Implementing a Data-Driven Approach to Natural Resource Management

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Final Project

Project Purpose

This quarter our team set out to work with San Mateo County Parks Department in establishing a database of Wildlife biodiversity information to inform land management decisions in the county. Our goal this quarter was to accurately organize and visualize the existing camera trap data for the San Mateo County Parks Department, helping to create a comprehensive Wildlife Picture Index for our region that will be used to provide quantitative evidence for land management decisions in the greater San Mateo County.

Our community partner this quarter for our Wildlife Biodiversity project was the Parks Department of San Mateo County. The County's Parks Department manages 20 separate parks encompassing over 17,000 acres of land. The county is covered 42% by protected lands and reaches across a wide diversity of natural ecosystems and biodiversity in plants and wildlife. Funding structure in public organizations is critical to how projects are completed and what the Parks Department is able to do. The department is funded out of the San Mateo County general fund, which is split between parks and many other critical county services, such as healthcare. Our primary contact is David Jaeckel who is a Management Fellow in the Office of Sustainability within the Parks Department. Our team also worked with Ramona Arechiga who is the Natural Resource Manager for the County, who was hired in recent years as the park transitions to a stronger focus on sustainable land management.

The Parks Department is constantly assessing the parks space and how it can be best managed in the interest of the people and the natural ecosystems. The parks department previously worked with the focus of preserving the parks for mainly for human enjoyment and experience. In recent years the park has been able to access funding and hired a Natural Resource Manager (Ramona Arechiga) for the county parks to take action on broader ecosystem and species management. In order to achieve these goals for the county, the Parks Department needs to assess new projects and ways to utilize the county park space in order to protect the environment and make the spaces more enjoyable for the county. In our project is was crucial to understand how these decisions are made and with what organizations the parks department interacts with in various approval processes. Our baseline dataset would be immensely influential and helpful to the parks department in quantifying the benefits of the ecosystem to the county and navigating discussions with various governmental organizations in the approval process. The Parks Department works with San Mateo County Planning Department for general permitting purposes. When proposed projects are in the coastal zone, the department with work with the California Coastal Commission. For projects which are adjacent to sensitive habitats or water bodies, the parks department will work with California Fish and Wildlife or the California Regional Water Quality Control Board.

There are specific challenges that San Mateo County faces with natural resource management and park program assessment which are important to consider. When the parks department makes land management decisions and must work with the aforementioned organizations to come to an agreement, it is often difficult to make a data-driven case for the department. It can be very difficult to quantify the benefits of natural landscapes and ecosystems, and because of this, many natural resource managers use anecdotal evidence versus actual data. It is immensely important to give land managers data on which to strengthen their case when attempting to acquire land or implement natural resource management actions to improve the ecology of a protected landscape.

Our project helps with this challenge by working with the San Mateo County Parks Department to support data-driven decisions in natural resource management by searching and providing baseline data to inform future actions. Our team also helped to install wildlife cameras to start the County's Wildlife Picture Index project. With this work, we are happy to support data-driven decisions in land management for local government in the Bay Area.

A Wildlife Picture Index (WPI) is an innovative tool that combines photos from camera traps with important environmental data in order to understand how well efforts to protect biodiversity are functioning. WPI helps natural resource managers to monitor biodiversity and fluctuations in populations of medium and large mammals and birds. There are currently projects all over the globe including Brazil, Costa Rica and Indonesia in order to monitor large mammals such as Elephants or large cats. There are many ways that a WPI will be helpful to San Mateo County as they set up their first camera traps. First this project will help to develop a baseline dataset to show what animal species are present in the parks, and how these species are being monitored over time. This dataset will also be helpful for the county to think more broadly about habitat fragmentation and wildlife corridor continuity. Second, the WPI project for San Mateo will provide insights on mountain lion frequency and presence of non-native or exotic species (such as feral pigs, red foxes and turkeys) in the parks. Finally this WPI will be influential in kickstarting civic engagement in connecting the public with images of wildlife from local parks. These images can also helpful in establishing strong relationships with other local sustainability and conservation groups. Stakeholders include but are not limited to the following: San Mateo County Parks Department, regional public/nonprofit organizations, surrounding semi-urban areas, county residents, the natural environment, and local biosphere. In our literature review we review sources which consider stakeholder differences and equitable solutions for sustainability. These complex issues are important to consider when attempting to best understand our stakeholders in the context of our project and the Bay Area as a whole.

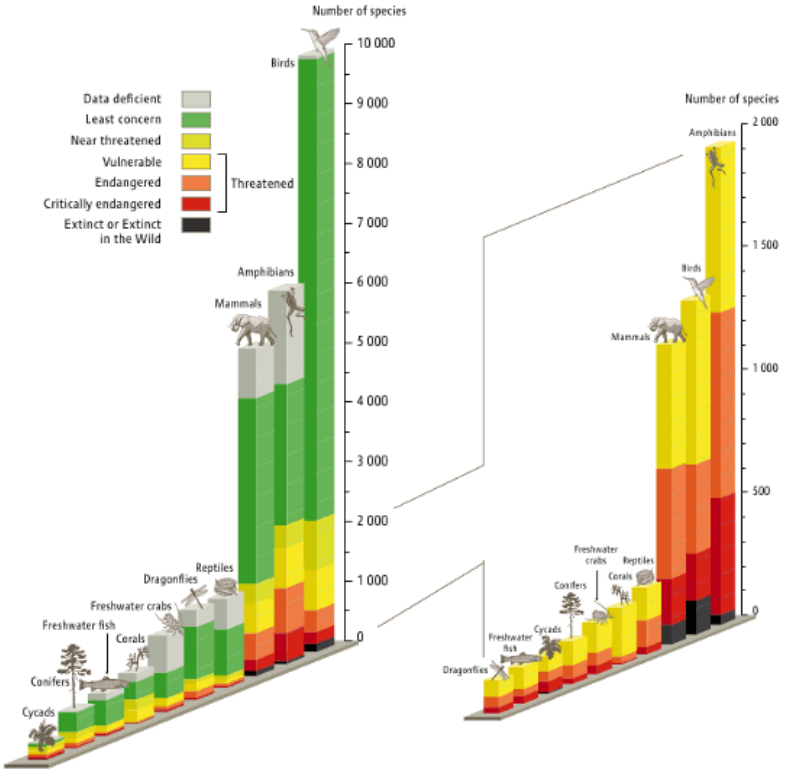
In both the beginning and throughout our course, we discussed the Sustainability Framework as it relates to Sustainable Cities and urban initiatives. The framework helps to break down our modern and wholesome understanding of sustainability and has four main pillars: Environmental Quality, Economic Vitality, Cultural Continuity and Social Equity. These pillars are an important reminder and framework that we brought to our project this quarter, but are also important to bring into all sustainability projects in the future. Our work this quarter, in supporting good land management decisions, directly affects the natural landscapes and ecosystems in San Mateo County Parks and thus ties back to Environmental Quality. We have worked to create this baseline dataset with the hope of enabling natural resource managers to make stronger arguments for project funding which benefits our ecosystems. In this way we are supporting the long-term funding continuity of San Mateo County Parks Department project funding, which ties back to Economic Vitality for the County. This funding and ability for the County to pursue other projects will help ensure that the Parks are an important part of San Mateo County for years to come, and this outcome relates back to long-term Cultural Continuity. Finally, there are low-income populations who are unable to afford a car or transportation and thus are not able to have the same access to appreciate our parks system or learn about the environment. While the County is working on a shuttle system to provide greater access to a wider variety of socio-economic levels, our project, in providing accessible and understandable ecosystem and wildlife data to the public, gives broader environmental learning opportunities to those who do not have access to a car. This broader accessibility to all populations of various

