permitting process. Research permits occasionally must be renewed yearly rather than upon conclusion of the project, presenting additional hurdles for long-term monitoring efforts as outlined by the IVUMF.

The social implications of utilizing drones for protected area monitoring may pose the largest challenge to implementing scientifically robust methodology. Depending on the type of indicator and threshold data being collected, drone use may pose a privacy risk to visitors and employees within protected areas. Drones often instill a fear of confidentiality violations in individuals who spot an aircraft overhead. This fear may incite visitors to question the decisions of protected area managers to allow flight in a public land, even if the drone in question is not equipped with cameras. Conversely, individuals may question why a drone is flying in an area where visitors are not permitted fly their own aircraft for recreational purposes. Special care should be taken to interpret the purpose of the drone to concerned visitors and staff, as well as ensure no unlawful personal information is collected. Visitors and staff should be educated on the value of the data collected to aid in making managerial decisions that reduce recreational impact to the site. If the drone is equipped with a camera, flight missions should be planned to coincide with periods of low visitation and at an altitude where individual features cannot be distinguished. FAA guidelines in the United States mandate that it is unlawful to operate small UAS directly above any individual. Extra caution must be taken when indicator and threshold data is based on visitation rates or visitor dispersion, as this type of data often includes visitors within each photograph. However, as there is no assumption of privacy within many types of protected area, the managing agency ultimately has the final say as to the level of personal data collected during monitoring efforts.

Future Applications

In conclusion, managers of parks and other protected areas would greatly benefit from applying drones for monitoring recreational impacts. This methodology provides a significant amount of data while reducing the economic and logistical constraints of traditional fieldwork required to carry out traditional long-term monitoring techniques. Furthermore, repeated drone flights allow researchers to observe not only the severity of impacts occurring as a result of recreational use, but also temporal patterns and the rate of impact occurring over time. It may not be possible to prevent ecological impacts to the resource altogether, but this type of long-term monitoring allows managers to contain impacts to limited areas of a site and better utilize park resources to reduce impact. Monitoring of the resulting management actions via the Interagency Visitor Use Management Framework will also be simplified through the use of drones to monitor future impacts and landscape changes and determine the efficacy of enacted management decisions. Drones have a bright future in protected area monitoring and may be considered one of the greatest boons to simplifying the long-term monitoring process in protected areas across the world.

Chapter 3 - A Comprehensive Guide to the Recreational Impact Monitoring Protocol Implemented in Little Jerusalem Badlands State Park

An Introduction to Little Jerusalem

Little Jerusalem Badlands State Park, opened to the public in October 2019, is a 330-acre property located in Logan County, Kansas. This area is ecologically unique, home to the largest Niobrara Chalk formation in Kansas with a fossil record dating back 85-million years. Formed following the recession of the Western Inland Sea during the late Cretaceous, Niobrara Chalk is composed of millions of years of compacted organic material which has been consistently exposed to the elements over millions of years. Erosion of the chalk due to wind, rain, and wildlife activity has resulted in hundreds of towering chalk spires looming over the property, some as tall as 100 feet (Figure 3.1). Erosion of the chalk still occurs today at a rate upwards of two inches per year, adding depth to the eroded canyons and further defining the chalk towers. The unique chalk formations attract many specialized flora and fauna species not found anywhere else in the region including Black-footed ferret (*Mustela nigripes*), Ferruginous hawks (*Buteo regalis*), Cliff swallows (*Petrochelidon pyrrhonota*), Great Plains wild buckwheat (*Polygonum convolvulus*), and many more. Only two thirds of the site are comprised of chalk formations, while the remaining one third a native shortgrass prairie ecosystem of great natural and landscape value. As 80% of Kansas' shortgrass prairie has been converted to other uses, mainly agricultural, the preservation and proper management of Little Jerusalem is of the utmost importance to ecological conservation.

Figure 3.1 The Niobrara Chalk formations of Little Jerusalem Badlands State Park.

The property also maintains a high level of historical value. Native American use dates back thousands of years, as one of the newly established park trail systems passes a buffalo jump utilized by native tribes. Settlers traveling west during the period of westward expansion would often stop on the property to gather the standing water that collects in the eroded canyons, many of whom left personalized carvings in the walls of the chalk spires. It is even rumored that "Buffalo Bill" Cody, Wild Bill Hickock, and over 100 families of African American settlers crossed Little Jerusalem before completing their westbound journeys.

Prior to becoming a state park, this land was part of the McGuire family ranch for five generations and utilized as seasonally rotated cattle grazing land. The McGuire family deeded

Little Jerusalem to The Nature Conservancy (TNC) via land trust agreement with the stipulation that the land must be open to the public for as long as it is in TNC's possession. The Nature Conservancy partnered with the Kansas Department of Wildlife, Parks, and Tourism to pursue the necessary legislation to designate Little Jerusalem as a state park and continue to co-manage the property. TNC retains ownership of the property and is responsible for natural resource management, while KDWPT manages outdoor recreational activities. As a result, the management plan of Little Jerusalem Badlands State Park is approved and upheld by both agencies in conjunction. At the request of TNC, the Kansas State University Applied Park Science Lab was selected as a partner to aid with the development of this monitoring protocol and the resulting suggestions for site management based on the collected data.

As the property was utilized prior to its turnover to TNC, evidence of visitor use and grazing impacts are clearly denoted across the landscape. At the request of the previous owner, a second stipulation of the land-trust agreement states that the property will be utilized for cattle grazing into the foreseeable future. On top of this, the property retains a high level of local fame, as the previous landowners hosted many community events on site and allowed frequent visitation. This reputation has led to a high amount of trespassing prior to park opening, resulting in further impact to the site. Although the purpose of a monitoring effort is to maintain the integrity of the natural resource, Little Jerusalem was not in pristine condition at the time of acquisition due to prior visitation and trespassing before opening, coupled with historic and future grazing on site. These are important factors to consider when conducting a monitoring effort and analyzing the resulting indicator data.

The current park infrastructure is basic, providing only the necessary improvements to qualify Little Jerusalem as a state park, such as restrooms, a parking lot, educational signage, an

ADA-accessible hiking trail, and a rim trail system. The current trail system focuses on keeping visitors on three specific trails around the rim rather than allowing access into the chalk formation itself (Figure 3.2). Both cooperating agencies have expressed the desire to keep the area "as natural as possible," with very little unnecessary recreational infrastructure to be installed even in future years.

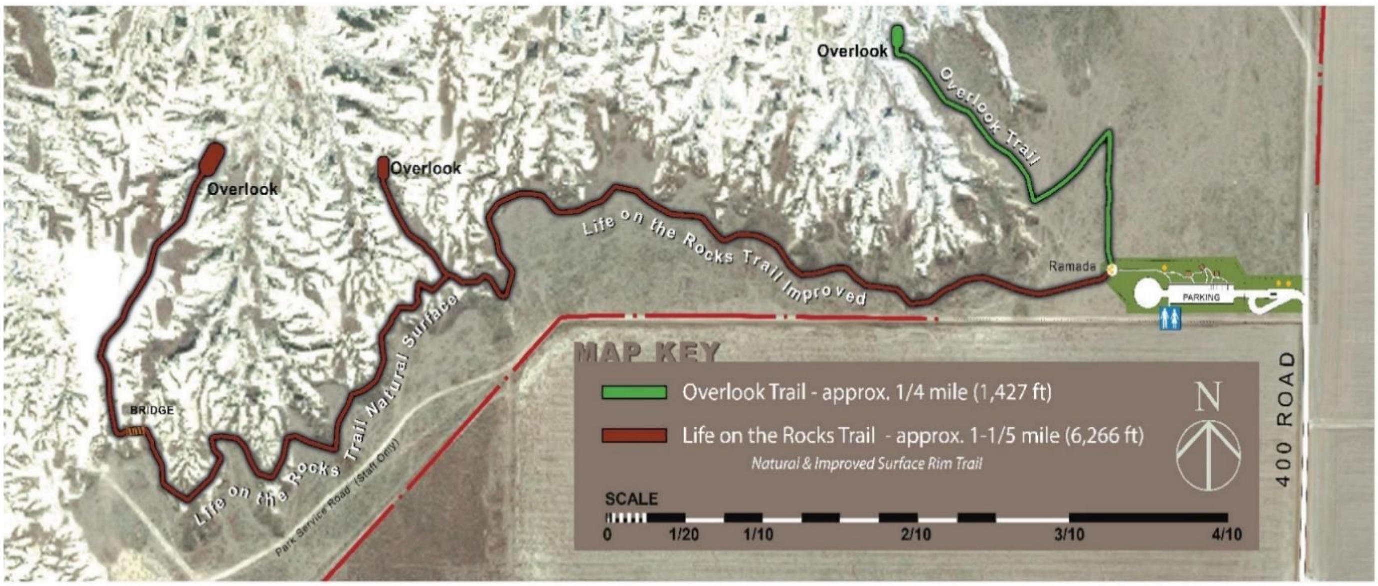

Figure 3.2 A map of all three trails currently constructed at Little Jerusalem Badlands State Park, as well as the parking lot and ramada structure location.

