Using Spatial Data to Improve Recovery Under the Endangered Species Act

Consultants Assessing the Recovery of Endangered Species (CARE)

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Executive Summary

Many species protected under the Endangered Species Act (ESA) are making slow and insufficient progress towards long-term recovery. Various studies have examined the recovery planning process in order to identify related challenges and suggest improvements to science and management efforts. In 2002, Society for Conservation Biology (SCB) published a comprehensive study that provided 15 diverse recommendations for improving recovery plan quality, implementation and overall effectiveness. To increase the probability of wide-scale incorporation, these recommendations were targeted at NOAA National Marine Fisheries Service's "Interim Endangered and Threatened Species Recovery Planning Guidance" (Interim Guidance). However, notably absent in both the SCB study and the Interim Guidance is any discussion of spatial data collection and its use for creating multi-layered maps. This is of particular concern because spatial data has increasingly been recognized for its unique potential to assist in long-term species recovery.

In order to fully assess the potential use and inclusion of spatial data within the recovery planning process, we identified three research objectives. The first objective was to assess how well SCB recommendations have been incorporated into both the Interim Guidance and individual recovery plans. This evaluation would allow us to determine the relationship between the two documents and how well recovery plans follow the Interim Guidance. The second objective was to determine the feasibility of creating a spatial tool for all species listed under the ESA given available data types and formats. While maps can aid management decisions, known data deficiencies for many species are expected to make the creation of such maps challenging. By assessing a taxonomically representative subset of species recovery plans, we could evaluate the relative availability of spatial data across different groups of species. Our third objective was to create a single-species proof-of-concept map for the development of a large-scale, online mapping tool. This process would allow us to evaluate how useful a spatial tool and online Google mapping platform could be to those interested in improving species recovery.

As a result of our analysis we conclude that the more fully a recommendation is incorporated within the Interim Guidance, the better it will be expressed within individual recovery plans. Therefore, if the Interim Guidance explicitly requires spatial data collection, more specific-specific spatial data will likely become available. Through our feasibility study we found large data gaps for all species and only 20% or less of all applicable data layers for amphibians, clams, and snails in particular. Additionally, while we found biological data most frequently, threats, recovery actions, and ESA legal requirements were largely absent in any spatial format. In order to create a diverse multi-layered map for all species, spatial data collection must be prioritized among all data categories and for low-profile species. Our proof-of-concept map for the Utah prairie dog (found at: http://www.google.org/crisismap/a/gmail.com/CARE_UtahPrairieDog), demonstrates that multi-layered maps can currently be created for select species after expansive data searching and mode rate use of geo-spatial programs such as ArcGIS. These maps can directly support Defender's own internal purposes as well as uniquely support USFWS and NMFS's ongoing efforts in spatial tool development.

Introduction

Problems with Species Recovery Under the Endangered Species Act (ESA)

Since Congress passed the ESA in 1973, over 2,100 threatened and endangered species have been listed under the law's protection (NMFS 2014). Under section 4 of the ESA, the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) are responsible for administering the conservation and survival of each federally listed species by developing recovery plans (ESA; 16 U.S.C. § 1533(f)). These plans are intended to outline objective and measureable criteria which, when met, will result in the species' removal from the list of endangered and threatened species (ESA; Himes Boor 2014). Full recovery for most protected species is projected to take up to 50 years (Gies 2012; Nazzaro 2006). Consequently, recovery plans are required to undergo revision and review every five years to more accurately assess and track a species' progress towards long-term survival.

Although the recovery planning process has become standard practice for nearly every species listed under the ESA, progress has often been slow and there have been many critiques of its overall effectiveness and scope (e.g. Glick 2005; Gregory et al. 2012; Himes Boor 2014; Neel et al. 2012). For example, there is a clear gap between available resources (e.g. funding, staff, etc.) and the needs of recovery plan programs (Restani and Marzluff 2002). This gap is even more apparent among particular taxonomic groups, with large charismatic megafauna receiving the most funding (Miller 2012). Furthermore, recovery plans themselves can be tedious and unwieldy documents that vary greatly in quality (Foin et al. 1998; Boersma et al. 2001). Poorly developed recovery plans often exhibit limited nonfederal participation and are typically linked to a lack of dynamic and explicit science within the recovery planning process (Boersma et al. 2001; Weijerman et al. 2014).

Given these limitations, it can be difficult to fully assess and mitigate known threats and in turn identify the best site-specific management practices that will lead to full species recovery (Lawler et al. 2002). The pattern of decline for threatened and endangered species protected under the ESA varies taxonomically and geographically but is often related to significant information and data gaps (Leidner and Neel 2011). One published study in particular suggested that while recovery goals for approximately 90% of invertebrates required a specified number of populations for downlisting or delisting the species, the current number of populations was not known for 35% of these species (Tear et al. 1995). Furthermore, even when revised recovery plans make efforts to include more information regarding species biology, status, and threats, they simultaneously fail to clearly link this information to management actions, monitoring protocols, or recovery criteria (Harvey et al. 2002).

The Role of Spatial Data in Improving the Recovery Planning Process

In 2002, Society for Conservation Biology (SCB) published a comprehensive analysis of 181 species recovery plans, which quantified the attributes and effectiveness of existing recovery plans and provided recommendations for improving plan quality, implementation, and effectiveness (Clark et al. 2002). Building off of an existing body of literature aimed at determining and addressing the largest impediments to species recovery, SCB collaborated with USWFS and the National Center for Ecological Analysis and Synthesis to determine the components of an effective recovery plan (e.g. Brigham et al. 2002; Clark et al. 1994). Upon completion of the study, SCB offered 15 recommendations ranging from better identification and mitigation of threats, to improved fund tracking and more diverse coordinating committees (Clark et al. 2002).

One of the immediate targets of such an analysis was NMFS's Interim Endangered and Threatened Species Recovery Planning Guidance (Interim Guidance), which "strives to ensure consistency in approach to the application of statutory, regulatory, and policy requirements in the development of recovery plans" (NMFS 2010). USFWS and NMFS have continued to make revisions to the recovery planning process and published several iterations of the Interim Guidance, the most recent being Version 1.3, updated in 2010. However, it is unknown how well SCB recommendations have been incorporated into USFWS's recovery planning process and within individual recovery plans as there have been no follow-up studies published to date. Furthermore, it remains unclear how well data concerning species biology, ESA legal actions, and threats to recovery have been documented and used to inform management decisions across all species listed under the ESA (Gerber et al. 2001). Most notably, there is no explicit mention of spatial data within either the Interim Guidance or the SCB study.

The complete absence of spatial data is noteworthy because species-relevant spatial data is expected to make recovery plans easier to update and aid in long-term species recovery (e.g. Evans et al. 2011; Kerr et al. 2004; Wallace and Marsh 2005). Despite the potential of spatial data to inform conservation-planning decisions, current maps very rarely display multiple layers at the same time. By combining various data layers on a single map, practitioners are more likely to visualize how threats, recovery actions, and a species' biological needs interact in space and over time if data is regularly updated. Multi-layered maps may prove to be particularly helpful when prioritizing various management activities, such as finding the least threatened patches of habitat for critical habitat designation.

Furthermore, from a regulatory perspective, well-developed maps can help USFWS, and NGOs such as Defenders of Wildlife, monitor Habitat Conservation Plans (HCPs) and Safe Harbor Agreements. Both of these actions, legally permitted under the ESA, can have negative impacts on endangered species if they are made without careful geographic analysis (Shiling 1997). In some instances, these decisions are made without assessing the overall impacts that could occur across the landscape and in turn pose a greater threat to species recovery than previously acknowledged or understood.

Both NMFS and USFWS have recognized the growing potential to make recovery plans "spatial" through the ongoing development of both NOAA's Recovery Action Mapping Tool for Pacific Salmon and steelhead and USFWS's Information, Planning, and Conservation (IPaC) tool. The goal of the Recovery Action Mapping Tool is to allow users to interact with data layers in order to track recovery action implementation and to access real-time action data on the web (NOAA 2014). Using Geographic Information Systems (GIS) as the primary mapping platform, this tool is the first of its kind within the agency and is currently in the final phases of development. While this tool maps multiple species-specific layers simultaneously, its scope is limited to only a few fish species.

The primary purpose of USFWS's IPaC tool is to show which development projects will potentially impact endangered species and require an ESA section 7 or section 10 "take" permit (Horton 2014; ESA 1973; 16 U.S.C. § 1533(f)). On USFWS's website, project developers can draw a shapefile over an interactive map, outlining where their project will be (developers may also upload shapefiles, which provides greater precision), select from a dropdown menu what type of development project they are proposing, and then select from a list of project activities what will be performed (Horton 2014). IPaC is then able to link these activities to potential impacts through a model of "effect pathways" (Horton 2014). These pathways identify the severity of development types and activities on various endangered species. As developers select more activities under their project type, IPaC creates more effect pathways to predict the full range of ecological and biological impacts on species. Despite the tool's highly advanced modeling capacity, it does not allow the user to display all layers specific to a single species. Furthermore, the most optimistic projections suggest that IPaC will not be fully populated with data until 2020.

One major concern of spatial tool development has been displaying the specific location of endangered species. As some species are highly prized by collectors or poachers, a detailed map may encourage exploitation. In other instances, knowing where a species is located may encourage developers or private landowners to "shoot, shovel, and shut up," thus precluding them from having to comply with ESA regulations. Private landowners also present another problem with mapping. In certain parts of the country, landowners are especially skeptical of government involvement in land management, fearing large "land-grabs." If an endangered species occurs on both federal and private land, private landowners may believe that the government is using a map to identify and purchase their property (Olive and Raymond 2010). Overcoming these aforementioned challenges are necessary if maps are to be useful and dynamic in conservation planning and long-term species recovery.

Primary Objectives of CARE's Study

Given these challenges with the recovery planning process, CARE from the University of Maryland, developed a multi-phased project to assess three primary research objectives. Our goal is to improve the recovery planning process and make recovery plans easier to update and revise. One of the central components of this analysis is to better understand the role of spatial data and spatial tools in improving the current recovery planning process.

Objective 1: Assess the Incorporation of SCB Recommendations

The comprehensive nature of the 2002 SCB study provides a framework for addressing many aspects of recovery plan development. However, twelve years have passed since the study was first published and there is little knowledge of how well SCB recommendations have been incorporated into the recovery planning process. The key question underlying this objective is whether or not the SCB recommendations that are incorporated into the Interim Guidance, are in turn incorporated into recovery plans. Furthermore, we are interested in assessing how thoroughly these recommendations have been incorporated into the recovery documents. This approach highlights the importance of determining the relationship between the recovery documents, specifically considering how well recovery plans follow the Interim Guidance. A strong relationship between the two may suggest that it is very important to provide recommendations for spatial data collection at the beginning of the recovery planning process, to ensure that this data is incorporated within all recovery plans.

Objective 2: Determine the Feasibility of a Spatial Tool for All Species

While the literature suggests that spatial data can uniquely support long-term species recovery, data deficiencies may limit the creation of a spatial tool for every species protected under the ESA. In order to determine the feasibility of a spatial tool, we will assess 1) the type and format of available spatial data; 2) the potential influence of monitoring efforts and/or the length of time a species is listed under the ESA on data availability; 3) potential differences in data availability among taxonomic groups and among problematic species. As there is a diverse array of species listed under the ESA, each of these aforementioned assessments provides a basis for determining how data availability may vary among different species groupings.

Objective 3: Create a Proof-of-Concept Spatial Tool

Federal agencies have begun to recognize the potential of spatial tools to aid in species recovery. However, both the NMFS's Recovery Action Mapping Tool and USFWS's IPaC tool are still under development and have potential limitations in their scope. Additionally, the lack of multi-layered species-specific maps available on the web, suggests a limited framework for spatial tool use and development. In order to guide the possible development of a large-scale online mapping tool, we are interested in a creating a single-species proof-of-concept map using an interactive web-based platform. We are particularly interested in assessing what a feasible species-specific map could look like and how both the federal government and NGOs like Defenders could use it.

Methodology

<u>Objective 1: Assess the Incorporation of SCB Recommendations</u>

To complete the first objective, we collectively identified all recommendations proposed by SCB in their publication, *Improving U.S. Endangered Species Act Recovery plans: Key Findings and Recommendations of the SCB Recovery plan Project* (Clark et al. 2002). The fifteen recommendations identified within the report can be found in Appendix 1. Following this identification, each team member read the most recent version of the Interim Guidance (Version 1.3) and twelve individual recovery plans (see Appendix 2) to assess which of the fifteen recommendations were incorporated within these documents. The recovery plans were provided by Defenders and selected because they were written or updated after NOAA and USFWS published the most recent version of the Interim Guidance in 2010.

The assessment process for both sets of documents included a simple scoring system that assigned each recommendation a value of 1, 2, or 3, signifying the extent to which a recommendation was or was not incorporated within the document. A score of 1 was the best and indicated that the recommendation was fully incorporated into the document and had action items explicitly linked to it. A score of 2 indicated that the recommendation was partially incorporated, but remained incomplete in scope or vague in its application. A score of 3 indicated that the recommendation was not incorporated into the document or was too vaguely alluded to within the document to have specific action items associated with it.

To reduce any potential variation due to reviewer subjectivity, each team member conducted an independent assessment of both the Interim Guidance and the Alabama Sturgeon (*Scaphirhynchus suttkusi)* recovery plan. We then compared our scores and discussed any discrepancies in the individual interpretation of the scoring criteria. We eliminated subjectivity as much as possible and set guidelines for further plan review. For the Interim Guidance, we came to a consensus concerning the final scores for each recommendation. At the conclusion of our recovery plan review, the assessments for each plan were compiled into a single Excel database for easy cross-comparison. The scores were then averaged for each recommendation to assess how well recommendations were incorporated into recovery plans.

Objective 2: Determine the Feasibility of a Spatial Tool for All Species

To assess how feasible it would be for USFWS or Defenders to spatially display recovery plans, we expanded our initial sample size of twelve recovery plans to 144 recovery plans. The new sample size represented approximately 10% of all species listed under the ESA that have recovery plans (see Appendix 3 for full list of species). The taxonomic breakdown of these plans was proportional to the taxonomic diversity of species protected under the ESA, resulting in nine mammals, ten birds, two amphibians, four reptiles, thirteen fish, four insects, one arachnid, three snails, seven clams, two crustaceans, eighty-six flowering plants, and three ferns. The twelve original species given to us by Defenders were included in this sample size. All remaining recovery plans were found on USFWS's Environmental Conservation Online System (ECOS) website (http://ecos.fws.gov/ecos/home.action) and selected with a random number generator (http://www.random.org/).

Randomization of species was important to ensure that there was no bias in species selection within various taxonomic groups. For example, there are 86 mammals listed under the ESA, so the random number generator used a numerical range of 1 to 86. Each randomly generated number for each taxonomic group was matched to a species listed alphabetically by common name within the group. If the random number generator selected a species that was already given to us by Defenders, the generator was run again until a new species was selected. In some cases, the same species was listed multiple times by USFWS because different recovery plans had been developed for that species in different regions (for example: Bull trout). If two or more of the random numbers selected the same species, the random number generator was run again until a new species was selected.