income-levels ties back to the pillar of Social Equity in the Sustainability framework which we have discussed in class and amongst our group.

Literature Review

Massive Extinctions From Human Activity

The current extinction rate is approaching 1000 times the rate between mass extinctions and is expected to rise to 10,000 times this rate, creating a loss similar to past extinctions. The Millennium Ecosystem Assessment noted that this biodiversity loss is irreversible with 30-40% of mammals facing extinction. At threat of extinction are approximately 1 out of 8 birds, 1 out of 4 mammals, and 6 out of 7 marine turtles to name a few. 75% of agricultural genetic diversity has also been lost along with one-third of reef-building corals being threatened by extinction. All



of these species are part of what makes the planet work and thus necessary for human survival.

The UN's Global Biodiversity Outlook noted that biodiversity loss is not decreasing because pressure on the ecosystem is not decreasing. Specifically, habitat loss and degradation, climate change, excessive nutrient load and other forms of pollution, over-exploitation and unsustainable use, and invasive alien species continue to break down ecosystems around the world. The Red List is an indicator that monitors species overtime and created the image on the side to demonstrate the level of extinction risk for various animal groups. Some of the causes of these high levels of extinction risk are overuse of resources, ocean acidification, habitat destruction, and fragmented habitats.Unfortunately, research of long term fossil records show that the rebound rate of biodiversity after species extinctions is very limited suggesting it will

take a long time for the world to recover from the level of extinction mapped in Figure 1 and predicted to be over a million species over the next 50 years. This mass extinction will have vast ramifications throughout ecosystems across the globe potentially causing large scale agricultural problems among others.

The Socio-Economic Costs of Biodiversity Loss

Mass extinctions naturally occur with five known mass extinctions occurring over the Earth's lifetime but normally phenomena such as ice ages or meteor strikes precede them. In the period between these mass extinctions, extinctions generally occur at a rate of .1 to 1 species per million species. However, global change through changes in land use, climate change, overexploitation of resources, and the expansion of invasive species has caused extinction rates 100 to 1000 times higher in the two centuries since the industrial revolution. Due to this increased rate of extinction, some scientists are referring to this period as the "sixth great extinction". Unfortunately, biodiversity plays an important role in the welfare of human society through ecosystem services. While direct benefits from the environment such as food and resources are easily measured, other cultural or societal benefits such as the protection mangroves provide are often overlooked or financially miscalculated. In the case of mangroves in Thailand, a study showed that the mangroves saved more money through coastal protection than the same area turned into a shrimp farm could produce. This study highlights the issue of macro-economic calculators solely relying on data through trades in the market reflected in GDP causing the final calculation to undervalue vital ecosystem services.

The Economics of Ecosystems and Biodiversity released a report attempting to assess the economic benefits of the ecosystem and biodiversity. The report came to the conclusion that the economic value of the environment accounts for 10 to 100 times the cost of conservation. The report also states that in 2050 7% of global welfare risks being lost, a number cited as conservative given that the report did not take some ecosystems like the arctic and deserts into account. While the aim of economically validating conservation is important, often there is a lack of data to prove conservation is worth the money. In these cases it is important for conservation for its own right to be enough to convince policy makers it is worthwhile or at least that the value might be worth it in the future.

Conservation Easements: Biodiversity Protection and Private Use

This paper discusses the concept and importance of "conservation easements," which are essentially voluntary agreements with private landowners in which land trusts or government agencies restrict land land use in exchange for payments and/or tax reduction (Rissman et al, 710). These agreements are important because private land is often important for conservation efforts. In fact, some or all of the habitat for 85% of federally listed endangered species is found on private land (Rissman et al., 710). The issue, however, is that many conservation easement contracts are allowing for activities that seem contrary to the interests of the species being conserved, such as construction of commercial or residential buildings. Even industries like ranching, forestry, or farming, which directly impact the natural environment, are being allowed on more than half of easement properties surveyed by this study (Rissman et al., 715). Though the primary purpose of these conservation easements is to limit development, it seems as though the terms of the restriction vary greatly, and some private landowners are taking advantage of the easements for undeserved personal gain. As such, the study recommends that a closer look be

taken at conservation regulation, and to strengthen the regulation so that more of the land is actually conserved for the species the program is intended to protect.

This paper highlights a tactic that public entities have used to aid in conservation efforts, as well as the difficulties in finding a balance between private and public interest. For our project, we are operating mostly in public land, but the fauna we are aiming to conserve are rarely constrained to our arbitrarily-drawn lines. Because of this, working together with private landowners is essential to create wildlife corridors that species can use to travel from one protected area to the next with minimal human interference. By mapping out potential wildlife corridors as a part of our (and the greater Wildlife Picture Index) project, we are identifying areas of private land that are likely to be important for species protection. If the land is vital to certain species, it may be necessary to negotiate something like a conservation easement with the property owner. Though we wouldn't be in charge of that negotiation, it is good for the team to know that conservation easement is an option that allows for a form of public/private collaboration in conservation efforts.

The Why, What, and How of Global Biodiversity Indicators Beyond the 2010 Target

The 193 signatories of the 2002 Convention on Biological Diversity(CBD) agreed to "significantly reduce the rate of biodiversity loss by 2010." While this well intended plan might not have achieved the results it set out for, the conversation is not over. Post 2010 targets are now being considered with an emphasis on the indicators used to verify whether or not the target is reached. Indicators represent the nexus of learning about a system, detecting change, raising awareness among policy makers, auditing management actions, and informing policy decisions.Using reliable indicators is important because each indicator pulls funding from other conservation efforts and thus the benefit of the information must outweigh the loss of the money for other programs supporting conservation.