Why is Monitoring Necessary?

Impacts to a site as a result of visitation may manifest in many ways, including ecological damage, degradation of park infrastructure, or impacts to the visitor experience. This project focuses specifically on damage to the natural resource itself, utilizing techniques developed within a discipline known as recreation ecology (Marion, Leung, Eagleston, & Burroughs 2016; Hammit, Cole, & Monz, 1998). Increased visitation to protected areas is being observed across the board, from the smallest of state parks to some of the largest national parks in the world. Although just recently established, Little Jerusalem State Park is no exception, welcoming a steady flow of visitors from dawn to dusk every day since park opening. While this increase of people experiencing nature should be viewed as positive, it poses a significant challenge for protected area managers. Managers are tasked with maintaining a high-quality recreational experience for the visitor, while also protecting the natural resource itself. If managers have a simple and cost-effective method to continuously monitor recreational impacts in their parks, negative effects to the resource may be caught early on, and action can be taken to mitigate the damage before it becomes severe.

Any ecosystem exposed to anthropogenic activity will be impacted to some degree. Although ecological communities are often resilient systems with the ability to rebound following damage, continuous visitation to a site, such as use associated with recreational activity, may result in too small of a convalescence period for the resource to recover. Even robust systems may experience irreversible impacts associated with prolonged recreational use, but this concern is amplified when observing delicate ecosystems such as that of Little Jerusalem. As previously discussed, this property was not in pristine condition at the time of TNC's acquisition, but the ecosystem itself is still functional, providing habitat for many specialized flora and fauna specifically evolved to live amongst the chalk. Unlike ecosystems which may simply regrow following severe impact, such as forests or grasslands, the Niobrara Chalk formations of Little Jerusalem are finite strictures. If erosion occurs as a result of visitor use, there is no way to build up the chalk once again to replace that which was lost. This makes long-term monitoring especially important at Little Jerusalem, as the future of the site relies on effective management of recreational impacts. Collectively, the ecosystem value, presence of specialized wildlife species, natural resource importance, and historical significance make proper management of Little Jerusalem Badlands a momentous concern. Effective long-term monitoring will provide the necessary conditional data to make effective managerial decisions to minimize negative impact to the individual resources and to the site overall.

What Framework is Utilized to Ensure Effective Monitoring?

Historically, land managers have chosen to address resource impacts utilizing a model of "carrying capacity," determining a maximum level of allowable use and setting direct management actions to keep visitor use at or below this determined threshold. However, decades of research have revealed that the solution to resource impact issues is exceedingly complex, linking the disciplines of recreation ecology, social science, environmental biology, and management to provide a thorough research-based solution. A multipart framework, developed in 2016, drew inspiration from the concept of carrying capacity and past frameworks (such as Limits of Acceptable Change, Visitor Experience and Resource Protection, etc...) to provide a systematic basis to address managerial decision-making needs in public lands: The Interagency Visitor Use Management Framework (IVUMF). The ICUMF relies on a diverse array of management strategies and actions, often termed a "management toolbox," for resolving visitor impact problems. This "toolbox" includes strategies such as restoration ecology, professional development of visitor management staff, modifying visitor behavior, increasing resource resilience, and many others. The IVUMF provides additional guidance to professionalize the process for the continued preservation of natural conditions and processes in our protected natural areas and the sustained administration of high-quality recreational experiences. It is intended to provide a process that is legally defensible, transparent, meets all law and policy requirements regarding public land management, and ensures agency accountability in managerial decisions and actions. It is currently applied by the Bureau of Land Management, the National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, National Oceanic and Atmospheric Administration, and U.S. Army Corps of Engineers to assist in managerial decisions for the administration of public lands retained by each agency.

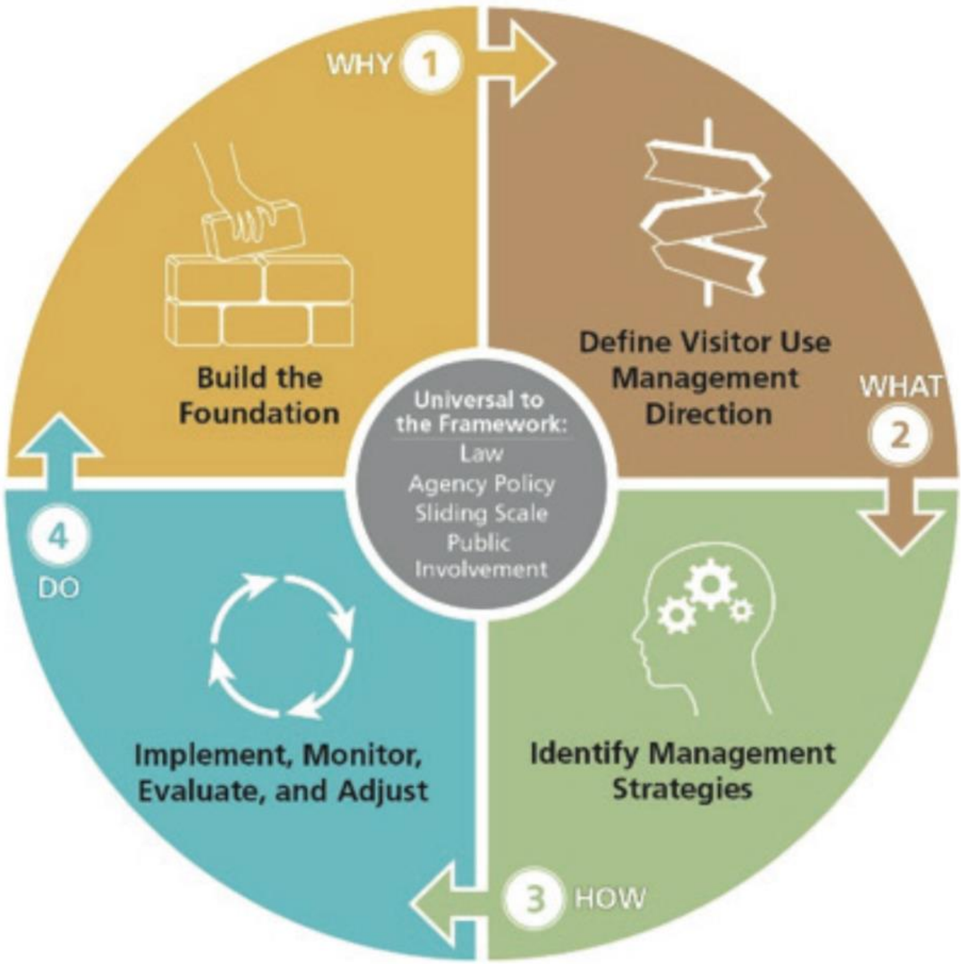

Figure 3.3 An introductory diagram detailing the four major steps of the Interagency Visitor Use Management Framework.

The framework is divided into four major elements: (1) Build the foundation, (2) Define visitor use management direction, (3) Identify management strategies, and (4) Implement, monitor, evaluate, and adjust. In step one, the project need is clarified, and the area of interest is defined before assessing current conditions and developing a plan of action. Step two identifies desired conditions, appropriate visitor activities, facilities, and services, then selects indicators and establishes thresholds. Step three compares the existing conditions to the desired conditions, then identifies management efforts and a monitoring strategy to help achieve the desired conditions. Lastly, step four implements the decided management actions, then conducts ongoing monitoring to evaluate the effectiveness of the management actions and adjust the strategy should the need arise.