For each species we collected information on a variety of data classifications and layers. Through this process we 1) identified the taxonomic group to which it belonged; 2) recorded the USFWS region responsible for writing and implementing the recovery plan; 3) recorded if the species was a problem or non-problem species; 4) noted the date the species was listed under the ESA; and 5) evaluated the presence of monitoring efforts (see Appendix 4 for an expanded discussion). Species were considered a problem if they were migratory, transboundary, controversial, and/or data-deficient. Some species had multiple problems and were denoted in the spreadsheet as multi-problem. We identified monitoring efforts by assessing the species' recovery plan and the plan's five-year reviews. All information was recorded on an Excel spreadsheet for more efficient data management and analysis.

On a separate spreadsheet, we assessed the presence and absence of 27 different data layers which were selected for their potential to create a comprehensive spatial map (see Appendix 5 for full list). We organized each of these data layers within three overarching categories of spatial data: biological, ESA features, and anthropogenic. Species-specific biological data included spatial layers such as current range, historic range, and habitat suitability. ESA data layers are associated with legal designations such as Habitat Conservation Plans, Safe Harbor Agreements and critical habitat. Species-specific threats and recovery actions were categorized as anthropogenic data layers.

We evaluated data layer presence for each species by first determining what layers were applicable to that species. If the data layer was applicable to the species, it received a designation of either "0" if absent/not found or "1" if present and found. If the data layer was not applicable to a reviewed species, it received an "NAN" (Not a Number). For example, the "migration route" data layer applies to the whooping crane, and upon assessment the species would receive either a "0" or "1." Alternatively, the Pine-pink Orchid would automatically receive an "NAN" for this layer since it is not a migratory species. In order to reduce any potential subjectivity associated with the review process, each team member independently evaluated five species, and collectively discussed potential discrepancies in data layer evaluation. This process set guiding principles for further assessment and we discussed and resolved additional issues in the scoring process as they arose.

The scope of our spatial data search was confined to nine different sources including the most recent version of each species recovery plan. We selected these nine sources because of their reputation and the likelihood of finding spatial data relevant to endangered species conservation through these sites. Since multiple sources may have the same data layer, only the top three sources for any one layer were recorded for a given species. Government sources were prioritized in this search as they were assumed to be the most accessible for USFWS. The nine sources and their corresponding source code (used in the database for identification purposes), listed in in order of priority in Table 1.

We also assessed the variety of data formats available for each data layer and within each data source. The six data formats we identified as most likely to be discovered are: altitudinal range, downloadable data, interactive maps, latitude and longitude (LAT/LONG), static maps, or other. We recorded up to three formats for each data source and prioritized downloadable data due to its direct applicability for spatial tool development. The organization of all data types, sources, and formats within Microsoft Excel can be found in Appendix 6.

Table 1: Feasibility study data sources in order of prioritization
These original nine sources have reputations for hosting species-specific spatial data. Government sources were prioritized in this search, as they are likely to provide USFWS with more direct and easy assess to the data.

Data Source	Database Code
USFWS Recovery plans	USFW
USFWS ECOS site	ECOS
USFS BISON site	BISN
USGS GAP Analysis Site	USGS
State Departments of Fish and Game	DEPT
Conservation Registry	CONR
NatureServe	NATR
IUCN Red List	IUCN
Data Basin	BASN

Given the information we collected for each species, we assessed data availability across a variety of categories. First, we compared the availability of biological, ESA features, and anthropogenic data layers by noting how many times they were respectively recorded. This analysis allowed us to identify the most available data type as well as any potential data gaps. Second, we looked at each data layer and determined which layer was most frequently available among all evaluated species. This analysis also allowed us to identify which layers were absent across all data sources. Third, we compared each of the nine data sources in order to determine which sources contained the most available spatial data and in what format. From this analysis, we were able to assess the potential usefulness of each data source for spatial tool development. Finally, we recorded how difficult it was to find available spatial data within each data source in order to determine the ease of site navigation. Further information about this classification and all subsequent analysis can be found in Appendix 7.

To identify potential trends and causal links between spatial data presence and species categorization (i.e. taxonomic group and problem species classification), we first determined the proportion of available data for each grouping. Since not all spatial data layers were applicable to each species (for example, all flowering plants received an NAN for 'migration route'), we calculated the number of present spatial layers over the total number of applicable spatial layers. We then determined if there was a relationship between increased availability of spatial data and both the length of time a species has been listed under the ESA and the presence of monitoring efforts. Initially, we totaled the number of monitoring activities present and plotted it against the proportion of available spatial data to determine any potential correlation (see Appendix 4 for a more complete discussion). We followed the same process to assess potential correlation between the length of time a species was listed under the ESA and available spatial data.

<u>Objective 3: Create a Proof-of-Concept Spatial Tool</u>

To fully assess the usefulness and potential of a species-specific spatial tool, we focused on a species that was likely to provide a high amount of diverse and available spatial data. We selected the Utah prairie dog (*Cynomys parvidens*) as our pilot species for four primary reasons. First, this species has been listed under the ESA since 1973, the same year the Act became effective. Our hypothesis was that the longer a species has been listed under the Act, the greater our chance of finding applicable spatial data. Second, the Utah prairie dog had one of the best-scoring recovery plans from our initial analysis in objective one. Because the plan specifically included many SCB recommendations and was recently revised in 2012, we hypothesized that this species would have a high amount of available spatial data. Third, the Utah prairie dog is covered by seven Habitat Conservation Plans (HCP), three Safe Harbor Agreement, a number of ESA consultations, and a special 4(d) rule. The presence of this ESA-related data was important to the selection process since Defenders is particular interested in the impacts of these authorized "takes" and where they occur spatially in relationship to species-specific biological layers. Finally, the Utah prairie dog has a narrow range and is non-migratory. Our hypothesis was that a narrow species range would simplify the development of the map and likely increase the number of data layers we would find.

To make spatial tool development easier for a wide range of species, we designed a Tiered Mapping System. This system provided a standardized categorization and structure for all potential data layers. We initially evaluated the original 27 data layers from the feasibility study and expanded them to highlight specific sub-layers (See Appendix 8 for full organization). We then categorized these layers within a three-tiered system to highlight the bare minimum amount of spatial data needed for a species to be mapped with our tool (see Appendix 9 for complete definition of tiers). Under this system, a species needs all of the applicable layers defined in Tier 1 in order to create a usable map. Generally speaking, data layers were divided into Base Layers, which will be present for each species, and Species-Specific Layers, which will vary species-to-species.

We expanded our search for spatial data beyond the original nine sources we identified in our feasibility study. This allowed us to examine if our original sources would be sufficient in finding all the data needed to create a map. In the event that we did not find a high number of data layers from within our original pool of sources, this expansion would increase the likelihood of data discovery. We initially contacted the Utah prairie dog's lead recovery biologist, Nathan Brown from USFWS Region 6. Brown provided us with a number of data layers, and gave us insight into what kind of data he believed existed in a spatial format. Based on Brown's suggestions we began contacting other organizations and government offices that hosted a variety of data layers. For example, we searched a number of species-specific web-based sources such as the USDA Plant Database, which contained information on invasive plant species. Other websites included the USDA Forest Service, National Conservation Easement Database, and state universities in Utah.

We created the spatial tool using Google Crisis Maps in conjunction with Google Maps Engine. Google Crisis Maps was chosen to be the main platform for the spatial tool because it was easily sharable, allowed for a wide range of importable data formats, and had a user-friendly and professional interface. Most data layers were directly uploaded to Google Maps Engine where they could be stylized and published on their own map. If the data layer was in the format of a static map, it was geo-referenced with ArcGIS 10 before being uploaded. We then imported the data from Google Maps Engine into Google Crisis Maps for easier map navigation. With Google Crisis Maps, users can select which layers they turn on and off and view a legend highlighting all available data layers simultaneously.

Results

Objective 1: SCB Recommendations

We determined that seven of the 15 recommendations made by the SCB were fully incorporated within the Interim Guidance and consequently received a score of 1. These recommendations were primarily related to targets, goals, and threats. The remaining eight recommendations were split evenly between partial and vague levels of incorporation. Poor scoring recommendations were primarily related to administrative duties and the structure of coordinating committees.

We found that the twelve recovery plans scored similarly to the Interim Guidance for most recommendations (see Appendix 10). Therefore if a recommendation received a score of 1 within the Interim Guidance, almost all recovery plans would also receive a score of 1 for that same recommendation. However, there was an exception with the recommendation "trend line data is present and collected regularly." Recovery plans did better at incorporating this than the Interim Guidance, and the scores among recovery plans were evenly distributed. The varied interpretation of this recommendation may have resulted from the vague direction in the Interim Guidance. Generally though, these findings suggest that recommendations included in the Interim Guidance will also be included in recovery plans. Additionally, the better a recommendation is incorporated into the Interim Guidance, the better it will be incorporated into recovery plans.

Objective 2: Feasibility Study

Among all species in our study, biological data was by far the most common data category available. These data layers were found 511 times among all data sources. The next most common data type was anthropogenic, which was found 148 times. ESA features were the least common spatial layers, found only 89 times. Additionally, spatial data considered to be at the Tier 1 level was most commonly found. We were able to find Tier 1 data 579 times while Tier 2 data layers Tier 3 data layers were found 81 and 88 times respectively. The fact that we found more Tier 3 data layers than Tier 2 layers was unexpected and may imply that our ranking system needs revision. For instance, we may have incorrectly categorized a single data layer at the Tier 3 level, and its frequent discovery would have skewed our results.

Of the 27 layers we search for within our analysis, “current range” was by far the most common (See Table 5). It is likely that the high frequency of this one data layer caused biological data to be the most available data category. There were also large data gaps for many of the other layers. For example, 16 of the 27 layers were found 6 times or less among all species and sources reviewed. Furthermore, 3 of these data layers were not found for any species.

Of the nine sources we assessed, the majority of spatial data came from recovery plans, the USFWS ECOS website, and the USGS BISON website. These three government sources provided 78% of all available spatial data. More specifically, recovery plans provided 31% of this spatial data, while the ECOS and USGS BISON websites provided 28% and 20% respectively. The remaining six data sources collectively hosted the remaining 21% of available spatial data. Since government sources were the most populated, USFWS should have easier access to available spatial data.

Additionally we assessed spatial data format as a proxy for data quality. Almost all available data from recovery plans were in the form of a static map. The data from the USFWS ECOS website had a wider variety of formats with half the data available has an interactive map. Because this data was not downloadable, it is necessary to access to the backend of ECOS in order to obtain relevant shapefiles. More than a quarter of data from ECOS was also available as a static map, the least usable format for spatial tool development. Finally, the USGS BISON website had both downloadable data and interactive maps for all available spatial data.

Table 2: Frequency of data layers across all species
Current range was the most available spatial data layer. There were significant data gaps for all other spatial layers, with 16 of 27 data layers recorded 6 times or less among all species and data sources.

Data Layer	Frequency	Tier
Current range	391	1
Historic range	67	1
Critical habitat	53	1

Recovery - Invasive/disease control	39	3
Habitat suitability	38	3
Threat- Invasive species and/or Disease	37	2
Recovery - Habitat restoration/conservation	33	1
Recovery Units	14	2
Monitoring/Research	11	1
Habitat Use	11	1
Recovery - Captive breeding releases	11	2
HCP	6	1
Threat - Habitat loss/alteration	6	1
Threat - Physical obstruction	6	1
Safe harbor	5	1
Recovery - Other	5	3
Migration route	4	2
Recovery - Habitat connectivity	3	2
Threat - Other	3	3
Recovery - Buffer areas	1	1
Threat - Pollution source	1	2
Recovery - Recreation limits	1	3
Threat - Habitat susceptibility	1	3
Recovery - Pollution control	1	3
Section 7 takes	0	1
Threat - Climate change	0	3
Threat - Recreational disturbance	0	3

For each taxonomic group, we calculated the proportion of available data out of the total number of applicable layers (See Table 6). Crustaceans had the largest proportion of available data while amphibians had the smallest proportion. However, none of the taxonomic groups had higher than 36% of their applicable spatial data available. Because our sample size was representative of the taxonomic breakdown in the ESA, some groups had a very small sample size and may not have provided representative results. For instance, we only assessed two crustacean species within our sample and both were covered by the same recovery plan. Although randomly sampled, this may have skewed our results.

Since the goal of the spatial tool was to determine how different data categories spatially interact with each other on a map, it was important to assess the relative diversity of available data. Species with a more even distribution of biological, anthropogenic, and ESA feature data would have higher data diversity. A species with both high data availability and high data diversity can facilitate the creation of a highly useful recovery map, however many taxonomic groups are lacking in one data category or the other. For example, while crustaceans had the largest proportion of available spatial data, they were not necessarily the most feasible to be mapped as their data diversity was lower than many other taxa. As shown in Figure 1, mammals, fish, birds and reptiles all have both a large amount of data and high data diversity. In contrast, snails, amphibians and clams have low data availability and diversity. Both snails and amphibians were missing data from an entire data category (i.e. ESA features or Anthropogenic).

Table 3: Differences in spatial data availability among taxonomic groups
Not all data layers were applicable for each taxonomic group. We first assessed if a spatial data layer was applicable to the species, and subsequently noted the layer's presence or absence. Based on the presence of applicable spatial layers for each species, crustaceans were the taxonomic group with the most spatial data available.

Taxonomic Group	Present	Absent	Total	Proportion Available
Crustacean	10	18	28	36%
Reptile	12	26	38	32%
Birds	46	106	152	30%
Mammal	40	93	133	30%
Ferns	9	22	31	29%
Fish	51	130	181	28%
Insect	15	40	55	27%
Arachnid	4	12	16	25%
Flowering Plants	188	659	847	22%
Clam	17	67	84	20%
Snail	7	37	44	16%
Amphibian	3	22	25	12%

We also assessed the differences in spatial data availability for problem species by calculating the proportion of available data layers out of the total number of applicable layers (See Table 4). We found that problem species had a higher proportion of spatial data available in comparison to non-problem species. The only problem category that did not follow this pattern was data-deficient species. The increase in available data for problem species may reflect extensive research and visualization for migratory and transboundary species. These species frequently travel great distances requiring collaboration between nations and states. Controversial species, which often create tension between USFWS, landowners and developers, are likely more researched as a means to mitigate some of these tensions. However, spatial data available among problem species was not diverse, with the majority of available data categorized as biological. This suggests that while problem species have more data available, they are not immediately feasible for spatial tool development.

Figure 1: Relationship between data availability and data diversity among taxonomic groups

The most effective maps have both a large quantity of available data as well as a diverse data set. Taxa with greater data diversity had a more equal distribution of biological, anthropogenic, and ESA features spatial data. The taxa that have the highest data availability and diversity are mammals, birds, reptiles, and fish. These groups are the most feasible to map. The least feasible taxa to map are snails, amphibians, and clams due to low data availability and diversity.