Indicators are evaluated by a multitude of criteria to measure performance. One of the primary benchmarks is cost effectiveness. Given the limited amount of conservation funding, an indicator that requires less money but produces an equally important indication will overtake other current indicators. For reference, the Forest Resource Assessment cost $25 million over the past 5 years while the World Database of Protected Areas costs $1 million annually to maintain. The Living Planet index costs $250,000 annually while the Red List Index costs $1.6 million annually. All of these are current biodiversity loss indicators that are at the forefront of biodiversity loss analysis and measurement.

Subsidiary yet important criteria help evaluate whether an indicator is cost effective. The taxonomic diversity of an indicator helps show its relevance through sheer quantity of species monitored. Relating to this is the concept of pertaining to multiple regions. The pertinence of an indicator to larger regions such as continents or larger ecosystems makes an indicator more useful across the globe and thus more useful in general. Among other gauges of effectiveness, an indicator must be meaningful to the public. The more publicity an indicator gets the more money it will potentially receive while concurrently spreading awareness of the necessity for conservation.

Biodiversity indicators can exist without representing every aspect of biodiversity in every region of the world if they present a necessary aspect of biodiversity well and at a low cost. Measuring biodiversity loss costs a lot yet provides necessary data to inform the public and policy makers of the state of our planet. Specifically for policy makers and protected land

managers, biodiversity indicators also provide real time feedback for management techniques and changes, allowing the managers of these spaces to react promptly and appropriately. Biodiversity indicators serve an important purpose but still have room to grow and improve based on the guidelines mentioned with a primary focus on cost effectiveness.

Evaluation of a Multiple-Species Approach to Monitoring Species at the Ecoregional Scale

Species monitoring is a necessity for conservationists and land managers alike in order to evaluate land and species management. However, an in-depth study of many species is costly in time, effort, and funding. Because of this, organizations often resort to "shortcuts" in order to reduce costs (Manley et. al., 296). One of the most commonly used shortcuts is to study a few species in-depth. The idea is that "the status of a small set of carefully chosen individual species can represent the integrity of an entire ecosystem" (Manley et al, 296). Since monitoring many species is costly, the approach makes sense from a practical perspective. However, it has a few important flaws. The species that are chosen as indicators are often subjective, meaning the few chosen species may not represent any other species or show strong relationships with management, serve as indicators of current stressors or future threats, and may simply be difficult to accurately monitor with certainty (Manley et al, 297). Since a lot is invested into the analysis of the whole ecosystem based on the indicator species, the approach is very risky.

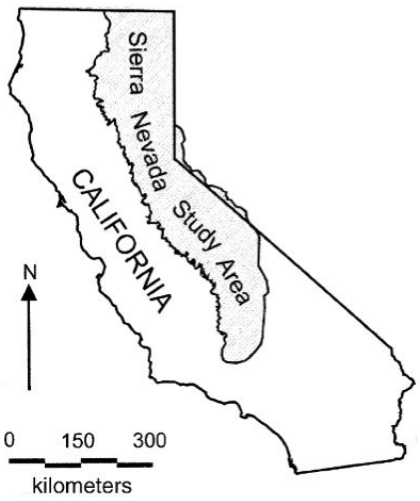


FIG. 1. Location and bounds of the Sierra Nevada study area in California and Nevada, USA.

To combat these issues with that common approach, this paper describes a method by which multiple species are monitored and used as indicators for the overall health of the ecoregional system. Instead of attempting to determine complex relationships between a few species and every other, this new approach uses basic absence-presence data on a large number and breadth of species all across an area (Manley et al, 297). In this way, a greater number of species could be tracked and used as a representation of the whole ecoregion. In addition, instead of needing to infer complex relationships between species, simple presence-absence data could lead to finding new connections between species and their environment.

The study itself took place in a section of the Sierra Nevada, in both California and Nevada. The area is shown in Figure 1. The study area was then filled with a grid of camera traps, as shown in Figure 2. Since the target of the study was vertebrates, the team curated a list of 465 vertebrate species (excluding fish) that they were looking to detect. The study found that of the 465 species, approximately 76% of them could be adequately detected using the wide range presences-absence method (Manley et al, 302). This shows that the approach is at the least viable, and presents a reasonable, low-cost alternative to resource-intensive single- or few-species indicators.

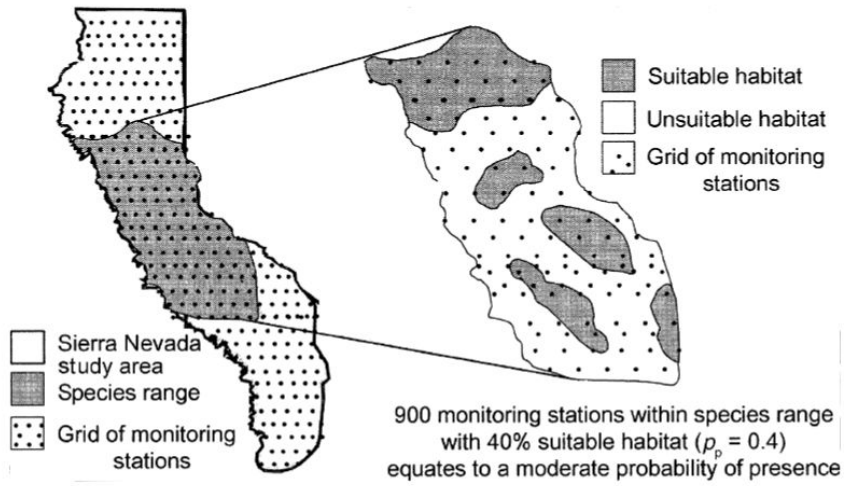


FIG. 2. Example calculation of number of monitoring stations within a species' range and probability of presence (p_p), the proportion of the range occupied by suitable habitat.

This research paper essentially confirms the viability of wide-range presence-absence data collection for monitoring species. Since this approach is essentially the foundation of the Wildlife picture index, this paper reassures us that the San Mateo County Parks Department's methodology of species detection is valid. This means our project will be able to effectively contribute to species conservation in San Mateo County.

The Wildlife Picture Index: monitoring top trophic levels

The Convention on Biological DIversity(CBD) mandated the use of indicators to monitor biodiversity by 2010. Most indicators rely on assumptions, secondary data, or expert opinion but lack little primary data to back these theories up. Here the Wildlife Picture Index(WPI) steps in as a primary and concrete measurement of medium to large sized birds and mammals across the world. The WPI then creates a geometric mean based on the data it collects from various points on a landscape-scale to provide a better picture of the rate of biodiversity loss. The first step in slowing biodiversity loss is the protected lands across the world creating safe spaces for animals. However, there is little data to prove that these areas are actually stalling or slowing biodiversity loss, a necessary measurement the WPI provides.

The WPI consists of camera trapping data coupled with occupancy analysis and generalized additive models. This is the most concrete indicator to date as it relies on primary evidence in the form of photos to analyze and predict where animals are and at what frequency they appear in a region. Camera data has increased its efficiency as technology has developed to allow the cameras to catch better photos, more photos, and good night time photos. At the same time, abundance equations have improved to provide a more accurate overview of an area. Abundance analysis becomes faulty, however, when species are not accounted for or there is a rare species in the dataset.