At the core of the IVUMF is the need to measure indicators and thresholds to both provide sound rationale on which to base new management decisions as well as measure the efficacy of enacted decisions over a long period of time. Indicators are a type of experiential attribute that can be measured to track changes in conditions, whereas thresholds are minimally acceptable conditions associated with each indicator. For example, when collecting indicator data to maintain an existing hiking trail system against wear, the indicator may be trail depth in inches and the threshold may not exceed three inches of added depth to the original trail level. Indicators and thresholds are defined in step two of the framework, and are utilized in every step thereafter, including long-term monitoring in step four. Thus, indicators must be simple to measure in order to provide agencies with the flexibility required for long-term monitoring to ensure management decisions remain effective. If indicator data is too resource-intensive to gather, necessitates confusing methodology to collect, or entails special training or certification of staff to measure, the long-term monitoring required by the IVUMF may not be carried out, thus reducing the overall success of the framework to make sound decisions to address threats to public lands. Striking a balance between recreational quality and ecological integrity is of the highest concern to land managers, thus, taking the correct type of management action is key to accomplishing this goal.

What Indicators are Studied at Little Jerusalem?

This project is especially unique, as the park was still closed to the public when data collection began. This granted the opportunity to collect baseline data over a year prior to the park opening. This baseline allowed us to compare data from a previously "untouched" version of the site to data collected following the start of visitation to study exactly how visitor use effects the site's ecology. Multi-faceted data collection began in June 2018 seeking to collect baseline ecological and visitation data. Methodology for continuous indicator and threshold monitoring following the standards of the IVUMF was designed to continue indefinitely, even following the conclusion of TNC's cooperation with Kansas State University.

Five trail cameras placed throughout Little Jerusalem, recurrent photographs of several "key" monitoring locations, detailed field notation, and a visitor counter located at the entrance of the site provided a randomly sampled list of animal species present, as well as the estimated rate of unauthorized visitation prior to opening. As the Niobrara chalk formations posed a challenging landscape to collect thorough landscape-wide baseline indicator data, the use of a drone was employed in January 2019. The primary concerns of the two land management agencies were the proliferation of visitor-created trails, erosion of the chalk, vegetation loss, and wildlife displacement. The previously employed methods of recurrent photographs and trail cameras were sufficient to monitor wildlife displacement and baseline erosion due to visitation, but data collection under the updated methodology documenting visitor-created trails and vegetation loss utilizes aerial drone photography.

Types of Equipment Utilized

The monitoring protocol developed for Little Jerusalem relies on technology as a means to simplify the data collection process for park staff, managers, and researchers. Implementing high-tech solutions to monitor recreational impacts allows for the collection of a large amount of conditional information either on a continuous basis or with a protocol which only requires a short amount of time to conduct. The following equipment is utilized for on-site data collection related to the visitor use monitoring of Little Jerusalem:

- 5 Spypoint and Moultrie Trail Cameras
- 1 Spypoint Cellular Trail Camera
- 1 Nikon Coolpix P900 Digital Camera
- 1 TRAFx Infrared Trail Counter
- 1 Yuneec Typhoon H Hexacopter Drone

Equipment Purpose

Type of Equipment	Monitoring Type (Ecological or Visitor Use)	Data Provided	Resulting Analysis
Trail Cameras	Ecological and Visitor Use	Photos of trespassers, employees, and construction prior to opening, photos of wildlife species present on site.	Two Excel spreadsheets detailing all individuals and all wildlife captured on camera.
Cellular Trail Camera	Ecological and Visitor Use	Photos of individuals wandering off the designated Overlook Trail in real-time.	Two Excel spreadsheets detailing all individuals and all wildlife captured on camera.
Digital Camera	Ecological	Photos of selected "key" monitoring locations and miscellaneous site impacts as a result of visitor use.	Comparison of photographs over time exploring vegetation change, erosion, and other visitor impacts.
Trail Counter	Visitor Use	A count of the number of visitors entering and exiting the Life on the Rocks trail.	Analysis of visitor-use patterns over time which can be related to other types of data.
Drone	Ecological	Aerial photographs of 6 "key" monitoring locations from an overhead view and a "profile" view.	Analysis of visitor-created trails and vegetation loss at each location over time.

Table 3.1 A table noting the purpose of each type of equipment within the monitoring protocol implemented at Little Jerusalem Badlands State Park.

Equipment Placement

Although Little Jerusalem Badlands State Park is only 330-acres, monitoring every square inch of the site would pose a time-consuming, unrealistic challenge for park staff, managers, and researchers. To reduce the time needed for data collection and encourage the continued effort of long-term monitoring, "key" locations at Little Jerusalem were selected to best represent the site as a whole (Figure 3.3). These locations were selected both by land managers and members of the Applied Park Science Lab at Kansas State University based upon exposure to visitor use, notable fragile elements, or areas that may tempt visitors to travel off the official trail system.

Locations of critical importance include three overlooks at the end of each of the trails (Life on the Rocks Trail Overlook and both Rim Trail overlooks), a bridge structure along the Rim Trail gapping a canyon that may entice visitors to climb down, a ramada structure where all three trails begin and end, an active breeding Ferruginous hawk nest, and a large chalk slab inscribed with names and dates back to the 1840s deemed the "inscription wall." The inscription wall was is located a far distance away from the trail system but concerns of vandalism in this area were especially high due to the historical value of this setting. The active Ferruginous hawk nest is also a moderate distance from the designated trail, but as this species is especially sensitive to anthropogenic activity, presence or absence of hawks utilizing the nest following park opening would be telltale of disturbance due to visitation.

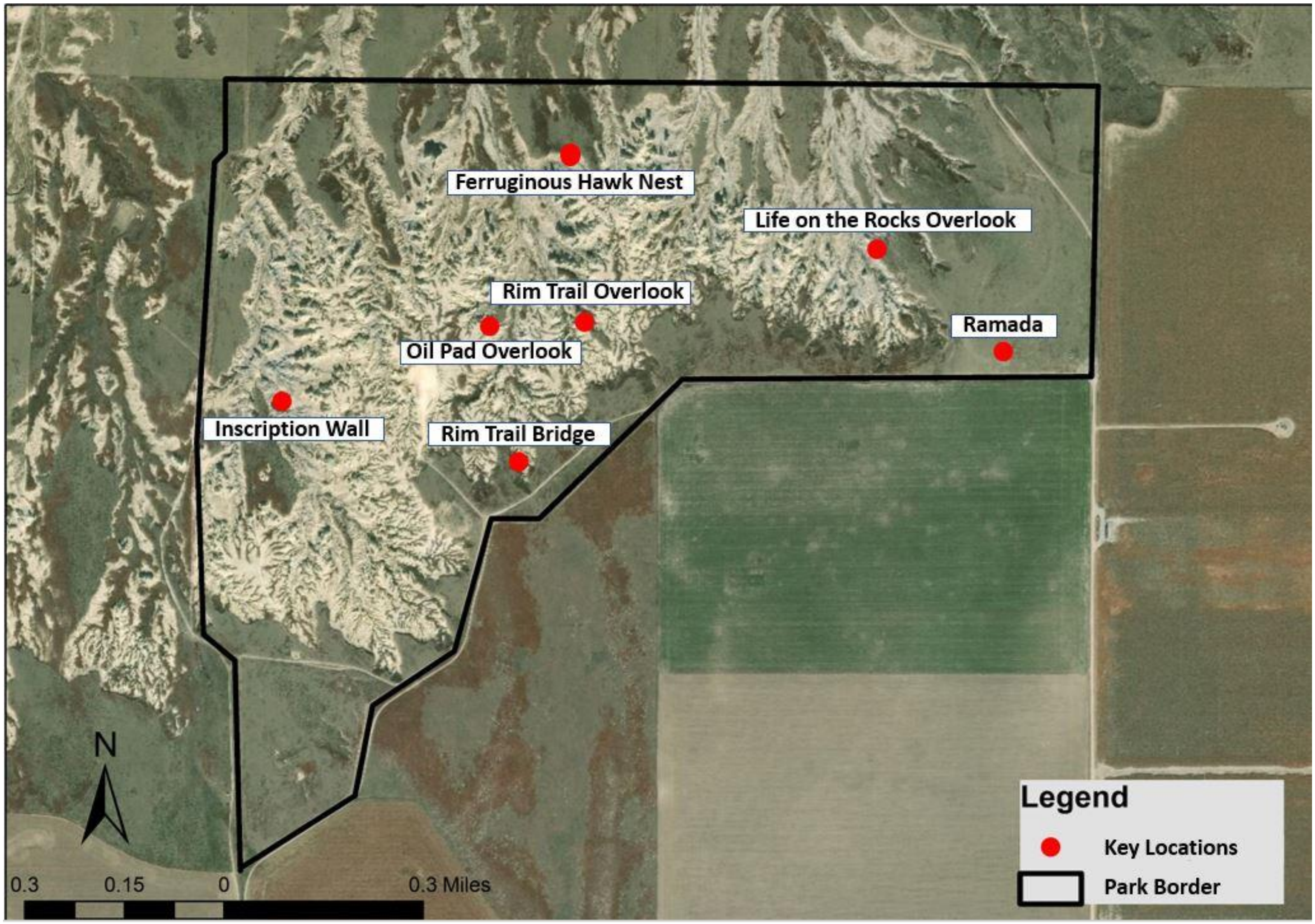

Figure 3.4 A map of the "key locations" in Little Jerusalem Badlands State Park as selected by TNC managers and the Kansas State APS Lab.