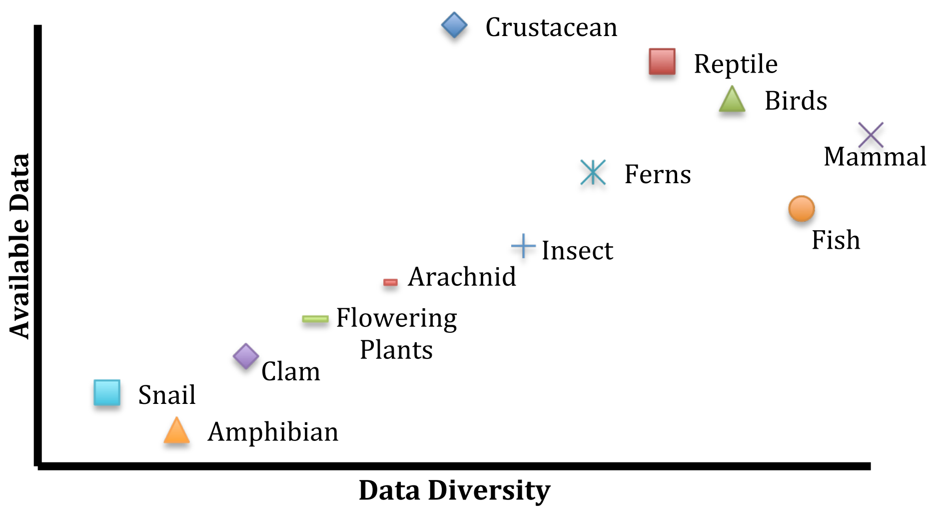


Table 4: Differences in spatial data availability among problem species

More data was spatially available for every problem category except for data deficient species. Some of these problems may actually promote spatial data collection.

Problem Category	Present	Absent	Total	Proportion Available
Migratory	32	66	98	33%
Transboundary	20	48	68	29%
Multi-Problem	32	78	110	29%
Controversial	60	155	215	28%
Non-Problem	212	630	842	25%
Data Deficient	110	411	521	21%

We found that a species' listing date under the ESA and presence of monitoring efforts did not influence spatial data availability (see Appendix 11 and Appendix 12 for complete data set). For example, the flowering plant, Hooker's Manzanita (*Arctostaphylos hookeri*), has only been listed on the ESA for 2 years, and has 2 of 10 applicable spatial layers available. In contrast, while the Devils Hole Pupfish (*Cyprinodon diabolis*) has been listed for 47 years, it also has only 2 of 11 applicable spatial layers available. Additionally, while the Pygmy Rabbit (*Brachylagus idahoensis*) has had little monitoring and research, 7 of its 11 applicable spatial layers were found. In comparison, the Whooping Crane (*Grus Americana*), which has been extensively monitored, had only 5 of its 23 applicable spatial layers available.

Objective 3: Spatial Tool

Characteristics of Mapped Data

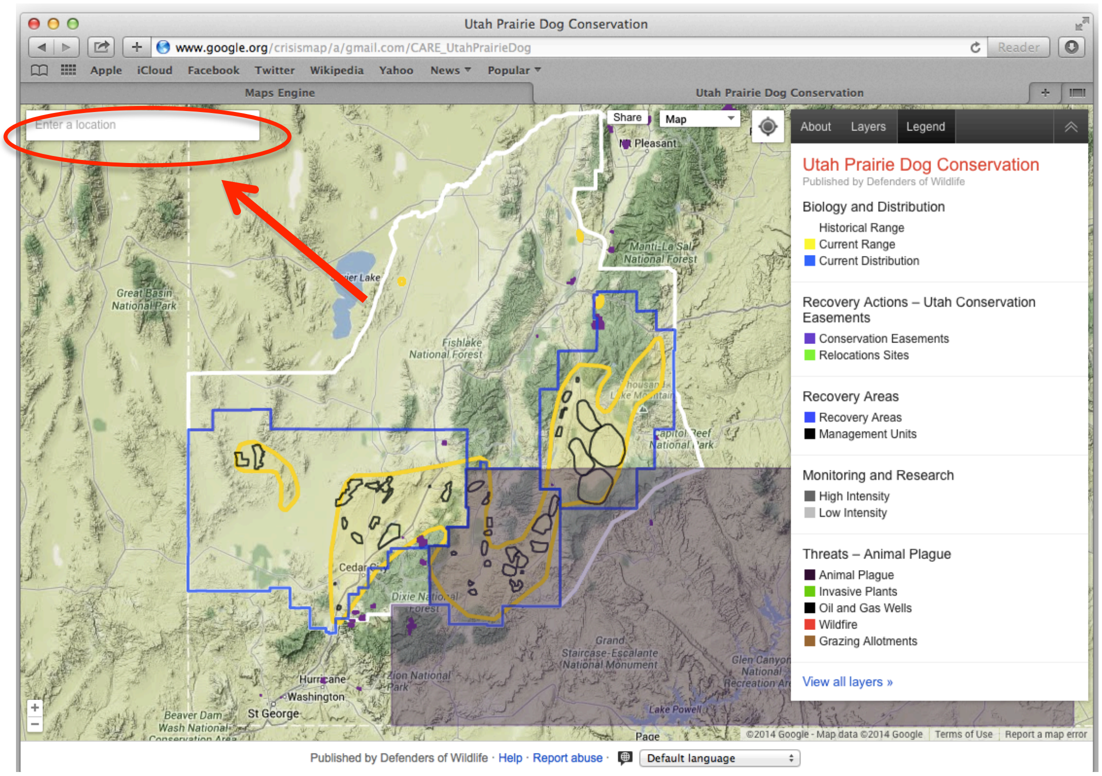
The final map included 20 unique data layers relevant to the Utah prairie dog (*Cynomys parvidens*). Six of the 20 layers came from the original nine sources specified in the feasibility study while the remaining 14 layers came from a variety of outside sources (see Appendix 13). This data distribution suggests that our nine original sources do not provide sufficient data to create a useful and diverse map. Furthermore, as a standardized set of sources will likely be unsuitable for data collection among all species, sources will need to be individually tailored to each species.

Based on the recovery plan for the Utah prairie dog, we determined that there were 33 possible spatial layers that were applicable to the species. With 20 intersecting layers we were able to include more than half of the total applicable species layers in our spatial tool. Based on the definitions outlined in the Tiered Mapping System, 12 of our 20 spatial layers belonged to Tier 1, seven were in Tier 2, and one was classified as Tier 3. The mapped Tier 1 data layers included federal lands, historical range, current range, current distribution, recovery areas, survey intensity, 4(d) Rule, Iron County Habitat Conservation Plan, Low Effect Iron County Habitat Conservation Plan, Garfield County Habitat Conservation Plan, Henrie Safe Harbor Agreement, and Utah prairie dog Conservation Bank Safe Harbor Agreement. We were able to find seven Tier 2 layers including management units, oil and gas wells, grazing allotments, animal plague, invasive plant species, conservation easements, and relocation sites. Additionally, we mapped wildfire occurrences, which was considered a Tier 3 layer.

Navigating the Tool via Google Crisis Maps

The proof-of-concept tool can be easily accessed online at: http://www.google.org/crisismap/a/gmail.com/CARE_UtahPrairieDog. Using Google Crisis Maps, each of these layers can be turned on and off by navigating from the Legend window to the Layers window using the buttons in the upper right corner of the map (See Figure 2). To make the map more visually appealing, some layers such as “Survey Intensity”, and “Current Distribution” are initially turned off. For the same reason, we made the “Recovery Actions” and “Threats” layers “single selection,” meaning only one layer within the category can be displayed at any one time.

Figure 2: Initial view of Utah prairie dog spatial tool
The search bar in the upper left corner allows managers and developers to search for addresses, parks, or other geographic locations.



A notable feature of Crisis Maps is that the search box in the upper left hand corner can be used to quickly navigate to a specific physical address. This could be potentially useful for developers as they assess whether their project overlaps with species current range or management units. It could also be useful for landowners to see if their property is near the current range of a species.

The Utah prairie dog map could be used to help pick new species relocation sites. By looking at each Threats layer, a new site could be identified by finding the least vulnerable habitat patch. For instance, if basing this decision off historical wildfire locations (red points), a new relocation site should not be placed at the indicated location in Figure 3. While some of the densest wildfire areas are not within the species' current range (yellow polygon), they are close enough to this patch of habitat to make it susceptible to spreading wildfire. In addition, the map shows that although within the species range, there is a lack of relocation sites (green circles) in the eastern most recovery area (blue polygon).

Figure 3: New relocation site option based on wildfire locations
A densely clustered record of wildfire locations (red points) near or within the species range can negatively impact prairie dog populations. Relocation sites should avoid areas that are likely to experience intense fires. This process can be repeated for many other threats and recovery actions.

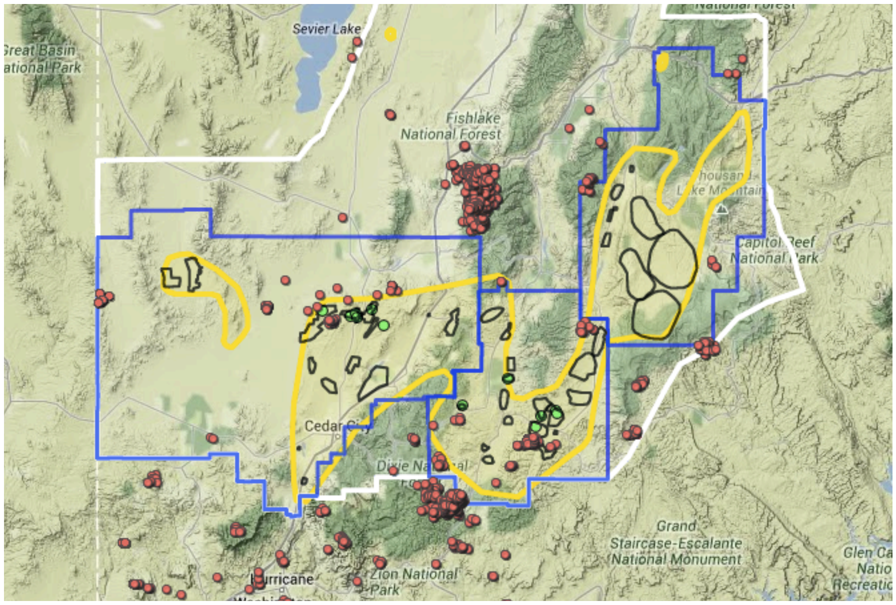
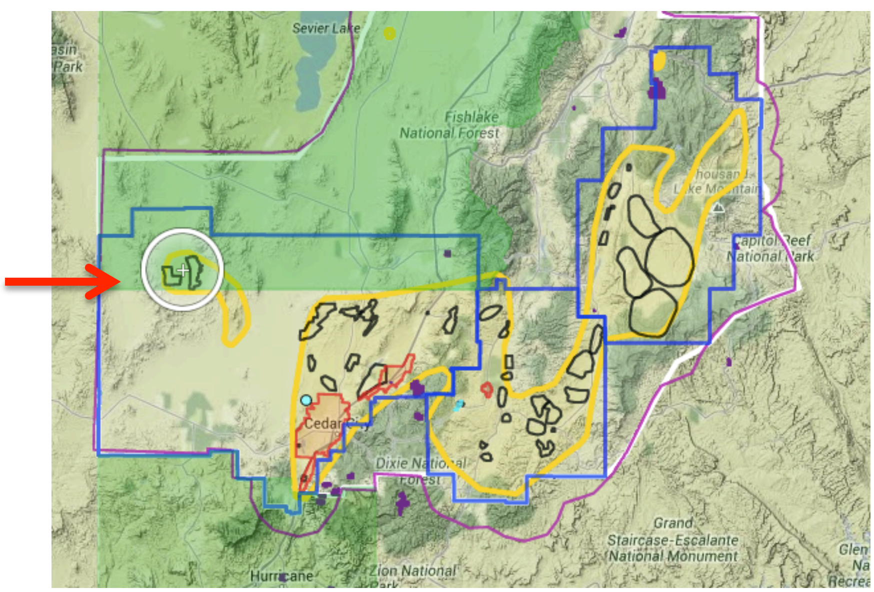


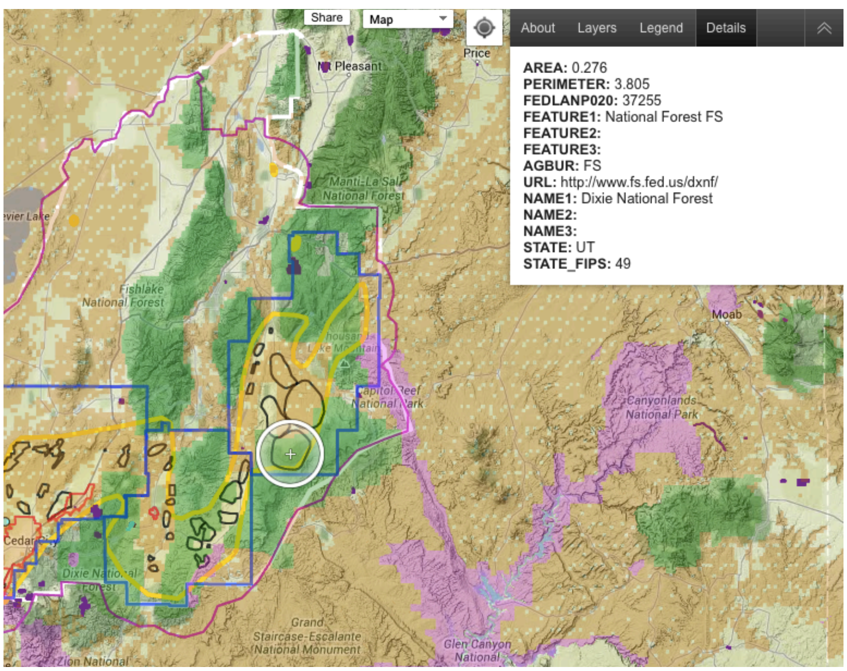
Figure 4: Management unit decisions based on threat identification
Not all management units are threatened with invasive grasses (green polygon). By identifying the exact location of threats in comparison to species range, management plans can be more specific, focused, and effective.



The Utah prairie dog map can also be used to advise management unit decisions. For example, if a biologist was interested in updating the recovery actions for the two most western management units (focus area indicated by the white circle in Figure 4) they would see that they should address the invasive plant species, Scotch Thistle (*Onopordum acanthium*), which is denoted by the green polygon. The map also shows that there are no spatial data available for recovery actions that may be addressing this threat across the entire range of the species. This demonstrates that the map also can be used to display gaps in recovery action for various threats.

The map can also tell biologists or developers what federal agencies have direct jurisdiction in many species areas. For example, by turning on the Federal Lands base layer and clicking the management unit indicated by the white circle in Figure 5, the "Details" window opens in the upper right hand corner. This information in this box indicates that the management unit is almost completely within US Forest Service land. If the biologist in this management unit has not yet begun recovery actions, this map may suggest a potential partnership with the Forest Service during the planning stages.

Figure 5: Federal agency collaboration by land ownership
Maps allow planners to know the agencies that administer land on which a species persists.