The Wildlife Conservation Society's WPI in Bukit Barisan Selatan National Park in southwest Sumatra, Indonesia provided a solid base for analysis of the efficacy of a WPI as a biodiversity indicator. From 1998 to 2006, five camera trap studies were conducted in the 3568km^2 area. From their images they created a WPI based on 25 mammals and 1 bird species all of which were photographed enough times to create significant datasets. Over the course of the study they calculated a 36% decrease in the biodiversity of the area. This data coupled with

data mapping forest loss showed that species decline was greater than forest loss pointing to hunting as another form of biodiversity loss. The trend of loss was also shown to be increasing in more recent years. This analysis proves the usefulness of a WPI and creates a guideline for future WPI's.

Primary data created by camera trappings provides a missing and crucial aspect to any basis of a biodiversity indicator. The images coupled with abundance analysis leads to a reliable indication of biodiversity loss overtime. Comparing this data to other data such as forest loss allows policymakers more insight into what is causing the biodiversity loss we so highly aim to limit. While WPI's have their own limitations and setbacks, they provide important information that no other indicator has provided as efficiently.

Effects of Management of Domestic Dogs and Recreation on Carnivores in Protected Areas in Northern California

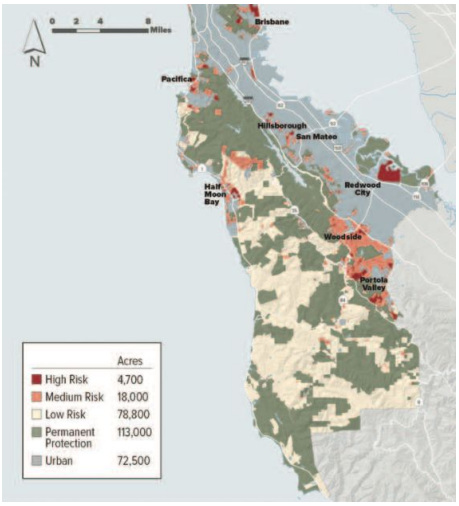
This study looks to address a question that came up during one of our discussions on the importance of using wildlife cameras in protected land. Parks often want to establish policies that don't hinder the native species' existence too much. The question of people bringing dogs into protected lands has been an issue for quite a while, as the fact that they are a non-native species poses some threat to the native animals. Domestic dogs may carry disease vectors, attack smaller species, and generally disturb or destroy the natural environment (Reed & Merenlender, 505). Because of these potential problems, some parks have been considering banning dogs in protected lands or restricting them to leashes.

The study took place in an area within California's Sonoma, Marin, and Napa counties. This was an ideal location for some of the larger carnivores the study was trying to track. Luckily, that's only slightly North of San Mateo county, so the results of the study are fairly translatable to our area of concern. What really interested me, however, was the methodology of the experiment. The researchers' method of collecting data on the species' included taking scat samples and using that to approximate data for the large species (Reed & Merenlender, 506). I believe that the researchers would have had an easier time collecting the data if they used a camera trap array, similar to the one San Mateo County Parks Department is planning. Doing so would prevent the researchers from needing to physically visit the sites so many times. However, the scat sampling may have been able to produce more numerical results. The researchers were looking for a clear connection between domestic dogs and lowered species presence. However, they found that a lower species presence was more correlated to simply human presence, rather than the dogs in particular.

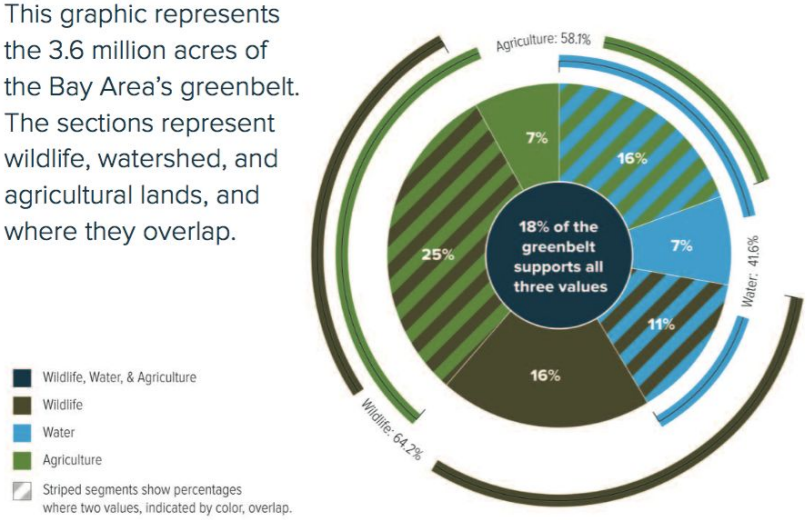
This article looks at a method some researchers used to answer a question similar to the ones that SMC Parks would be trying to answer with its Wildlife Picture Index. I believe that the methodology used in this paper may lead to slightly more accurate numerical results. However, establishing a WPI would actually require less manpower and analysis for similar levels of resulting rigor. The maintenance of cameras is also much easier for volunteers to manage, making the WPI effort a bit more scalable. I don't know yet if SMC is putting effort into solving these questions in the early stages of camera trap deployment, but I believe that the method will be viable as the project expands.

At Risk: Bay Area Greenbelt

This report, commissioned and funded by the California State Coastal Conservancy, takes a thorough look at land-use management in the Bay Area and explore relevant issues and at-risk areas. Natural land and green spaces in the county provide not just a beautiful landscape for members of our community, there are many more benefits that these lands provide which are less tangible. For example these lands and important ecosystems are critical to our environment in the face of climate change. Wetlands can provide protection from sea-level rise and flooding and watersheds can provide clean drinking water. Not only this but our natural landscapes provide innumerable ecosystem resources for indigenous plant and wildlife in the Bay Area. Housing prices in the area have exploded in recent years due to the booming economy in the Bay Area, and while this is can be great for our region from an economic perspective, this has brought many issues as well. This influx has led to an increase in development projects which often encroach on our natural landscapes.