Not every facet of the monitoring protocol takes place only at the seven key locations selected by the park managers and research team. Several sites outside of the seven original points were selected later as a result of ease of access, impacts revealed by the data collected at that point in the project, or sites that were moved or added following construction in a specific area of the park (Figure 3.4). For example, a photo point was added to the oil pad, a flattened area of chalk which the previous landowner had prepared for drilling but never opened for extraction. The flattened piece of land was a desirable "turnaround" point for large vehicles and tour busses coming to visit the park, but due to the natural erosion rate of the chalk and instability of a flattened piece of land within such a dynamic landscape, the structure is collapsing. Thus, a photo point at this location provides a visual timeline of the collapse of the pad and may help managers determine the safety and efficacy of allowing vehicles to access it. Additional points include a trail counter added at the Rim Trail trailhead following trail construction, the cellular trail camera added at the end of the Life on the Rocks Trail following trail construction, one trail camera added at the park entrance vehicle lot and another above the road above the oil pad following park opening, and a trail camera placed in a grassy field adjacent to the inscription wall after researchers noted ample wildlife activity in the area.

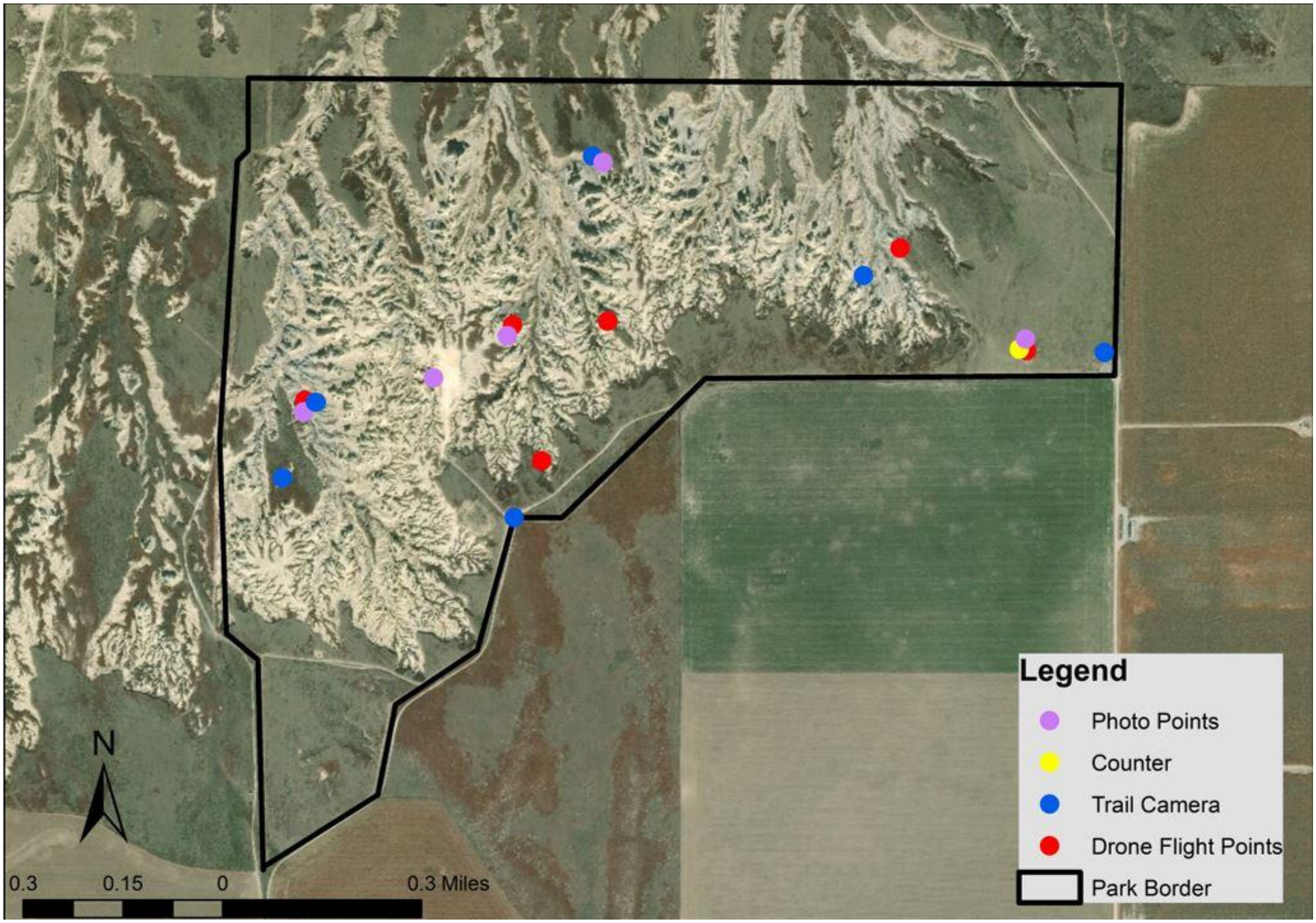

Figure 3.5 A map depicting all monitoring locations and equipment placement sites at Little Jerusalem Badlands State Park.

Data Collection Process

Collection Trip Frequency

Data collection trips have taken place once a month from June 2018 until February 2020. However, the frequency of data collection may be reduced to once every two months or once every three depending on the severity of site impact, rate of visitation, or weather concerns. The frequency of data collection, once determined, must not deviate from year to year as to maintain the continuity of the information collected. Trends in visitor impacts are often temporally based, and as such, a rigid timeline for data collection should be followed.

Thus far, the same rate of visitor impact has been observed year-round, even during the winter months. This is likely due to the mild winter weather usually experienced in western Kansas which is still conducive to recreational use of Little Jerusalem. On top of this, the moderate climate does not influence a significant amount of seasonal vegetational change, and thus, the impacts studied on site are not reduced due to a lack of vegetation on site during the colder months of the year.

Order of Operations

Around seven hours are required to complete the monitoring protocol each trip, although equipment malfunction, weather events, or other outside factors may alter this approximated timetable. After arriving at Little Jerusalem Badlands, working backwards from the Inscription Wall is the most efficient route to take. Utilize the perimeter road to travel if conditions are suitable, otherwise, simply hike to each location. When hiking, attempt to move along the cattle and wildlife trails which already exist on site to prevent further impact. These trails are denoted by a loss of vegetation in a straight line and hardened portions of the chalk which have been compacted over time. Many of the monitoring locations serve multiple roles within the monitoring framework as to minimize the effort and cost of data collection. For example, the Inscription Wall serves as the location for a trail camera, the inscription wall itself is a photopoint, and the area is also a drone flight location. Rather than returning to the same site multiple times, complete each step concurrently to save time. Below is a current order of operations directory, but this may be altered if necessary to incorporate new equipment or monitoring methods:

1. Inscription Wall
    a. Photopoint of the wall itself
    b. Maintain panoramic trail camera in the formation adjacent to the wall
    c. Drone flight 1 (Inscription Wall above and profile)
2. Kill Field (Field on the way back from the Inscription Wall)
    a. Maintain trail camera strapped to the only chalk formation
3. Above Oil Pad, on road
    a. Maintain trail camera strapped to the post next to the road overlooking the oil pad
4. Oil Pad
    a. Photopoint at the erosion site on the pad itself
    b. Drone flight 2 (Oil pad overlook above and profile, rim trail bridge above and profile, rim trail overlook above and profile)
5. Active Ferruginous Hawk Nest
    a. Photopoint at the nest itself
    b. Maintain trail camera hidden within a formation in front of the nest
6. Interpretive Ramada
    a. Photopoints of the ramada itself and surrounding construction progress
    b. Maintain counter attached to the Rim Trail gate
    c. Drone flight 3 (Ramada above and profile, Life on the Rocks Trail overlook above and profile)
    d. Maintain trail camera attached to the second entrance gate post
7. Life on the Rocks Trail Overlook

a. Maintain the cellular trail camera on the designated formation adjacent to the overlook

8. Miscellaneous sites

    a. Additional photopoints to document recreational impacts, changes in the resource, or any other factors determined to require future analysis

    b. Make note of any large changes to the site, such as the addition of new infrastructure, natural disasters, or extreme weather events

Trail Cameras

The trail cameras serve two purposes within the monitoring protocol: Capture a random sample of wildlife present on site and provide a sample of site visitation. Before park opening, the trail cameras documented construction workers, law enforcement, individuals from TNC and KDWPT, wildlife presence, and most importantly, trespassers. Following park opening, the trail cameras still capture wildlife presence data to compare to presence prior to park opening, but also catch visitors who wander off the designated trails. Photos of visitors on the trail cameras may help explain certain impacts to the site noted by other aspects of the monitoring process. Detailed instructions on how to collect the photographs from the trail camera memory cards and upload them to the project hard drive can be found in the equipment maintenance section of this document.