Finally, additional data can be incorporated into the attribute tables of each data layer. This data would then be viewable in the "Details" window of Crisis Maps. Of particular interest to Defenders was displaying data from monitoring reports, which are an annual requirement for all habitat conservation plans. Monitoring reports provide information concerning the maximum take, the actual number of individuals taken, the number of acres taken from habitat, the number of animals trapped, the number of animal take mitigated, and the number of acres of mitigated habitat loss. With the help of recovery biologist, Nathan Brown, we were able to access monitoring reports for the Iron County Habitat Conservation Plan with data from 2000 to 2005 and 2008 to 2013. We incorporated this data into the attribute table for that layer (See Figure 6). If this spatial tool is further developed, monitoring data can be more fully integrated into all relevant windows and the tool can show exactly where animals or habitat are being lost or gained. A potential use of this data can be seen in Figure 7, which displays how much habitat for the Utah prairie dog has been taken and mitigated every year since 2000. In years where take outnumbered mitigation, habitat is permanently lost. While the incorporation of such data would make our spatial tool even more useful, it should be noted that accessing monitoring reports was difficult and we would not have found as much data if Brown was not able or available to share it with us.

While the aforementioned analysis only outlines a handful of readily apparent management decisions, the map provides several other management applications for both the Utah prairie dog and other mappable species. With more data layers, the tool's ability to influence and inform management decisions will likely improve.

Figure 6: Incorporating monitoring report data into attribute tables
Monitoring data can be displayed on the map via the "Details" tab. This allows for managers to both determine where authorized actions are occurring in the space and their relative degree of impact.

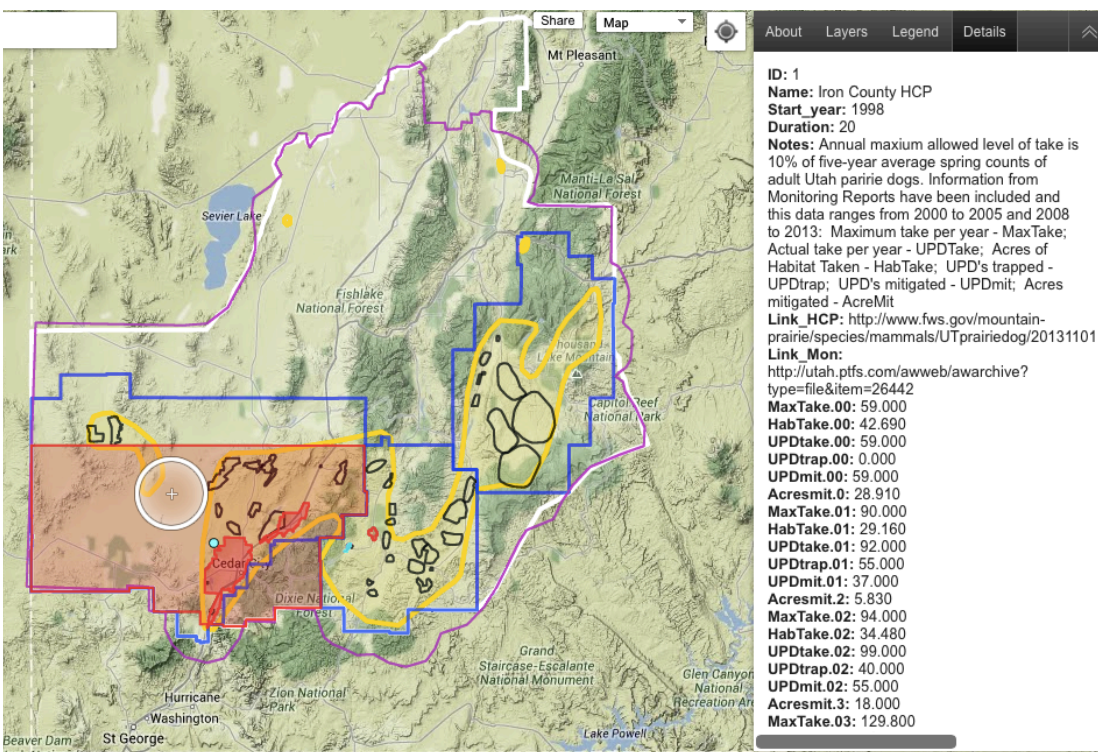
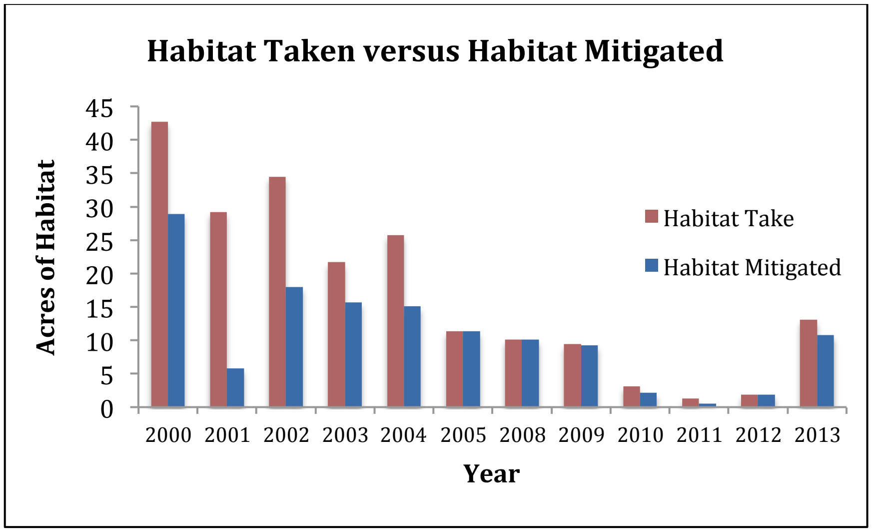


Figure 7: Potential for incorporating monitoring report data into the spatial tool
From 2000 to 2013, 204 total acres of Utah prairie dog habitat was legally taken and 130 acres of habitat loss have been mitigated. This data shows that throughout the early 2000's, more habitat was lost than mitigated. When combined with our spatial tool, these reports can aid in advocacy and legal efforts by identifying those HCPs that are under-performing and causing excessive animal or habitat loss.



Discussion

Objective 1: Improving recovery plans with the Interim Guidance

From our analysis on the incorporation of SCB recommendations, we found that recovery plans largely follow the Interim Guidance. In order to improve long-term species recovery, Defenders should work with USFWS to revise the guidance and prioritize the collection of spatial data among all recovery plans. In order to be most effective, language in the Interim Guidance must be clear and explicit. Vague suggestions will result in a lack of action within recovery plans. Currently, activities such as monitoring are mentioned and encouraged in the Interim Guidance, but not explicitly required nor prioritized. This may account for the lack of sufficient monitoring plans in place among many recovery plans.

Given the multiple constraints on USFWS (lack of time, funding, staff, etc.) it is unrealistic to assume that such a change to the Interim Guidance will result in the collection of spatial data for every threat, recovery action, legal designation, and biological constraint for every species. It may also take considerable time for changes within the Interim Guidance to fully matriculate in all recovery plans. Recovery plans will only include updated requirements (like the collection of spatial data) if the plans are written or updated after the Interim Guidance has been revised. For some species, it may take decades before their plans are updated to include these new requirements. However, spatial data may make plans easier to update moving forward and resolve ongoing problems between connecting species biology, status, and threats to related management actions, monitoring protocols, or recovery criteria (Harvey et al. 2002).

Additionally, despite many of these challenges, updating the Interim Guidance can still lead to significantly more available spatial data for endangered species. Given the significant spatial data gaps for all species, any increased data collection would be beneficial. Although only half of all SBC recommendations were fully incorporated within the Interim Guidance, USFWS and NOAA's growing commitment to spatial tool development suggests that requiring spatial data collection within the recovery planning process may be well received. Furthermore, USFWS's ECOS website, which currently serves as a centralized database, could easily serve as a storehouse for all collected spatial data.

Objective 2: The Feasibility of Creating Future Maps

While the literature suggests several clear benefits to spatially mapping recovery plans, there is uncertainty about the feasibility of creating maps for all species listed under the ESA (e.g. Evans et al. 2011; Kerr & Deguise 2004; Wallace and Marsh 2005). The results of our feasibility study provided insight into potential challenges and data gaps that can be expected when creating future maps. The majority of the data we found came from USFWS, either in the recovery plans or on ECOS. Most of this data was biological data. While important, data from this category is not the only kind needed for the creation of a usable map. Without knowing the location of threats or the boundaries of various ESA legal designations, recovery planning becomes increasingly difficult. This data was also rarely in a downloadable or easily manipulated format.

While USFWS is likely to have easier access to this data in alternative formats (such as downloadable data), third parties like Defenders would have a harder time using this data to create a map without contacting the data owners. The map we created for the Utah prairie dog was largely facilitated by our good working relationship with the recovery biologist, Nathan Brown, who provided us with shapefiles that were otherwise unavailable on the web. Had Brown been unable or unavailable to help, the time it took to create our spatial tool would have significantly increased due to the need to geo-reference many static maps. Furthermore, the geo-referencing process can lead to inaccuracies. For example, some of the static maps we came across were of very poor quality, especially those from plans written prior to 2000. In those cases, it would have been nearly impossible to geo-reference the map accurately.

Of all the spatial data found through the study, the most common data category, by far, was biological data. Anthropogenic and ESA Features were hardly present in a spatial form. It is particularly interesting that data related to threats were not spatially represented because one of the best incorporated SCB recommendations was "recovery plans clearly identify threats to the species." This disconnect indicates that while recovery biologists have done an excellent job at identifying what threats are, they have not necessarily identified where the threats occur. In order to make a high-quality map for species recovery, all three data categories are necessary. While knowing spatial aspects of a species biology is extremely helpful, it alone will not advise recovery biologists about what threats are impacting various populations, or if development is being planned in critical habitat (Shiling 1997). Useful recovery maps cannot be created for the majority of species as a result of this heavy slant toward biological data.

Some species groups have significantly larger data gaps than others. When looking at the differences in spatial data availability among taxonomic groups and problem groups, it is clear that high-profile and charismatic species tend to have more available spatial data (especially mammals, birds, and reptiles). For species that are non-controversial, small, or sedentary, the spatial data gaps are significant. Amphibians, snails, clams, and plants especially lack spatial data, which is concerning since these species are some of the most endangered and underfunded species domestically and globally (Restani and Marzluff 2002). Without more spatial data for these species, recovery maps cannot be created. This limitation only increases the risk of extinction for many low-profile species within these taxa.

Objective 3: Mapping Opportunities and Challenges

One of the primary benefits of our proof-of-concept map is that it is extremely easy to share. Anyone can with access to the published URL can view and interact with the map. In addition, Google Crisis Maps provides the html code needed to embed the map on a host website should an organization find this more conducive for their outreach goals. Another benefit is that no additional software needs to be downloaded, and most people are familiar enough with Google Maps that there will likely be an insignificant learning curve for the general public. Similarly, the map is user-friendly with simple buttons and easy-to-understand functions. Lastly, the map is also accessible on smart phone browsers and GPS. This means there is some potential for biologists to use and update the map in the field.

Another reason Google Crisis Maps is a great platform for this tool is because of the wide range of importable data formats. By linking Google Crisis Maps to Google Map Engine, the number of format options increases. Google Maps Engine can work with csv files, KML's, shapefiles, and rasters. Google Crisis Maps can additionally link to online tables, Google spreadsheets, Google Fusion Tables and other web-mapping servers. While many format options are great in theory, we had trouble using some of these functions due to technical difficulties. For instance, we were not able to upload raster files to Google Maps Engine, which usually gave us a vague and unsolvable systems error. Furthermore, we could not upload anything to Google Crisis Maps directly, and had to pull all files to the tool via Google Maps Engine. We also tried linking Google Crisis Maps to web-based mapping services hosting land cover data, Google spreadsheets, and Google Fusion Tables but had no success. These errors prevented us from displaying land cover data and wind energy development potential. Although these technical challenges are somewhat limiting, many issues may be resolved in time as Google further develops Crisis Maps.

An additional benefit of Google Crisis Maps is that it has a very professional interface. For instance, it creates a useful formatted legend making maps much easier to understand. However, the legend is not automatically generated and each time the style of a layer is changed, the legend also has to be manually adjusted. The legend also only displayed colors, not symbology. This is an issue that Google should address in subsequent updates to the platform. There were other stylization limits that required us to be strategic in our choices to avoid making a cluttered map given our high number of data layers. It was unclear to us how to organize and layer our data on Google Crisis Maps, meaning we could not control which data layer was on top of another. To work around this, we made some layers slightly opaque, and configured the map to launch with some layers turned off. Users could later turn these layers on and off based on their needs.

We believe our spatial tool would be a unique and extremely useful online map since many of the similar mapping tools we assessed during the project did not display as many layers as we included. For example, IUCN Red list and USGS BISON were limited to displaying only biological data. However, creating a multi-layered map of this scale takes significant time and may be one of the reasons there are not more maps like our proof-of-concept. We had to search extensively outside of our original nine sources for spatial data, which involved more time and effort. Furthermore, the sites we found for the Utah prairie dog are not necessarily applicable to maps for all other species, and we spent substantial time waiting for contacts and researchers to respond to data-access requests. Due to these delays, we were not able to include shrub steppe habitat data layer, which would have been useful for identifying suitable habitat for the prairie dog. We were also unable to pay the processing fees required to obtain shapefiles for the Iron County HCP. We recommend budgeting for response time and processing fees if this tool is to be produced on a wider scale. In addition, we spent a significant amount of time pre-processing data using ArcGIS. For example, the county occurrences of plague and invasive species were not in a downloadable format, so we created them by manipulating a Utah county shapefile. Unless Google adds some of these manipulation functions into their mapping software, the development of recovery maps cannot happen within Google alone.

Despite these challenges, we believe launching a spatial tool similar to the one we created would be extremely beneficial to the recovery planning process. It is important that both Defenders and USFWS enter into this process with a clear understanding of the challenges and limitations of this undertaking. While we were able to make a useful map in a relatively short amount of time, much of this is due to the fact that the main recovery biologist was willing to help and had access to a number of the data layers that we requested. Additionally, the species we selected for the proof-of-concept had a lot of available data, so it may be harder to create a map for data-limited species like amphibians and snails. Overall, significant effort will be needed to create these maps on a larger scale.

The Applicability of Maps for Defenders of Wildlife

Defenders can use maps like the one created for the Utah prairie dog for multiple internal purposes such as advocacy and legal efforts. Defenders staff have already used Google maps to find an illegal road interfering with species recovery (Sheppard and Li, personal communication). These maps can also be used to communicate campaigns to the general public as visual representation can make it easier to understand both the location and the scope of problems and projects. This tool may also boost activist engagement and fundraising efforts. Finally, because Defenders has already begun using maps in programmatic and scientific work, this tool may be more easily integrated into normal work practices (Sheppard and Li, personal communication). Mapping tools can specifically enhance the work of Defenders' advocates, outreach staff, fundraisers, conservation planners, and scientists, and allow Defenders to make better-informed planning recommendations. These tools can also serve as platform for further analysis of projected and actual species range shifts due to climate change.

Despite these benefits, developing these maps can be challenging. One of the biggest difficulties will be finding the necessary data, which takes considerable time. The original nine sources we used for our feasibility study did not have enough data for us to build a useful map. Some data will only be present in a static map, increasing the amount of time Defenders time may spend pre-processing data. It may also be necessary to pay processing fees to obtain particular data sets from the state or federal government. If Defenders plans to augment its current operations with maps like the one we created, it will need to invest additional funds and staff time into project development.