The paper addresses this issue of development into green spaces by stating that urban sprawl is not the solution to the Bay Area's problems, and performed critical analysis on what areas will be most threatened by development in the coming 30 years. "Today, 293,100 acres of the region's farmland and natural areas are threatened with development within the next 30 years. This is an area of 458 square miles, almost 10 times the size of San Francisco"(Garcia, 4). This paper outlines through geospatial analysis a map of all areas in the Bay Area which are at-risk for



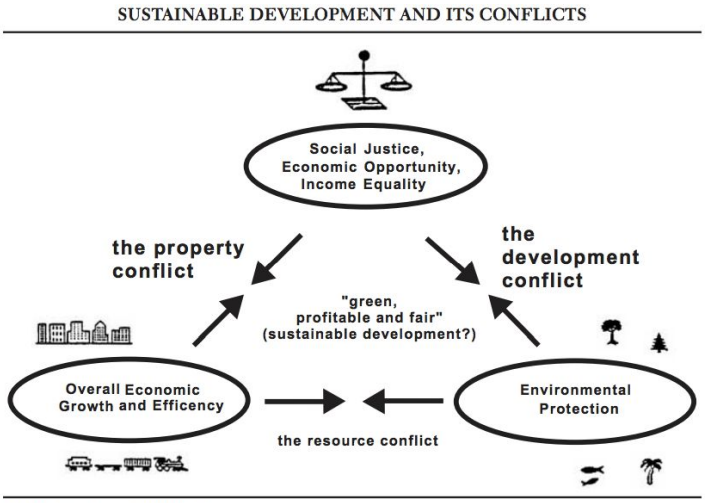
zoning restructuring or building developments in the next 30 years. Through this analysis the study concluded that Contra Costa county has the most total land at high-risk of development with 1 of every 5 acres of land currently at-risk.

In response to this spatial analysis, Greenbelt Alliance hopes to work with local communities and governments to develop policies to protect critical lands. "Greenbelt Alliance's

focus for over 50 years has been policy protection...such as urban growth boundaries, hillside protections, or agricultural zoning—to encourage development in central urban areas, rather than on remote natural lands."(Garcia, 6) The paper when on to examine all the different counties, including San Mateo and dove into a few specific building projects in the county. "On the Bay, northeast of Redwood City, a major waterfront development is being considered for 1,500 acres of salt ponds owned by Cargill. With up to 12,000 homes, this would be the largest Bay development in 50 years."(Garcia, 19) San Mateo county contains a significant amount of natural resources, which make this region an incredibly important area for protection and thoughtful natural resource management. "[Although] San Mateo is the region's smallest county, it has the second most above-ground stored carbon at risk: 257,700 metric tons."(Garcia, 19). The paper goes on to point out that if we develop these at-risk lands in the Bay Area, this could have immense detrimental effects on our local and global climate. "If these lands are developed, the carbon that would be released is equivalent to putting 1.3 million cars on the road every year"(Garcia, 28). Here the At-Risk report does an excellent job at quantifying ecosystem benefits, an often difficult task. The paper also goes on to consider the role of the housing crisis in natural resource management and preservation. Ultimately the paper calls for the right development in appropriate locations for the Bay Area, in order to preserve our natural resources.

Toward Just Sustainability in Urban Communities: Building Equity Rights with Sustainable Solutions

In this article, authors Agyeman and Evans highlight environmental justice and sustainability as two disciplines. These concepts have developed separately and despite many foreseeable differences, these two areas have some significant areas of overlap. It is these overlapping areas which have the most potential for solutions in our society which are the best place for social movements to begin which can bring about equitable sustainable communities in the future. For this reason, the article choses to discuss this area of overlap between environmental justice and sustainability in the United States and specifically to observe certain areas of sustainable development. Specifically the authors work to present sustainable models in the following development areas of environmental justice: transportation, residential energy use, toxic chemical use, solid waste and land use planning. The models presented seek to satisfy issues of environmental justice and sustainability in urban spaces. The work first began with defining Environmental justice and sustainability in order to understand these terms. Environmental justice was defined to be the concept that all people deserve to benefit from a healthy environment and in making decisions about policies and plans for our environment, we need to include all parties in a equitable and just way. Further the paper outlined the definition of sustainability as "the need to ensure a better quality of life for all, now and into the future, in a just and equitable manner, whilst living within the limits of supporting ecosystems"(Agyeman, 37). The authors then speak to the dynamic and relationship between Social Equity, Economic Growth and Environmental Protection, and how these issues interact and come in conflict with one another.



SOURCE: Campbell (1996).

In the report, the authors take issue with ongoing sustainability movements in the United States. Particularly to point out that these movements have failed to focus on social justice and equity concerns as they relate to these sustainability goals, despite the good intentions of these programs. The paper goes on to ask "Can we achieve sustainable development and sustainable communities... by tweaking existing policies, which we are doing at present, or do we need a rethink: a paradigm shift away from our present market-driven, resource-intensive development paradigm...to one in which society and social values come before economics"(Agyeman, 39). To consider practical solutions to these questions, Agyeman and Evans outline several programs which would highlight the compatibility between sustainability and environmental justice. Specifically they discuss Urban Ecology, an organization in Oakland that focuses on land-use planning for low-income urban environments. The program "has developed a process to bring the services of city planners into communities to engage in local needs assessments and community visioning...Although the needs of the community are given first priority, Urban Ecology staff often promote ideas such as transit access, pedestrian-friendly streetscapes, and affordable infill housing to help revitalize neighborhoods with sustainability principles in mind"(Agyeman, 42). Here the emphasis is on community-driven solutions for sustainability. This three-dimensional approach is extremely important to consider in local sustainability initiatives today. For example these considerations for the equity implications of our Wildlife Data project for our course are extremely important to consider and take into consideration.

Working Together to Protect Species at Risk: Strategies Recommended by Local Government to Improve Conservation on Municipal, Regional, and Private Lands in British Columbia

This paper discusses the importance of species diversity and preservation within both private and public land, and emphasizes the need for collaboration between local groups, municipalities, and regional government in ensuring that the local flora and fauna are fairly undisturbed by human activity. According to the paper, biodiversity is the foundation of human economy - an example being the impact of the loss of native bee species on agricultural productivity (Group, 2). Local governments play an important role in conservation efforts, as they can directly affect the number of species present in their area. Local governments have the

ability to regulate land use on both public and most private property, meaning they can work to protect areas where large amounts of species risk occurs, even if the area is private (Group, 4).

One local government rarely has the ability to affect land use regulation over the area of an entire species, however. That is why it is important for local governments to collaborate - the strength of local regulation, applied over a wide range to protect species. This paper discusses efforts organizations took to try and get local governments to tackle species risk issues individually. Local government representatives had a few worries about including those responsibilities under local government. They were concerned that the roles of local government in species conservation was unclear, that there are few incentives for local government to take responsibility, that they lack the resources and expertise to conserve effectively, and that species protection is just low on their list of priorities as a local government (Group, 5).

This is why collaboration is important - establishing a group that makes species risk a priority would lessen the strain on individual governments. The governments would all utilize the group's effort, and they could be funded jointly. Having a united group would also keep all governments involved informed, and allow data and technique sharing among them. The responsibilities of species protection would also be shared among governments, with one join body being held accountable. In this way, conservation efforts are actively made, but with minimal interference with other local government matters, combined oversight, and the ability to be effective both locally and throughout the region.