New trail cameras may be added or removed at the researcher's discretion if the original placements are no longer providing sufficient data. If heavy impact is noted from the digital photographs or aerial drone photographs, the trail cameras may act as a tool to provide explanation as to why such effects are taking place. Due to the lack of trees on site, trail cameras may need to be fixed to a chalk formation or simply hidden on the ground. Select new locations carefully and try to impact the resource as minimally as possible.

Digital Photography

Digital photography is a traditional photogrammetric technique which has historically provided park managers with visual representations of impact occurring within their parks. Two digital photography methods are employed within the recreational impact monitoring protocol at Little Jerusalem: Recurrent site photographs, and random sampling photography. As denoted in *figure IV*, five established “photopoint” locations have been selected to document baseline ecological change and impacts to the resource as a result of visitor use. Photographs at these five locations should be taken at the same angle, same location, focusing on the same subject during each data collection. Example photographs at each photopoint may be found on the project hard drive. Repeated sampling of the same locations is a viable method to document change over time, especially at locations which may feature sensitive elements of the site or attract many visitors.

Random sampling photography is simply a means of capturing notable site features that do not occur at any of the five “photopoint” locations. Photographs may be taken anywhere on the site at any point during the data collection process to document significant site impacts, wildlife presence, construction of new infrastructure, or any other subject which may pertain to the effective management of Little Jerusalem. Although these random photographs cannot be compared over time, random occurrence of recreational impacts represents one of the most challenging obstacles for managers to mitigate, as they often occur in areas of the site deemed to be “low risk.” If visitors are not permitted to be in an area in the first place, random documentation of site impacts may be the only method which will alert managers to the problem.

If impacts are observed in the same place during multiple data collection trips, photopoints may always be added to the methodology to continuously document change within a specific location. Digital photography is arguably the most flexible portion of this monitoring protocol, as the portability of the equipment allows for even the most isolated site changes to be documented and addressed if need be.

Trail Counter

The single trail counter on site, posted at the trailhead of the Rim Trail, constantly counts visitors entering and exiting the trailhead. This piece of equipment is a boon for visitor use research, as this data may be analyzed for temporal patterns of site use over any scale, from hour to hour, day to day, month to month, or even between multiple years. For the purpose of this project, the Rim Trail is the most secluded trail on the property, as well as the longest in terms of distance. Understanding visitor use patterns along this trail may help to explain site impacts documented by the aerial drone photography portion of this recreational impact monitoring methodology. For example, if one month of recreational use results in a significantly higher rate of vegetation loss than observed previously, the rate of visitation documented by the counter may provide an explanation as to why such changes occurred. Analysis of the counter data may even result in the notation of a specific day where an usually high number of visitors utilized the Rim Trail, which may then be linked to the detected loss of vegetation.

Additional counters may be added to other trail systems within the park. The Life on the Rocks trailhead does not currently have a counter, but one may be placed in the future to compare use between the two trails or to assist in explaining any future impacts to the Life on the Rocks trail. The construction of future trails may also prompt the placement of new counters.

Detailed instructions on how to collect visitor use data from the counter may be found in the equipment maintenance section of this document.

Drone

Aerial drone photography represents perhaps the most technologically challenging portion of the Little Jerusalem recreational monitoring methodology. However, the use of the drone also saves the most time during data collection and simplifies the process for researchers and park staff. This project is likely the first time a drone has been employed to collect recreational impact data from a protected area in the United States, may be the first-time drones have been utilized with this intent within a state park, and is likely the first time this methodology has been employed in a newly established park to collect thorough baseline data prior to park opening. Although, on the surface, the use of drones for recreational monitoring may seem complicated, drones will bolster the efficacy of the IVUMF for indicator and threshold monitoring, thus granting land managers valuable data at a fraction of the cost of traditional photogrammetric techniques and with minimal pilot training required. Drone use is especially effective among the terrain at Little Jerusalem, which may be challenging to traverse if traditional data collection methods are being utilized.

FAA and University Requirements

For the purposes of this project, it is extremely important to note that to fly the drone for data collection purposes, **the pilot must possess a Federal Aviation Administration Part 107 Small UAS license.** Alternatively, the person operating the aircraft controls may be supervised by an FAA Part 107 licensed pilot, known as the pilot in command (PIC). In the United States, the Federal Aviation Administration requires a small UAS pilot's license to operate drones weighing less than 55 pounds for research purposes. However, newly introduced legislation to the U.S. congress in 2019 proposes the elimination of licensing requirements to operate a small UAS for research purposes, potentially simplifying the process and making this methodology more accessible to protected area managers in the future without the need for partnership with a licensed pilot. The PIC is ultimately responsible for the operation of the aircraft and safety during flight. Information regarding the FAA Part 107 licensing process may be found on the FAA website. The drone must be registered with the FAA every three years, with the serial number affixed to the body of the aircraft. Our drone registration does not expire until December 2022.

Kansas State University also has its own Unmanned Aircraft Systems Policy which requires all drone flights operated on Kansas State property or for any university-sponsored event (such as research) to receive approval from the university. This project is approved until December 2020, then it must be renewed utilizing the university UAS request form. University policy also requires drone liability insurance of at least $500,000 for each flight. Thus far, insurance has been purchased from Verifly, an app which allows the user to pay for drone insurance at an hourly rate rather than requiring an annual policy. **Insurance must be purchased prior to the data collection flight**. The receipt and policy details must then be emailed to Loleta Sump (Loleta@ksu.edu) after each flight.

Preparation for Flight

The Typhoon H utilized in this protocol has many autonomous flight capabilities, including flying to specific GPS points and elevations, an "orbit mode" for getting a better look at large landmarks, and a follow mode where the aircraft autonomously follows behind the pilot. These options are what made this model so desirable for recreational impact research. The pilot can program a flight path while operating the aircraft, and the drone will save both the GPS coordinates and altitude to fly the same path whenever necessary with minimal training. The six drone photopoints at Little Jerusalem are broken up into three autonomous flight paths programmed into the Typhoon H. **Thoroughly read the user manual prior to operating the aircraft**. A copy of the user manual can be found on the project hard drive. A quick start guide and instructional DVD are also provided inside the carrying case.

To prepare for a drone flight, remove the drone from the carrying case and fold the six arms upwards until they lock in place. Attach the rotor blades to the end of each arm, ensuring to match the color of the arm to the color represented on each rotor. Match black rotors with black arms, and white rotors with white arms. The blade should click into position. Ensure the battery is secure in the battery compartment and the micro SD card is secure in the SD slot on the back of the gimbal. Remove the flight control tablet from the drone case. Before powering on the flight control tablet, ensure the following switches are in the correct positions:

- Tilt Mode: Middle
- Pan Mode: Up (F)
- Pan Control: Middle
- Aux: Off
- Obstacle Avoid: Off
- Flight Type: Angle
- Proportional Control Rate Slider (Back of Controller): As desired
- Gimbal Tilt Control Sider (Back of Controller): As desired

Takeoff

Place the aircraft on a stable and level surface and remove the gimbal cover. Once the aircraft has been thoroughly inspected and the flight control tablet switches are correct, power on the tablet. Once the screen is visible, hold the drone power button on the aircraft until a rising tune is heard, then release the button. The drone will take approximately one minute to connect to the control tablet, access the GPS satellites required for flight, and display the camera live feed onto the tablet screen. Do not touch the drone until the initialization process is complete. The gimbal camera will spin to the front position, the main aircraft LED will blink red, green, and blue rapidly during the process of initialization.

Once initialization is complete, press and hold the red start/stop button to start the aircraft motors. Step back to a safe distance and slowly raise the left stick to above the center position. The drone will take off slowly and climb until the stick is returned to the center position, then hover at the desired altitude until further commands are given. Raise the landing gear by flipping the landing gear switch on the top of the control tablet to the up position.