Collaborating with USFWS

As we developed our mapping tool for Defenders, USFWS was in the midst of developing the Information, Planning, and Conservation (IPaC) decision support system. The primary purpose of IPaC is to identify which threatened and endangered species will likely be impacted (and the degree to which they will be impacted) by section 7 and 10 development. While the system is still under development, the model created for IPaC is extensive. One of the key components of this model is the "effect pathways," which gives developers and recovery biologists a good idea as to what threats they can anticipate and the degree to which it will impact a species (Horton 2014). This system has the potential to significantly improve planning decisions and mitigation tasks. However, IPaC has some limitations. Since the system focuses primarily on section 7 and 10 development projects, users are unable to view a single species and its associated threats, recovery actions, and legal designations. We are also generally skeptical about the speed at which the system will be fully populated with data. USFWS currently estimates that IPaC will be live in five years (by 2019), but this is contingent on funding from Congress (Horton 2014). Given previous budget cuts, this time estimate may be overly optimistic.

Despite some of these constraints, we believe IPaC can become part of a two-pronged recovery mapping system. In conjunction with a spatial tool like ours, USFWS can create highly informed species-specific maps built from the spatial data recovery biologists would collect as part of the recovery planning process. This species-specific data can then be stored on ECOS alongside data IPaC will collect from developers on section 7 and 10 projects. Both ECOS and IPaC can bring this data together into a single map for each species. By combining the biological data already on ECOS with the anthropogenic and ESA feature data from IPaC, USFWS can create more diverse and useful recovery maps. The NOAA Fisheries Northwest Region has created a spatial tool very similar to ours for the Pacific salmon and steelhead. While we have not assessed the quality of this map, it may be able to serve as a model for other maps to be developed.

Conclusion

Concerned about the insufficient progress many threatened and endangered species have made towards full recovery under the protection of the ESA, this project has focused on the important role of spatial data in supporting the recovery planning process. It is evident that every species is restricted by a lack of spatial data to some extent. In addition, much of the spatial data that may exist is largely inaccessible to the public. Overall, USFWS needs to collect more spatial data throughout the recovery planning process and make it easily accessible for mapping purposes. Additionally, the collection of spatial data for anthropogenic and ESA features needs to be emphasized in order to create multi-layered and informative maps. The Interim Guidance in particular needs to be updated to require spatial data collection within recovery plans. While this change may help all species obtain more spatial data, there are some species groups that need further assistance. USFWS should first prioritize data-collection efforts on low-profile species such as amphibians, clams, and snails. Due to the slow process of plan revision, this data collection may need to happen outside of the species' formal recovery plans.

While many species are limited by the availability of spatial data, some can be presently mapped like mammals, birds, and reptiles. Consequently, many of Defenders' priority species could be mapped in a way to benefit various internal operations. Although Defenders will need to invest significant time and money into spatial tool development, the process can begin immediately. In the long run, however, Defenders should collaborate with USFWS to enhance the mapping of endangered species in the context of IPaC tool development. If more spatial data can be collected and stored in ECOS through the recovery planning process, it can lead to a single, diverse, and helpful recovery map.

Literature Cited

Boersma P Dee, Peter Kareiva, William F. Fagan, Clark J. Alan, and Jonathan M. Hoekstra. (January 01, 2001). How Good Are Endangered Species Recovery Plans? *Bioscience*, 51, 8, 643-649.

Brigham, C. A., A. G. Power, and A. Hunter (2002). Evaluating the internal consistency of recovery plans for federally endangered species: a tool for assessing the efficacy of endangered species planning. *Ecological Applications* 12:648–654.

Brown, Nathan. (2014). *Utah Prairie Dog Historic Range Data Layer.* Retrieved via personal correspondence.

Brown, Nathan. (2014). *Utah Prairie Dog Management Unit Data Layer.* Retrieved via personal correspondence.

Brown, Nathan. (2014). *Utah Prairie Dog Recovery Area Data Layer.* Retrieved via personal correspondence.

Clark, S. G., Reading, R. P., & Clarke, A. L. (1994). Endangered species recovery: Finding the lessons, improving the process. Washington, D.C: Island Press.

Clark, J. A., Hoekstra, J. M., Boersma, P. D., & Kareiva, P. (December 01, 2002). Improving U.S. Endangered Species Act Recovery Plans: Key Findings and Recommendations of the SCB Recovery Plan Project. *Conservation Biology*, 16, 6, 1510-1519.

Endangered Species Act of 1973. 16 U.S.C. § 1533(f)). (2001). Retrieved from http://www.nmfs.noaa.gov/pr/laws/esa/text.htm

Evans, M. C., Watson, J. E. M., Fuller, R. A., Venter, O., Bennett, S. C., Marsack, P. R., & Possingham, H. P. (April 01, 2011). The Spatial Distribution of Threats to Species in Australia. *Bioscience*, 61, 4, 281-289.

Foin, T. C., Riley, S. P. D., Pawley, A. L., & Ayres, D. R. (January 01, 1998). Improving Recovery Planning for Threatened and Endangered Species. *Bioscience Washington*, 48, 3, 177-184.

Garfield County Commission. (September 24, 2013). *Draft Low-Effect Habitat*

Conservation Plan for the Utah Prairie Dog in Residential and Comercial Development Areas of Garfield County, Utah. Retrieved from http://www.fws.gov/mountainprairie/species/mammals/utprairiedog/ FinalDraftLowEffectGarfiel%20CountyUPD_HCP_092413.pdf

Gerber, L. R., & Schultz, C. B. (January 01, 2001). Authorship and the Use of Biological Information in Endangered Species Recovery Plans. *Conservation Biology*, 15, 5, 1308-1314.

Gies, Erica. (May 05, 2012). Report: Endangered Species Act Works. Retrieved from http://www.forbes.com/sites/ericagies/2012/05/30/endangered-species-act-works-says-report/2/.

Glick, D. (January 01, 2005). Back from the Brink: An endangered species story with happy endings? From soaring bald eagle populations to rebounding grizzly bears, there have been more successes than you might expect. *Smithsonia*n, 36, 6, 54-63.

Gregory, R., Long, G., Colligan, M., Geiger, J. G., & Laser, M. (August 30, 2012). When experts disagree (and better science won't help much): Using structured deliberations to support endangered species recovery planning. *Journal of Environmental Management*, 105, 30-43.

Harvey, E., Hoekstra, J. M., O, C. R. J., & Fagan, W. F. (January 01, 2002). Recovery plan revisions: progress or due process?. *Ecological Applications*, 12, 682-689.

Himes, B. G. K. (February 01, 2014). A framework for developing objective and measurable recovery criteria for threatened and endangered species. *Conservation Biology*, 28, 1, 33-43.

Hoekstra, J. M., Clark, J. A., Fagan, W. F., & Boersma, P. D. (January 01, 2002). A comprehensive review of Endangered Species Act recovery plans. *Ecological Applications*, 12, 630-640.

Horton, Mike (March 31, 2014). *IPaC tool and recovery planning process*. Informal presentation at the U.S. Fish & Wildlife Headquarters, Washington DC.

Iron County Commission. (August 23, 2013). *Draft Low-Effect Habitat Conservation Plan for the Utah Prairie Dog in Residential and Comercial Development Areas of Iron-County, Utah.* Retrieved from http://www.fws.gov/mountain prairie/species/mammals/utprairiedog/2013_August23_DraftIronCountyHCP.pdf

Kavalunas, Adam (2014). *Utah Prairie Dog Habitat Relocation Sites Data Layer.* Retrieved via personal correspondence.

Kerr, J. T., & Deguise, I. (December 01, 2004). Habitat loss and the limits to endangered species recovery. *Ecology Letters*, 7, 12, 1163-1169.

Leidner, A. K., & Neel, M. C. (January 01, 2011). Taxonomic and geographic patterns of decline for threatened and endangered species in the United States. *Conservation Biology*: the Journal of the Society for Conservation Biology, 25, 4, 716-25.

Lawler, J. J., Campbell, S. P., Guerry, A. D., Kolozsvary, M. B., O'Connor, R. J., & Seward, L. C. N. (January 01, 2002). Recovery Plans for Endangered Species – The scope and treatment of threats in endangered species recovery plans. *Ecological Applications: a Publication of the Ecological Society of America*, 12, 3, 663.

Lundquist, C. J., Diehl, J. M., Harvey, E., & Botsford, L. W. (January 01, 2002). Recovery Plans for Endangered Species - Factors affecting implementation of recovery plans. *Ecological Applications: a Publication of the Ecological Society of America*, 12, 3, 713.

Miller, J. K., J. M. Scott, C. R. Miller, and L. P. Waits. (2002). The Endangered Species Act: dollars and sense? *BioScience*, 52:163–168.

National Marine Fisheries Service (NMFS). (2014). Endangered and Threatened Marine Species. Retrieved from http://www.nmfs.noaa.gov/pr/species/esa/

National Marine Fisheries Service (NMFS). (2010). Interim Endangered and Threatened Species Recovery Planning Guidance: Version 1.3. Retrieved from http://www.nmfs.noaa.gov/pr/pdfs/recovery/guidance.pdf

National Oceanic and Atmospheric Administration. (2014). Recovery Action Mapping Tool. Retrieved from: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_action_mapping_tool.html

Nazzaro, Robin. (April 06, 2006). *Endangered Species: Time and Costs Required to Recover Species Are Largely Unknown (*GAO-06-463R). Retrieved from Government Accountability Office website http://www.gao.gov/assets/100/94110.pdf.

Neel, M. C., Leidner, A. K., Haines, A., Goble, D. D., & Scott, J. M. (July 01, 2012). By the Numbers: How is Recovery Defined by the US Endangered Species Act?. *Bioscience*, 62, 7, 646-657.

Olive, A., & Raymond, L. (December 01, 2010). Reconciling norm conflict in endangered species conservation on private land. *Natural Resources Journal*, 50, 2, 431-454.

Restani, Marco & Marzluff, John M. (February 01, 2002). Funding Extinction? Biological Needs and Political Realities in the Allocation of Resources to Endangered Species Recovery. *Bioscience*, 52, 2, 169-177.

Shepard, Anderson and Ya-Wei Li. (March 28, 2014). *Google Geo Tools Brown Bag*. Informal presentation at Defenders of Wildlife, Washington DC.

Shilling, F. (January 01, 1997). Do Habitat Conservation Plans Protect Endangered Species?. *Science*, 276, 5319, 1662.

Tear, T. H., J. M. Scott, P. H. Hayward, and B. Griffith. (1995). Recovery plans and the Endangered Species Act—are criticisms supported by data. *Conservation Biology* 9:182–195.

U.S. Fish and Wildlife Service. (2012). *Final Environmental Assessment of 4(d) Protective Regulations for the Utah Prairie Dog.* Retrieved from http://www.fws.gov/mountain-prairie/species/mammals/utprairiedog/2012_August_FinalEnvironmentalAssessmentProposed4dRule.pdf

U.S. Fish and Wildlife Service. (2005). *Henrie Safe Harbor.* Retrieved from http://ecos.fws.gov/conserv_plans/PlanReport?plan_id=1467&region=6&type=HA&rtype=1

U.S. Fish and Wildlife Service. (July 1993). *Management of Prairie Dog Complexes for the Reintroduction of the Black-footed Ferret.* Retrieved from http://pubs.usgs.gov/fedgov/70039171/report.pdf

USDA Forest Service. (2014). *Fire Detection GIS Data.* Available from USDA Remote Sensing Application Centers Center Web site: http://activefiremaps.fs.fed.us/gisdata.php

USDA Natural Resources Conservation Science. (2014). *Musk Thistle and Scotch Thistle data.* Available from USDA Natural Resources Conservation Science Web site: http://plants.usda.gov/java/

Wallace, C. S. A., & Marsh, S. E. (January 01, 2005). Characterizing the spatial structure of endangered species habitat using geostatistical analysis of IKONOS imagery. *International Journal of Remote Sensing*, 26, 12, 2607-2629.

Weijerman, M., Dunlap, M. J., Birkeland, C., Piniak, G. A., Miller, M. W., Eakin, C. M., McElhany, P., Brainard, R. E. (April 01, 2014). Endangered species act listing: Three case studies of data deficiencies and consequences of ESA 'threatened' listing on research output. *Current Opinion in Environmental Sustainability*, 7, 15-21.

U.S. Fish and Wildlife Service (USFWS). (2003). Working Together: Partnerships for Endangered Species Recovery. Retrieved from http://digitalmedia.fws.gov/cdm/ref/collection/document/id/1842

Appendix 1: SCB Recommendations for Improving U.S. Endangered Species Act Recovery Plans

The fifteen recommendations identified within the report (Clark 2002) include:

1. Recovery plans clearly identify threats to the species
2. Recovery plans identify tasks that mitigate the identified threats
3. Recovery plans identify concrete criteria and goals for recovery and down-listing
4. The management plan for recovery is linked to the biological needs and constraints of the species
5. Innovative tools are implemented in the Recovery plan
6. Trend line data on the species' population is collected regularly
7. Monitoring plans are in place for the Recovery plan
8. Critical habitat designation for the species is explained and justified
9. There is a centralized database where information is stored
10. Recovery plans follow the recommended template put forward in the Interim Guidance
11. Roles in the Coordinating Committee are clearly defined.
12. The Coordinating Committee's membership is diverse, coming from various sectors and stakeholders
13. Coordinating Committees are small
14. Personnel are trained
15. Funds for the Recovery plan are tracked

Appendix 2: Twelve Individual Recovery Plans Used to Assess the Incorporation of SCB Recommendations

CARE assessed the recovery plans of the following species:

- Alabama sturgeon (*Scaphirhynchus suttkusi*)
- Ivory-billed woodpecker (*Campephilus principalis*)
- Northern sea otter (*Enhydra lutris kenyoni*)
- St. Andrew beach mouse (*Peromyscus polionotus peninsularis*)
- Utah prairie dog (*Cynomys parvidens*)
- Bexar County Invertebrates (multi-species plan)
- Lost River sucker (*Deltistes luxatus*)
- Black-footed ferret (*Mustela nigripes*)
- North Atlantic right whale (*Eubalaena glacialis*)
- Pygmy rabbit (*Brachylagus idahoensis*)
- Rouge and Illinois Valley Vernal Pool and Wet Meadow Ecosystems (multi-species/ecosystem-based plan)

Appendix 3: Randomly generated ESA species used for Feasibility Study

Recovery plans for all the following species can be access on the USFWS ECOS website (http://ecos.fws.gov/ecos/home.action)