This paper pretty much describes what we're trying to accomplish by bringing all of the local organizations in the bay area together. When each group is operating individually on conservation efforts, time, money, and effort is often wasted on repetition. By building out a database that will be shared with various nonprofit and local government organizations, we hope to inspire more collaboration between them as they work to protect species in the bay area. Though we're starting with only San Mateo County, we hope that the effort will expand into a bay-area-wide, or even California-wide, endeavor.

Biodiversity of the urban environment: The importance of indigenous species and the role urban environments can play in their preservation

This work by Given and Meurk begins by highlighting the significance of biodiversity on a global scale. The paper highlights that while all environments and organisms were equal with the human race, through our actions we have put the global biosphere at risk. In the world there are countries and regions considered "hot spots" for strong biodiversity. It is these areas that have more focus for sustainable initiatives and conservation of biodiversity. Meanwhile this is problematic as it has as a result led to less focus on biodiversity efforts in cities. Urban spaces are not considered to be hotspots for biodiversity but when one thoughtful considers the landscapes of these areas, it is clear that cities often have many opportunities for biodiversity. Urban environments call for, "access to transport which, at least in the past, has often meant rivers and coastal harbours reliable water sources, either underground (but often artesian) or above ground proximity to high-fertility soils suitable for agriculture"(Given, 23) and many other ecosystem services which are inherent for both human life and general biodiversity. The study goes on to look at biodiversity measures in different cities in New Zealand, looking at the number of unique species and seeing how this fits into the country as a whole. "The total number of vascular plants in each of our main cities and comparable cultural landscapes ranges from 350

to just over 550 species. This represents 14-22% of New Zealand's total flora at each site."(Given, 26) There is often a juxtaposition with understanding how natural wilderness fits into urban landscapes, as many see that wilderness is antithetical to civilization and thus not compatible. If this is the case, it is easy to ask: can wilderness exist in cities at all? But here the reality is that it can exist and must exist for a sustainable future. Wilderness will need a slightly different definition as it exists in cities. It may not be possible for there to be rolling hills of natural spaces in cities, but rather a form of wilderness that is smaller and gives one the chance to escape from the city. For example a river running through a city, a set of hills or a pond. And finally the author ends, noting, "Society needs wilderness, not like it needs cosmetic surgery, but like it needs food, fuel and shelter. Moreover, society needs it close to and within urban environments"(Given, 32). This need for wilderness in urban spaces is immensely important to keep in mind with land management issues in the future.

Methodology

Data from outside sources provides the foundation for our project and the basis of our deliverable. Given the importance of the data we needed to collect, we set about on a mission to accumulate as much data as we could in the first two weeks to provide a baseline from which to initiate our project. Luckily for us, David Jaeckel, our community partner, provided the contact points for multiple organizations that potentially had data we could use.We contacted each of the contacts early on and received some responses. Overall collection of the data was quite easy with few hitches other than unanswered emails.

Our deliverable of a visualization platform for camera trapping data relied on collecting data from outside sources including Pathways for Wildlife, Golden Gate National Recreation Area (GGNRA), Santa Cruz Puma Project, Bay Area Puma Project, Felidae Fund, Peninsula Open Space Trust (POST), and Midpeninsula Regional Open Space District. Most of these organizations have cameras in the field and have been collecting data from them that the San Mateo County Parks Department deemed useful to their study of the wildlife in their parks. We emailed all of the above organizations and while we received some amazing responses quite quickly, we still have yet to hear back from some sources 10 weeks later after many attempts. This process highlighted how lucky we were to receive the data we did from GGNRA, Pathways for Wildlife, and most notably Felidae Fund.

The objective of accumulating this data was to compile it all into a visualization tool to help map out the county's wildlife across its' parks for study over multiple years to help measure biodiversity and its potential loss. When aggregating the data Bay Area Puma Project and Felidae Fund noted that they were under the same organization and thus already shared data making an extra copy of the data from the second source superfluous. This sharing of data accentuated a potential outcome for the project of connecting the sources so that all had access to the shared data and its findings. The data provides a vast amount of information including animal sightings categorized by species, time, and location that the animal was caught on camera. This geographical data formed the backbone for the visualization platform. Meanwhile the GGNRA data was exclusively ".jpeg" format and included actual images from their various wildlife trappings, but did not include locations. This made the data hard to include in our compiled data set, as having location information is critical to adding the data to a map.

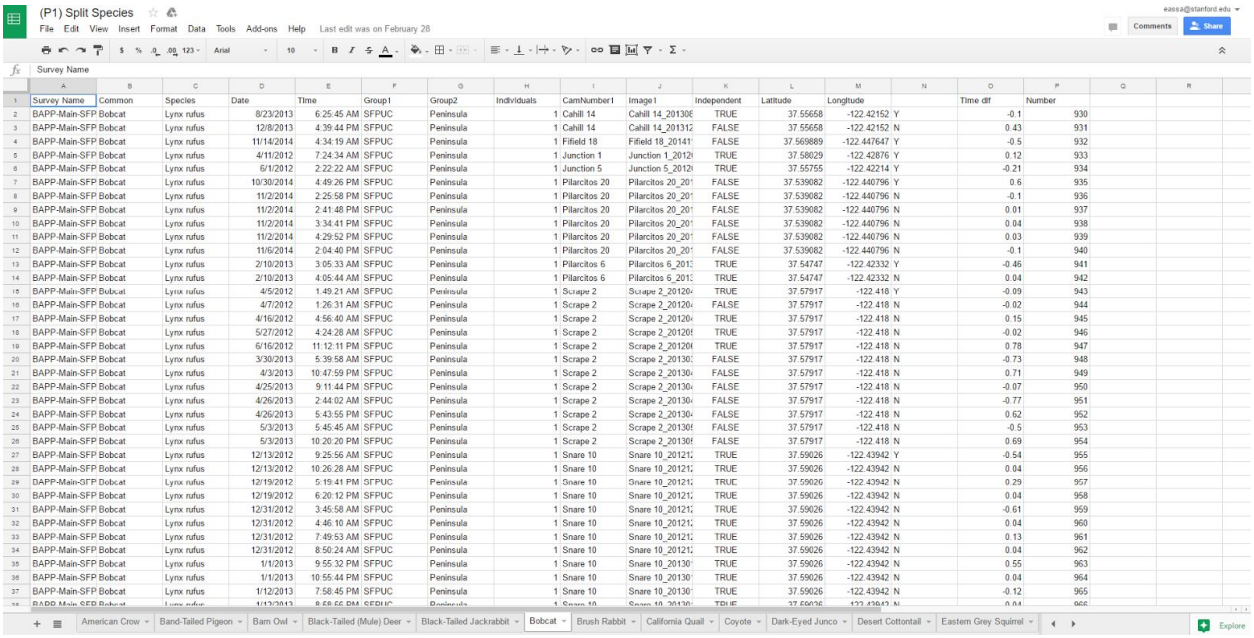
The method of collecting data already in existence across multiple organizations was the idea of David Jaeckel. This method provided the fastest way to accumulate the vast amount of data that we did with the smallest amount of man hours possible. While we collected this data in less than a week, the limitation of using outside sources camera data means that most of the images are not actually in San Mateo County Parks but rather in the protected land surrounding it. While any information gleamed from the camera data may correlate to SMC parks because some of the animals roam distances that would most likely put them in SMC parks, the lack of images in the parks weakens the ability of the parks department to claim all of the animals being in the parks due to the lack of actual data saying so.