Data Collection

Take time learning how the Typhoon H responds to various control inputs while flying. The left stick controls altitude and heading, while the right stick controls direction and speed. The control tablet display will provide a measure of altitude, speed, battery life, as well as a live feed of the gimbal camera's view. A green arrow will always point back towards the pilot and may be useful in locating the drone if the pilot loses track of its orientation. Always keep the drone in visual line of sight (VLOS), being extra careful not to lose the drone amongst the chalk formations. It is against the FAA Part 107 rule to operate a small UAS out of VLOS, directly above people, at night, or at an altitude higher than 400 feet. Always keep the Part 107 rules and safety in mind. Immediately land the drone upon the first low battery warning.

The curved cable cam mode allows the user to create an invisible route for the drone to fly along. Once the pilot sets the point, the drone will fly to each location remembering the altitude and heading, as well as the angle of the gimbal camera. The six monitoring points with two photos each are already programmed into the Typhoon H, but the drone cannot reach all six features from just one takeoff location. The Inscription Wall flight path contains 2 photo points, the Oil Pad overlook takeoff location can capture 6 photo points, and the Ramada takeoff location captures 4 photo points. To enter curved cable cam mode, tap the task/camera icon in the bottom right hand corner of the tablet touch screen. The task icon should become orange, then the interface will display five different functions. Tap the curved cable cam function and select “list.” Three lists of points should appear corresponding to each takeoff location. Tap the location you are currently at and move the slider to start the flight path. The drone should automatically begin flying along its route to point 1. To adjust the speed of the drone, hold the left stick to the right of center to gain speed, or the left of center to reduce speed.

Once the drone reaches its first point, it will stop. Press the photo capture button indicated by a camera located near the bottom left corner of the control tablet. Quickly flick the left stick above center once to command the drone to move to its next point. Repeat this process for each point along the flight path. Once aerial photographs have been captured at each point, tap the exit button and then tap the task/camera icon again to enter manual flight mode once more.

Landing

The drone may be returned to the pilot utilizing two different options: Manual flight, or the home flight mode. To manually fly the drone back to the pilot, follow the indicator arrow on the flight tablet display until the drone is close to the pilot, but still a sufficient distance away to safely land. Lower the altitude of the aircraft by lowering the left stick below center. Lower the landing gear by flipping the landing gear switch to the down position. Slowly lower the altitude of the drone until the landing gear barely touches the ground. Turn off the motors by holding down the red on/off button on the top of the flight control tablet. Alternatively, flip the flight mode switch on the top right of the flight control tablet to “home.” The aircraft will fly itself back to the home point and land. Following landing, always turn off the Typhoon H before the flight control tablet. Do so by holding the power button on the drone, then turn off the flight control tablet. Replace the gimbal cover, remove the rotor blades, and remove the drone battery to cool. Detailed instructions on drone maintenance and downloading the images from the micro SD card may be found in the equipment maintenance section of this document.

Equipment Maintenance

Trail Cameras

Each of the five trail cameras are anchored to a landmark or anthropogenic feature using a strap fed through the protective case on the camera. The protective case features a python cable lock, fed through the holes on the case to deter theft. Approach the camera and use the smallest Masterlock keys to unlock the python lock. Remove the lock entirely from the protective case, then detach the front cover. Remove the camera from the case and power it on. Check the battery status and number of photographs on the memory card by placing the camera into “photo” mode. If the battery charge is lower than 50%, replace all the batteries in the camera with new batteries. Replace the memory card with the empty designated memory card from the carrying case. Ensure the photo count is zero and the battery charge is full, then place the camera back into photo mode. A timer counting down from 60 seconds should be visible on screen. Place the camera back in the case, replace the front cover, and relock the python cable. Tuck the end of the python lock into itself to minimize perceptibility caused by a hanging cable. Retighten the strap and check that the angle of the camera is looking straight ahead. Upon return to Manhattan, upload the photos from the memory card onto the project hard drive into the correct folder. Once all photos are confirmed to have been uploaded, empty the memory card entirely and place the empty card back into the designated slot in the memory card carrying case.

Cellular Trail Camera

The number of photographs on the cellular camera and the battery status may be checked from the Spypoint app login associated with the camera (Username: Kstatepmc@gmail.com Password: Ksupmc). Only service this camera if the battery charge has less than one third remaining. Like the other trail cameras, the single cellular trail camera utilized in this monitoring protocol is anchored to a chalk formation overlooking the end of the interpretive trail. However, unlike the other cameras, the cellular camera has no lock or case as to not interfere with the cellular service nor field of view. When servicing this camera specifically, climb the back of the formation where there are natural footholds present so the formation is not eroded further. Remove the camera from the mounting screw by twisting the camera from the base. Power on the camera and confirm that the battery status is one third or less. Replace batteries and remove the old memory card to be replaced with the empty designated memory card in the carrying case. Confirm that the batteries are now fully charged, enter photo mode once again, and ensure the 60 second countdown begins before remounting the camera on the base. The angle of the camera should be aimed slightly downward to capture the trail overlook and surrounding vegetated area. Climb down the formation utilizing the same natural footholds to limit degradation to the resource. Upon return to Manhattan, upload the photos from the memory card onto the project hard drive into the correct folder. Once all photos are confirmed to have been uploaded, empty the memory card entirely and place the empty card back into the designated slot in the memory card carrying case.

Digital Camera

The digital camera must be fully charged before each trip to the site. Keep the lens cap on the camera whenever not in use. Once data collection is complete, upload the photos from the camera memory card onto the project hard drive. Once all photos are confirmed to have been uploaded, empty the memory card and place it back into the camera.

Trail Counter

The trail counter, located on the fencepost adjacent to the interpretive ramada, surveys foot traffic entering and exiting the Rim Trail. Approach the counter and unlock the padlock securing the protective case using the hexagonal Masterlock key. Place the side panel aside and remove the counter and its attached scope camera from the protective case. Open the plastic housing to expose the counter mechanism. To connect the counter to a computer for data retrieval, remove the counter from the housing to connect the counter to the dock. Confirm the dock is in PC mode by identifying the flashing red light is highlighted next to PC mode. If the dock is not in PC mode, press the button on the side of the dock until PC mode is highlighted. Push the counter's gold contacts directly into the slot on the PC dock. Connect the USB to serial adapter to the serial slot on the dock, then plug the USB connector into the USB port on the APS Lab Surface Pro. Launch the TRAFx software on the Surface Pro, and click the large "GO" button in the upper left hand corner of the software. The counter should begin to communicate with the computer, and text should be visible in the main box of the software. If the counter does not communicate with the software, replace the batteries and try again.

To download the counter data onto the Surface Pro, click the "Download+" button in the software to save the counter log as a text file. Save the file to the appropriate project folder, and confirm the save was successful by opening the file. Once the file has been downloaded into the project folder, enter the letter “E” into the software textbox to erase the previous logs from the counter. To prepare the counter for data collection, type “C” into the software text box to enter configuration mode. Enter the date and time in the correct format and press enter. To launch the counter, type “L” into the software text box and enter the required start time information. If successful, the software should relay that the counter has been launched. Remove the counter from the dock, place it back inside the plastic housing, and place the entire unit back into the metal case. The camera should be facing out of the hole straight ahead with nothing impeding the lens’ viewpoint. The entire setup should be directed towards one section of trail, not an area where two sections overlap which may cause inaccurate counts. Replace the side panel of the metal case and relock with the padlock. Upon return to Manhattan, place the downloaded text file into the proper folder on the project hard drive.

Drone

The Typhoon H is powered by a 5400mAH 14.8v lithium polymer battery which gives approximately 25 minutes of flight on a full charge. The APS lab has three batteries for the drone, all three of which must be entirely depleted after each flight. If the batteries are allowed to sit for an extended period while fully charged, the lifespan of the battery may decrease, maximum flight time may be reduced, and leaking may occur. It is very important that all batteries which were charged for the flight are fully depleted before packing up the drone. Batteries may be recharged one to two days before the next research trip. Only charge the batteries utilizing the charger included with the Typhoon H. To remove the battery from the aircraft, pull the lever on the back of the battery and remove from the airframe. Install the battery firmly onto the charger and check for the red flashing light. Each battery takes approximately two hours to charge and should be removed promptly once the “full charge” warning beep sounds from the charger. To reinsert the battery, push the battery firmly into the slot on the back of the aircraft until an audible "click" is heard. The flight control tablet may be charged from the same charging station using the included micro USB cable. Simply plug the cable into the base and charge the tablet.