Species Name (common)	Scientific name	Taxonomy	ESA Listing Date	Recovery Plan Date	Lead USFWS Region
Round-leaved chaff flower	Achyranthes splendens var. rotundata	Flowering Plant	1986	1993	1
No common name	Alsinidendron viscosum	Flowering Plant	1996	1998	1
Kearney's blue-star	Amsonia kearneyana	Flowering Plant	1989	1993	2
Lange's metalmark butterfly	Apodemia mormo langei	Insect	1976	1984	8
Shale barren rock cress	Arabis serotina	Flowering Plant	1989	1991	5
San Francisco mazanita	Arctosyaphylos franciscana	Flowering Plant	2012	2013	8
No common name	Aristida chaseae	Flowering Plant	1993	1995	3
Pelos del diablo	Aristida portoricensis	Flowering Plant	1990	1994	4
Welsh's milkweed	Asclepias welshii	Flowering Plant	1987	1992	6
Guthrie's ground-plum	Astragalus bibullatus	Flowering Plant	1991	2011	4
Desert slender salamander	Batrachoseps aridus	Amphibian	1973	1982	8
Pygmy Rabbit	Brachylagus idahoensis	Mammal	2001	2013	1
San Diego fairy shrimp	Branchinecta sandiegonensis	Crustacean	1997	1998	8
Pua'ala	Brighamia rockii	Flowering Plant	1992	1996	1
Vahl's boxwood	Buxus vahlii	Flowering Plant	1985	1987	4
Ivory-billed woodpecker	Campephilus principalis	Bird	1967	2010	4
Navajo sedge	Carex specuicola	Flowering	1985	1987	2

		Plant			
Coyote ceanothus	Ceanothus ferrisae	Flowering Plant	1995	1998	8
Akoko	Chamaesyce remyi var. kauaiensis	Flowering Plant	2010	2010	1
Western snowy plover (Pacific coastal pop.)	Charadrius alexandrinus nivosus	Bird	1993	2007	8
Ben Lomond spineflower	Chorizanthe pungens var. hartwegiana	Flowering Plant	1994	1998	8
Government Canyon Bat Cave Spider	Cicurina vespera	Arachnid	2000	2011	2
Alabama leather flower	Clematis socialis	Flowering Plant	1986	1989	4
Oha wai	Clermontia oblongifolia ssp. Brevipes	Flowering Plant	1992	1996	1
No common name	Cordia bellonis	Flowering Plant	1997	1999	4
Pennell's bird's-beak	Cordylanthus tenuis ssp. Capillaris	Flowering Plant	1995	1998	8
No common name	Cranichis ricartii	Flowering Plant	1991	1996	4
Pauoa	Ctenitis squamigera	Fern	1994	1998	1
Haha	Cyanea acuminata	Flowering Plant	1996	1998	1
Haha	Cyanea grimesiana ssp. grimesiana	Flowering Plant	1994	2002	1
Haha	Cyanea grimesiana ssp. Obatae	Flowering Plant	1994	1998	1
Utah Prairie Dog	Cynomys parvidens	Mammal	1973	2012	6
Devils Hole pupfish	Cyprinodon diabolis	Fish	1967	1990	8
Leagy prairie-clover	Dalea foliosa	Flowering Plant	1991	1996	4
Rugel's pawpaw	Deeringothamnus rugelii	Flowering Plant	1986	1988	4

No common name	Delissea rhytidosperma	Flowering Plant	1994	1995	1
Lost River Sucker	Deltistes luxatus	Fish	1988	2013	8
Asplenium-leaved diellia	Diellia erecta	Fern	1994	1999	1
No common name	Diellia mannii	Fern	2010	Unknown	1
Devils River minnow	Dionda diaboli	Fish	1999	2005	2
Iowa Pleistocene snail	Discus macclintocki	Snail	1978	1984	3
Na'ena'e	Dubautia planteginea magnifolia	Flowering Plant	2010	Unknown	1
Marcescent dudleya	Dudleya cymosa ssp. Marcescens	Flowering Plant	1997	1999	8
Sana Monica Mountains dudleyea	Dudleya cymosa ssp. Ovatifolia	Flowering Plant	1997	1999	8
Santa Cruz Island dudleya	Dudleya nesiotica	Flowering Plant	1997	2000	8
Guajon	Eleutherodactylus cooki	Amphibian	1997	2004	4
Northern Sea Otter	Enhyra lutris kenyoni	Mammal	2005	2013	7
Puerto Rican boa	Epicrates inornatus	Reptile	1970	1986	4
Hawksbill sea turtle	Eretmochelys imbricata	Reptile	1970	1998	4
Gypsum wild-buckwheat	Eriogonum gypsophilum	Flowering Plant	1981	1984	2
San Diego button-celery	Eryngium aristulatum var. parishii	Flowering Plant	1993	1998	8
Duskytail darter	Etheostoma percnurum	Fish	1993	1994	4
North Atlantic Right Whale	Eubalaena glacialis	Mammal	1970	2010	11
El Segundo blue butterfuly	Euphilotes battoides allyni	Insect	1976	1998	8
Telephus spurge	Euphorbia telephioides	Flowering Plant	1992	1994	4

Heau	Exocarpos luteolus	Flowering Plant	1994	1995	1
Mehamehame	Flueggea neowawraea	Flowering Plant	1994	1999	1
Johnston's frankenia	Frankenia johnstonii	Flowering Plant	1984	1988	2
Hawaiian common moorhen	Gallinula chloropus sandvicensis	Bird	1967	2012	1
Hutton tui chub	Gila bicolor ssp.	Fish	1985	1998	1
Bonytail chub	Gila elegans	Fish	1980	2002	6
Gopher tortoise	Gopherus polyphemus	Reptile	1987	1990	4
Whooping crane	Grus americana	Bird	1970	2007	2
Guam Micronesian kingfisher	Halcyon cinnamomina cinnamomina	Bird	1984	2008	1
Honohono	Haplostachys haplostachya	Flowering Plant	1979	1993	1
Virginia sneezeweed	Helenium virginicum	Flowering Plant	1998	2000	5
Nukupu'u (honeycreeper)	Hemignathus lucidus	Bird	1986	2006	1
No common name	Hesperomannia arborescens	Flowering Plant	1994	1998	1
Hau kuahiwi	Hibiscadelphus woodii	Flowering Plant	1996	1995	1
Water howellia	Howellia aquatilis	Flowering Plant	1994	1996	6
Hilo ischaemum	Ischaemum byrone	Flowering Plant	1994	1996	1
Aupaka	Isodendrion longifolium	Flowering Plant	1996	1999	1
No common name	Kadua degeneri	Flowering Plant	1991	1998	1
Koki'o	Kokia drynarioides	Flowering Plant	1984	1994	1
Alabama lampmussel	Lampsilis virescens	Clam	1976	1985	4

Banbury Springs limpet	Lanx sp.	Snail	1992	1995	1
Beach layia	Layia carnosa	Flowering Plant	1992	1998	8
Scaleshell Mussel	Leptodea leptodon	Clam	2001	2010	3
Dudley Bluff's bladderpod	Lesquerella congesta	Flowering Plant	1990	1993	6
Large-flowered woolly meadowfoam	Limnanthes pumila grandiflora	Flowering Plant	2002	2013	1
San Clemente Island woodland-star	Lithophragma maximum	Flowering Plant	1997	1984	8
No common name	Lobelia gaudichaudii ssp. Koolauensis	Flowering Plant	1996	1998	1
Alani	Melicope paniculata	Flowering Plant	2010	2010	1
Alani	Melicope zahlbruckneri	Flowering Plant	1996	1998	1
Waccamaw silverside	Menidia extensa	Fish	1987	1993	4
Black-Footed Ferret	Mustela nigripes	Mammal	1967	2013	6
Spreading navarretia	Navarretia fossalis	Flowering Plant	1998	1998	8
No common name	Neraudia angulata	Flowering Plant	1991	1998	1
American burying beetle	Nicrophorus americanus	Insect	1989	1991	2
Eskimo curlew	Numenius borealis	Bird	1967	Exempt	7
Oregon chub	Oregonichthys crameri	Fish	1993	1998	1
Kanab ambersnail	Oxyloma haydeni kanabensis	Snail	1991	1995	6
Brady pincushion cactus	pediocactus bradyi	Flowering Plant	1979	1985	2
Peedles Navajo cactus	Pediocactus peeblesianus var.	Flowering Plant	1979	1984	2

	peeblesianus				
Goldline darter	Percina aurolineata	Fish	1992	2000	4
St. Andrew beach mouse recovery plan	Peromyscus polionotus peninsularis	Mammal	1998	2010	4
No common name	Phyllostegia hispida	Flowering Plant	2009	2013	1
No common name	Phyllostegia mannii	Flowering Plant	1992	1996	1
No common name	Phyllostegia mollis	Flowering Plant	1991	1998	1
Red-cockaded woodpecker	Picoides borealis	Bird	1970	2003	4
Ho'awa	Pittosporum napaliense	Flowering Plant	2010	Unknown	1
Rough popcornflower	Plagiobothrys hirtus	Flowering Plant	2000	2003	1
Kuahiwi laukahi	Plantago hawaiensis	Flowering Plant	1994	1996	1
Clubshell	Pleurobema clava	Clam	1993	1994	5
Geogia pigtoe	Pleurobema hanleyianum	Clam	2010	2013	4
Ovate clubshell	Pleurobema perovatum	Clam	1993	2000	4
Rough pigtoe	Pleurobema plenum	Clam	1976	1984	4
Mann's bluegrass	Poa mannii	Flowering Plant	1994	1995	1
Virginia fringed mountain snail	Polygyriscus virginianus	Snail	1978	1983	5
Alabama heelsplitter	Potamilus inflatus	Clam	1990	1993	4
Harperella	Ptilimnium nodosum	Flowering Plant	1988	1991	5
Colorado pikeminnow	Ptychocheilus lucius	Fish	1967	2002	6
Bull trout	Salvelinus confluentus	Fish	1998	2002	1
No common name	Sanicula mariversa	Flowering Plant	1991	1998	1

Alabama canebrake pitcher-plant	Sarracenia rubra ssp. Alabamensis	Flowering Plant	1989	1992	4
Pallid sturgeon	Scaphirhynchus albus	Fish	1990	2014	6
Alabama Sturgeon	Scaphirhynchus suttkusi	Fish	2000	2013	4
Ma'oli'oli	Schiedea apokremnos	Flowering Plant	1991	1995	1
No common name	Schiedea helleri	Flowering Plant	1996	1998	1
No common name	Schiedea membranacea	Flowering Plant	1996	1995	1
No common name	Schiedea nuttallii	Flowering Plant	1996	1999	1
Delmarva Peninsula fox squirrel	Sciurus niger cinereus	Mammal	1967	1993	5
Tobusch fishhook cactus	Sclerocactus brevihamatus ssp. Tobuschii	Flowering Plant	1979	1987	2
Large-flowered skullcap	Scutellaria montana	Flowering Plant	1986	1996	4
Huyan lagu OR Tronkon guafi	Serianthes nelsonii	Flowering Plant	1987	1994	1
Kirtland's warbler	Setophaga kirtlandii	Bird	1967	1985	3
No common name	Silene alexandri	Flowering Plant	1992	1998	1
Aiakeakua, popolo	Solanum sandwicense	Flowering Plant	1994	1995	1
Short's goldenrod	Solidago shortii	Flowering Plant	1985	2005	4
Riverside fairy shrimp	Streptocephalus woottoni	Crustacean	1993	1998	8
Eureka Dune grass	Swallenia alexandrae	Flowering Plant	1978	1982	8
Pamakani	Tetramolopium capillare	Flowering Plant	1994	1997	1
No common name	Tetramolopium rockii	Flowering Plant	1992	1998	1
No common name	Tetraplasandra flynnii	Flowering Plant	2010	Unknown	1

Kretschmarr Cave mold beetle	Texamaurops reddelli	Insect	1988	1994	2
Howell's spectacular thelypody	Thelypodium howellii spectabilis	Flowering Plant	1999	2002	1
Ashy dogweed	Thymophylla tephroleuca	Flowering Plant	1984	1988	2
Santa Cruz Island fringepd	Thysanocarpus conchuliferus	Flowering Plant	1997	2000	8
No common name	Trematolobelia singularis	Flowering Plant	1996	1998	1
West Indian Manatee	Trichechus manatus	Mammal	1967	2001	4
San Miguel Island Fox	Urocyon littoralis littoralis	Mammal	2004	2012	8
Nani'wai'ale'ale	Viola kauaiensis var. wahiawaensis	Flowering Plant	1996	1998	1
Dwarf iliau	Wilkesia hobdyi	Flowering Plant	1992	1995	1
Rota bridled white-eye	Zosterops rotensis	Bird	2004	2007	1

Appendix 4: Types of Monitoring Identified within the Interim Guidance

Per the objectives of the spatial tool feasibility study, we were interested in assessing the potential relationship between monitoring presence and data availability. The Interim Guidance lists three different types of monitoring that are described as follows:

1) Compliance Monitoring: Tracks the implementation of recovery actions to determine when a recovery plan has been fully implemented. This type of monitoring is typically tracked and recorded through 5-year reviews of the species.
2) Status/Trend Monitoring: Tracks populations and threats to assess if they are increasing or decreasing. These monitoring activities are particularly usefully in making projections into the future about how populations and/or threats will change.
3) Cause/Effect Monitoring: Tests hypotheses and innovative recovery actions to determine if actions are effective. Activities that mirror adaptive management are typically identified through these monitoring activities.

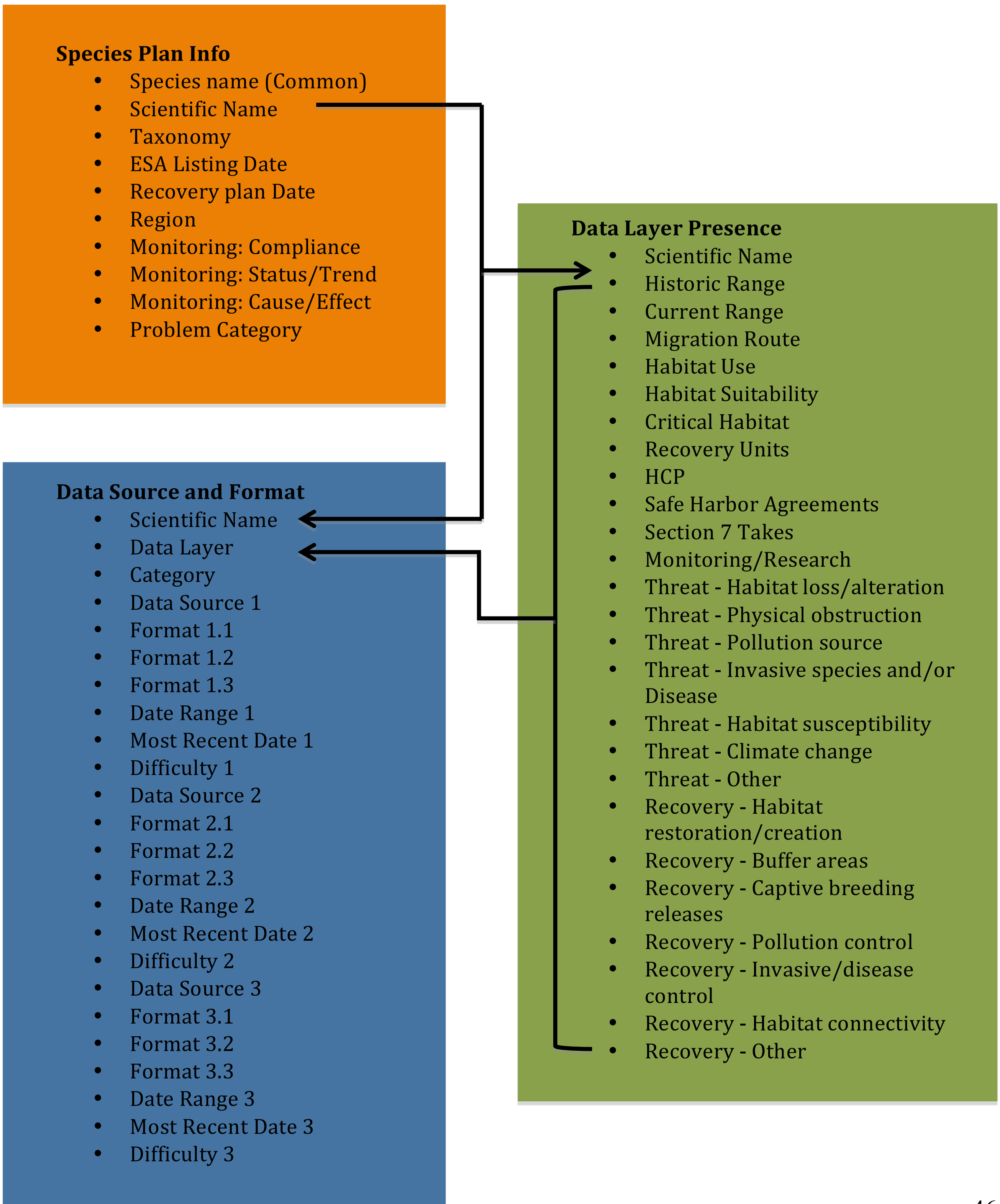
Initially we assessed the presence and absence of each type of monitoring data for each species in the feasibility study. However, when we ran statistical analysis on our results, we did not find a notable correlation between the monitoring type and amount of data availability. Due to our binary analysis (noting simply absence or presence) of each monitoring type, we decided that it would be more beneficial to look more generally at the relationship between monitoring (regardless of type) and data availability. Therefore the monitoring described in the report represents presence or absence of any or all monitoring types.