Multiple stakeholders are involved in that each of the aforementioned organizations has a stake in the wildlife in the area. We reached out to all the organizations in the area that were known or suspected of having camera data. Some of these organizations are decision-makers if they own or manage the land such as GGNRA and POST while the other organizations hold more importance in the data collection and funding of certain projects.

While many different groups seem to survey the same issues and locations such as biodiversity and wildlife in the bay area, each has their own focus and their data is not shared across organizations. At the same time certain data is more valuable in certain contexts than other data because of the extra information points linked to it such as location allowing it to fit into a map visualization. However, access to photos was also a huge part of the project's aim as the public is more likely to respond to a photo of an animal than a map of where it roams. Enhancement of the efficiency and potential ability of the aforementioned organizations may come with further integration and sharing of data to allow for new insights and avoidance of funding on projects similar to ones already undertaken by other organizations.

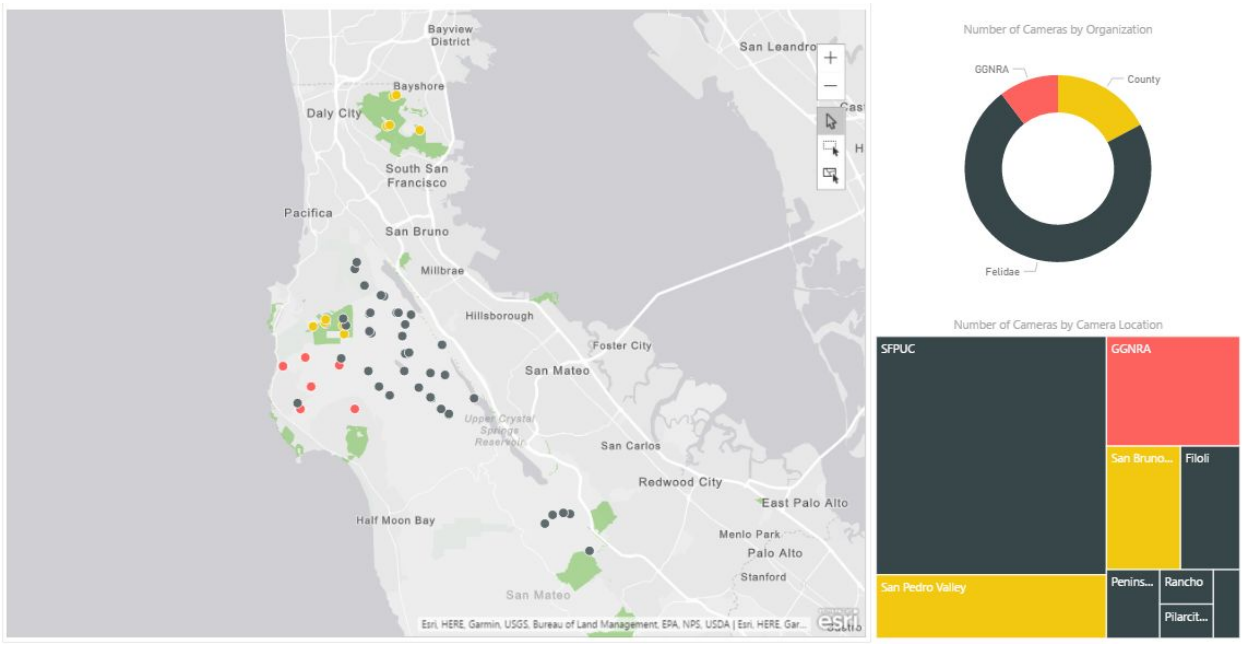
Deliverables - Summary and Recommendations

The deliverables for our project consisted of a formatted spreadsheet consolidating all the data we had collected and an ArcGIS map of the various species we observed in San Mateo County. The formatted spreadsheet looks similar to the image below, and will be provided to the San Mateo County Parks Department. Essentially, we filtered the data we received, then divided

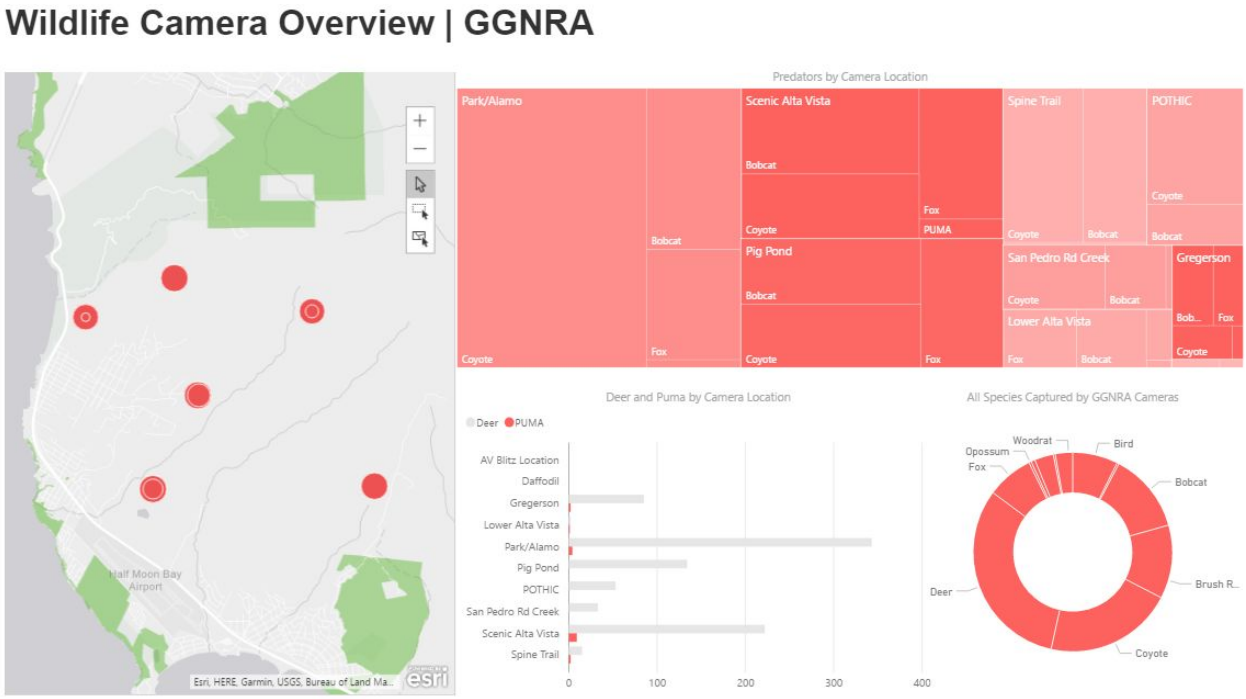


it into tabs based on the particular species. In this way, we could easily add the data to an ArcGIS Online map. The ArcGIS interactive map can be found at the following link: http://stanford.maps.arcgis.com/apps/View/index.html?appid=ee17f6d702574107b699d97391c95054. As you can see, we were able to upload the spreadsheet data, one sheet at a time, into layers on the interactive map. Using this, we can more visually see the presence or absence of species in protected areas in San Mateo County.