Thoroughly inspect the drone airframe after each research trip, checking for cracks, damaged plastic, loose wires, or missing parts. Do not conduct further flights unless the drone is in pristine condition. Use the included cleaning cloth to wipe the lens of the camera and clean all dust and debris off the body of the drone. Damaged rotor blades should be discarded to prevent accidental use. Inspect the batteries for leaking, bulging, or other forms of damage and do not use them if any of these conditions are noted.

To retrieve the aerial photographs from the drone memory card, remove the protective plastic cover from the gimbal. Remove the micro SD card from the back of the gimbal by pushing gently on the card in the slot. Once the card pops out, remove the card and insert it into the included SD card adapter. Insert the adapter into an SD card to USB adapter and download all photos onto the designated project hard drive into the appropriate folder. Once the photos are confirmed to have successfully transferred onto the hard drive, delete all files from the SD card, remove the micro SD card from the SD card adapter, and reinsert the card back into the slot on the drone. Ensure the SD card clicks into place and is secure. Replace the gimbal cover once data retrieval is complete.

Data Analysis

Visual Inspection

When dealing with photogrammetric data, visual inspection is a tried and true method to quickly and easily identify change in a set of photographs. This monitoring protocol relies on visual inspection to identify visitor created trails and miscellaneous site impacts which are not specifically listed as indicators of interest but may still play a role in determining the management plan for Little Jerusalem.

To inspect the aerial drone photographs for new visitor created trails, simply sort through the photographs at each key location and record any instance of what looks to be a visitor created trail. Keep detailed notes, mark up the photographs, and create Excel spreadsheets as needed. The same may be done to identify miscellaneous impacts. The digital photographs taken during data collection trips will often contain images meant to document impacts to the park outside of the identified key locations. Remember, the results of this protocol are to be used for applied management of the park rather than scientific publication, so data should be easy for managers and park staff to interpret. Visual data is often more effective at encouraging pro-conservation managerial action than tables or figures, so use this method to your advantage. If a visual inspection identifies severe impacts which may need managerial attention, other "on the ground" methodology may be utilized to further explore the problem. Visual inspection is a perfectly viable preliminary method to identify problem areas in the park.

Excel Spreadsheets for Wildlife Presence and Visitation Rate

Several steps within this monitoring protocol yield data in the form of photographs. While visual inspection may be enough to point out obvious changes to the makeup of Little Jerusalem or large impacts to the site's ecology, quantifying certain elements found within the trail camera photographs, aerial drone photographs, and digital photographs may help to better represent long-term impacts. As the managers of Little Jerusalem were concerned with wildlife displacement, it made sense to catalogue all the wildlife captured within the photographs collected at the park, especially those of the trail cameras. The trail cameras occupy specific fixed locations in several different areas of the park; thus, this step of the monitoring process provides a randomized sample of wildlife presence in areas of the park which may or may not be subject to visitation. Better yet, the ability to collect baseline data before the park opened to the public allows for the comparison of wildlife on site pre-and post- opening to gauge the effect that recreational use may have on wildlife displacement.

Cataloguing people captured on the trail cameras also bolsters the efficacy of this monitoring protocol. Again, as the trail cameras occupy set locations across the park, the unsanctioned movement of visitors off the official trail system may be documented and utilized to help explain significant impacts to certain areas of the park. On top of this, the trail cameras recorded the baseline visitation rate prior to park opening, documenting trespassers, park employees, and construction crews whose activity may have caused degradation to the site's ecology even before official visitor use was permitted.

To catalogue the pictorial data from the various cameras utilized in the monitoring protocol, open the two Excel spreadsheets located on the project hard drive titled "LJB Species Classification" and "LJB Visitation Spreadsheet." These two documents serve as the catalogues to translate the subjects in the thousands of images captured at Little Jerusalem into quantitative data which can be used to aid in the site management process. Simply scroll through each individual photograph and enter the required information into the proper rows on the spreadsheets. Ensure that visitors are entered into the visitor spreadsheet and wildlife are entered into the wildlife spreadsheet. To classify visitors, enter each photograph with a person into the spreadsheet, regardless of intentions (Enter all employees, visitors, cars, ect.). If the same individual or group of individuals are spotted in repeated images, enter only the first image in which they appeared, adding the information pertaining to the last image and time they were seen in the comments section of the entry. For wildlife, enter all confirmed instances of wildlife occurrence, but do not enter images that simply look similar to wildlife or cannot provide the level of evidence necessary to classify the image. Repeat this process after each month of data collection, adding to the same spreadsheets over time.

Counter Graphs

Following data collection, the counter data should be uploaded to the TRAFx website for analysis, www.TRAFx.net/datanet (Login: RLSharp@gmail.com Password: KSUPMC). Once logged into the website, upload data by clicking the "upload" button along the upper page banner. View the Little Jerusalem counter data from the home screen. From here, the website can analyze the desired time frame of data in the selected units and present various graphs, tables, and more. This process is far simpler than analyzing the data in Excel and provides the user with a plethora of options to best present the data to park managers.

Drone Aerial Photograph Analysis

Recall that the aerial drone photographs provide indicator data for two site impacts: Visitor created trails and vegetation loss. Visitor created trails are identified through a rigorous visual inspection of each overhead photograph from month-to-month and may be conducted in conjunction with the vegetation loss analysis. Conversely, vegetation loss is quantified utilizing SamplePoint, a simple program which facilitates vegetative cover measurements from aerial imagery by superimposing a systematic array of crosshairs which target single image pixels. These pixels are then classified by means of user-defined categories, and data is saved automatically to an Excel spreadsheet. The program presents a free scientifically-sound method for quantifying vegetation loss from repeat drone photo points from month-to-month, while maintaining ease of use and simple interpretation of results.

To begin vegetative cover analysis, download SamplePoint onto your computer and open the program. Ensure all images taken from the drone are separated into folders based on location, and the date the photograph was taken is present in the file name. Overhead photos only should be used for analysis of vegetation loss. For example, one folder containing all overhead photographs taken at the Inscription Wall, another folder containing all overhead photographs taken at the Oil Pad Overlook, and so forth will be placed into individual folders. In the options menu in the upper left corner, select “create database.” Type an appropriate name, then select populate database and highlight all the aerial photographs to be analyzed for that one specific location. Open the new database by selecting the “load database” button from the options menu. Select the Excel file automatically created by SamplePoint. The number of images to be analyzed should appear in a pop-up box.

The SamplePoint program is pre-configured with default “buttons,” selection options which allow for the classification of pixels in the aerial images. The Little Jerusalem monitoring protocol utilizes custom buttons specific to this project to classify the sample pixels. To create a custom button file, mouse over “custom buttons” in the options menu and select “create custom button files.” A screen will appear with blank boxes to define the custom buttons. Create buttons with the following categories:

- Visitor
- Trail
- Manmade
- Bare
- Vegetation

The visitor button will be used to define pixels in which visitors are present rather than the natural topography. Similarly, the trail button is selected to define a pixel which is sampled along the official designated trail system captured in locations such as the overlooks or Rim Trail bridge. Manmade is a classification which may be used to identify a pixel contained by a manmade object such as an interpretive sign, bench, trash can, or other manmade structure. The bare and vegetation buttons are the two most important classifications, used to define a pixel contained by a patch of bare ground or a pixel which is composed of vegetation. The custom buttons are an extremely important part of measuring the vegetation loss indicator, as the default buttons prepacked with SamplePoint are not conducive to a park setting. Save the custom button file in an easily accessible folder and load the custom button file by selecting “load custom button file” from the options menu. The custom buttons should replace the default buttons along the bottom of the screen.

Now, we are ready to begin image analysis. By default, SamplePoint has a grid size of 10x10, meaning 100 crosshairs are overlaid onto the image for sampling. The program has options to increase the number of points sampled, or even randomize the location of the points in each image, but 100 sample locations is standard protocol in the literature for vegetation sampling. In the options menu, ensure the grid size is set to the 10x10 default, then click the “begin” button in the upper right corner. The first image will appear on screen, along with the 100 crosshairs to be defined. When classifying each sample location, classify only the center most pixel inside of the crosshair, not the area around the pixel. Click the corresponding button which matches the pixel inside the crosshair and repeat this process for all 100 sample locations within each image. To properly orient the location of each crosshair or get a closer look at an individual pixel, the zoom function may be accessed using the arrow keys or mouse wheel. Once all 100 points in the first image are classified, click the “next image” button in the upper right corner of the software. Complete this process for all images in the database and inspect the resulting Excel spreadsheet to ensure the data has been properly recorded. Lastly, SamplePoint has an option to create a statistics file for each database, resulting in an Excel spreadsheet which displays the percentage of each category in every aerial photograph. Upon completion of each database, select “create statistics files” from the options menu. Create databases for the rest of the drone flight locations and repeat the process until a statistics file is generated for each location. The percentile data contained in the statistics files may then be compiled into a single spreadsheet for further analysis and the creation of graphs, tables, or other figures.