Appendix 5: Data Layer Categories and Types Searched for within the Feasibility Study

Data Category	Data Layer Type
Biological Data	Historic Range
	Current Range
	Migration Route
	Habitat Use
	Habitat Suitability
ESA Features	Critical Habitat
	Recovery Units
	Habitat Conservation Plans (HCP)
	Safe Harbor Agreements
	Section 7 Take Permits
	Monitoring and Research Activities
Anthropogenic Activities	Threat – Habitat Loss/Alteration
	Threat – Physical Obstruction
	Threat – Pollution Source
	Threat – Invasive Species and/or Disease
	Threat – Habitat Susceptibility to Disaster
	Threat – Climate Change
	Threat – Recreational Disturbance
	Threat – Other
	Recovery – Habitat Restoration/Creation
	Recovery – Buffer Area
	Recovery – Captive Breeding Release Sites
	Recovery – Pollution Control
	Recovery – Invasive Species/Disease Control
	Recovery – Habitat Connectivity
	Recovery – Recreation Limits
	Recovery – Other

Appendix 6: Database organization

Relationship between the spreadsheets species plan information, data layer presence, and data source and format. The arrows show the connections between spread sheets. Scientific name was the common data point to join the spreadsheets.



Appendix 7: Assessing the Difficulty Level of Finding Available Spatial Data

Each time we found available spatial data, we recorded how difficult that data layer was to find from a particular data source. The intent of this effort was to determine which data layers and sources may prove to be most challenging for spatial tool development.

We categorized the difficulty of finding the spatial data as "easy," "moderate" or "difficult." A designation of "easy" meant that we had clear access to the data on the main webpage of the source and that it required little time or effort to locate. A designation of "moderate" was used to signify that the data required us to follow multiple links and/or was not clearly accessible or easy to find without searching through various webpages within a source. A designation of "difficult" indicated that the data took considerable effort to find and/or it was unclear how to access it except through extensive searching.

While we reduced potential reviewer subjectivity by reviewing discrepancies among individual difficulty categorizations, we felt that this data was not robust enough to statistically analyze. Therefore all difficulty classifications are noted in the database and briefly summarized below but not expanded upon within this report.

Data Layer	Easy	Moderate	Difficult
Historic range	58	8	1
Current range	372	16	3
Migration route	4	0	0
Habitat Use	9	1	1
Habitat suitability	26	11	1
Crtical habitat	20	30	3
Recovery Units	9	4	1
HCP	3	3	0
Safe harbor	2	3	0
Section 7 takes	0	0	0
Monitoring/Research	9	2	0
Threat - Habitat loss/alteration	3	2	1
Threat - Physical obstruction	5	1	0
Threat - Recreational disturbance	0	0	0
Threat - Pollution source	0	1	0
Threat - Habitat susceptibility	1	0	0
Threat - Climate change	0	0	0
Threat - Other	2	1	0
Recovery - Habitat restoration/conservation	25	6	2
Recovery - Buffer areas	0	1	0
Recovery - Captive breeding releases	7	3	1
Recovery - Invasive/disease control	16	20	3

Recovery - Recreation limits	1	0	0
Recovery - Other	3	2	0
Recovery - Habitat connectivity	2	1	0
Number of Times Rated	577	116	17

Appendix 8: Tiered mapping system

Tier 1 layers are green, Tier 2 layers are blue, and Tier 3 layers are orange.

Base Layers:

- Land Ownership
    - Federal Land
        - BLM
        - USFWS
        - NPS
        - USFS
        - USDA
    - Private
    - State
        - Protected areas
        - Non-protected areas
    - Tribal
        - Protected areas
        - Non-protected areas

- Land cover

- LandSat

Species-Specific Layers

- Biology and Distribution
    - Historic Range
    - Current Range
        - Home Range
        - Habitat use
            - Summer vs. winter habitat
            - Spawning, breeding, and mating grounds
            - Nursery grounds
            - Feeding ground
        - Migration routes
    - Habitat Suitability
        - Climate
        - Vegetation
        - Human disturbance
        - Proximity to key resources
            - Obligate species range
            - Key abiotic factor/resource

- Threats
    - Habitat loss and alteration
        - Urban development
            - Housing
            - Roads
            - Industry
        - National resource extraction
            - Timber
            - Energy
            - Mining
            - Other
        - Conversion
            - Agricultural pressure
            - Rangeland expansion
            - Altered water flow
    - Physical obstructions
    - Pollution
        - Point
        - Non-point

	o Invasive species and disease
	o Habitat susceptibility
	    ▪ Fire
	    ▪ Drought
	    ▪ Flood
	    ▪ Hurricane/severe storms
	    ▪ Other
	o Climate Change
	    ▪ Range shift projections
	    ▪ Water pattern change projections
	    ▪ Temperature change projections

• Recovery Actions
    o Habitat restoration
    o Habitat creation
    o Buffer areas
    o Captive breeding release sites
    o Pollution control activities
    o Invasive species control/removal activities
    o Stakeholder Actions
        ▪ State
        ▪ Tribal
        ▪ Local
        ▪ Private
        ▪ Non-profit	

• Recovery Areas
    o Critical Habitat
    o Recovery Units
    o Other protected areas
        ▪ National Parks
        ▪ National Wildlife Refuges
        ▪ Wilderness Areas
        ▪ State protected areas
        ▪ Tribal protected areas
• Conservation easements (nonprofit and private)
	• Authorized Take
	    o HCP
	        ▪ Location of take action
	        ▪ Location of mitigation tasks
	    o Section 7 Takes
	        ▪ Number of takes per permit
	        ▪ Location of take
	    o Safe Harbor Agreements

• Monitoring and Research
    o Monitoring station/site
    o Research sites	

Appendix 9: Complete Tier Definitions

- Tier 1 - These spatial layers are assumed to be the easiest to map, the most readily available, and the minimum data needed to create a usable map.
- Tier 2 - These spatial layers are assumed to be slightly more difficult to collect, less available, and not needed for every recovery plan. However, we should note that some species may need spatial layers from Tier 2 to be usable (for example, migratory species will need the "Migratory Route" spatial layer).
- Tier 3 - These spatial layers are assumed to be very difficult to collect and may not be widely available. However, we believe that Tier 3 spatial layers would be very helpful for recovery plans and will aid in adaptive management plans.

Appendix 10: SCB Recommendation Scores for the Interim Guidance and Recovery Plans

The average recovery plan score represents the average score for each recommendation across twelve individual recovery plans.

SCB Recommendation	Interim Guidance Score	Recovery Plan Average Score
Threats are clearly identified	1	1.08
Plan identifies concrete tasks/goals	1	1.17
Plan identifies tasks in order to mitigate threats	1	1.25
Monitoring plan in place	1	1.58
Management plan is linked to biology of species	1	1.75
Plan follows suggested template	1	1.75
Roles in coordinating committee are clearly defined	1	2.83
Coordinating committee is diverse	2	1.92
Innovative tools are implemented	2	2.08
Critical habitat designation is explained and justified	2	2.33
Coordinating committee is small	2	2.50
Trend line data is present and collected regularly	3	2.00
Centralized data base for information gathered	3	2.50
Personnel have been trained	3	3.00
Funds are clearly tracked	3	3.00

Appendix 11: Collected data used to assess the relationship between available spatial data and time listed under the ESA

Scientific name	ESA Listing Date	Total Years Listed	Present Layers	Absent Layers	Total Data Needed	Available Spatial Data
Achyranthes splendens var. rotundata	1986	28	3	13	16	19%
Alsinidendron viscosum	1996	18	2	6	8	25%
Amsonia kearneyana	1989	25	1	10	11	9%
Apodemia mormo langei	1976	38	3	8	11	27%
Arabis serotina	1989	25	3	7	10	30%
Arctosyaphylos franciscana	2012	2	2	8	10	20%
Aristida chaseae	1993	21	1	5	6	17%
Aristida portoricensis	1990	24	3	5	8	38%
Asclepias welshii	1987	27	2	7	9	22%
Astragalus bibullatus	1991	23	1	12	13	8%
Batrachoseps aridus	1973	41	1	11	12	8%
Brachylagus idahoensis	2001	13	7	4	11	64%
Branchinecta sandiegonensis	1997	17	5	9	14	36%
Brighamia rockii	1992	22	5	7	12	42%
Buxus vahlii	1985	29	1	6	7	14%
Campephilus principalis	1967	47	3	11	14	21%
Carex specuicola	1985	29	1	6	7	14%
Ceanothus ferrisae	1995	19	1	10	11	9%
Chamaesyce remyi var. kauaiensis	2010	4	3	7	10	30%
Charadrius alexandrinus nivosus	1993	21	8	11	19	42%
Chorizanthe pungens var. hartwegiana	1994	20	2	11	13	15%
Cicurina vespera	2000	14	4	12	16	25%
Clematis socialis	1986	28	1	9	10	10%
Clermontia oblongifolia ssp. Brevipes	1992	22	4	8	12	33%
Cordia bellonis	1997	17	1	5	6	17%
Cordylanthus tenuis ssp. Capillaris	1995	19	2	12	14	14%
Cranichis ricartii	1991	23	1	5	6	17%
Ctenitis squamigera	1994	20	4	8	12	33%
Cyanea acuminata	1996	18	4	8	12	33%
Cyanea grimesiana ssp. grimesiana	1994	20	4	8	12	33%
Cyanea grimesiana ssp. Obatae	1994	20	5	7	12	42%
Cynomys parvidens	1973	41	5	18	23	22%
Cyprinodon diabolis	1967	47	2	9	11	18%

Dalea foliosa	1991	23	2	5	7	29%
Deeringothamnus rugelii	1986	28	1	5	6	17%
Delissea rhytidosperma	1994	20	2	6	8	25%
Deltistes luxatus	1988	26	5	15	20	25%
Diellia erecta	1994	20	4	7	11	36%
Diellia mannii	2010	4	1	7	8	13%
Dionda diaboli	1999	15	3	9	12	25%
Discus macclintocki	1978	36	1	11	12	8%
Dubautia planteginea magnifolia	2010	4	1	7	8	13%
Dudleya cymosa ssp. Marcescens	1997	17	1	6	7	14%
Dudleya cymosa ssp. Ovatifolia	1997	17	1	9	10	10%
Dudleya nesiotica	1997	17	2	8	10	20%
Eleutherodactylus cooki	1997	17	2	11	13	15%
Enhyra lutris kenyoni	2005	9	2	15	17	12%
Epicrates inornatus	1970	44	3	4	7	43%
Eretmochelys imbricata	1970	44	5	12	17	29%
Eriogonum gypsophilum	1981	33	2	9	11	18%
Eryngium aristulatum var. parishii	1993	21	4	10	14	29%
Etheostoma percnurum	1993	21	1	9	10	10%
Eubalaena glacialis	1970	44	5	7	12	42%
Euphilotes battoides allyni	1976	38	4	10	14	29%
Euphorbia telephioides	1992	22	2	7	9	22%
Exocarpos luteolus	1994	20	1	8	9	11%
Flueggea neowawraea	1994	20	1	7	8	13%
Frankenia johnstonii	1984	30	1	10	11	9%
Gallinula chloropus sandvicensis	1967	47	4	16	20	20%
Gila bicolor ssp.	1985	29	2	10	12	17%
Gila elegans	1980	34	3	15	18	17%
Gopherus polyphemus	1987	27	4	10	14	29%
Grus americana	1970	44	5	18	23	22%
Halcyon cinnamomina cinnamomina	1984	30	3	13	16	19%
Haplostachys haplostachya	1979	35	2	7	9	22%
Helenium virginicum	1998	16	1	6	7	14%
Hemignathus lucidus	1986	28	6	4	10	60%
Hesperomannia arborescens	1994	20	2	6	8	25%
Hibiscadelphus woodii	1996	18	2	11	13	15%
Howellia aquatilis	1994	20	5	7	12	42%
Ischaemum byrone	1994	20	1	7	8	13%
Isodendrion longifolium	1996	18	3	9	12	25%

Kadua degeneri	1991	23	0	8	8	0%
Kokia drynarioides	1984	30	3	9	12	25%
Lampsilis virescens	1976	38	2	11	13	15%
Lanx sp.	1992	22	2	10	12	17%
Layia carnosa	1992	22	5	6	11	45%
Leptodea leptodon	2001	13	3	11	14	21%
Lesquerella congesta	1990	24	1	8	9	11%
Limnanthes pumila grandiflora	2002	12	4	8	12	33%
Lithophragma maximum	1997	17	3	7	10	30%
Lobelia gaudichaudii ssp. Koolauensis	1996	18	2	6	8	25%
Melicope paniculata	2010	4	3	10	13	23%
Melicope zahlbruckneri	1996	18	1	12	13	8%
Menidia extensa	1987	27	3	9	12	25%
Mustela nigripes	1967	47	8	7	15	53%
Navarretia fossalis	1998	16	7	10	17	41%
Neraudia angulata	1991	23	2	6	8	25%
Nicrophorus americanus	1989	25	4	11	15	27%
Numenius borealis	1967	47	3	9	12	25%
Oregonichthys crameri	1993	21	8	10	18	44%
Oxyloma haydeni kanabensis	1991	23	1	10	11	9%
pediocactus bradyi	1979	35	1	13	14	7%
Pediocactus peeblesianus var. peeblesianus	1979	35	3	8	11	27%
Percina aurolineata	1992	22	2	8	10	20%
Peromyscus polionotus peninsularis	1998	16	2	13	15	13%
Phyllostegia hispida	2009	5	4	8	12	33%
Phyllostegia mannii	1992	22	1	7	8	13%
Phyllostegia mollis	1991	23	5	4	9	56%
Picoides borealis	1970	44	3	10	13	23%
Pittosporum napaliense	2010	4	1	7	8	13%
Plagiobothrys hirtus	2000	14	6	5	11	55%
Plantago hawaiensis	1994	20	1	7	8	13%
Pleurobema clava	1993	21	3	10	13	23%
Pleurobema hanleyianum	2010	4	2	9	11	18%
Pleurobema perovatum	1993	21	4	9	13	31%
Pleurobema plenum	1976	38	2	7	9	22%
Poa mannii	1994	20	1	7	8	13%
Polygyriscus virginianus	1978	36	3	6	9	33%
Potamilus inflatus	1990	24	1	10	11	9%
Ptilimnium nodosum	1988	26	3	9	12	25%