Moving even further, the data we collected was also uploaded into a tool called Microsoft Power BI, which allows users to combine both mapping and analytics very visually on one platform. Power BI is especially good for someone working on the more analytics-focused end of the spectrum, because it allows for more advanced data manipulation and sorting than ArcGIS alone. It is also a great platform for collaboration, because it is possible to chart the map data points to individual organizations, so there is still a sense of ownership over data. Essentially, the Power BI platform could allow collaboration without forcing organizations to completely give up ownership of their resources. It would allow for both individual organization as well as comprehensive analyses, which would be appealing to most groups. These organizations would provide their data, prevent redundancy in data-gathering, and be able to pull from a much larger pool of information than they would be able to achieve on their own. Thus, the movement from ArcGIS alone to Power BI is a great one, but may require a bit more expertise from staff.



[Screenshot of SMC Parks Department Microsoft Power BI interface, cameras by organization ownership]



[Screenshot of data within GGNRA cameras, broken down by species and location]

What we see through the map is fairly interesting, though highly preliminary. What we immediately notice is the stark difference between the presence of some species over others. For example, pumas have been seen at almost every camera station. This could indicate a large population of pumas, or an indication that the pumas are prone to patrolling a wide area. Knowing that pumas are very territorial, the latter would be our best guess. When a species is

very prevalent in the camera trap data, answering questions on behavior and presence is relatively easy. On the other hand, if a species very rarely shows up on the cameras, it is a lot more difficult to infer behavior. The lone barn owl sighting, for instance, would indicate very little other than the fact that there was a barn owl there at the time. With only a few data points, it's difficult to make conclusions. This is what makes long-term camera trapping projects so important - the longer you collect data, the more data points you collect, the more insight you can gather on animal behavior and the effects that human activity may have on it.

Due to the nature of the project, we haven't done much in the way of actual analytics on the data, other than basic presence/absence confirmation of the various species. Because of this, our first recommendations are simply to continue the current camera trapping data collection, and to expand it if possible. From there, have a person (or people) who can format the data and add it to a communal database of camera trap data. As the database grows, organizations can begin conducting more detailed analysis of the species in San Mateo County's protected lands, and answer some of the more specific questions that aren't feasible with small amounts of data. This will require some expertise, so having a designated data analyst may be important in the future - potentially one jointly funded by the organizations using the communal database.
On the public-facing front, it should be possible to start turning the data we have into a more interactive web application that park visitors and San Mateo County residents can use to see where animals are found in their county. This visualization would have to be more specialized, as it could only include areas that citizens are allowed to visit, and it may not be wise to tell families that their local county parks have large carnivores wandering around (to ease public apprehension). A well-curated database of local fauna would be great outreach for the county parks, and may provide additional proof of the parks' worth to the surrounding communities.

Conclusions, Key Findings, and Next Steps

This project was a phenomenal learning experience for everyone on the team. Coming into this project, we knew very little about local conservation and natural resource preservation. Through this project, we were able to go out into the field and learn, hands-on, about our local protected lands and some of the issues surrounding them. Through our project experience this quarter, we've developed a greater understanding of local government, natural resource/protected land management, species preservation, and the techniques used to aid those efforts. We've also learned to use impressive tools, like ArcGIS, for analytics and visualization of large amounts of information.

From this project, we've managed to compile a few key takeaways for both ourselves, the SMC Parks Department, and even local residents and nonprofit organizations:

1. Planning for the local environmental future can be difficult. We can try to understand the issues now, but we can't accurately predict the ecological problems of the future.
2. Even so, it's important now to both preserve the natural resources we currently possess, as well as informing the general public about the usefulness and importance of our natural resources.
3. Keeping people invested in the parks and protected lands is also key because it aids in securing funding for their preservation. These resources need to be maintained, and having a secure budget will improve the odds of the land and species being adequately taken care of.

4. When planning programs or projects around natural resource conservation, there are various stakeholders involved, from local governments to nonprofit organizations. Collaboration, or at the very least, communication, is vital for long term preservation.

Keeping these key takeaways in mind will aid any organization that wants to act in the interests of species or land protection do so effectively. It is also useful for individuals who are simply curious or concerned about the state of their local natural resources.

As much as we've accomplished in only a quarter, there is still a lot to do in the larger scheme of the San Mateo County Parks Department's Wildlife Picture Index. There are three main components that can be moved forward as the project progresses - the continuous collection of data through camera trapping, the curation and analysis of the data for organizational use and research, and the visualization of data for public outreach and learning. For the first part, the Parks Department is already moving forward with setting up additional camera traps for data collection. Because of this, we feel that most of the expertise and future work will be towards the last two efforts. We've outlined a few suggestions for moving forward with them, both for the Parks Department and a potential Stanford team of students.

1. For data curation and analytics: Finding a way to easily allow organizations to upload camera trap data to a platform like Microsoft Power BI, then running analyses regularly to follow trends in species behavior would be incredibly valuable. The Parks Department would do well to hire someone with Power BI experience or teach a department member to do it. For a Stanford team, an appropriate project would be to run an analysis on the data to determine species behavior for specific species of interest in the area.
2. For data visualization for the public, someone with web application experience would be needed to transform the raw analytical and map data into a visually appealing platform that the public can enjoy. A good project for a future Stanford team could be designing the layout of the interface, and the Parks Department could follow-up by actually hiring a developer to make the interface a reality.

Both of these proposed next steps help pave the way toward better preserved San Mateo County protected land. Once a way of quantitatively evaluating the condition of the parks is established, it will be easier to convince lawmakers that change may be needed. With the outreach made possible by a public "learning dashboard," the Parks Department can better inform residents and visitors of the importance of these protected lands. Either way, these projects help build a foundation for the Parks Department to ensure long-term conservation and preservation for the precious land and the fragile ecosystems they sustain.

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