Management Plan

The rigorous process of data collection and analysis in accordance with the Little Jerusalem Badlands State Park recreational impact monitoring protocol would be for naught if the results are not regularly shared with park managers. An effort should be made to draft a management plan with the most up to date scientifically sound recommendations for management based on the collected data to be presented to park managers and staff at least once per year. This document should be simply written, avoiding any scientific jargon, and presenting key information in the most user-friendly manner possible. The utilization of pictures, tables, and graphs is preferable to written analysis or to compliment written recommendations. Be sure to pair data from the monitoring process with applicable solutions to slow or correct the noted impacts to the site. On top of the yearly written report, continuous contact with staff from each of the management agencies, TNC and KDWPT, is a must to maintaining an effective working relationship and acting on the best interests of Little Jerusalem. The ecological health of the park may depend on the successful partnership between the Kansas State University APS lab and the two land management agencies responsible for Little Jerusalem. A momentous level of care should be taken to guarantee this monitoring protocol continues to yield useful data to aid in the decision-making process and protect this unique Kansas gem for many generations to come.

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Appendix A - Overhead Drone Photograph Dataset

Oil Pad Overlook

Figure 3.6 An aerial drone photograph of the Oil Pad Overlook, September 2019.

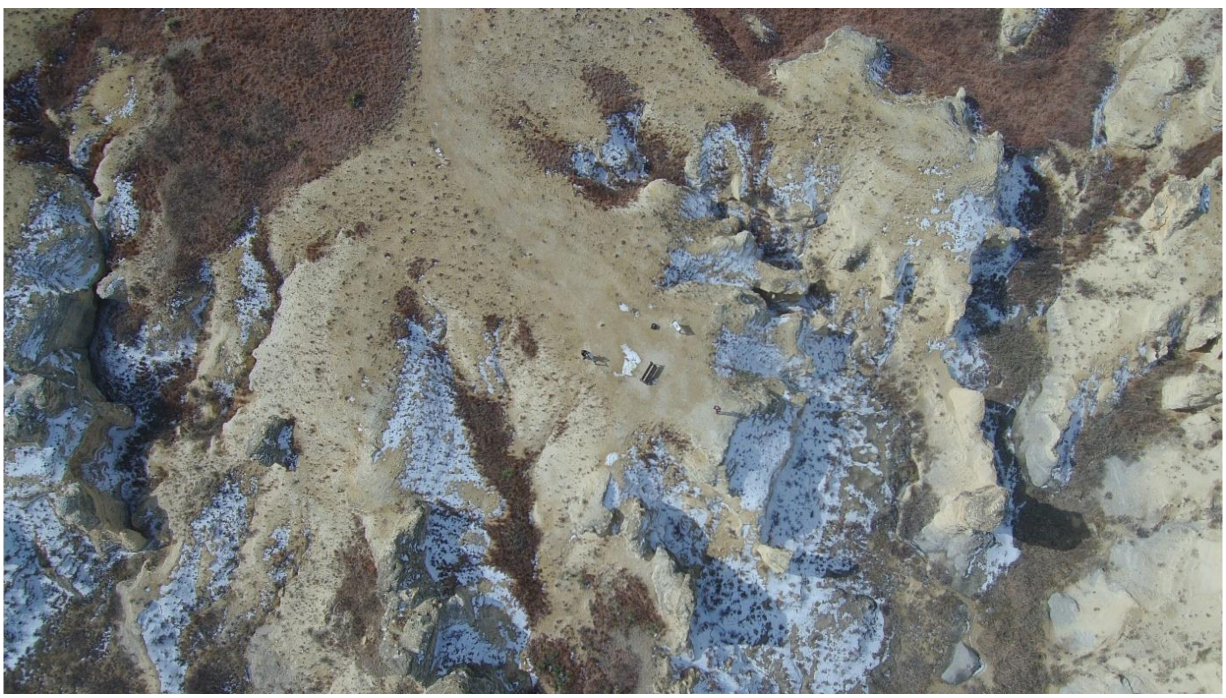

Figure 3.7 An aerial drone photograph of the Oil Pad Overlook, February 2020.

Rim Trail Bridge

Figure 3.8 An aerial drone photograph of the Rim Trail Bridge, September 2019.

Figure 3.9 An aerial drone photograph of the Rim Trail Bridge, February 2020.

Rim Trail Overlook

Figure 3.10 An aerial drone photograph of the Rim Trail Overlook, September 2019.

Figure 3.11 An aerial drone photograph of the Rim Trail Overlook, February 2020.

Inscription Wall

Figure 3.12 An aerial drone photograph of the Inscription Wall, September 2019.

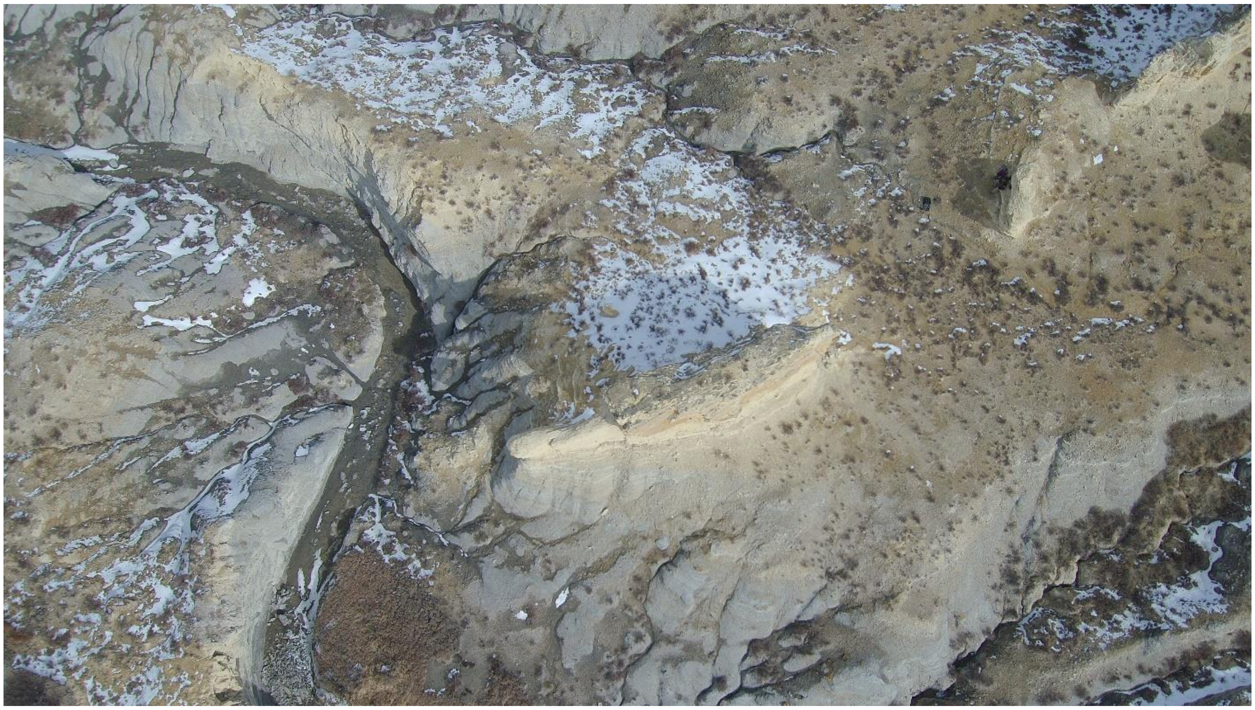

Figure 3.13 An aerial drone photograph of the Inscription Wall, February 2020.

Ramada

Figure 3.14 An aerial drone photograph of the Ramada, September 2019.

Figure 3.15 An aerial drone photograph of the Ramada, February 2020.

Life on the Rocks Trail Overlook

Figure 3.16 An aerial drone photograph of the Life on the Rocks Trail Overlook, September 2019.

Figure 3.17 An aerial drone photograph of the Life on the Rocks Trail Overlook, February 2020.