Ptychocheilus lucius	1967	47	5	11	16	31%
Salvelinus confluentus	1998	16	7	8	15	47%
Sanicula mariversa	1991	23	2	6	8	25%
Sarracenia rubra ssp. Alabamensis	1989	25	3	8	11	27%
Scaphirhynchus albus	1990	24	5	12	17	29%
Scaphirhynchus suttkusi	2000	14	5	5	10	50%
Schiedea apokremnos	1991	23	1	7	8	13%
Schiedea helleri	1996	18	2	6	8	25%
Schiedea membranacea	1996	18	3	6	9	33%
Schiedea nuttallii	1996	18	1	7	8	13%
Sciurus niger cinereus	1967	47	5	7	12	42%
Sclerocactus brevihamatus ssp. Tobuschii	1979	35	0	9	9	0%
Scutellaria montana	1986	28	1	7	8	13%
Serianthes nelsonii	1987	27	1	10	11	9%
Setophaga kirtlandii	1967	47	6	9	15	40%
Silene alexandri	1992	22	2	6	8	25%
Solanum sandwicense	1994	20	3	8	11	27%
Solidago shortii	1985	29	1	10	11	9%
Streptocephalus woottoni	1993	21	5	9	14	36%
Swallenia alexandrae	1978	36	3	7	10	30%
Tetramolopium capillare	1994	20	2	11	13	15%
Tetramolopium rockii	1992	22	2	6	8	25%
Tetraplasandra flynnii	2010	4	1	7	8	13%
Texamaurops reddelli	1988	26	4	11	15	27%
Thelypodium howellii spectabilis	1999	15	1	6	7	14%
Thymophylla tephroleuca	1984	30	4	6	10	40%
Thysanocarpus conchuliferus	1997	17	2	7	9	22%
Trematolobelia singularis	1996	18	2	6	8	25%
Trichechus manatus	1967	47	4	12	16	25%
Urocyon littoralis littoralis	2004	10	2	10	12	17%
Viola kauaiensis var. wahiawaensis	1996	18	1	7	8	13%
Wilkesia hobdyi	1992	22	3	9	12	25%
Zosterops rotensis	2004	10	5	5	10	50%

Appendix 12: Collected data used to assess the relationship between spatial data availability and the presence monitoring efforts

Scientific name	Monitoring: Compliance	Monitoring: Status/ Trend	Monitoring: Cause/ effect	Total Monitoring	Present Layers	Absent Layers	Total Applicable Layers	Available Spatial Data
Achyranthes splendens var. rotundata	1	1	1	3	3	13	16	19%
Alsinidendron viscosum	0	1	0	1	2	6	8	25%
Amsonia kearneyana	0	1	0	1	1	10	11	9%
Apodemia mormo langei	0	1	1	2	3	8	11	27%
Arabis serotina	0	0	0	0	3	7	10	30%
Arctosyaphylos franciscana	0	0	0	0	2	8	10	20%
Aristida chaseae	0	1	0	1	1	5	6	17%
Aristida portoricensis	1	1	0	2	3	5	8	38%
Asclepias welshii	0	0	0	0	2	7	9	22%
Astragalus bibullatus	0	1	0	1	1	12	13	8%
Batrachoseps aridus	0	0	0	0	1	11	12	8%
Brachylagus idahoensis	0	1	0	1	7	4	11	64%
Branchinecta sandiegonensis	0	0	0	0	5	9	14	36%
Brighamia rockii	1	1	0	2	5	7	12	42%
Buxus vahlii	1	1	0	2	1	6	7	14%
Campephilus principalis	0	1	0	1	3	11	14	21%
Carex	0	1	0	1	1	6	7	14%

specuicola								
Ceanothus ferrisae	0	0	0	0	1	10	11	9%
Chamaesyce remyi var. kauaiensis	0	0	0	0	3	7	10	30%
Charadrius alexandrinus nivosus	0	1	1	2	8	11	19	42%
Chorizanthe pungens var. hartwegiana	0	1	0	1	2	11	13	15%
Cicurina vespera	1	1	1	3	4	12	16	25%
Clematis socialis	0	0	0	0	1	9	10	10%
Clermontia oblongifolia ssp. Brevipes	1	1	0	2	4	8	12	33%
Cordia bellonis	0	1	1	2	1	5	6	17%
Cordylanthus tenuis ssp. Capillaris	1	1	0	2	2	12	14	14%
Cranichis ricartii	0	1	1	2	1	5	6	17%
Ctenitis squamigera	0	0	0	0	4	8	12	33%
Cyanea acuminata	0	0	0	0	4	8	12	33%
Cyanea grimesiana ssp. grimesiana	0	0	0	0	4	8	12	33%
Cyanea grimesiana ssp. Obatae	0	1	0	1	5	7	12	42%
Cynomys parvidens	0	1	1	2	5	18	23	22%
Cyprinodon	0	0	0	0	2	9	11	18%

diabolis								
Dalea foliosa	0	1	1	2	2	5	7	29%
Deeringothamnus rugelii	1	1	1	3	1	5	6	17%
Delissea rhytidosperma	0	1	1	2	2	6	8	25%
Deltistes luxatus	1	1	0	2	5	15	20	25%
Diellia erecta	0	1	0	1	4	7	11	36%
Diellia mannii	0	0	0	0	1	7	8	13%
Dionda diaboli	0	1	0	1	3	9	12	25%
Discus macclintocki	0	0	0	0	1	11	12	8%
Dubautia planteginea magnifolia	0	0	0	0	1	7	8	13%
Dudleya cymosa ssp. Marcescens	0	1	0	1	1	6	7	14%
Dudleya cymosa ssp. Ovatifolia	0	1	0	1	1	9	10	10%
Dudleya nesiotica	1	1	1	3	2	8	10	20%
Eleutherodactylus cooki	0	1	0	1	2	11	13	15%
Enhyra lutris kenyoni	0	1	1	2	2	15	17	12%
Epicrates inornatus	1	1	0	2	3	4	7	43%
Eretmochelys imbricata	0	1	1	2	5	12	17	29%
Eriogonum gypsophilum	0	0	0	0	2	9	11	18%
Eryngium aristulatum var. parishii	1	1	0	2	4	10	14	29%
Etheostoma percnurum	0	0	0	0	1	9	10	10%

Eubalaena glacialis	0	1	0	1	5	7	12	42%
Euphilotes battoides allyni	0	0	0	0	4	10	14	29%
Euphorbia telephioides	1	1	0	2	2	7	9	22%
Exocarpos luteolus	0	1	1	2	1	8	9	11%
Flueggea neowawraea	0	1	0	1	1	7	8	13%
Frankenia johnstonii	0	1	0	1	1	10	11	9%
Gallinula chloropus sandvicensis	0	1	0	1	4	16	20	20%
Gila bicolor ssp.	1	1	1	3	2	10	12	17%
Gila elegans	0	0	0	0	3	15	18	17%
Gopherus polyphemus	0	1	0	1	4	10	14	29%
Grus americana	1	1	1	3	5	18	23	22%
Halcyon cinnamomina cinnamomina	0	1	0	1	3	13	16	19%
Haplostachys haplostachya	0	1	0	1	2	7	9	22%
Helenium virginicum	0	1	1	2	1	6	7	14%
Hemignathus lucidus	1	1	1	3	6	4	10	60%
Hesperomannia arborescens	0	1	0	1	2	6	8	25%
Hibiscadelphus woodii	0	0	0	0	2	11	13	15%
Howellia aquatilis	1	1	1	3	5	7	12	42%
Ischaemum byrone	0	1	1	2	1	7	8	13%

Isodendrion longifolium	0	0	0	0	3	9	12	25%
Kadua degeneri	0	1	0	1	0	8	8	0%
Kokia drynarioides	0	1	0	1	3	9	12	25%
Lampsilis virescens	0	0	0	0	2	11	13	15%
Lanx sp.	0	1	0	1	2	10	12	17%
Layia carnosa	0	0	0	0	5	6	11	45%
Leptodea leptodon	0	0	0	0	3	11	14	21%
Lesquerella congesta	0	0	0	0	1	8	9	11%
Limnanthes pumila grandiflora	0	1	0	1	4	8	12	33%
Lithophragma maximum	1	1	0	2	3	7	10	30%
Lobelia gaudichaudii ssp. Koolauensis	0	1	0	1	2	6	8	25%
Melicope paniculata	0	1	0	1	3	10	13	23%
Melicope zahlbruckneri	0	1	0	1	1	12	13	8%
Menidia extensa	1	1	0	2	3	9	12	25%
Mustela nigripes	1	1	1	3	8	7	15	53%
Navarretia fossalis	0	0	0	0	7	10	17	41%
Neraudia angulata	0	1	0	1	2	6	8	25%
Nicrophorus americanus	0	1	0	1	4	11	15	27%
Numenius borealis	0	0	0	0	3	9	12	25%

Oregonichthys crameri	1	1	1	3	8	10	18	44%
Oxyloma haydeni kanabensis	0	1	0	1	1	10	11	9%
pediocactus bradyi	0	1	0	1	1	13	14	7%
Pediocactus peeblesianus var. peeblesianus	1	1	0	2	3	8	11	27%
Percina aurolineata	0	1	0	1	2	8	10	20%
Peromyscus polionotus peninsularis	0	1	1	2	2	13	15	13%
Phyllostegia hispida	0	1	0	1	4	8	12	33%
Phyllostegia mannii	0	1	0	1	1	7	8	13%
Phyllostegia mollis	1	1	0	2	5	4	9	56%
Picoides borealis	0	1	1	2	3	10	13	23%
Pittosporum napaliense	0	0	0	0	1	7	8	13%
Plagiobothrys hirtus	1	1	1	3	6	5	11	55%
Plantago hawaiensis	0	1	1	2	1	7	8	13%
Pleurobema clava	0	1	0	1	3	10	13	23%
Pleurobema hanleyianum	0	1	0	1	2	9	11	18%
Pleurobema perovatum	1	1	0	2	4	9	13	31%
Pleurobema plenum	0	0	0	0	2	7	9	22%
Poa mannii	0	1	1	2	1	7	8	13%
Polygyriscus	0	0	0	0	3	6	9	33%

virginianus								
Potamilus inflatus	0	1	0	1	1	10	11	9%
Ptilimnium nodosum	0	1	0	1	3	9	12	25%
Ptychocheilus lucius	0	0	0	0	5	11	16	31%
Salvelinus confluentus	0	1	0	1	7	8	15	47%
Sanicula mariversa	0	1	0	1	2	6	8	25%
Sarracenia rubra ssp. Alabamensis	0	0	0	0	3	8	11	27%
Scaphirhynchus albus	1	1	0	2	5	12	17	29%
Scaphirhynchus suttkusi	0	0	1	1	5	5	10	50%
Schiedea apokremnos	0	1	1	2	1	7	8	13%
Schiedea helleri	0	1	0	1	2	6	8	25%
Schiedea membranacea	0	1	0	1	3	6	9	33%
Schiedea nuttallii	0	1	1	2	1	7	8	13%
Sciurus niger cinereus	0	1	0	1	5	7	12	42%
Sclerocactus brevihamatus ssp. Tobuschii	1	1	0	2	0	9	9	0%
Scutellaria montana	0	1	1	2	1	7	8	13%
Serianthes nelsonii	0	1	1	2	1	10	11	9%
Setophaga kirtlandii	0	1	1	2	6	9	15	40%
Silene alexandri	0	1	0	1	2	6	8	25%

Solanum sandwicense	0	1	0	1	3	8	11	27%
Solidago shortii	1	1	0	2	1	10	11	9%
Streptocephalus woottoni	0	0	0	0	5	9	14	36%
Swallenia alexandrae	0	0	0	0	3	7	10	30%
Tetramolopium capillare	1	1	0	2	2	11	13	15%
Tetramolopium rockii	0	1	0	1	2	6	8	25%
Tetraplasandra flynnii	0	0	0	0	1	7	8	13%
Texamaurops reddelli	0	1	1	2	4	11	15	27%
Thelypodium howellii spectabilis	0	1	1	2	1	6	7	14%
Thymophylla tephroleuca	0	0	0	0	4	6	10	40%
Thysanocarpus conchuliferus	1	1	0	2	2	7	9	22%
Trematolobelia singularis	0	1	0	1	2	6	8	25%
Trichechus manatus	1	1	1	3	4	12	16	25%
Urocyon littoralis littoralis	1	1	1	3	2	10	12	17%
Viola kauaiensis var. wahiawaensis	0	1	0	1	1	7	8	13%
Wilkesia hobdyi	0	0	0	0	3	9	12	25%
Zosterops rotensis	0	1	0	1	5	5	10	50%

Appendix 13: Data layers used for proof-of-concept spatial tool

Data Layer	Data Category	Tier	Source
Federal Lands	Base Layer	1	USGS National Map
Current Range	Biological	1	IUCN Redlist
Current Distribution	Biological	1	USGS Bison
Historical Range	Biological	1	Nathan Brown – USFWS Region 6 Ecologist
Relocation sites	Anthropogenic	2	Adam Kavalunas – Utah Division of Wildlife Resources Biologist
Conservation Easements	Anthropogenic	1	NCED
Recovery Areas	Anthropogenic	2	Nathan Brown – USFWS Region 6 Ecologist
Management Units	ESA Feature	2	Nathan Brown – USFWS Region 6 Ecologist
Survey Intensity	ESA Feature	1	Nathan Brown – USFWS Region 6 Ecologist
Oil and Gas Wells	Anthropogenic	2	Data basin
Wildfire	Anthropogenic	3	USDA Forest Service
Grazing Allotments	Anthropogenic	2	Data basin
Animal Plague	Anthropogenic	2	USFWS Prairie Dog Symposium Proceedings
Invasive plants	Anthropogenic	2	USDA Plants Database
4(d) Rule	ESA Feature	1	USFWS
Iron County HCP	ESA Feature	1	USFWS
Low Effect Iron County HCP	ESA Feature	1	USFWS
Garfield County HCP	ESA Feature	1	USFWS
Henrie SHA	ESA Feature	1	USFWS - ECOS
Utah Prairie Dog Conservation Bank SHA	ESA Feature	1	Conservation Registry